Contemporary Fixed Prosthodontics



Rosenstiel • Land • Fujimoto

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Fourth Edition

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CONTEMPORARY FIXED PROSTHODONTICS

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Preface

"If the magnifying glass is powerful enough, you can always find something that can be improved," said the seasoned restorative dentist. That sentiment aptly describes almost all aspects of Fixed Prosthodontics and undoubtedly also applies to this fourth edition of *Contemporary Fixed Prosthodontics.*

It is a privilege to have had the opportunity to once again try to comprehensively chronicle our chosen field. As we embarked on this new edition, we had many objectives in mind, including improving readability, making the nomenclature correct and consistent throughout, and, in the now established tradition, thoroughly updating the content and references. Our biggest challenge, though, was the conversion of all photographs to full color. At times, this seemed an almost overwhelming task. Soon after our editor said, "How would you like to do your next edition in full color?" it became painfully apparent that we could not simply substitute the original photographs. Thus, a gargantuan task evolved, with the indirect benefit that we were forced to look for alternative means of illustrating and clarifying content. It made us revisit the underlying rationale for the use of all illustrations throughout the text. Thus, as the process unfolded, we identified a substantial number of instances in which either a slight shift in focus or perhaps a new approach in presentation of content will help both the novice and the experienced practitioner to more quickly grasp the various concepts that are presented.

Today, the skills and understanding taught by Fixed Prosthodontics faculty are in extremely high demand in practice. Concurrently, dental education programs have found it difficult to attract and retain an adequate number of qualified faculty members. Without qualified faculty, programs are unable to sustain continuity in their curriculum and to fully develop their programs in keeping with the many technological advances in the field. The "baby-boomer generation" is confronted with increasingly complex treatment needs in a society that is demanding more and more esthetic treatment options, one of the many areas in which content continues to evolve and expand. Since publication of the first 500-page edition in 1988 (followed by the 1995 and 2000 editions), the size of this text has approximately doubled. Rather than adding indiscriminantly, we have relied on feedback from our readers at all levels: students, graduate students, practitioners, researchers, and manufacturers all have shared their insights and suggestions. Without such input, the qualitative improvements that we hope to have achieved would not have been attainable. We are very grateful to all those who have made the helpful suggestions and asked the many thoughtful questions along the way.

We hope this new edition will serve as the comprehensive resource it is intended to be: a text that is suitable for preclinical, clinical, and postdoctoral training in Fixed Prosthodontics. It can serve as a well-indexed reference, allowing rapid retrievability of evidence-based information for the busy practitioner, while simultaneously being a reliable, well-referenced, in-depth source for researchers and dental manufacturers.

ORGANIZATION

The text once again retains the popular four-part format: Part I: Planning and Preparation; Part II: Clinical Procedures: Section I; Part III: Laboratory Procedures; and Part IV: Clinical Procedures: Section II. Also retained from the third edition, relevant basic science information is present in each chapter as applicable, and each chapter features Study Questions at the end. Key Terms appear at the beginning of specific chapters. These terms are defined in two ways: in the Glossary appearing at the end of the chapter and in the material presented within the chapter itself.

NEW TO THIS EDITION

The use of color throughout this text is instantly apparent and has vastly improved reader comprehension and interpretation of all content. Van Gogh said, "Color in a picture is like enthusiasm in life." The impact of the use of color in the line art and photography throughout this work is massive.

Publication of the revised Eighth Edition of the Glossary of Prosthodontics Terms (GPT-8) preceded our manuscript completion by mere weeks. Every effort has been made to incorporate the preferred new nomenclature throughout, although undoubtedly errors of omission remain. Glossary terms can be found at the end of specific chapters, and the GPT-8 is reprinted in its entirety at the end of the text.

A significant change in GPT-8 has been a change in the nomenclature for prosthetic restorations, which are now standardized in the form*:

{modifier} (type) **prosthesis** <descriptor>
coordinate adjective(s) noun adjective clause

Modifier: {anatomic location} maxillary, mandibular, inferior, superior
{form} complete, partial, splint, stent, carrier, bar, ovoid, round
{material} ceramic, metal, resin
{retention} fixed, removable, cement, screw, friction, tissue
{support} tooth, implant, tissue
{time} surgical, temporary, interim, definitive
{other} soft, zirconium, etc.

Type: (dental, maxillofacial, ancillary)

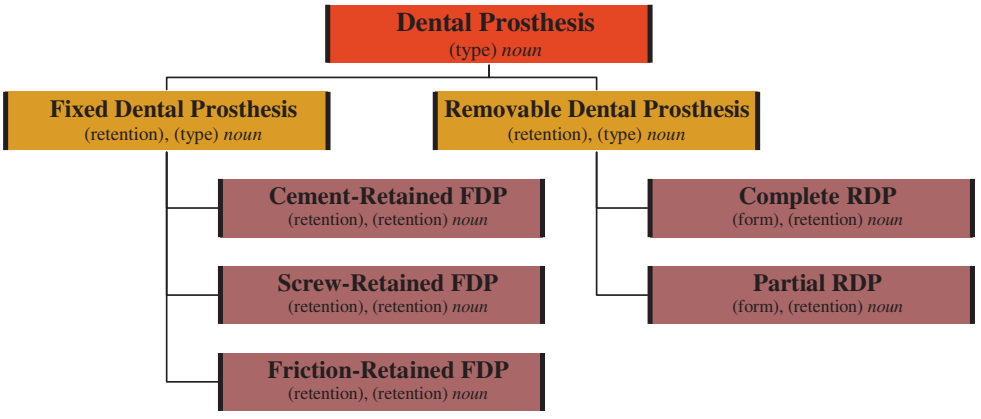
Descriptor: <support> tissue borne, implant borne, tooth/implant borne
<other modifiers>

Examples:

dental prosthesis
maxillary removable partial dental prosthesis
surgical obturator maxillofacial prosthesis
mandibular fixed partial dental prosthesis on dental implants #28, #30, and #31
cemented fixed partial dental prosthesis on teeth #12 and #14
cemented fixed partial dental prosthesis on dental implant #12 and tooth #14
ceramic fixed partial dental prosthesis on dental implants #3 and #5

Examples to be avoided:

rigid interim mandibular removable partial dental prosthesis replacing teeth
#23-#30 *(five coordinate adjectives)*
hybrid prosthesis *(of what?)*
hybrid denture prosthesis *(of what?)*
interim plate *(poor noun selection)*



With the support of the American College of Prosthodontics (ACP), Chapter 1 now includes the Prosthodontic Diagnostic Index (PDI), the official classification system for edentulous, partially edentulous, and dentate patients developed by the ACP. The system classifies patients into one of four categories: Class I (ideal or minimally compromised), Class II (moderately compromised), Class III (substantially compromised) or Class IV (severely compromised). These guidelines are becoming widely taught and adopted and will help practitioners determine appropriate treatments for their patients.

Content in **Part I: Planning and Preparation** has been streamlined, illustrations of older equipment and materials have been replaced with contemporary versions, and selected illustrations have been redrawn for clarity.

In **Part II: Clinical Procedures: Section I,** the chapter on tooth preparation has been thoroughly updated to include the most recent findings, and

*See Simon H, Yanase RT: Terminology for implant prostheses. Int J Oral Maxillofac Implants 18:539, 2003.

new illustrations of metal-ceramic crowns and inlay and onlay preparations have been created in the same style as in the previous editions. The chapters on restoration of the endodontically treated tooth, tissue management, and impression making now include a number of new step-by-step examples of various techniques in addition to thorough content revision. Changes in the area of implant prosthodontics have also been incorporated.

In **Part III: Laboratory Procedures,** the chapter on communication with the dental laboratory technician has been brought in line with the most current policies of the American Dental Association (ADA) and the National Association of Dental Laboratories (NADL). In response to specific requests from readers, the scope of the chapter on retainers for partial removable dental prostheses was expanded to now include a number of examples of the more popular intracoronal and extracoronal attachments. And we must say that it is a pleasure to be able to present the principles of color science and esthetics in actual color! New knowledge on perception of esthetics and objective tooth color measurement have been incorporated, which allows logical flow of content with that in the chapters on metal-ceramics, all-ceramics, and evaluation and characterization.

In **Part IV: Clinical Procedures: Section II,** the chapter on postoperative care has been expanded and updated to include new treatment presentations with even longer term follow-up of contemporary fixed prosthodontic practice that has been rendered, consistent with the philosophies and techniques described throughout the text.

Both of the indexes have been thoroughly updated, and selected illustrations were incorporated in the product index.

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Acknowledgments

In recognition of so many colleagues and friends

Where to begin? After more than two decades, achieving absolute accuracy in crediting all of those whose selfless contributions to the development of this text have helped it evolve is unlikely. Whenever we asked, we met with a willingness to share concepts, new technology, illustrations, photographs, materials, and whatever we requested. Permissions were routinely granted and invariably most kindly approved. We again have made every effort to accurately and precisely give credit to all of those to whom credit is due. Any errors and omissions are absolutely unintentional and the sole responsibility of the authors—we apologize if such should have occurred.

A special thank you to...

James Cockerill, RBP, who once again provided selected photographic support consistent with his previous contributions.

Krystina Srodulski, who rejoined the team and delivered her superb artwork that makes this text in many ways so different and superior.

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The outstanding team at Elsevier who continued to believe in our ability to complete this task, and whose relentless pursuit of quality has helped make this our finest edition yet: Publisher, Penny Rudolph; Senior Editor, John Dolan; Associate Developmental Editor, Courtney Sprehe; Book Production Manager, Linda McKinley; and Project Manager, Gena Magouirk for their help, patience, and understanding throughout.

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Only those who have lived with textbook authors can appreciate the sacrifices that our spouses have made. Enid, Karen, and Yoshiko continue to support us. They did so when we first met at Indiana University, when we subsequently taught together at the University of Florida for a few years, and throughout our subsequent individual careers. Our spouses are very special to us, as is their continued support. They deserve a very special thank you.

The fourth edition of *Contemporary Fixed Prosthodontics* is as close as we have been able to come to what we initially envisioned. We hope that it will help advance the art and science of what is undoubt-

edly one of the most challenging clinical specialties at all levels. We certainly cannot claim to have all the answers, but we hope that students, practitioners, and researchers who are willing to commit the significant amount of time and discipline necessary to achieve mastery of Fixed Prosthodontics will be able to find many, if not most, of the answers they seek.

Stephen F. Rosenstiel, Columbus, Ohio
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Junhei Fujimoto, Tokyo, Japan

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1

HISTORY TAKING AND CLINICAL EXAMINATION



KEY TERMS

chief complaint
click
communication
dental history
fixed prosthodontics
fremitus
medical history
palpation
percussion
periodontal examination
slide
systemic conditions
temporomandibular joint (TMJ) dysfunction

Fixed prosthodontic treatment involves the replacement and restoration of teeth by artificial substitutes that are not readily removable from the mouth. Its focus is to restore function, esthetics, and comfort. **Fixed prosthodontics** can offer exceptional satisfaction for both patient and dentist. It can transform an unhealthy, unattractive dentition with poor function into a comfortable, healthy occlusion capable of years of further service and greatly enhance esthetics (Fig. 1-1*A* and *B*). Treatment can range from the fairly straightforward restoration of a single tooth with a cast crown (Fig. 1-1*C*) or replacement of one or more missing teeth with a fixed dental prosthesis (Fig. 1-1*D*) or implant-supported restoration to a highly complex restoration involving all the teeth in an entire arch or the entire dentition.

To achieve predictable success in this technically exacting and demanding field, there must be meticulous attention to every detail: from the initial patient interview and diagnosis, through the active treatment phases, and to a planned schedule of follow-up care. Otherwise, the result is likely to be unsatisfactory and frustrating for both dentist and patient, resulting in disappointment and loss of confidence in each other.

Problems encountered during or after treatment can often be traced to errors and omissions during history taking and initial examination. An inexperienced clinician may plunge into the treatment phase before collecting sufficient diagnostic information that helps predict likely pitfalls.

Making the correct diagnosis is prerequisite for formulating an appropriate treatment plan. This requires that all pertinent information be obtained. A complete history includes a comprehensive assessment of the patient's general and dental health, individual needs, preferences, and personal circumstances. This chapter reviews fundamentals of history taking and clinical examination, with special emphasis on obtaining the necessary information to make appropriate fixed prosthodontic treatment decisions.



Fig. 1-1
A severely damaged maxillary dentition (A) restored with metal-ceramic fixed prostheses (B). C, Complete cast crown restores mandibular molar. D, Three-unit fixed dental prosthesis replacing missing mandibular premolar. *(C, Courtesy of Dr. X Lepe. D, Courtesy of Dr. J. Nelson.)*

HISTORY

A patient's history should include all pertinent information concerning the reasons for seeking treatment, along with any personal information, including relevant previous medical and dental experiences. The **chief complaint** should be recorded, preferably in the patient's own words. A screening questionnaire (Fig. 1-2) is useful for history taking; it should be reviewed in the patient's presence to correct any mistakes and to clarify inconclusive entries. If the patient is mentally impaired or a minor, the guardian or responsible parent must be present.

Chief Complaint

The accuracy and significance of the patient's primary reason or reasons for seeking treatment should be analyzed first. These may be just the obvious features, and careful examination often reveals problems and disease of which the patient is unaware; nevertheless, the patient perceives the chief complaint as the major problem. Therefore, when a comprehensive treatment plan is proposed, special attention must be given to how the chief complaint can be resolved. The inexperienced clinician trying to prescribe an "ideal" treatment plan can lose sight of the patient's wishes. The patient may then become frustrated because the dentist apparently does not understand or does not want to understand the patient's point of view.

Chief complaints usually belong to one of the following four categories:

- Comfort (pain, sensitivity, swelling)
- Function (difficulty in mastication or speech)
- Social (bad taste or odor)
- Appearance (fractured or unattractive teeth or restorations, discoloration)

Comfort

If pain is present, its location, character, severity, and frequency should be noted, as well as the first time it occurred, what factors precipitate it (e.g., hot, cold, or sweet things), and any changes in its character. Is it localized or more diffuse in nature? It is often

HEALTH QUESTIONNAIRE

REG. NO. _____

Name _____ Date _____ Age _____

Write Yes or No.

1. Have you been hospitalized or under the care of a physician with the last 2 years? _____
2. Has there been a change in your general health within the past 2 years? _____
3. Are you allergic to penicillin or any other drugs? _____
4. Indicate **Yes** or **No** to any of the conditions below for which you are being treated or you have had:

Y / N	Heart attack	Y / N	Hives, skin rash	Y / N	Substance abuse
Y / N	Heart trouble	Y / N	Cancer treatment	Y / N	AIDS
Y / N	Heart surgery	Y / N	Radiation therapy	Y / N	HIV infection
Y / N	Angina (chest pain)	Y / N	Ulcers	Y / N	Diabetes
Y / N	High blood pressure	Y / N	Gastritis	Y / N	Hepatitis
Y / N	Prolapsed mitral valve	Y / N	Hiatus hernia	Y / N	Kidney trouble
Y / N	Heart murmur	Y / N	Easy bruising	Y / N	Psychiatric treatment
Y / N	Artificial heart valves	Y / N	Excessive bleeding	Y / N	Fainting spells
Y / N	Congenital heart lesions	Y / N	Artificial joint	Y / N	Seizures
Y / N	Cardiac pacemaker	Y / N	Arthritis	Y / N	Epilepsy
Y / N	Rheumatic fever	Y / N	Asthma	Y / N	Anemia
Y / N	Stroke	Y / N	Persistent cough		
Y / N	Allergies	Y / N	Emphysema		

Women only
Y / N Currently pregnant
Y / N Nursing
Y / N Female problems

Do you use tobacco? Y / N Type _____ How much? _____

Do you drink alcohol? Y / N Type _____ How much? _____

5. Have you had any serious illness, disease, or condition not listed above? _____
   If so, explain _____
6. Indicate date of your last physical examination _____
7. Name and address of your personal physician _____
8. List any medications you are currently taking _____
9. Have you had any problems or anxiety associated with previous dental care? _____
   If so, explain _____

DENTAL QUESTIONNAIRE

Indicate Yes or No to the following:

Y / N 10. Does it hurt when you chew?
Y / N 11. Is a tooth sensitive or tender?
Y / N 12. Do you have frequent toothaches or gum pain?
Y / N 13. Do your gums bleed a lot when you brush your teeth?
Y / N 14. Do you have occasional dryness or burning in your mouth?
Y / N 15. Do you have occasional pain in the jaws, neck, or temples?
Y / N 16. Does it hurt when you open wide or take a big bite?
Y / N 17. Does your jaw make "clicking or popping" sounds when you chew or move your jaw?
Y / N 18. Do you suffer from headaches?
Y / N 19. Do you have occasional ear pain or pain in front of the ears?
Y / N 20. Does your jaw "feel tired" after a meal?
Y / N 21. Do you ever have to search for a place to close your teeth?
Y / N 22. Does a tooth ever get in the way?

23. Is there anything you wish to tell us that has not been asked?
24. Were there any items you did not understand?

I will inform the Clinic of any changes in the above

Person completing form sign here: _____

self parent guardian

Circle relationship
If minor: parent or legal guardian signature

Date signed: _____

Fig. 1-2
Screening questionnaire.

helpful to have the patient point at the area while the dentist pays close attention.

If swelling is present, the location, size, consistency, and color are noted, as well as how long it has been felt and whether it is increasing or decreasing.

Function

Difficulties in chewing may result from a local problem such as a fractured cusp or missing teeth; it may also indicate a more generalized malocclusion or dysfunction.

Social aspects

A bad taste or smell often indicates compromised oral hygiene and periodontal disease. Often social pressures prompt the patient to seek care.

Appearance

Compromised appearance is a strong motivating factor for patients to seek advice as to whether improvement is possible (Fig. 1-3). Such patients may have missing or crowded teeth, or a tooth or restoration may be fractured. Their teeth may be unattractively shaped, malpositioned, or discolored, or there may be a developmental defect.

Personal Details

The patient's name, address, phone number, sex, occupation, work schedule, and marital and financial status are noted. Much can be learned in a 5-minute, casual conversation during the initial visit. In addition to establishing rapport and developing a basis for the patient to trust the dentist, small and seemingly unimportant personal details often have considerable influence in establishing a correct diagnosis, prognosis, and treatment plan.

Medical History

An accurate and current general **medical history** should include any medication the patient is taking, as well as all relevant medical conditions. If necessary, the patient's physician or physicians can be contacted for clarification. The following classification may be helpful:

1. Conditions affecting the treatment methods (e.g., any disorders that necessitate the use of antibiotic premedication, any use of steroids or anticoagulants, and any previous allergic responses to medication or dental materials). Once these are identified, treatment usually can be modified as part of the comprehensive treatment plan, although some factors may severely limit available options.
2. Conditions affecting the treatment plan (e.g., previous radiation therapy, hemorrhagic disorders, extremes of age, and terminal illness). These can be expected to modify the patient's response to dental treatment and may affect the prognosis. For instance, patients who have previously received radiation treatment in the area of a planned extraction require special measures (hyperbaric oxygen) to prevent serious complications.
3. **Systemic conditions** with oral manifestations. For example, periodontitis may be modified by diabetes, menopause, pregnancy, or the use of anticonvulsant drugs (Fig. 1-4); in cases of gastroesophageal reflux disease, bulimia, or anorexia nervosa, teeth may be eroded by regurgitated stomach acid[1,2] (Fig. 1-5); certain drugs may generate side effects that mimic temporomandibular disorders[3] or reduce salivary flow.[4,5]



Fig. 1-3
Poor appearance is a common reason for seeking restorative dental treatment.



Fig. 1-4
Severe gingival hyperplasia associated with anticonvulsant drug use. *(Courtesy of Dr. P. B. Robinson.)*



Fig. 1-5
A, Extensive damage caused by self-induced acid regurgitation. Note that the lingual surfaces are bare of enamel except for a narrow band at the gingival margin. **B,** Teeth prepared for partial-coverage restorations. **C,** Definitive cast. **D** and **E,** The completed restoration.

4. Possible risk factors to the dentist and auxiliary personnel (e.g., patients who are suspected or confirmed carriers of hepatitis B, acquired immunodeficiency syndrome, or syphilis).

Dental offices practice "universal precautions" to ensure appropriate infection control. This means that full infection control is practiced for every patient; no additional measures are needed when dentists treat known disease carriers.[6]

Dental History

Clinicians should be cautious when commenting before a thorough examination is completed. With adequate experience, a clinician can often assess preliminary treatment needs during the initial appointment. However, fairly assessing the quality of a previously rendered treatment can be difficult, because the circumstances under which the treatment was rendered are seldom known. When such an assessment is requested for legal proceedings, the patient should be referred to a specialist familiar with the "usual and customary" standard of care.

Periodontal history

The patient's oral hygiene is assessed, and current plaque-control measures are discussed, as are previously received oral hygiene instructions. The frequency of any previous débridement should be recorded, and the dates and nature of any previous periodontal surgery should be noted.

Restorative history

The patient's restorative history may include only simple composite resin or dental amalgam fillings, or it may involve crowns and extensive fixed dental prostheses. The age of existing restorations can help establish the prognosis and probable longevity of any future fixed prostheses.

Endodontic history

Patients often forget which teeth have been endodontically treated. These can be readily identified with radiographs. The findings should be reviewed periodically so that periapical health can be monitored and any recurring lesions promptly detected (Fig. 1-6).



Fig. 1-6
Defective endodontics has led to recurrence of a periapical lesion. Re-treatment is required.



Fig. 1-7
Apical root resorption after orthodontic treatment.

Orthodontic history

Occlusal analysis should be an integral part of the assessment of a postorthodontic dentition. If restorative treatment needs are anticipated, they should be undertaken by the restorative dentist. Occlusal adjustment (reshaping of the occlusal surfaces of the teeth) may be needed to promote long-term positional stability of the teeth and reduce or eliminate parafunctional activity. On occasion, root resorption (detected on radiographs) (Fig. 1-7) may be attributable to previous orthodontic treatment. As the crown/root ratio is affected, future prosthodontic treatment and its prognosis may also be affected. Restorative treatment can often be simplified by minor tooth movement. When a patient is contemplating orthodontic treatment, considerable time can be saved if minor tooth movement (for restorative reasons) is incorporated from the start. Thus, good **communication** between the restorative dentist and the orthodontist may prove very helpful.

Removable prosthodontic history

The patient's experiences with removable prostheses must be carefully evaluated. For example, a partial removable dental prosthesis may not have been worn for a variety of reasons, and the patient may not even have mentioned its existence. Careful questioning and examination usually elicits discussion concerning any such devices. Listening to the patient's comments about previously unsuccessful removable prostheses can be very helpful in assessing whether future treatment will be more successful.

Oral surgical history

Information about missing teeth and any complications that may have occurred during tooth removal is obtained. Special evaluation and data collection procedures are necessary for patients who require prosthodontic care after orthognathic surgery. Before any treatment is undertaken, the prosthodontic component of the proposed treatment should be fully coordinated with the surgical component.

Radiographic history

Previous radiographs may prove helpful in judging the progress of dental disease. They should be obtained if possible, because it is generally better to avoid exposing the patient to unnecessary ionizing radiation. Dental practices usually forward radiographs or acceptable duplicates promptly on request. In most instances, however, a current diagnostic radiographic series is essential and should be obtained as part of the examination.

Temporomandibular joint dysfunction history

A history of pain or clicking in the TMJs or neuromuscular symptoms, such as tenderness to **palpation,** may be caused by **TMJ dysfunction,** which should normally be treated and resolved before fixed prosthodontic treatment begins. A screening questionnaire efficiently identifies these problems. The patient should be questioned regarding any previous treatment for joint dysfunction (e.g., occlusal devices, medications, biofeedback, or physical therapy exercises).

EXAMINATION

An examination consists of the clinician's use of sight, touch, and hearing to detect conditions outside the normal range. To avoid mistakes, it is critical to record what is actually observed rather than to make diagnostic comments about the condition. For example, "swelling," "redness," and "bleeding on probing of gingival tissue" should be recorded, rather than "gingival inflammation" (which implies a diagnosis).

Thorough examination and data collection are needed for the prospective fixed prosthodontic patient, and the protocol for this effort can be obtained from various textbooks of oral diagnosis.[7,8]

General Examination

The patient's general appearance, gait, and weight are assessed. Skin color is noted for signs of anemia or jaundice. Vital signs, such as respiration, pulse, temperature, and blood pressure, are measured and recorded. Fixed prosthodontic treatment is often indicated in middle-aged or older patients, who can be at higher risk for cardiovascular disease. Relatively inexpensive cardiac monitoring units are available for in-office use (Fig. 1-8). Patients with vital sign measurements outside normal ranges should be referred for a comprehensive medical evaluation before definitive treatment is initiated.

Extraoral Examination

Special attention is given to facial asymmetry because small deviations from normal may hint at serious underlying conditions. Cervical lymph nodes are palpated, as are the TMJs and the muscles of mastication.

Temporomandibular joints

The clinician locates the TMJs by palpating bilaterally just anterior to the auricular tragi while the

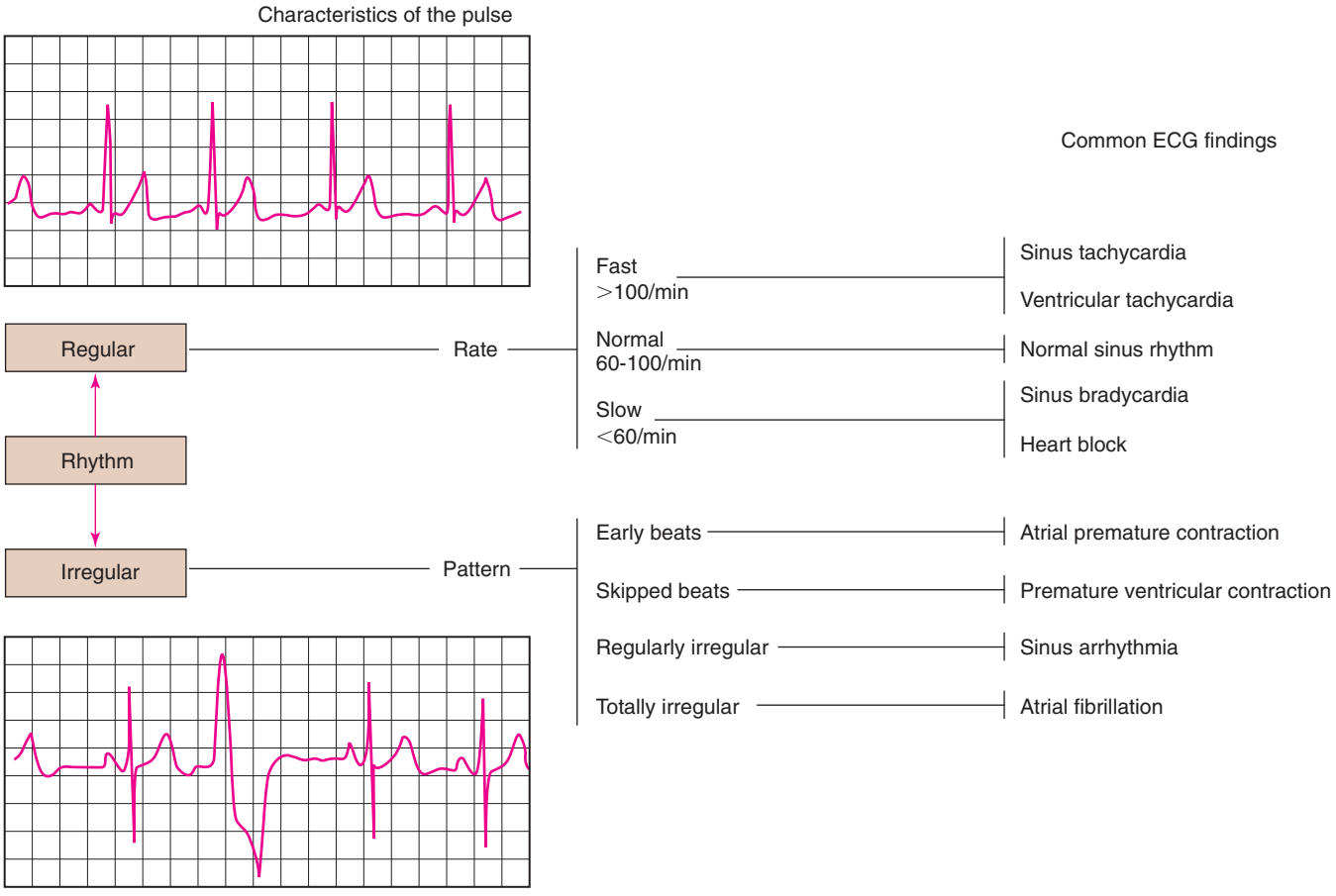


Fig. 1-8
Cardiac monitoring printout. *(Courtesy of Dr. T. Quilitz.)*

patient opens and closes the mouth. This permits a comparison between the relative timing of left and right condylar movements during the opening stroke. Asynchronous movement may indicate an anterior disk displacement that prevents one of the condyles from making a normal translatory movement (see Chapter 4). Auricular palpation (Fig. 1-9) with light anterior pressure helps identify potential disorders in the posterior attachment of the disk. Tenderness or pain on movement is noted and can be indicative of inflammatory changes in the retrodiscal tissues, which are highly vascular and innervated. Clicking in the TMJ is often noticeable through auricular palpation but may be difficult to detect in palpation directly over the lateral pole of the condylar process, because the overlying tissues can muffle the **click.** Placement of the fingertips on the angles of the mandible helps identify even a minimal click, because very little soft tissue lies between the fingertips and the mandibular bone.



Fig. 1-9
Auricular palpation of the posterior aspects of the temporomandibular joints.

A maximum mandibular opening resulting in less than 35 mm of interincisal movement is considered restricted, because the average opening is greater than 50 mm.[9,10] Such restricted movement on opening can be indicative of intracapsular changes in the joints. Similarly, any midline deviation on opening and/or closing is recorded. The maximum lateral movements of the patient can be measured (normal is about 12 mm) (Fig. 1-10).



Fig. 1-10
Maximum opening of more than 50 mm (**A**) and lateral movement of about 12 mm (**B**) are normal.

Muscles of mastication

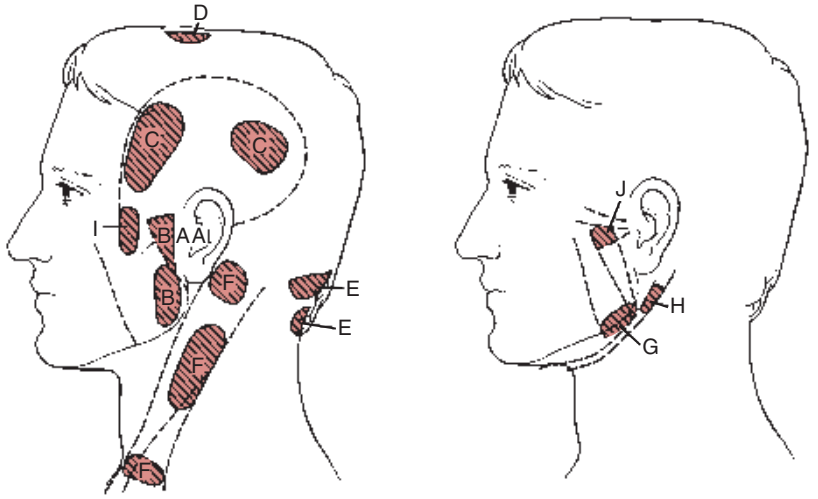
Next, the masseter and temporal muscles, as well as other relevant postural muscles, are palpated for signs of tenderness (Fig. 1-11). Palpation is best accomplished bilaterally and simultaneously. This allows the patient to compare and report any differences between the left and right sides. Light pressure should be used (the amount of pressure one can tolerate when gently pushing on one's closed eyelid without feeling discomfort is a good comparative measure), and if any difference is reported between the left and right sides, the patient is asked to classify the discomfort as mild, moderate, or severe. If there is evidence of significant asynchronous movement or TMJ dysfunction, a systematic sequence for comprehensive muscle palpation should be followed as described by Solberg[9] and Krogh-Poulsen and Olsson.[11] Each palpation site is given a numerical score based on the patient's response. If neuromuscular or TMJ treatment is initiated, the examiner can then repalpate the same sites periodically to assess the response to treatment (Fig. 1-12).

Lips

The patient is observed for tooth visibility during normal and exaggerated smiling. This can be critical in fixed prosthodontic treatment planning,[12] especially for margin placement of certain metal-ceramic crowns. Some patients show only their maxillary teeth during smiling. More than 25% do not show the gingival third of the maxillary central incisors during an exaggerated smile[13] (Fig. 1-13). The extent of the smile depends on the length and mobility of the upper lip and the length of the alveolar process. When the patient laughs, the jaws open slightly and a dark space is often visible between the maxillary and mandibular teeth (Fig. 1-14). This has been called the *negative space*.[14] Missing teeth, diastemas, and fractured or poorly restored teeth disrupt the harmony of the negative space and often require correction.[15]



Fig. 1-11
Muscle palpation. **A,** The masseter. **B,** The temporal muscle. **C,** The trapezius muscle. **D,** The sternocleidomastoid muscle. **E,** The floor of the mouth.



Palpation is best done bilaterally, simultaneously asking the patient to identify any differences between left and right.

Fig. 1-12
Palpation sites for assessing muscle tenderness. *A,* Temporomandibular joint capsule: lateral and dorsal. *B,* Masseter: deep and superficial. *C,* Temporal muscle: anterior and posterior. *D,* Vertex. *E,* Neck: nape and base. *F,* Sternocleidomastoid muscle: insertion, body, and origin. *G,* Medial pterygoid muscle. *H,* Posterior digastric muscle. *I,* Temporal tendon. *J,* Lateral pterygoid muscle. *(From Krogh-Poulsen WG, Olsson A: Occlusal disharmonies and dysfunction of the stomatognathic system. Dent Clin North Am 10:627, 1966.)*



Fig. 1-13
Smile analysis is an important part of the examination, particularly when anterior crowns or fixed dental prostheses are being considered. **A,** Some individuals show considerable gingival tissue during an exaggerated smile. **B,** Others may not show the gingival margins of even the central incisors.



Fig. 1-14
The "negative space" between the maxillary and mandibular teeth is assessed during the examination.

Intraoral Examination

The intraoral examination can reveal considerable information concerning the condition of the soft tissues, teeth, and supporting structures. The tongue, floor of the mouth, vestibule, cheeks, and hard and soft palates are examined, and any abnormalities are noted. This information can be evaluated properly during treatment planning only if objective indices, rather than vague assessments, are used.

Periodontal Examination

Robert F. Baima

A periodontal examination[16] should provide information regarding the status of bacterial accumulation, the response of the host tissues, and the degree of reversible and irreversible damage. Because long-term periodontal health is essential for successful fixed prosthodontics (see Chapter 5), existing periodontal disease must be corrected before any definitive prosthodontic treatment is undertaken.

Gingiva

The gingiva should be lightly dried before examination so that moisture does not obscure subtle changes or detail. Color, texture, size, contour, consistency, and position are noted and recorded. The gingiva is then carefully palpated to express any exudate or pus that may be present in the sulcular area.

Healthy gingiva (Fig. 1-15*A*) is pink, stippled, and firmly bound to the underlying connective tissue. The free margin of the gingiva is knife-edged, and sharply pointed papillae fill the interproximal spaces. Any deviation from these findings should be noted. With the development of chronic marginal gingivitis (Fig. 1-15*B*), the gingiva becomes enlarged and bulbous, loss of stippling occurs, the margins and papillae are blunted, and bleeding and exudate are observed.

The width of the band of attached keratinized gingiva around each tooth may be assessed by measuring the surface band of keratinized tissue in an apicocoronal dimension with a periodontal probe and subtracting the measurement of the sulcus depth. Another method of obtaining this measurement by visual examination is to gently depress the marginal gingiva with the side of a periodontal probe or explorer. At the mucogingival junction (MGJ), the effect of the instrument is seen to end abruptly, indicating the transition from tightly bound gingiva to more flexible mucosa. Injecting anesthetic solution into the nonkeratinized mucosa close to the MGJ to make the mucosa balloon slightly is a third method of visualizing the MGJ. However, this is done only if the other methods do not provide the desired information.

Periodontium

The periodontal probe (Fig. 1-16*A*) is one of the most reliable and useful diagnostic tools available for



Fig. 1-15

A, Healthy gingiva: pink, knife-edged, and firmly attached. **B,** Gingivitis: Plaque and calculus have caused marginal inflammation, with changes in color, contour, and consistency of the free gingival margin. Inflammation extends into the keratinized attached gingiva.

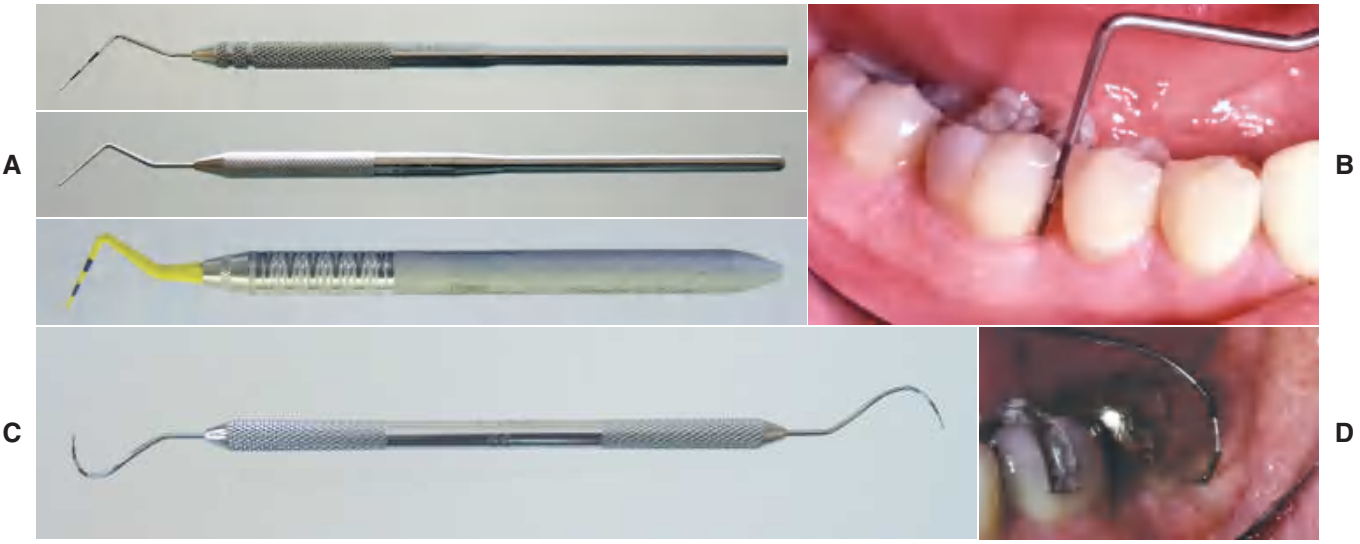


Fig. 1-16

A, Three types of sulcus/pocket-measuring probes. **B,** Correct position of a periodontal probe in the interproximal sulcular area, parallel to the root surface and in a vertical direction as far interproximally as possible. **C** and **D**, Graduated furcation probe. (***A*** *and* ***C****, From Boyd: Dental Instruments, 2nd ed. St. Louis, WB Saunders, 2005.)*

examining the periodontium. It provides a measurement (in millimeters) of the depth of periodontal pockets and healthy gingival sulci on all surfaces of each tooth. In this examination, the probe is inserted essentially parallel to the tooth and is "walked" circumferentially through the sulcus in firm but gentle steps; the examiner determines the measurement when the probe is in contact with the apical portion of the sulcus (Fig. 1-16*B*). Thus, any sudden change in the attachment level can be detected. The probe may also be angled slightly (5 to 10 degrees) in the interproximal areas to reveal the topography of an existing lesion. Probing depths (usually six per tooth) are recorded on a periodontal chart (Fig. 1-17), which also contains other data pertinent to the periodontal examination (e.g., tooth mobility or malposition, open or deficient contact areas, inconsistent marginal ridge heights, missing or impacted teeth, areas of inadequate attached keratinized gingiva, gingival recession, furcation involvements, and malpositioned frenum attachments).

Clinical Attachment Level

Documenting the level of attachment helps the clinician determine the amount of periodontal destruction that has occurred and is essential in rendering a diagnosis of periodontitis (loss of connective tissue attachment).[17,18] This measurement also provides the clinician with more detailed and

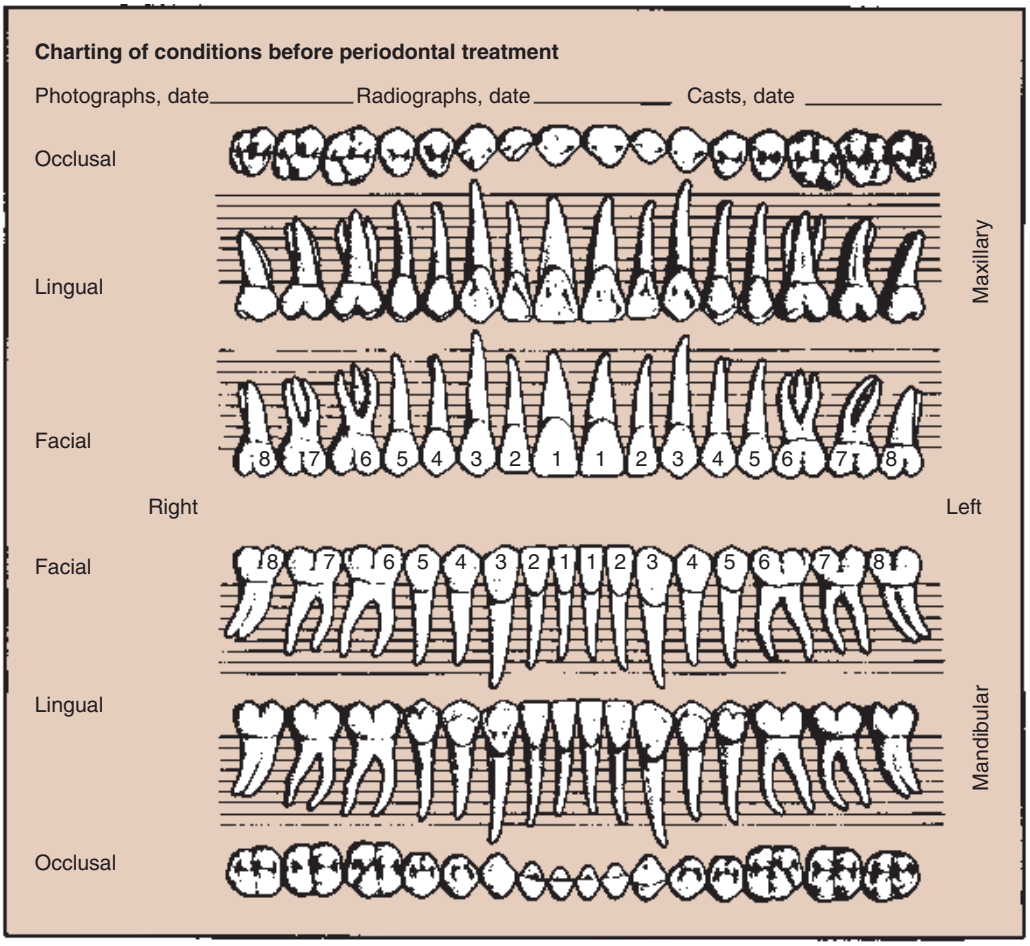


Fig. 1-17

Chart for recording pocket depths. The parallel lines are approximately 2 mm apart. The notations involved in using the chart are as follows: 1, Block out any missing teeth. 2, Draw a red *X* through the crown of any tooth that is to be extracted. 3, Record the gingival level with a continuous blue line. 4, Record pocket depths with a red line interrupted at the proximal surfaces of each tooth. 5, Shade the pocket form on each tooth with a red pencil (between the red and blue lines). 6, Indicate bifurcation or trifurcation involvements with a small red *X* at the involved area. 7, Record open contacts with vertical parallel lines (||) through the area. 8, Record improper contacts with a wavy red line through the area. 9, Record gingival overhang(s) with a red spur (^) through the area. 10, Outline cavities and faulty restorations of periodontal significance in red. 11, Indicate rotated teeth by outlining in blue to show their actual position. *(Modified from Goldman HM, Cohen DW: Periodontal Therapy, 5th ed. St. Louis, Mosby, 1973.)*

accurate information regarding the prognosis of an individual tooth. The clinical attachment level is determined by measuring the distance between the apical extent of the probing depth and a fixed reference point on the tooth, most commonly either the apical extent of a restoration and/or the cementoenamel junction (CEJ). This measurement can be documented on modified periodontal charts (Fig. 1-18) and incorporated with the standard periodontal documentation (see Fig. 1-17) to complete the clinical periodontal examination. When the free margin of the gingiva is located on the clinical crown and the level of the epithelial attachment is at the CEJ, there is no loss of attachment, and recession is noted as a negative number. When the level of the epithelial attachment is on root structure and the free margin of the gingiva is at the CEJ, the attachment loss equals the probing depth, and the recession is 0. In a situation in which there is increased periodontal destruction and recession, the loss of attachment measurement equals the probing depth plus the measurement of recession[19] (see Fig. 1-18*B* and *C*). Clinical attachment loss is a measure of periodontal destruction at a site, rather than current disease activity, and it may be considered the diagnostic "gold standard" for periodontitis.[20] It should be documented in the initial periodontal examination.[21] It is an important consideration in the devel-

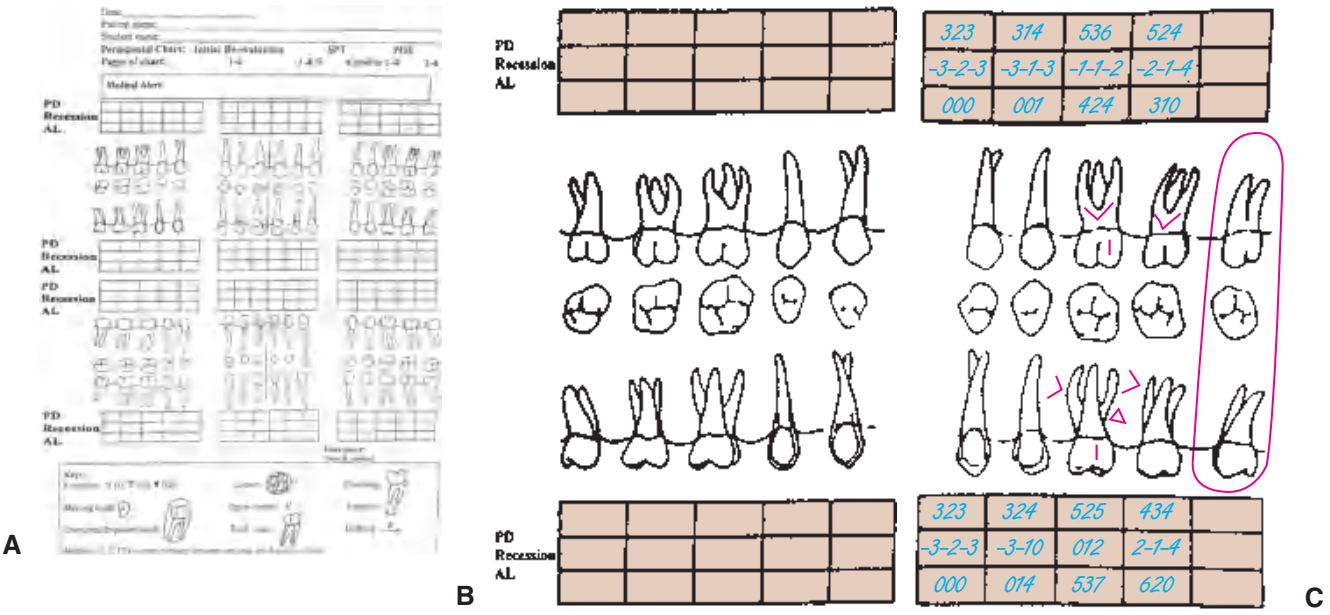


Fig. 1-18

A, Modified periodontal chart. **B,** Maxillary right sextant of modified periodontal chart with areas to record probing depths (PD), recession, and attachment loss (AL). **C,** Maxillary left sextant of modified periodontal chart exhibiting clinical documentation. *(Courtesy of the University of Detroit Mercy School of Dentistry, Department of Periodontology and Dental Hygiene, Detroit, Michigan.)*

opment of the overall diagnosis, treatment plan, and prognosis of the dentition and can be an effective research tool.

Dental Charting

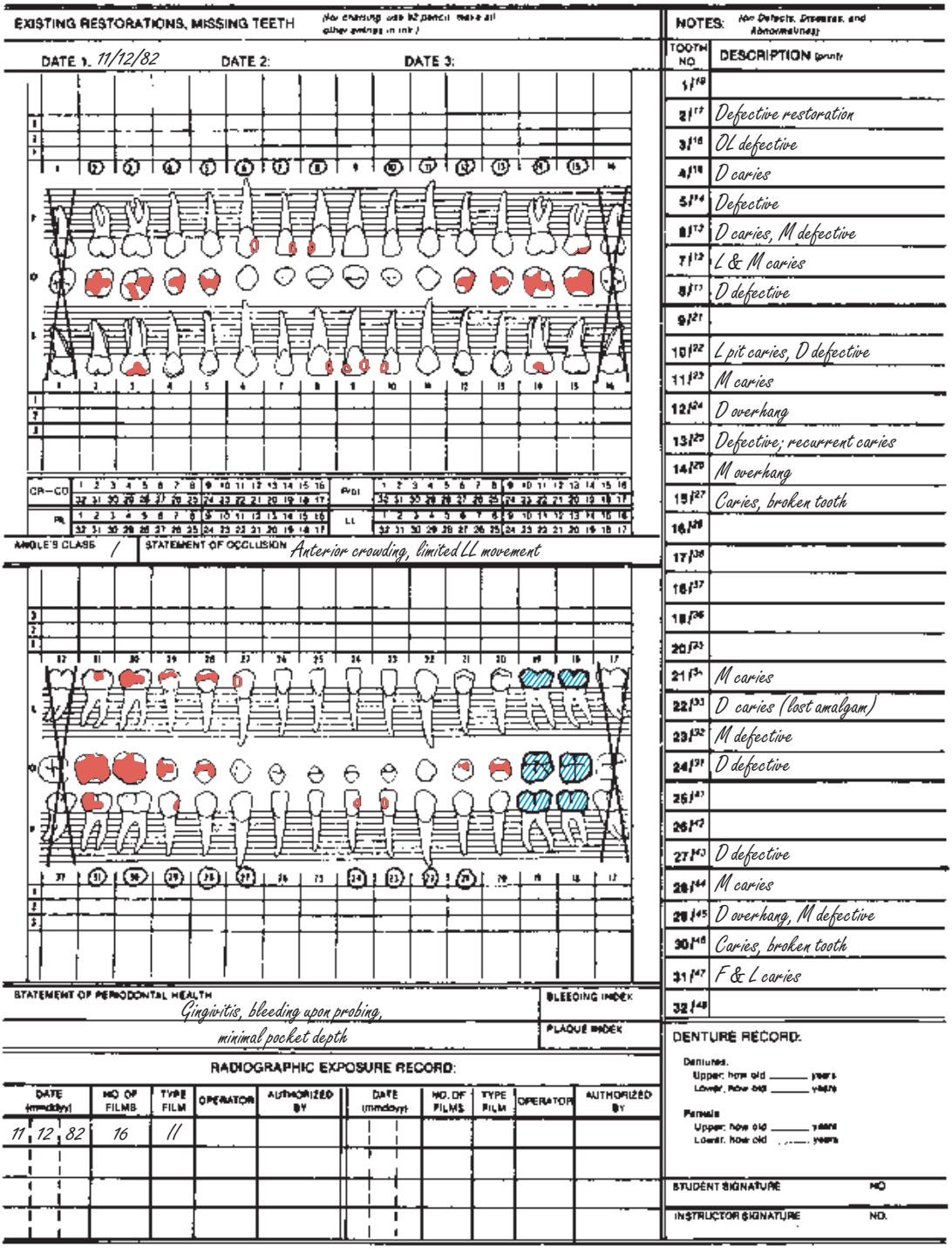
An accurate charting of the state of the dentition reveals important information about the condition of the teeth and facilitates treatment planning. Adequate charting (Fig. 1-19), in addition to all periodontal information, must show the presence or absence of teeth, dental caries, restorations, wear faceting and abrasions, fractures, malformations, and erosions. Missing teeth often have an effect on the position of adjacent teeth (see also the section on arch integrity in Chapter 3). Similarly, the presence of dental caries on one interproximal surface should alert the examiner to carefully inspect the adjacent proximal wall, even if caries is not apparent radiographically. The degree and extent of caries development over time can have a considerable effect on the eventual outcome of fixed prosthodontic treatment. The condition and type of the existing restorations are noted (e.g., amalgam, cast gold, composite resin, all-ceramic). Open contacts and areas where food impaction occurs must also be identified. The presence of wear facets is indicative of sliding contact sustained over time and thus may indicate parafunctional activity (see Chapter 4). Wear facets are often easier to see on diagnostic casts, however (see Chapter 2); during the clinical examination, the location of any observed facet is recorded. Fracture lines in teeth may necessitate fixed prosthodontic intervention, although minor hairline cracks in walls that are not subject to excessive loading can often go untreated and simply be observed at recall appointments (see Chapter 32). The location of fractures should be indicated on the chart, as should any other abnormalities.

Occlusal examination

The initial clinical examination starts with the clinician's asking the patient to make a few simple opening and closing movements while the clinician carefully observes the opening and closing strokes. The objective is to determine to what extent the patient's occlusion differs from the ideal (see Chapter 4) and how well the patient has adapted to this difference. Special attention is given to initial contact, tooth alignment, eccentric contacts, and jaw maneuverability.

Initial tooth contact

The relationship of teeth in both centric relation (see Chapter 4) and the maximum intercuspation should be assessed. If all teeth come together simultaneously at the end of terminal hinge closure, the centric relation (CR) position of the patient is said to coincide with the maximum intercuspation (MI) (see Chapters 2 and 4). The patient is guided into a terminal hinge closure to detect where initial tooth



A

Fig. 1-19

A, An appropriate charting system designates the location, type, and extent of existing restorations and the presence of any disease condition, all of which become part of the permanent patient record.

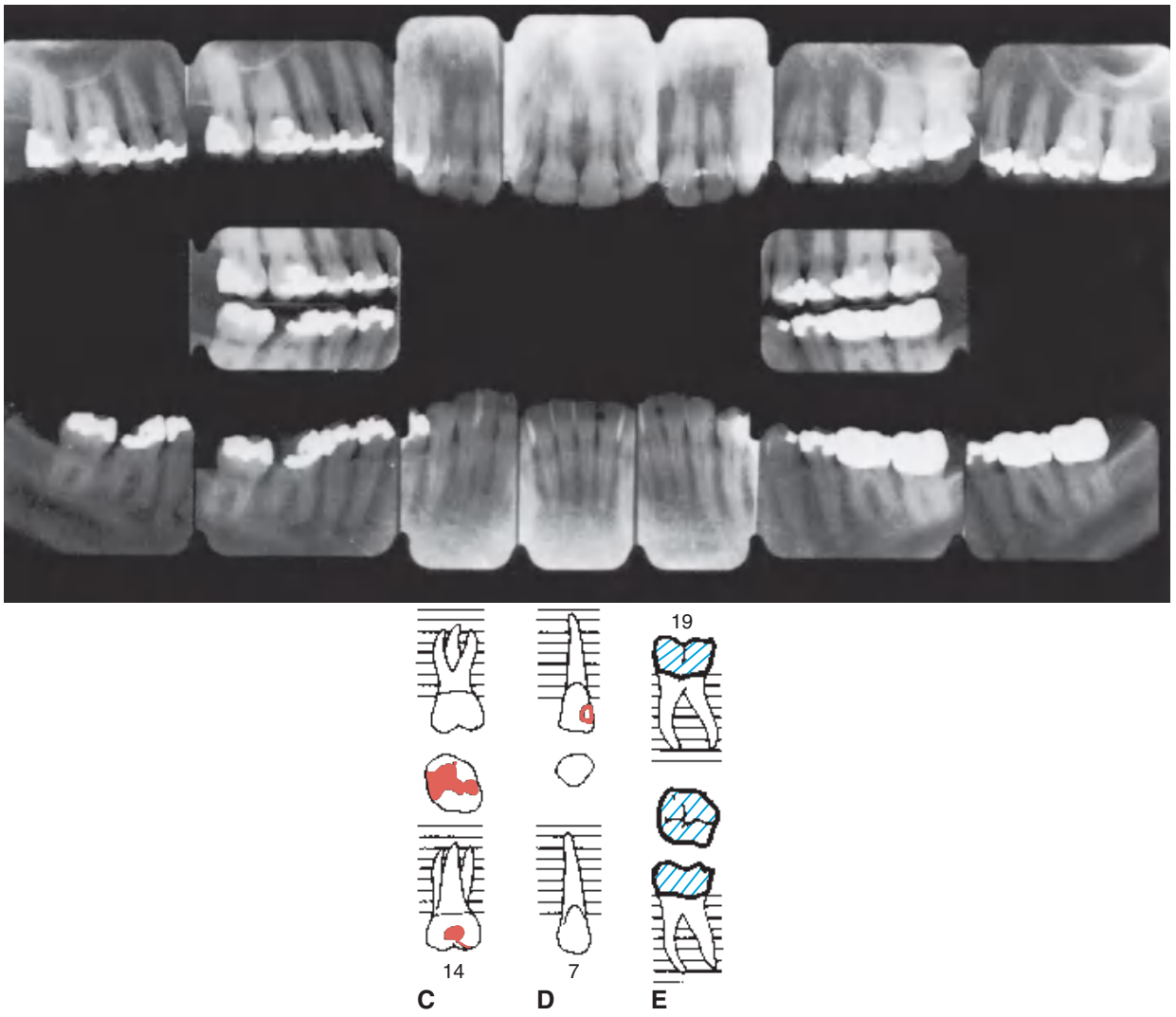


Fig. 1-19, cont'd

B, Radiographic findings obtained from a full-mouth series are correlated with the clinical findings and noted in the record. **C** to **E,** Charting is performed to provide a quick reference to conditions in the mouth. The following may be useful: (1) Amalgam restorations (**C**) are depicted by an outline drawing blocked in solidly to show the size, shape, and location of the restoration. (2) Tooth-colored restorations (**D**) are depicted by an outline drawing of the size, shape, and location of the restoration. (3) Gold restorations (**E**) are depicted by an outline drawing inscribed with diagonal lines to show the size, shape, and location of the restoration. (4) Missing teeth are denoted by a large *X* on the facial, lingual, and occlusal diagrams of each tooth that is not visible clinically or on radiographs. (5) Caries is recorded by circling the tooth number located at the apex of the involved tooth and noting the presence and location of the cavity in the description column corresponding to the tooth number on the right. (6) Defective restorations are recorded by circling the tooth number and noting the defect in the description column. *(Modified from Roberson T, et al: The Art and Science of Operative Dentistry, 4th ed. St. Louis, Mosby, 2002.)*

contact occurs (see the sections on bimanual manipulation and terminal hinge closure in Chapters 2 and 4). The clinician should ask the patient to "close feather-light" until any of the teeth touch and to have the patient help identify where that initial contact occurs by asking him or her to point at the location. If initial contact occurs between two posterior teeth (usually molars), the subsequent movement from the initial contact to the MI position is carefully observed and its direction noted. This is referred to as a ***slide from CR to MI***. The presence, direction, and estimated magnitude of the slide are recorded, and the teeth on which initial contact occurs are identified. Any such discrepancy between CR and MI should be evaluated in the context of other signs and symptoms that may be present (e.g., elevated muscle tone previously observed during the extraoral examination, mobility on the teeth where initial contact occurs, wear facets on the teeth involved in the slide).

General alignment

The teeth are evaluated for crowding, rotation, supraeruption, spacing, malocclusion, and vertical and horizontal overlap (Fig. 1-20). Teeth adjacent to edentulous spaces often have shifted position slightly. Small amounts of tooth movement can significantly affect fixed prosthodontic treatment. Tipped teeth affect tooth preparation design or, in severe cases, may result in a need for minor tooth movement before restorative treatment. Supraerupted teeth are often overlooked clinically but frequently complicate fixed dental prosthesis design and fabrication.

The relative relationship of adjacent teeth to teeth that require fixed prosthodontic treatment is important. A tooth may have drifted into the space previously occupied by the tooth in need of treatment because a large filling was previously lost. Such changes in alignment can seriously complicate or preclude fabrication of a cast restoration for the damaged tooth and may even necessitate its extraction.

Lateral and protrusive contacts

Excursive contacts on posterior teeth may be undesirable under certain circumstances (see Chapter 4).

The degree of vertical and horizontal overlap of the teeth is noted. When asked, most patients are capable of making an unguided protrusive movement. During this movement, the degree of posterior disclusion that results from the overlaps of the anterior teeth is observed.

The patient is then guided into lateral excursive movements, and the presence or absence of contacts on the nonworking side and then the working side is noted. Such tooth contact in eccentric movements can be verified with a thin Mylar strip (shim stock). Any posterior cusps that hold the shim stock are evident (Fig. 1-21). Teeth that are subject to excessive loading may develop varying degrees of mobility. Tooth movement (**fremitus**) should be identified by palpation (Fig. 1-22). If a heavy contact is suspected, a finger placed against the buccal or labial surface while the patient lightly taps the teeth together helps locate fremitus in MI.

Jaw maneuverability

The ease with which the patient moves the jaw and the way it can be guided through hinge closure and excursive movements should be assessed, because



A

B

Fig. 1-21

A, Eccentric tooth contact can be tested with thin Mylar shim stock (**B**).



Fig. 1-20

Alignment of the dentition can be assessed intraorally, although diagnostic casts allow a more detailed assessment. This patient has caries-free teeth in good alignment.



Fig. 1-22

Fremitus (movement on palpation) indicates tooth contact during lateral excursions.

these factors are a good guide to neuromuscular and masticatory function. If the patient has developed a pattern of protective reflexes, manipulating the jaw is difficult. The patient's restricted maneuverability is recorded.

Radiographic Examination

Radiographs provide essential information to supplement the clinical examination. Detailed knowledge of the extent of bone support and the root structure of each standing tooth is essential for establishing a comprehensive fixed prosthodontic treatment plan. Although radiation exposure guidelines recommend limiting the number of radiographs to only those that will result in potential changes in treatment decisions, a full periapical series (Fig. 1-23) is normally required for new patients so that a comprehensive fixed prosthodontic treatment plan can be developed. Patient exposure can be minimized by

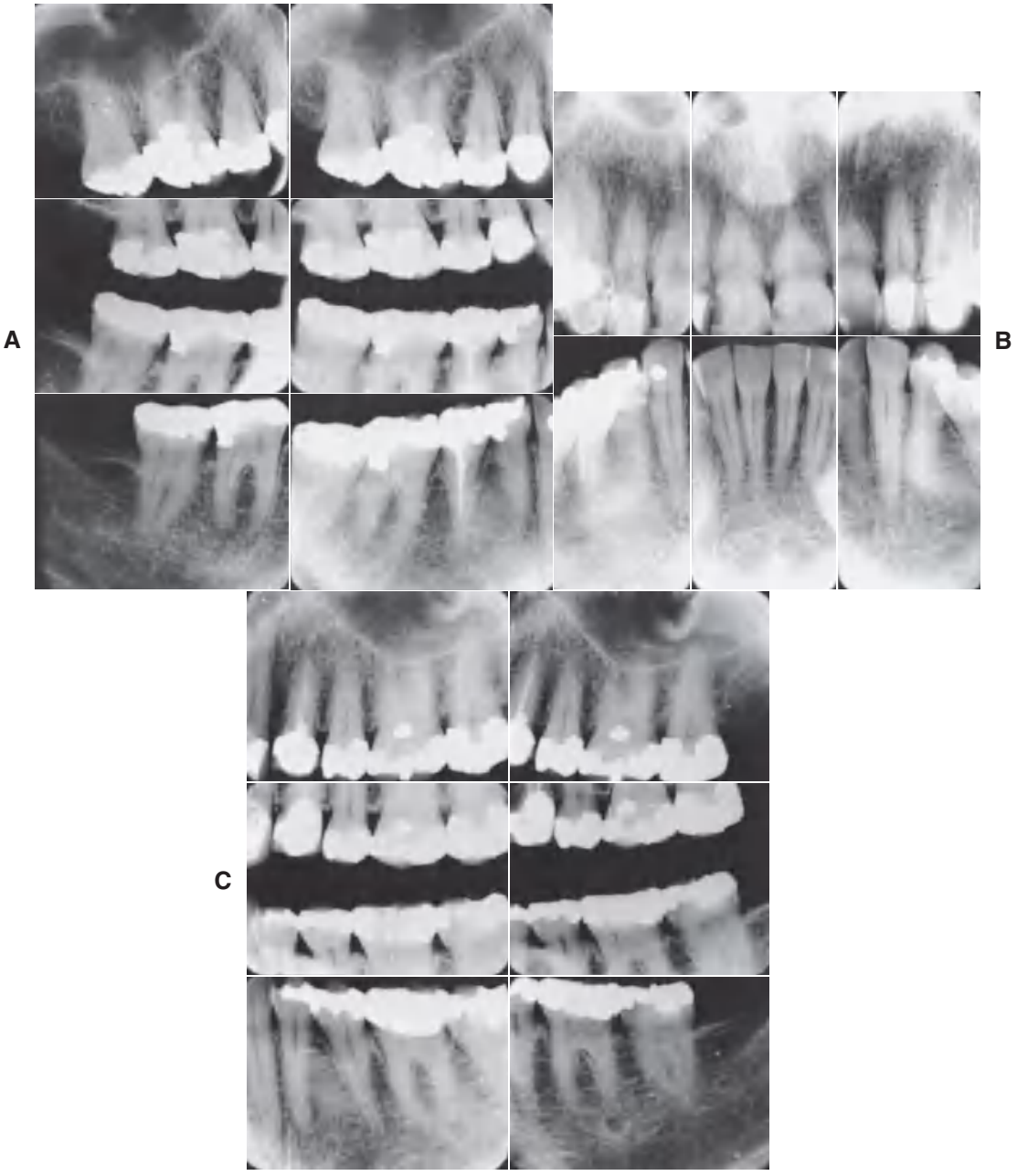


Fig. 1-23
A to **C**, A full-mouth radiographic survey should enable the dentist to make a detailed assessment of the structure of each tooth and its bone support.



Fig. 1-24
A panoramic film cannot be substituted for a full-mouth series because the image is distorted. Nevertheless, it is very useful for assessing unerupted teeth, screening edentulous areas for buried root tips, and evaluating the bone before implant placement.

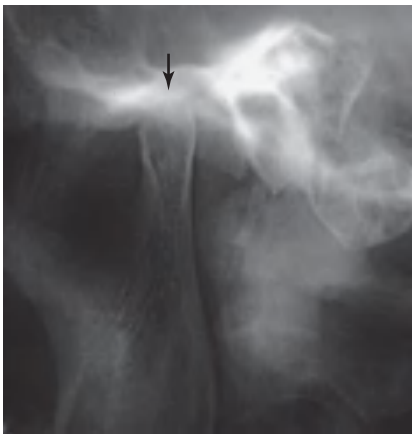


Fig. 1-25
A transcranial radiograph shows the lateral pole of the mandibular condyle (*arrow*).

using a technique that provides the most information with a minimal need for repeat films and by using appropriate protection. The use of digital radiography can further help reduce radiation exposure.

Panoramic films (Fig. 1-24) provide useful information about the presence or absence of teeth. They are especially helpful in assessing third molars and impactions, evaluating the bone before implant placement (see Chapter 13), and screening edentulous arches for buried root tips. However, they do not provide a sufficiently detailed view for assessing bone support, root structure, caries, or periapical disease.

Special radiographs may be needed for the assessment of TMJ disorders and a wide variety of pathologies ranging from bone and mineral disorders to metabolic disorders, genetic abnormalities, and soft tissue calcifications such as carotid artery calcification.[21] For assessment of the TMJs, a transcranial exposure (Fig. 1-25), with the help of a positioning device, reveals the lateral third of the mandibular condyle and can be used to detect structural and positional changes. However, interpretation may be difficult,[22] and more information may be obtained from other images[23] (Fig. 1-26).

Vitality Testing

Before any restorative treatment, pulpal health must be assessed, usually by measuring the response to gentle tapping with an instrument, or **percussion,** and thermal or electrical stimulation. A diagnosis of nonvitality can be confirmed by preparing a test cavity without the administration of local anesthetic. Vitality tests, however, assess only the afferent nerve supply. Misdiagnosis can occur if the nerve supply is damaged but the blood supply is intact. Careful inspection of radiographs is therefore essential in the examination of such teeth.

DIAGNOSIS AND PROGNOSIS

Not all patients seeking fixed prosthodontic treatment have diagnostic problems. Nevertheless, diagnostic errors are possible, especially when a patient complains of pain or symptoms of occlusal dysfunction. Treatment may be needed to eliminate obvious dental caries, to restore a fractured prosthesis, or to replace a missing tooth. A logical and systematic approach to diagnosis helps avoid mistakes.

Differential Diagnosis

When the history and examination are completed, a differential diagnosis is made. The practitioner should determine the most likely causes of the



Fig. 1-26
More sophisticated techniques permit the generation of computer-assisted images of clinician-determined cross-sections. A, A computerized tomographic (CT) scan. **B,** A magnetic resonance image (MRI) showing the soft tissue in greater detail. *(Courtesy of Dr. J. Petrie.)*

observed condition or conditions and record them in order of probability. A definitive diagnosis can usually be developed after such supporting evidence has been assembled.

A typical diagnosis condenses the information obtained during the clinical history taking and examination. For instance, a diagnosis could read as follows: "28-year-old male, no significant medical history; vital signs normal. Chief complaint: Mesiolingual cusp fracture on tooth #30. Teeth #1, #16, #17, #19, and #32 missing. Patient reports significant postoperative discomfort after previous molar extraction. High smile line. Caries: #6, mesial; #12, distal; #20, mesio-occlusal; and #30, mesio-occlusal-distal. Tooth #8 has received previous endodontic treatment. Generalized gingivitis four posterior quadrants, with recession noted on teeth #23, #24, and #25. 5-mm pockets on teeth #18, #30, and #31. Radiographic evidence of periapical pathology in tooth #30. Tooth #30 tests nonvital."

This hypothetical scenario summarizes the patient's problems, allowing subsequent prioritization as a treatment plan is developed (see Chapter 3). In this case, the patient's chief complaint likely has a longer term history that has only recently led to symptoms that the patient could identify, causing him to seek care.

Prognosis

The prognosis is an estimation of the likely course of a disease. It can be difficult to make, but its importance to patient management and successful treatment planning must nevertheless be recognized. The prognosis of dental disorders is influenced by general factors (age of the patient, lowered resistance of the oral environment) and local factors (forces applied to a given tooth, access for oral hygiene measures). For example, a young person with periodontal disease has a more guarded prognosis than does an older person with the same disease experience. In the younger person, the disease has followed a more virulent course because of the generally less developed systemic resistance; these facts should be reflected in treatment planning.

Fixed prostheses function in a hostile environment: the moist oral environment is subject to constant changes in temperature and acidity and considerable load fluctuation. A comprehensive clinical examination helps identify the likely prognosis. All facts and observations are first considered individually and then correlated appropriately.

General factors

The overall caries rate of the patient's dentition indicates future risk to the patient if the condition is left untreated. Important variables include the patient's understanding and comprehension of plaque-control measures, as well as the physical ability to perform those tasks. Systemic problems analyzed in the context of the patient's age and overall health provide important information. Diabetic patients are prone to a higher incidence of periodontal disease, and special precautionary measures may be indicated before treatment begins. Such conditions also affect the overall prognosis.

Some patients are capable of an extremely high occlusal force (see page 238), whereas others are

not. If an elevated muscle tone of hypertrophied elevator muscles is identified during the extraoral examination and multiple intraoral wear facets are observed, loading of the teeth is considerably higher than in the dentition of a frail 90-year-old who tires easily when asked to close. Other important factors in determining overall prognosis are the history and success of previous dental treatments. If a patient's previous dental care has been successful over a period of many years, a better prognosis can be anticipated than when apparently properly fabricated prostheses fail or become dislodged within a few years of initial placement.

Local factors

The observed vertical overlap of the anterior teeth has a direct effect on the load distribution in the dentition and thus can have an effect on the prognosis. In the presence of favorable loading, minor tooth mobility is less of a concern than in the presence of unfavorably directed or high load. Impactions adjacent to a molar that will be crowned may pose a serious threat in a younger individual, in whom additional growth can be anticipated, but it may be of lesser concern in an older individual.

Individual tooth mobility, root angulation, root structure, crown/root ratios, and many other variables all have an effect on the overall fixed prosthodontic prognosis. They are addressed later in this book.

Prosthodontic Diagnostic Index (PDI) for the Partially Edentulous and the Completely Dentate Patient

The American College of Prosthodontists (ACP) has developed diagnostic indices for partial edentulism[24] and for the completely dentate patient[25] on the basis of diagnostic findings that are summarized here with the permission and support of the ACP. These guidelines are intended to help practitioners determine appropriate treatments for their patients. For each index, four categories, Class I to Class IV, are defined; Class I represents an uncomplicated clinical situation and Class IV represents a complex clinical situation. The indices are designed for use by dental professionals involved in the diagnosis and treatment of partially edentulous and completely dentate patients. Potential benefits of the system include (1) improved intraoperator consistency, (2) improved professional communication, (3) insurance reimbursement commensurate with complexity of care, (4) improved screening tool for dental school admission clinics, (5) standardized criteria for outcomes assessment and research, (6) enhanced diagnostic consistency, and (7) simplified aid in the decision to refer a patient.

Each class is differentiated by specific diagnostic criteria (ideal or minimal, moderately compromised, substantially compromised, or severely compromised) of the following (for the partially edentulous):

1. Location and extent of the edentulous area or areas
2. Condition of the abutment teeth
3. Occlusal scheme
4. Residual ridge

For the completely dentate patient, only tooth condition and occlusal scheme are evaluated.

Location and Extent of the Edentulous Areas

In the *ideal or minimally compromised edentulous area*, the edentulous span is confined to a single arch and one of the following:

- Any anterior maxillary span that does not exceed two missing incisors
- Any anterior mandibular span that does not exceed four missing incisors
- Any posterior maxillary or mandibular span that does not exceed two premolars or one premolar and one molar

In the *moderately compromised edentulous area,* the edentulous span is in both arches, and one of the following conditions exists:

- The span includes any anterior maxillary span that does not exceed two missing incisors
- The span includes any anterior mandibular span that does not exceed four missing incisors
- The span includes any posterior maxillary or mandibular span that does not exceed two premolars or one premolar and one molar
- The maxillary or mandibular canine is missing

The *substantially compromised edentulous area* includes

- Any posterior maxillary or mandibular span that is greater than three missing teeth or two molars
- Any edentulous span, including anterior and posterior areas of three or more missing teeth

The *severely compromised edentulous area* includes

- Any edentulous area or combination of edentulous areas whose care requires a high level of patient compliance

Condition of the Abutment Teeth (Tooth Condition for Completely Dentate Patients)

Ideal or minimally compromised abutment teeth condition:

- No preprosthetic therapy is indicated

Moderately compromised abutment teeth condition:

- Tooth structure is insufficient to retain or support intracoronal restorations, in one or two sextants
- Abutments require localized adjunctive therapy (i.e., periodontal, endodontic, or orthodontic procedures in one or two sextants)

Substantially compromised abutment teeth condition:

- Tooth structure is insufficient to retain or support intracoronal or extracoronal restorations, in four or more sextants
- Abutments require extensive adjunctive therapy (i.e., periodontal, endodontic or orthodontic procedures- in four or more sextants)

Severely compromised abutment teeth condition:

- Abutments have a guarded prognosis

Occlusal Scheme

Ideal or minimally compromised occlusal scheme:

- No preprosthetic therapy required
- Class I molar and jaw relationships

Moderately compromised occlusal scheme:

- Occlusal scheme requires localized adjunctive therapy (e.g., enameloplasty on premature occlusal contacts)
- Class I molar and jaw relationships

Substantially compromised occlusal scheme:

- Entire occlusal scheme requires reestablishment but without any change in the occlusal vertical dimension
- Class II molar and jaw relationships

Severely compromised occlusal scheme:

- Entire occlusal scheme requires reestablishment with changes in the occlusal vertical dimension
- Class II, Division 2, and Class III molar and jaw relationships

Residual Ridge

The criteria published for the Classification System for Complete Edentulism[26] are used to categorize any edentulous span present in the partially edentulous patient.

Classification System

The four criteria and their subclassifications are organized into an overall classification system for partial edentulism; the two criteria provide the system for completely edentulous patients.

Class I

This class (Figs. 1-27 and 1-28) is characterized by ideal or minimal compromise in the location and extent of edentulous area (which is confined to a single arch), abutment conditions, occlusal characteristics, and residual ridge conditions. All four of the diagnostic criteria are favorable.

1. The location and extent of the edentulous area are ideal or minimally compromised:
   The edentulous area is confined to a single arch.
   The edentulous area does not compromise the physiologic support of the abutments.
   The edentulous area may include any anterior maxillary span that does not exceed two incisors, any anterior mandibular span that does not exceed four missing incisors, or any posterior span that does not exceed two premolars or one premolar and one molar.
2. The abutment condition is ideal or minimally compromised, with no need for preprosthetic therapy.
3. The occlusion is ideal or minimally compromised, with no need for preprosthetic therapy; maxillomandibular relationship consists of Class I molar and jaw relationships.
4. Residual ridge morphology conforms to the Class I complete edentulism description.

Class II

This class (Figs. 1-29 and 1-30) is characterized by moderately compromised location and extent of edentulous areas in both arches, abutment conditions necessitating localized adjunctive therapy, occlusal characteristics necessitating localized adjunctive therapy, and residual ridge conditions.

1. The location and extent of the edentulous area are moderately compromised:
   Edentulous areas may exist in one or both arches.
   The edentulous areas do not compromise the physiologic support of the abutments.
   Edentulous areas may include any anterior maxillary span that does not exceed two incisors, any anterior mandibular span that does not exceed four incisors, any posterior span (maxillary or mandibular) that does not exceed two premolars, or one premolar and one molar or any missing canine (maxillary or mandibular).
2. Condition of the abutments is moderately compromised:
   Abutments in one or two sextants have insufficient tooth structure to retain or support intracoronal or extracoronal restorations.
   Abutments in one or two sextants require localized adjunctive therapy.

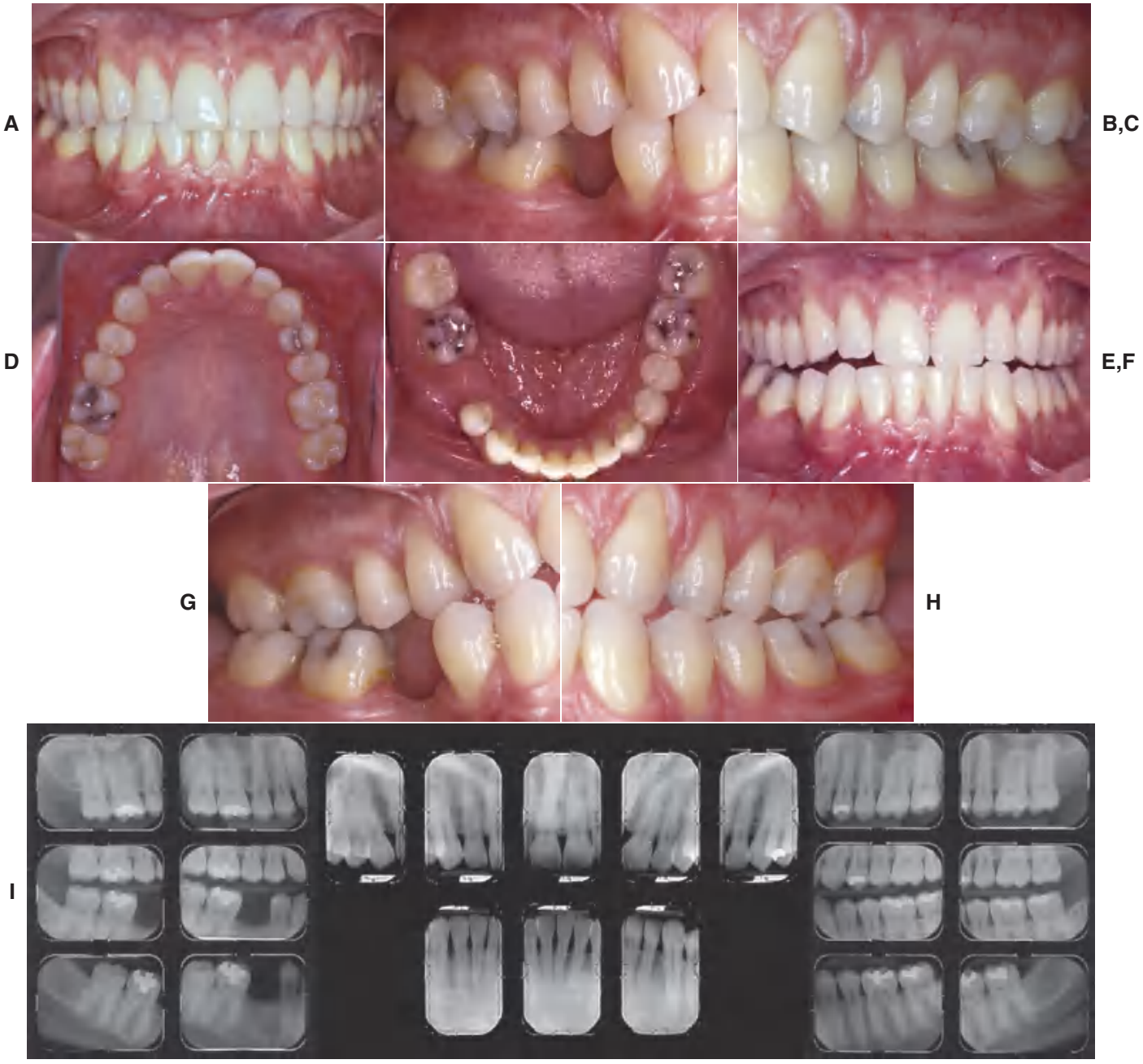


Fig. 1-27

Class I patient. This patient is categorized as Class I because of an ideal or minimally compromised edentulous area, abutment condition, and occlusion. There is a single edentulous area in one sextant. The residual ridge is considered type A. A, Frontal view, maximum intercuspation. B, Right lateral view, maximum intercuspation. C, Left lateral view, maximum intercuspation. D, Occlusal view, maxillary arch. E, Occlusal view, mandibular arch. F, Frontal view, protrusive relationship. G, Right lateral view, right working movements. H, Left lateral view, working movement. I, Full-mouth radiographic series. *(From McGarry TJ, et al: Classification system for partial edentulism. J Prosthodont 11:181, 2002.)*



Fig. 1-28

Class I patient. The patient is categorized as Class I because an ideal or minimally compromising tooth condition, and occlusal scheme is exhibited. A single large amalgam core restoration requires a complete coverage restoration in one sextant. A, Frontal view, maximum intercuspation. B, Right lateral view, maximum intercuspation. C, Left lateral view, maximum intercuspation. D, Occlusal view, maxillary arch. E, Occlusal view, mandibular arch. F, Panoramic radiograph. *(From McGarry TJ, et al: Classification system for the completely dentate patient. J Prosthodont 13:73, 2004.)*



Fig. 1-29

Class II patient. This patient is categorized as Class II because he has edentulous areas in two sextants in different arches. A, Frontal view, maximum intercuspation. B, Right lateral view, maximum intercuspation. C, Left lateral view, maximum intercuspation. D, Occlusal view, maxillary arch. E, Occlusal view, mandibular arch. F, Frontal view, protrusive relationship. G, Right lateral view, right working movement. H, Left lateral view, left working movement. I, Full-mouth radiographic series. *(From McGarry TJ, et al: Classification system for partial edentulism. J Prosthodont 11:181, 2002.)*



Fig. 1-30

Class II patient. The patient is categorized as Class II because one sextant exhibits three defective restorations with an esthetic component. Additional variables of gingival architecture and individual tooth proportions increase the complexity of diagnosis. A, Frontal view, maximum intercuspation. B, Right lateral view, maximum intercuspation. C, Left lateral view, maximum intercuspation. D, Occlusal view, maxillary arch. E, Occlusal view, mandibular arch. F, Panoramic radiograph. *(From McGarry TJ, et al: Classification system for the completely dentate patient. J Prosthodont 13:73, 2004.)*

3. Occlusion is moderately compromised:
   Occlusal correction requires localized adjunctive therapy.
   Maxillomandibular relationship: Class I molar and jaw relationships.
4. Residual ridge structure conforms to the Class II complete edentulism description.

Class III

This class (Figs. 1-31 and 1-32) is characterized by substantially compromised location and extent of edentulous areas in both arches, abutment condition necessitating substantial localized adjunctive therapy, occlusal characteristics necessitating re-establishment of the entire occlusion without a change in the occlusal vertical dimension, and residual ridge conditions.

1. The location and extent of the edentulous areas are substantially compromised:
   Edentulous areas may be present in one or both arches.
   Edentulous areas compromise the physiologic support of the abutments.

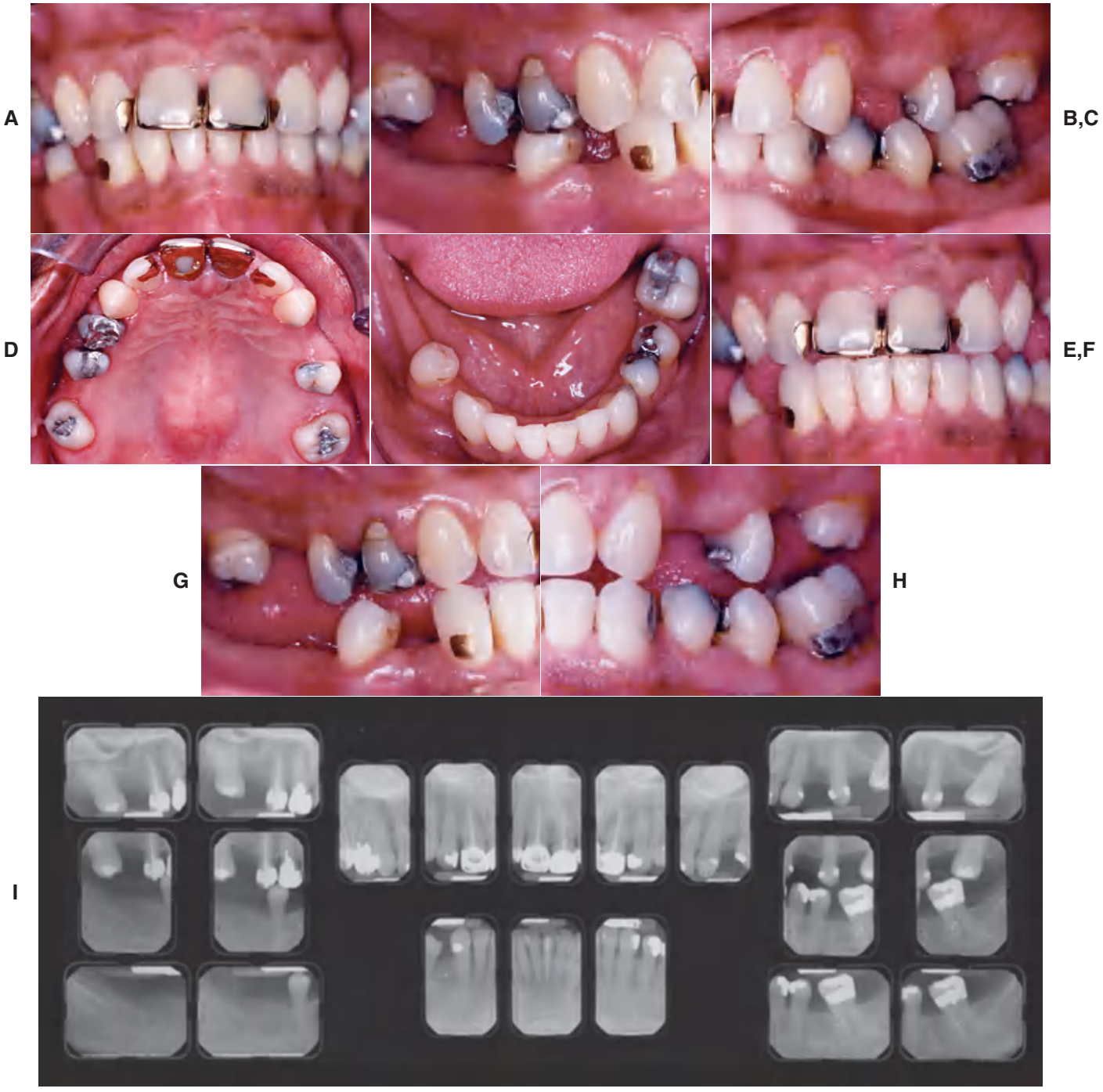


Fig. 1-31

Class III patient. This patient is categorized as Class III because the edentulous areas are located in both arches and there are multiple such locations within each arch. The abutment condition is substantially compromised as a result of the need for extracoronal restorations. There are teeth that are extruded and malpositioned. The occlusion is substantially compromised because reestablishment of the occlusal scheme is required without a change in the occlusal vertical dimension. A, Frontal view, maximum intercuspation. **B,** Right lateral view, maximum intercuspation. **C,** Left lateral view, maximum intercuspation. **D,** Occlusal view, maxillary arch. **E,** Occlusal view, mandibular arch. **F,** Frontal view, protrusive relationship. **G,** Right lateral view, right working movement. **H,** Left lateral view, left working movement. **I,** Full-mouth radiographic series. *(From McGarry TJ, et al: Classification system for partial edentulism. J Prosthodont 11:181, 2002.)*



Fig. 1-32

Class III patient. The patient is categorized as Class III because large defective amalgam and composite restorations are present in four sextants. The remaining tooth structure is substantially compromised in most posterior teeth. The occlusion is substantially compromised, necessitating reestablishment of the occlusal scheme without a change in the occlusal vertical dimension. A, Frontal view, maximum intercuspation. B, Right lateral view, maximum intercuspation. C, Left lateral view, maximum intercuspation. D, Occlusal view, maxillary arch. E, Occlusal view, mandibular arch. F, Panoramic radiograph. *(From McGarry TJ, et al: Classification system for the completely dentate patient. J Prosthodont 13:73, 2004.)*

Edentulous areas may include any posterior maxillary or mandibular edentulous area greater than three teeth or two molars or anterior and posterior edentulous areas of three or more teeth.

2. The condition of the abutments is moderately compromised:
   Abutments in three sextants have insufficient tooth structure to retain or support intracoronal or extracoronal restorations.
   Abutments in three sextants require more substantial localized adjunctive therapy (i.e., periodontal, endodontic or orthodontic procedures).
   Abutments have a fair prognosis.
3. Occlusion is substantially compromised:
   Requires reestablishment of the entire occlusal scheme without an accompanying change in the occlusal vertical dimension.
   Maxillomandibular relationship: Class II molar and jaw relationships.

4. Residual ridge structure conforms to the Class III complete edentulism description.

Class IV

This class (Figs. 1-33 and 1-34) is characterized by severely compromised location and extent of edentulous areas with guarded prognosis, abutments requiring extensive therapy, occlusion characteristics necessitating reestablishment of the occlusion with a change in the occlusal vertical dimension, and residual ridge conditions.

1. The location and extent of the edentulous areas result in severe occlusal compromise:
   Edentulous areas may be extensive and may occur in both arches.
   Edentulous areas compromise the physiologic support of the abutment teeth, and so the prognosis is guarded.
   Edentulous areas include acquired or congenital maxillofacial defects.
   At least one edentulous area has a guarded prognosis.
2. Abutments are severely compromised:
   Abutments in four or more sextants have insufficient tooth structure to retain or support intracoronal or extracoronal restorations.
   Abutments in four or more sextants require extensive localized adjunctive therapy.
   Abutments have a guarded prognosis.
3. Occlusion is severely compromised:
   Reestablishment of the entire occlusal scheme, including changes in the occlusal vertical dimension, is necessary.
   Maxillomandibular relationship: Class II, division 2, or Class III molar and jaw relationships.
4. Residual ridge structure conforms to the Class IV complete edentulism description.

Other characteristics include severe manifestations of local or systemic disease, including sequelae from oncologic treatment, maxillomandibular dyskinesia and/or ataxia, and refractoriness (a patient's presenting with chronic complaints after appropriate therapy).

Guidelines for the Use of PDI Classification System for Partial Edentulism and the Completely Dentate Patient

The analysis of diagnostic factors is facilitated with the use of a worksheet (Tables 1-1 and 1-2). Each criterion is evaluated and a checkmark placed in the appropriate box. In instances in which a patient's diagnostic criteria overlap two or more classes, the patient is categorized in the more complex class.

The following additional guidelines should be followed to ensure consistent application of the classification system:

1. Consideration of future treatment procedures must not influence the choice of diagnostic level.
2. Initial preprosthetic treatment and/or adjunctive therapy can change the initial classification level. Classification may need to be reassessed after existing prostheses are removed.
3. Esthetic concerns or challenges raise the classification by one level in Class I and Class II patients.
4. The presence of symptoms of temporomandibular disorder raises the classification by one or more levels in Class I and Class II patients.
5. In a patient presenting with an edentulous maxilla opposing a partially edentulous mandible, each arch is diagnosed according to the appropriate classification system; that is, the maxilla is classified according to the complete edentulism classification system, and the mandible is classified according to the partial edentulism classification system. The sole exception to this rule occurs when the patient presents with an edentulous mandible opposed by a partially edentulous or dentate maxilla. This clinical situation entails significant complexity and potential long-term morbidity and, as such, should be categorized as Class IV in either system.
6. Periodontal health is intimately related to the diagnosis and prognosis for partially edentulous patients. For the purpose of this system, it is assumed that patients receive therapy to achieve and maintain periodontal health so that appropriate prosthodontic care can be accomplished.

The classification system for partial edentulism is based on the most objective criteria available to facilitate uniform use of the system. Such standardization may lead to improved communications among dental professionals and third parties. This classification system serves to identify patients most likely to require treatment by a specialist or by a practitioner with additional training and experience in advanced techniques. This system should also be valuable to research protocols as different treatment procedures are evaluated. With the increasing complexity of patient treatment, this partial edentulism classification system, coupled with the complete edentulism classification system, helps dental school faculty assess entering patients for the most appropriate patient assignment for better care. On the basis of use and observations by practitioners, educators, and researchers, this system is modified as needed.



Fig. 1-33

Class IV patient. Edentulous areas are found in both arches, and the physiologic abutment support is compromised. Abutment condition is severely compromised as a result of advanced attrition and failing restorations, necessitating extracoronal restorations and adjunctive therapy. The occlusion is severely compromised, necessitating reestablishment of occlusal vertical dimension and proper occlusal scheme. **A,** Frontal view, maximum intercuspation. **B,** Right lateral view, maximum intercuspation. **C,** Left lateral view, maximum intercuspation. **D,** Occlusal view, maxillary arch. **E,** Occlusal view, mandibular arch. **F,** Frontal view, protrusive relationship. **G,** Right lateral view, right working movement. **H,** Left lateral view, left working movement. **I,** Full-mouth radiographic series. *(From McGarry TJ, et al: Classification system for partial edentulism. J Prosthodont 11:181, 2002.)*



Fig. 1-34
Class IV patient. The patient is categorized as Class IV because advanced attrition of the occlusal surfaces is present in more than three sextants. The occlusion is severely compromised with the need to reestablish occlusal vertical dimension and a proper occlusal scheme. A, Frontal view, maximum intercuspation. B, Right lateral view, maximum intercuspation. C, Left lateral view, maximum intercuspation. D, Occlusal view, maxillary arch. E, Occlusal view, mandibular arch. F, Panoramic radiograph. *(From McGarry TJ, et al: Classification system for the completely dentate patient. J Prosthodont 13:73, 2004.)*

SUMMARY

The history and clinical examination must provide sufficient data for the practitioner to formulate a successful treatment plan. If they are too hastily accomplished, details may be missed, which can cause significant problems during treatment, when it may be difficult or impossible to make corrections. Also, the overall outcome and prognosis may be adversely affected. In particular, it is crucial to develop a thorough understanding of special patient concerns relating to previous care and expectations about future treatment. Many problems encountered during fixed prosthodontic treatment are directly traceable to factors overlooked during the initial examination and data collection. A diagnosis is a summation of the observed problems and their underlying etiologies. The patient's overall prognosis is influenced by general and local factors.

Table **1-1** **Worksheet Used to Determine Prosthodontic Diagnostic Index Classification**

	Class I	Class II	Class III	Class IV
Location and Extent of Edentulous Areas				
Ideal or minimally compromised–single arch				
Moderately compromised–both arches				
Substantially compromised–>3 teeth				
Severely compromised–guarded prognosis				
Congenital or acquired maxillofacial defect				
Abutment Condition				
Ideal or minimally compromised				
Moderately compromised–1-2 sextants				
Substantially compromised–3 sextants				
Severely compromised–4 or more sextants				
Occlusion				
Ideal or minimally compromised				
Moderately compromised–local adjunctive treatment				
Substantially compromised–occlusal scheme				
Severely compromised–change in occlusal vertical dimension				
Residual Ridge				
Class I edentulous				
Class II edentulous				
Class III edentulous				
Class IV edentulous				
Conditions Creating a Guarded Prognosis				
Severe oral manifestations of systemic disease				
Maxillomandibular dyskinesia and/or ataxia				
Refractory condition				

Note: Individual diagnostic criteria are evaluated, and the appropriate box is checked. The most advanced finding determines the final classification.
Guidelines for use of the worksheet:
1. Possession of any single criterion of a more complex class places the patient into the more complex class.
2. Consideration of future treatment procedures must not influence the diagnostic level.
3. Initial preprosthetic treatment and/or adjunctive therapy can change the initial classification level.
4. If there is an esthetic concern/challenge, the classification is increased in complexity by one level in Class I and II patients.
5. In the presence of symptoms of temporomandibular disorder, the classification is increased in complexity by one or more levels in Class I and II patients.
6. In the situation in which the patient presents with an edentulous mandible opposing a partially edentulous or dentate maxilla, the patient is categorized as Class IV.

Table **1-2** **WORKSHEET USED TO DETERMINE PROSTHODONTIC DIAGNOSTIC INDEX CLASSIFICATION OF COMPLETELY DENTATE PATIENTS**

	Class I	Class II	Class III	Class IV
Teeth Condition				
Ideal or minimally compromised: 3 or fewer teeth in one sextant	x			
Moderately compromised: 1 or more teeth in one to two sextants		x		
Substantially compromised: 1 or more teeth in three to five sextants			x	
Severely compromised: 4 or more teeth, all sextants				x
Occlusal Scheme				
Ideal or minimally compromised	x			
Moderately compromised: anterior guidance intact		x		
Substantially compromised: extensive rest/same OVD			x	
Severely compromised: extensive rest/new OVD				x
Conditions Creating a Guarded Prognosis				
Severe oral manifestations of systemic disease				x
Maxillomandibular dyskinesia and/or ataxia				x
Refractory condition				x

Note: Individual diagnostic criteria are evaluated, and the appropriate box is checked. The most advanced finding determines the final classification.

Guidelines for use of the worksheet:

1. Consideration of future treatment procedures must not influence the diagnostic level.
2. Initial preprosthetic treatment and/or adjunctive therapy can change the initial classification level.
3. If there is an esthetic concern/challenge, the classification is increased in complexity by one or more levels.
4. In the presence of TMD symptoms, the classification is increased in complexity by one or more levels.
5. It is assumed that the patient will receive therapy designed to achieve and maintain optimal periodontal health.
6. Patients who fail to conform to the definition of completely dentate should be classified using the classification system for partial edentulism.

OVD, occlusal vertical dimension.

STUDY QUESTIONS

1. Discuss the importance of the chief complaint and its management during examination and treatment plan presentation.
2. What is the classification of conditions observed as part of the medical history?
3. Describe the various areas included when a comprehensive dental history is documented.
4. What systemic conditions may exhibit oral manifestations that can affect a fixed prosthodontic treatment plan?
5. What is included in a comprehensively conducted extraoral examination? Specify all structures included in palpation.
6. Discuss three critical observations that are part of a comprehensive periodontal examination. Why are they important for fixed prosthodontic evaluation?
7. What would be recorded as part of an intraoral charting?
8. Discuss the various types of radiographs available for diagnostic purposes. What are the advantages and limitations of each technique?
9. Give examples of general and local factors that may influence the patient's prognosis.

GLOSSARY*

acute closed lock \a-kyōōt′ klōzd lŏk\: a form of temporomandibular joint dysfunction characterized by limitation in jaw movement caused by anterior displacement of the intra-articular disc and associate with pain, limitation of jaw opening to 25 to 30 mm (as measured in the incisor area) and, with jaw opening, a deflection of the mandible toward the affected joint

acute pain: pain having a brief and relatively severe course

al·gi·nate *n* (ca. 1909): see IRREVERSIBLE HYDROCOLLOID

an·am·ne·sis \ăn′ăm-nē′sĭs\ *n, pl* **-ne·ses** (ca. 1593): **1:** a recalling to mind; a reminiscence **2:** the past history of disease or injury based on the patient's memory or recall at the time of interview and examination **3:** a preliminary past medical history of a medical or psychiatric patient

anatomic crown \ăn′a-tŏm′ĭk kroun\: the portion of a natural tooth that extends coronal from the cementoenamel junction—called also *anatomical crown*

anterior disk displacement: see DISK DISPLACEMENT

anterior guidance \ăn-tîr′ē-or gīd′ns\: **1:** the influence of the contacting surfaces of anterior teeth on tooth limiting mandibular movements **2:** the influence of the contacting surfaces of the guide pin and anterior guide table on articulator movements—*usage* see ANTERIOR GUIDE TABLE **3:** the fabrication of a relationship of the anterior teeth preventing posterior tooth contact in all eccentric mandibular movements—see ANTERIOR PROTECTED ARTICULATION, GROUP FUNCTION, MUTUALLY PROTECTED ARTICULATION

anterior programming device \ăn-tîr′ē-or prō′grăm′ĭng dĭ-vīs′\: an individually fabricated anterior guide table that allows mandibular motion without the influence of tooth contacts and facilitates the recording of maxillomandibular relationships; also used for deprogramming—see also *deprogrammer*

apex \ā′pĕks′\ *n, pl* **apex·es** or **api·ces** \ā′pĭ-sēz′, ăp′ĭ-\ (1601): 1: the uppermost point; the vertex 2: in dentistry, the anatomic end of a tooth root

ar·throg·ra·phy \är-thrŏp′a-thē\ *n*: **1:** roentgenography of a joint after injection of an opaque contrast material **2:** in dentistry, a diagnostic technique that entails filling the lower, upper, or both joint spaces of the temporomandibular joint with a contrast agent to enable radiographic evaluation of the joint and surrounding structures; used to diagnose or confirm disk displacements and perforations

[1]ar·tic·u·late \är-tĭk′ya-lāt′\ *vb* (1691): **1:** to join together as a joint **2:** the relating of contacting surfaces of the teeth or their artificial replicas in the maxillae to those in the mandible

[2]ar·tic·u·late \är-tĭk′ya-lāt′, -lĭt\ *adj* (1586): in speech, to enunciate clearly or be clearly spoken

ar·tic·u·la·tor \är-tĭk′ya-lā′tor\ *n*: a mechanical instrument that represents the temporomandibular joints and jaws, to which maxillary and mandibular casts may be attached to simulate some or all mandibular movements—*usage*: articulators are divisible into four classes Class I articulator: a simple holding instrument capable of accepting a single static registration. Vertical motion is possible—see NONADJUSTABLE A. Class II articulator: an instrument that permits horizontal as well as vertical motion but does not orient the motion to the temporomandibular joints. Class III articulator: an instrument that simulates condylar pathways by using averages or mechanical equivalents for all or part of the motion. These instruments allow for orientation of the casts relative to the joints and may be arcon or nonarcon instruments—see SEMI-ADJUSTABLE A. Class IV articulator: an instrument that will accept three dimensional dynamic registrations. These instruments allow for orientation of the casts to the temporomandibular joints and simulation of mandibular movements—see FULLY ADJUSTABLE A., FULLY ADJUSTABLE GNATHOLOGIC A.

aus·cul·ta·tion \ô′skal-tā′shun\ *n* (ca. 1828): the process of determining the condition of various parts of the body by listening to the sounds they emit

buccolingual relationship \bŭk′o-lĭng′gwal rĭ-lā′shun-shĭp\: any position of reference relative to the tongue and cheeks

case history *substand*: the collected data about an individual, family, environmental factors (including medical/dental history) and any other information that may be useful in analyzing and diagnosing conditions or for instructional purposes; best termed the *patient history*

[2]cast \kăst\ *n* (14c): a life-size likeness of some desired form. It is formed within or is a material poured into a matrix or impression of the desired form—see DENTAL C., DIAGNOSTIC C., FINAL C., PRELIMINARY C., REFRACTORY C., REMOUNT C.

cath·ode \kăth′ōd\ *n* (1834): the negative pole in electrolysis

CAT: *acronym* for *Computerized Axial Tomography*

centric relation record \sĕn′trĭk rĭ-lā′shun rĭ-kōrd\: a registration of the relationship of the maxilla to the mandible

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when the mandible is in centric relation. The registration may be obtained either intraorally or extraorally

centric slide \sĕn′trĭk slīd\ *obs*: the movement of the mandible while in centric relation, from the initial occlusal contact into maximum intercuspation (GPT-4)

chronic pain \krŏn′ik pān\: pain marked by long duration or frequent recurrence

click \klĭk\ *n* (1611): a brief sharp sound; with reference to the temporomandibular joint, any bright or sharp sound emanating from the joint—see CLICKING, EARLY CLOSING C., EARLY OPENING C., LATE CLOSING C., LATE OPENING C., MID OPENING C. RECIPROCAL C.

click·ing \klĭ′kĭng\ *n* (611): a series of clicks, such as the snapping, cracking, or noise evident on excursions of the mandible; a distinct snapping sound or sensation, usually audible (or by stethoscope) or on palpation, which emanates from the temporomandibular joint(s) during jaw movement. It may or may not be associated with internal derangements of the temporomandibular joint

computerized tomography \kom-pyōō′ta-rīzd tō-mŏg′ra-fē\: (CT) the technique by which multidirectional x-ray transmission data through a body is mathematically reconstructed by a computer to form an electrical cross-sectional representation of a patient's anatomy. CT is used as an acronym to designate any technical field associated with these techniques

condylar axis \kŏn′da-lar ăk′sĭs\: a hypothetical line through the mandibular condyles around which the mandible may rotate

condylar hinge position \kŏn′da-lar hĭnj pa-zĭsh′an\ *obs*: the position of the condyles of the mandible in the glenoid fossae at which hinge axis movement is possible (GPT-4)

crep·i·ta·tion \krĕp′ĭ-tā′shun\ *n*: a crackling or grating noise in a joint during movement, liken to the throwing of fine salt into a fire or rubbing hair between the fingers; the noise made by rubbing together the ends of a fracture

de·flec·tion \dĭ-flĕk′shun\ *n* (1605): **1:** a turning aside or off course **2:** a continuing eccentric displacement of the mandibular midline incisal path symptomatic of restriction in movement

de·min·er·al·iza·tion \dē-mĭn′er-ă-lī-zā′shun\ *n* (ca. 1903): **1:** loss of minerals (as salts of calcium) from the body **2:** in dentistry, decalcification, usually related to the dental caries process

dental cast \dĕn′tl kăst\: a positive life size reproduction of a part or parts of the oral cavity

de·pro·gram·mer \dē-prō′grăm′er\ n: various types of devices or materials used to alter the proprioceptive mechanism during mandibular closure

de·vi·a·tion \dē′vē-ā′shun\ *n* (15c): with respect to movement of the mandible, a discursive movement that ends in the centered position and is indicative of interference during movement

diagnostic cast \dī′ag-nŏs′tik kăst\: a life-size reproduction of a part or parts of the oral cavity and/or facial structures for the purpose of study and treatment planning

di·a·ste·ma \dī′a-stē′ma\ *n, pl* **-ma·ta** (1854): a space between two adjacent teeth in the same dental arch

differential diagnosis \dĭf′a-rĕn′shal dī′ag-nō′sĭs\: the process of identifying a condition by comparing the signs and symptoms of all pathologic processes that may produce similar signs and symptoms

disk derangement \dĭsk dĭ-rānj′ment\: an abnormal relationship of the articular disk to the condyle, fossa, and or/and eminence

dis·tal \dĭs′tal\ *adj* (1808): remote; farther from the point of reference; away from the median sagittal plane of the face following the curvature of the dental arch

dys·func·tion \dĭs-fŭngk′shun\ *n* (ca. 1916): the presence of functional disharmony between the morphologic form (teeth, occlusion, bones, joints) and function (muscles, nerves) that may result in pathologic changes in the tissues or produce a functional disturbance

eccentric \ĭk-sĕn′trĭk\ *adj* (14c): **1:** not having the same center **2:** deviating from a circular path **3:** located elsewhere than at the geometric center **4:** any position of the mandible other than that which is its normal position

en·am·el \ĭ-năm′el\ *n* (15c): in dentistry, the hard, thin, translucent layer of calcified substance that envelopes and protects the dentin of the coronal aspect of the tooth; it is the hardest substance in the body—called also adamantine layer

enamel projection: an apical extension of enamel, usually toward a furcation in the roots

e·ro·sion \ĭ-rō′zhun\ *n* (1541): **1:** an eating away; a type of ulceration **2:** in dentistry, the progressive loss of tooth substance by chemical processes that do not involve bacterial action producing defects that are sharply defined, wedge-shaped depressions often in facial and cervical areas—*comp* ABFRACTION, ABRASION, ATTRITION

etiologic factors \ē′tē-ō-lŏj′ĭk făk′tors\: the elements or influences that can be assigned as the cause or reason for a disease or lesion—see LOCAL E.F., SYSTEMIC E.F.

e·ti·ol·o·gy \ē′tē-ŏl′a-jē\ *n* (1555): **1:** the factors implicated in the cause or origin of a disease or disorder **2:** the study or theory of the factors causing disease

ex·am·in·a·tion \ĭg-zăm′a-nā′shun\ *n* (14c)**:** scrutiny or investigation for the purpose of making a diagnosis or assessment

ex·cur·sion \ĭk-skûr′shun\ *n* (1577)**: 1:** a movement outward and back or from a mean position or axis; also, the distance traversed **2:** in dentistry, the movement occurring when the mandible moves away from maximum intercuspation

fac·et \făs′ĭt\ *n* (1625)**:** a small, planar surface on any hard body—see WEAR FACET—*usage*: the French spelling of facet, *facette*, has continued to confuse the profession regarding pronunciation

fixed prosthodontics \fĭkst prŏs′tha-dŏn′tĭks**:** the branch of prosthodontics concerned with the replacement and/or restoration of teeth by artificial substitutes that not readily removed from the mouth

forces of mastication \fôrs-es ŭv măs′tĭ-kā′shun\ *obs***:** the motive force created by the dynamic action of the muscles during the physiologic act of mastication (GPT-4)

frem·i·tus \frĕm′ĭ-tus\ *n* (1879)**:** a vibration perceptible on palpation; in dentistry, a vibration palpable when the teeth come into contact

gingival crevice \jĭn′ja-val krĕv′ĭs**:** a shallow fissure between the marginal gingiva and the enamel or cementum. It is bounded by the tooth surface on one side, the crevicular epithelium on the other, and the coronal end of the junctional epithelium at its most apical point—called also *gingival sulcus*

high lip line \hī lĭp līn**:** the greatest height to which the inferior border of the upper lip is capable of being raised by muscle function

horizontal overlap \hôr′ĭ-zŏn-tl, hŏr′- ō′ver-lăp′**:** the projection of teeth beyond their antagonists in the horizontal plane

id·io·path·ic \ĭd′ē-ō-păth′ĭk\ *adj* (1669)**:** self-originated; of unknown causation

incisal guidance \ĭn-sĭ′zal gīd′ans**: 1:** the influence of the contacting surfaces of the mandibular and maxillary anterior teeth on mandibular movements **2:** the influence of the contacting surfaces of the guide pin and guide table on articulator movements

in·fra·oc·clu·sion \ĭn′fra-a-klōō′shun\ *n***:** malocclusion in which the occluding surfaces of teeth are below the normal plane of occlusion

initial occlusal contact \ĭ-nĭsh′al a-klōō′sal kŏn′tăkt**:** during closure of the mandible, the first or initial contact of opposing teeth between the arches

in·ter·cus·pa·tion \ĭn′ter-kŭs-pā′shun\ *n, obs***:** the interdigitation of cusps of opposing teeth (GPT-4)

interdental papilla \ĭn′ter-dĕn′tl pa-pĭl′a**:** a projection of the gingiva filling the space between the proximal surfaces of two adjacent teeth

interocclusal distance \ĭn′ter-a-klōō′sal dĭs′tans**:** the distance between the occluding surfaces of the maxillary and mandibular teeth when the mandible is in a specified position

joint crepitus \joint krĕp′ĭ-tŭs**:** the grating sensation caused by the rubbing together of the bony surfaces of joints—called also *articular crepitus*

lab·i·al \lā′bē-al\ *adj* (1594)**: 1:** of or pertaining to the lip **2:** toward the lip

la·bio·ver·sion \lā′bē-ō-vûr′shun\ *n***:** labial position of a tooth beyond the normal arch form

leaf gauge \lēf gāj**:** a set of blades or leaves of increasing thickness used to measure the distance between two points or to provide metered separation

lin·gual \lĭng′gwal\ *adj* (15c)**:** pertaining to the tongue; next to or toward the tongue

lip line: see HIGH L.L., LOW L.L.

local etiologic factors \lō′kal ē′tē-a-lŏj′ĭk făk′tarz**:** the environmental influences that may be implicated in the causation, modification, and/or perpetuation of a disease entity

low lip line \lō lĭp līn**: 1:** the lowest position of the inferior border of the upper lip when it is at rest **2:** the lowest position of the superior border of the lower lip during smiling or voluntary retraction

man·di·ble \măn′da-bal\ *n* (15c)**:** the lower jawbone

man·dib·u·lar \măn-dĭb′ya-lar\ *adj***:** of or pertaining to the mandible

mandibular hinge position \măn-dĭb′ya-lar hĭnj pa-zish′an\ *obs***:** the position of the mandible in relation to the maxilla at which opening and closing movements can be made on the hinge axis (GPT-4)

mandibular trismus \măn-dĭb′ya-lar trĭz′mas**:** reduced mobility of the mandible resulting from tonic contracture of the masticatory muscles

masticatory force \măs′tĭ-ka-tôr′ē fôrs, fōrs**:** the force applied by the muscles of mastication during chewing

masticatory pain \măs′tĭ-ka-tôr′ē pān**:** discomfort about the face and mouth induced by chewing or other use of the jaws but independent of local disease involving the teeth and mouth

masticatory system \măs′tĭ-ka-tôr′ē sĭs′tam**:** the organs and structures primarily functioning in mastication. These include the teeth with their supporting structures,

craniomandibular articulations, mandible, positioning and accessory musculature, tongue, lips, cheeks, oral mucosa, and the associated neurologic complex

max·il·la \măk-sĭl′a\ *n, pl* **max·il·lae** \măk-sĭl′ē\ (15c)**:** the irregularly shaped bone that, with its contralateral maxilla, forms the upper jaw. It assists in the formation of the orbit, the nasal cavity, and the hard palate; it contains the maxillary teeth

maxillary tuberosity \măk′sa-lĕr′ē tōō′ba-rŏs′ĭ-tē**:** the most distal portion of the maxillary alveolar ridge

max·il·lo·fa·cial \măk′sa-la-fā′shul\ *adj***:** pertaining to the dental arches, the face, head and neck structures

maxillofacial prosthesis \măk′sa-la-fā′shul prŏs-thē′sĭs**:** any prosthesis used to replace part or all of any stomatognathic and/or craniofacial structure. *Editorial Note*: the taxonomy for maxillofacial prostheses may include modifiers (adjectives) to provide descriptive evidence of the nature of the prosthesis including *anatomic location, retention, support,* time, *materials,* and *form*. Frequently the means of *retention* is used, and may encompass descriptive adjectives such as the adjacent tissue, teeth, dental/craniofacial implants or a combination of such, thus appropriate terminology can include *tissue retained MP, tooth retained MP, implant retained MP, tissue/implant retained MP*. Descriptive terminology may also be included to delineate *time* utilization such as *surgical, interim* and *definitive*

maxillofacial prosthetics \măk′sa-la-fā′shul prŏs-thĕt′iks**:** the branch of prosthodontics concerned with the restoration and/or replacement of the stomatognathic and craniofacial structures with prostheses that may or may not be removed on a regular or elective basis

me·nis·cus \ma-nĭs′kas\ *n, pl* **me·nis·ci** \ma-nĭs′ī**:** see DISK

me·si·al \mē′zē-al\ *adj* (1803)**:** near or toward the centerline of the dental arch; toward the median sagittal plane of the face, following the curvature of the dental arch

mo·bile \mō′bal, -bēl, -bīl\ *adj* (15c)**:** capable of moving or being moved; movable

mou·lage \mōō-läzh′\ *n* (1902)**: 1:** the negative impression of a body structure **2:** an impression or cast made for use, especially as evidenced in a criminal investigation **3:** impression or reverse likeness of a part that produces a model when converted to a positive replica, i.e., by means of plaster

MRI: *acronym* for *Magnetic Resonance Imaging*

muscle-splinting \mŭs′al-splĭnt′ĭng\ *slang***:** involuntary contraction (rigidity) of muscles occurring as a means of avoiding the pain caused by movement of the part (resistance to passive stretch). The involved muscle(s) relaxes at rest

musculoskeletal pain \mŭs′kya-lō-skĕl′ĭ-tl pān**:** deep, somatic pain that originates in skeletal muscles, facial sheaths, and tendons (myogenous pain), bone and periosteum (osseous pain), joint, joint capsules, and ligaments (arthralgic pain), and in soft connective tissues

myofascial trigger point \mī′a-făsh′al trĭg′ar point**:** a hyperirritable spot, usually within a skeletal muscle or in the muscle fascia, that is painful on compression and can give rise to characteristic referred pain, tenderness (secondary hyperalgesia), and autonomic phenomena

neu·ral·gia \nŏŏ-răl′ja\ *n* (ca. 1822)**:** neurogenous pain felt along the peripheral distribution of a nerve trunk

neu·ri·tis \nŏŏ-rī′tĭs\ *n* (1840)**:** inflammation of a nerve

neurogenous pain \nŏŏ-rŏj′a-nŭs pān**:** pain that is generated within the nervous system as a result of some abnormality of neural structures

NMR: *acronym* for *Nuclear Magnetic Resonance*; a radiologic procedure that gives images in any plane without radiation or any biologic after effect by picking up signals from resonating hydrogen nuclei

nonworking side interference \nŏn-wûr′kĭng sīd ĭn′tar-fîr′ans**:** undesirable contacts of the opposing occlusal surfaces on the nonworking side

oc·clude \a-klōōd′\ *vb* **oc·clud·ed**; **oc·clud·ing** *vt* (1597)**: 1:** to bring together; to shut **2:** to bring or close the mandibular teeth into contact with the maxillary teeth

oc·clu·sal \a-klōō′zal, -sal\ *adj* (1897)**:** pertaining to the masticatory surfaces of the posterior teeth, prostheses, or occlusion rims

occlusal force \a-klōō′zal, -sal fôrs, fōrs**:** the result of muscular force applied on opposing teeth; the force created by the dynamic action of the muscles during the physiologic act of mastication; the result of muscular activity applied to opposing teeth

oral mucosa \ôr′al, ōr′- myōō-kō′sa**:** the lining of the oral cavity

oro·phar·ynx \ôr′a-făr′ĭngks\ *n* (1887)**:** the part of the pharynx lying between the soft palate and the upper edge of the epiglottis—called also *oral pharynx, pars oralis pharyngis, pharyngooral cavity*, and *vestibule of the pharynx*

os·te·i·tis \ŏs′tē-ī′tĭs\ *n* (ca. 1839)**:** inflammation of bone

os·te·o·ar·thri·tis \ŏs′tē-ō-är-thrī′tĭs\ *n* (1878)**:** chronic degeneration and destruction of the articular cartilage and/or fibrous connective tissue linings of the joint components and disks, leading to bony spurs, pain, stiffness, limitation of movement, and changes in bone morphology. Advanced conditions may involve erosions and disk

degeneration with crepitus—*syn* DEGENERATIVE JOINT DISEASE

o·ver·hang \ō′var-hăng\ *n* (1864)**:** excess restorative material projecting beyond a cavity or preparation margin

pal·ate \păl′ĭt\ *n* (14c)**:** see HARD P., SOFT P.

pal·pate \păl′pāt′\ *vt* **pal·pat·ed** \păl-pā′tĭd\; **pal·pat·ing** \păl-pā′tĭng\ (1849)**:** to examine by touch—**pal·pa·tion** *n*

panoramic radiograph \păn′a-răm′ĭk rā′dē-ō-grăf′**:** a tomogram of the maxilla and mandible taken with a specialized machine designed to present a panoramic view of the full circumferential lengths of the maxilla and mandible on a single film—called also *orthopantograph*

per·cus·sion \pur-kŭsh′an\ *n* (1544)**: 1:** the act of striking a part with sharp blows as an aid in diagnosing the condition of the underlying parts by means of the sound obtained **2:** in dentistry, striking a part with short, sharp blows as a diagnostic aid in evaluation of a tooth or dental implant by the sound obtained

per·i·ap·i·cal \pĕr′ĭ-ăp′ĭ-kal, ā′pĭ-\ *adj***:** relating to tissues surrounding the apex of a tooth, including the alveolar bone and periodontal ligament

per·i·ra·dic·u·lar \pĕr′ĭ-răd′ĭ-kyōō-lar\ *adj***:** around or surrounding a tooth root

physical elasticity of muscle \fĭz′ĭ-kal ĭ-lă-stĭs′ĭ-tē, ē′lă-ŭv mŭs′al\ *obs***:** the physical quality of muscle of being elastic; that is, yielding to active or passive physical stretch (GPT-4)

preoperative record \prē-ŏp′ar-a-tĭv, -ŏp′ra-, -ŏp′a-rā-rĕk′ard\ *obs***:** any record made for the purpose of study or treatment planning (GPT-4)

pretreatment records \prē-trēt′mant rĕk′ardz**:** any records made for the purpose of diagnosis, recording of the patient history, or treatment planning in advance of therapy

prog·na·thism \prŏg-na-thĭz′um\ *n* (ca. 1864)**:** an overgrowth of the mandible in an anteroposterior direction; a protrusion of the mandible in relation to the maxillae

prosthetic restoration \prŏs-thĕt′ĭk\ *obs***:** an artificial replacement for an absent part of the human body (GPT-4)

pros·tho·don·tics \prŏs′tha-dŏn′tĭks\ *n, pl but sing or pl in constr* (1947)**:** prosthodontics is the dental specialty pertaining to the diagnosis, treatment planning, rehabilitation and maintenance of the oral function, comfort, appearance and health of patients with clinical conditions associated with missing or deficient teeth and/or maxillofacial tissues using biocompatible substitutes—see FIXED PROSTHODONTICS, IMPLANT PROSTHODONTICS, MAXILLOFACIAL PROSTHETICS, REMOVABLE PROSTHODONTICS

pros·tho·don·tist \prŏs′tha-dŏn-tĭst\ *n* (1917)**: 1:** a specialist in prosthodontics **2:** a dentist who has successfully completed an advanced education program in prosthodontics that is accredited by the appropriate accrediting body. In the United States, that body is the Commission on Dental Accreditation of the American Dental Association—see BOARD-CERTIFIED P., BOARD-ELIGIBLE P., EDUCATIONALLY QUALIFIED P.

prox·i·mal \prŏk′sa-mal\ *adj* (1727)**: 1:** situated close to **2:** next to or nearest the point of attachment or origin, a central point especially, located toward the center of a body—*comp* DISTAL—**prox·i·mal·ly** *adj*

pulpitis \pŭl′pĭ-tĭs\ *n***:** inflammation of the dental pulp

[1]ra·di·o·graph \rā′dē-ō-grăf′\ *n* (1880)**:** an image produced on any sensitive surface by means of electromagnetic radiation other than light; a x-ray photograph

ra·di·o·lu·cent \rā′dē-ō-lōō′sant**:** permitting the passage of radiant energy with relatively little attenuation by absorption

ra·di·o·paque \rā′dē-ō-pāk′\ (1917)**:** a structure that strongly inhibits the passage of radiant energy

range of motion \rānj ŭv mō′shun**:** the range, measured in degrees of a circle, through which a joint can be extended or flexed. The range of the opening, lateral, and protrusive excursions of the temporomandibular joint

reciprocal click \rĭ-sĭp′ra-kal klĭk**:** clicks emanating from the temporomandibular joint, one of which occurs during opening movement and the other during closing movement

reduced interarch distance \rĭ-dōōsd′ ĭn′tar-ärch**:** an occluding vertical dimension that results in an excessive interocclusal distance when the mandible is in rest position and in a reduced interridge distance when the teeth are in contact—called also *overclosure*

res·to·ra·tion \rĕs′ta-rā′shun\ *n* (1660)**:** a broad term applied to any material or prosthesis that restores or replaces lost tooth structure, teeth, or oral tissues

retruded contact position \rĭ-trōō′dĭd kŏn′tăkt pa-zĭsh′an**:** that guided occlusal relationship occurring at the most retruded position of the condyles in the joint cavities. A position that may be more retruded than the centric relation position

reverse articulation \rĭ-vûrs′ är-tĭk′ya-lā′shun**:** an occlusal relationship in which the mandibular teeth are located facial to the opposing maxillary teeth; the max-

illary buccal cusps are positioned in the central fossae of the mandibular teeth

root fracture \rōōt frăk′chur**:** a microscopic or macroscopic cleavage of the root in any direction

sub·lin·gual \sŭb′lĭng′gwal\ *adj* (1661)**:** pertaining to the region or structures located beneath the tongue

symp·tom \sĭm′tum, sĭmp-\ *n* (14c)**:** subjective evidence of disease or physical disturbance; something that indicates the presence of a bodily disorder

systemic etiologic factors \sĭ-stĕm′ĭk ē′tē-ō-lŏj′ĭk făk′turs**:** generalized biologic factors that are implicated in the causation, modification, and/or perpetuation of a disease entity

temporomandibular disorders \tĕm′pa-rō′măn-dĭb′ya-lar dĭs-ôr′derz**: 1:** conditions producing abnormal, incomplete, or impaired function of the temporomandibular joint(s) **2:** *(obs)* a collection of symptoms frequently observed in various combinations first described by Costen (1934, 1937), which he claimed to be reflexes due to irritation of the auriculotemporal and/or chorda tympanic nerves as they emerged from the tympanic plate caused by altered anatomic relations and derangements of the temporomandibular joint associated with loss of occlusal vertical dimension, loss of posterior tooth support, and/or other malocclusions. The symptoms can include headache about the vertex and occiput, tinnitus, pain about the ear, impaired hearing and pain about the tongue—*acronym* TMD

tin·ni·tus \tĭn′ĭtus\ *n* (1843)**:** a noise in the ears, often described as ringing or roaring

TMD: *acronym* for *TemporoMandibular Disorders*—see TEMPOROMANDIBULAR DISORDERS

[1]to·mo·graph \tŏm′a-grăf\ *n***:** a device for moving an x-ray source in one direction as the film moves in the opposite direction

[2]to·mo·graph \tŏm′a-grăf\ *n***:** a radiograph produced from a machine that has the source of radiation moving in one direction and the film moving in the opposite direction

to·mo·gra·phy \tō-mŏg′ra-fē\ *n***:** a general term for a technique that provides a distinct image of any selected plane through the body, while the images of structures that lie above and below that plane are blurred. Also, the term *body-section radiography* has been applied to the procedure, although the several ways of accomplishing it have been given distinguishing names

tor·us \tôr′us\ *n, pl* **tori** (1563)**: 1:** a smooth rounded anatomical protuberance **2.** in dentistry, prominence (s) sometimes seen on the lingual surface of the mandible and the midline of the hard palate

transcranial oblique radiograph \trăns-krā′nē-al ō-blēk′, a-blēk′ rā′dē-ō-grăf′**:** a flat radiographic projection in which the central beam travels across the cranium and through the temporomandibular joint on the opposite side showing an oblique lateral view of the condyle

trau·ma \trou′ma, trô′-\ *n, pl* **trau·ma·ta** \trou′ma-ta\ or **trau·mas** \trou′mas\, **trau·mat·ic** \trou′măt-ĭk\ *adj*—**trau·mat·i·cal·ly** \trou′măt-ĭ-kă-lē\ *adv* (1693)**:** an injury or wound, whether physical or psychic

trigger point \trĭg′ur point**:** a focus of hyperirritability in tissue which when palpated, is locally tender and gives rise to heterotopic pain

unstrained jaw relation \ŭn′rĭ-strānd′ jô rĭ-lā′shun\ *obs***: 1:** the relation of the mandible to the skull when a state of balanced tonus exists among all the muscles involved **2:** any jaw relation that is attained without undue or unnatural force and that causes no undue distortion of the tissues of the temporomandibular joints (GPT-4)

working side contacts \wûr′kĭng sīd kŏn′tăkts**:** contacts of teeth made on the side of the articulation toward which the mandible is moved during working movements

[1]X-ray \ĕks′rā\ *vt* (1896)**:** the process of exposing objects to roentgen rays and projecting their shadow on sensitized surfaces

xer·o·stomia \zîr′a-stō′mē-a\ *n***:** dryness of the mouth from lack of normal secretions

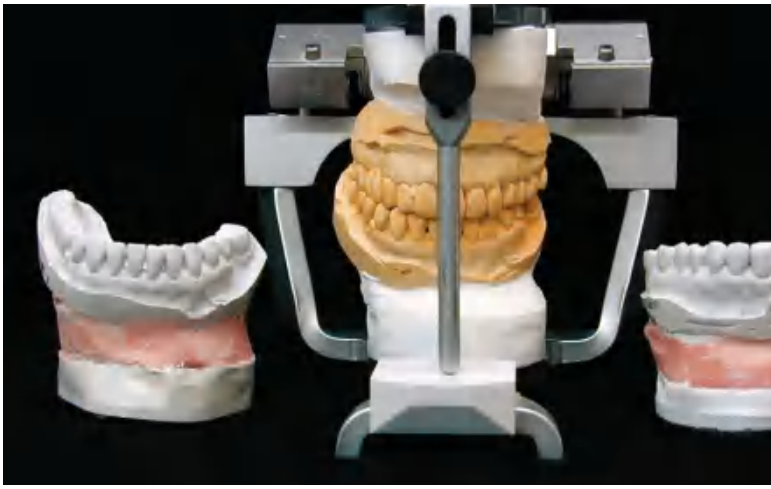
REFERENCES

1. Moazzez R, et al: Dental erosion, gastro-oesophageal reflux disease and saliva: how are they related? J Dent 32:489, 2004.
2. Milosevic A: Eating disorders and the dentist. Br Dent J 186:109, 1999.
3. Cope MR: Metoclopramide-induced masticatory muscle spasm. Br Dent J 154:335, 1983.
4. Pajukoski H, et al: Salivary flow and composition in elderly patients referred to an acute care geriatric ward. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 84:265, 1997.
5. Hunter KD, Wilson WS: The effects of antidepressant drugs on salivary flow and content of sodium and potassium ions in human parotid saliva. Arch Oral Biol 40:983, 1995.
6. Infection control recommendations for the dental office and laboratory. J Am Dent Assoc (Suppl):1, 1992.
7. Epstein O, et al: Clinical Examination, 3rd ed. St. Louis, Mosby, 2003.
8. Little JW, et al: Dental Management of the Medically Compromised Patient, 6th ed. St. Louis, Mosby, 2002.

9. Solberg WK: Occlusion-related pathosis and its clinical evaluation. In Clark JW, ed: Clinical Dentistry, vol 2, chap 35. Hagerstown, Md, Harper & Row, 1976.
10. Pullinger AG, et al: Differences between sexes in maximum jaw opening when corrected to body size. J Oral Rehabil 14:291, 1987.
11. Krogh-Poulsen WG, Olsson A: Occlusal disharmonies and dysfunction of the stomatognathic system. Dent Clin North Am 10:627, 1966.
12. Moskowitz ME, Nayyar A: Determinants of dental esthetics: a rational for smile analysis and treatment. Compend Contin Educ Dent 16:1164, 1995.
13. Crispin BJ, Watson JF: Margin placement of esthetic veneer crowns. I. Anterior tooth visibility. J Prosthet Dent 45:278, 1981.
14. Lombardi RE: The principles of visual perception and their clinical application to denture esthetics. J Prosthet Dent 29:358, 1973.
15. Rosenstiel SF, Rashid RG: Public preferences for anterior tooth variations: a web-based study. J Esthet Restor Dent 14:97, 2002.
16. Parameter on comprehensive periodontal examination. American Academy of Periodontology. J Periodontol 71:847, 2000.
17. Guidelines for periodontal therapy. American Academy of Periodontology. J Periodontol 69:405, 1998.
18. Carranza FA Jr, Newman MG: Clinical Periodontology, 8th ed. Philadelphia, WB Saunders, 1996.
19. Goodson JM: Selection of suitable indicators of periodontitis. In Bader JD, ed: Risk Assessment in Dentistry, Chapel Hill, N.C., University of North Carolina Dental Ecology, 1989.
20. American Academy of Periodontology: Parameters of Care, Chicago, American Academy of Periodontology, 1998.
21. Carter L: Clinical indications as a basis for ordering extraoral imaging studies. Compend Contin Educ Dent 25:351, 2004.
22. Van Sickels JE, et al: Transcranial radiographs in the evaluation of craniomandibular (TMJ) disorders. J Prosthet Dent 49:244, 1983.
23. Brooks SL, et al: Imaging of the temporomandibular joint: a position paper of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 83:609, 1997.
24. McGarry TJ, et al: Classification system for partial edentulism. J Prosthodont 11:181, 2002.
25. McGarry TJ, et al: Classification system for the completely dentate patient. J Prosthodont 13:73, 2004.
26. McGarry TJ, et al: Classification system for complete edentulism. The American College of Prosthodontics. J Prosthodont 8:27, 1999.

2

DIAGNOSTIC CASTS AND RELATED PROCEDURES



KEY TERMS

anterior guide table
anterior reference point
arbitrary facebow
arcon
articulator
centric relation (CR)
centric relation record
diagnostic waxing
hinge axis
irreversible hydrocolloid
kinematic facebow
nonarcon
pantograph
programming device

Accurate diagnostic casts (Fig. 2-1) transferred to a semiadjustable **articulator** are essential in planning fixed prosthodontic treatment. This enables static and dynamic relationships of the teeth to be examined without interference from protective neuromuscular reflexes, and unencumbered views from all directions reveal aspects of the occlusion not always easily detectable intraorally (e.g., the relationship of the lingual cusps in the occluded position). If the maxillary cast has been transferred with a facebow, a **centric relation** (**CR**) interocclusal record has been used for articulation of the mandibular cast, and the condylar elements have been appropriately set (such as with protrusive and/or excursive interocclusal records), reproducing the patient's movements with reasonable accuracy is possible. If the casts have been articulated in CR, assessing both the CR and the maximum intercuspation (MI) position is possible, because any slide can then be reproduced. Other critical information not immediately apparent during the clinical examination includes the occlusocervical dimension of edentulous spaces. On an articulator, these are readily assessed in the occluded position and throughout the entire range of mandibular movement. Relative alignment and angulation of proposed abutment teeth are easier to evaluate on casts than intraorally, as are many other subtle changes in individual tooth position. Articulated diagnostic casts permit a detailed analysis of the occlusal plane and the occlusion, and diagnostic procedures can be performed for a better diagnosis and treatment plan; tooth preparations can be "rehearsed" on the casts, and **diagnostic waxing** procedures allow evaluation of the eventual outcome of proposed treatment.



Fig. 2-1
Diagnostic casts mounted on a Whip Mix articulator. *(Courtesy of Whip Mix Corporation, Louisville, Kentucky.)*

IMPRESSION MAKING FOR DIAGNOSTIC CASTS

Accurate impressions of both dental arches are required. Flaws in the impressions result in inaccuracies in the casts that easily compound. For instance, a small void in the impression caused by the trapping of an air bubble on one of the occlusal surfaces results in a nodule on the occlusal table. If it is not recognized and carefully removed, it leads to an inaccurate articulator mounting, and the diagnostic data are incorrect.

As long as the impression extends several millimeters beyond the cervical line of the teeth, the borders of diagnostic impressions are usually not of great concern for fixed prosthodontic purposes, unless a removable prosthesis is also to be fabricated. Properly manipulated **irreversible hydrocolloid** (alginate) is sufficiently accurate and offers adequate surface detail for planning purposes. However, the material does not reproduce sufficient surface detail for suitable definitive casts and dies on which actual fixed prostheses are fabricated (see Chapter 17).

Irreversible Hydrocolloid

The irreversible hydrocolloids, or alginates, are essentially sodium or potassium salts of alginic acid and are therefore water soluble. They react chemically with calcium sulfate to produce insoluble calcium alginate. These materials contain other ingredients, chiefly diatomaceous earth (for strength and body), trisodium phosphate (Na_3PO_4), and similar compounds to control the setting rate as they react preferentially with calcium sulfate. When this reaction is complete and the retarder is consumed, gel formation begins. The clinician can control the reaction rate by varying the temperature of the mixing water. Because irreversible hydrocolloid is largely water, it readily absorbs (by imbibition) as well as gives off (by syneresis) liquid to the atmosphere, causing distortion of the impression. Alginate impressions must therefore be poured immediately.

Diagnostic Impression Technique

Armamentarium

- Impression trays
- Modeling compound
- Mixing bowl
- Mixing spatula
- Gauze squares
- Irreversible hydrocolloid
- American Dental Association (ADA) type IV or V stone
- Vacuum mixer
- Humidor
- Disinfectant

Tray selection

All impression materials require retention in the impression tray. This can be provided for irreversible hydrocolloid by using an adhesive or by making perforations or undercuts around the rim of the tray. All types of trays are capable of producing impressions with clinically acceptable accuracy.[1] For irreversible hydrocolloids, the largest tray that will fit comfortably in the patient's mouth should be selected. A greater bulk of material produces a more accurate impression (i.e., a bulky impression has a more favorable surface area/volume ratio and is less susceptible to water loss or gain and therefore unwanted dimensional change). In contrast, elastomeric impression materials work well with a relatively tightly fitting custom impression tray in which a uniform thin layer of material is used. This produces the most accurate impression (see Chapter 14).

Distortion of irreversible hydrocolloid can occur if any part of the impression is unsupported by the tray or if there is movement of the tray during setting. For these reasons, the tray may need to be extended and its perimeter modified with modeling compound (Fig. 2-2).



Fig. 2-2
Stock impression trays can be readily modified with modeling compound to provide better support for the alginate. The posterior border typically needs extension. If the patient has a high palate, the alginate should be supported here, too, although the compound should not block out the retentive area of the tray.

Impression making

For optimum results, the teeth should be cleaned and the mouth thoroughly rinsed. Some drying is necessary, but excessively dried tooth surfaces cause the irreversible hydrocolloid impression material to adhere. The material is mixed to a homogenous consistency and loaded into the tray, and its surface is smoothed with a moistened gloved finger.[2] Concurrently, a small amount of material is wiped into the crevices of the occlusal surfaces (Fig. 2-3*A*,*B*) before the tray is seated (Fig. 2-3*C*). Also, a small amount can be applied by wiping it into the mucobuccal fold. As the tray is inserted into the patient's mouth and seated, the patient is reminded to relax the cheek muscles. If a patient continues to stretch wide open while the tray is being fully seated, impression material is often squeezed out of the mucobuccal fold or from underneath the upper lip.

A loss of tackiness of the material (gelation) implies initial set. The tray should be removed quickly 2 to 3 minutes after gelation. Teasing or wiggling the set impression from the mouth causes excessive distortion as a result of viscous flow. Also, certain irreversible hydrocolloid materials become distorted if held in the mouth more than 2 or 3 minutes after gelation.[3] After removal (Fig. 2-3*D*), the impression should be rinsed and disinfected, dried slightly with a gentle air stream, and poured immediately. For disinfection, spraying with a suitable glutaraldehyde and placement in a self-sealing plastic bag for approximately 10 minutes is recommended, after which it can be poured. Alternatively, the impression can be immersed in iodophor or glutaraldehyde disinfectant. The disinfection protocol is an essential precaution for preventing cross-infection and protecting laboratory personnel (see Chapter 14). It should be noted that irreversible hydrocolloid impressions carry significantly higher numbers of bacteria than do elastomeric materials.[4] No significant loss of accuracy or surface detail is caused by the disinfection procedure.[5,6] To ensure accuracy, pouring should be completed within 15 minutes after the impression is removed from the mouth. Keeping an impression in a moist towel is no substitute for pouring within the specified time. Trimming off gross excess impression material before setting the tray down on the bench top is helpful. A vacuum-mixed ADA type IV or type V stone is recommended. The choice of the brand of stone is important because of the harmful surface interactions between specific irreversible hydrocolloid materials and gypsum products.[7]

After mixing, a small amount of stone is added in one location (e.g., the posterior aspect of one of the molars). Adding small amounts consistently in the same location helps minimize bubble formation (see the section on pouring stone dies in Chapter 17). If air is trapped, bubbles can be eliminated by poking at them with a small instrument (e.g., a periodontal probe or a wax spatula). While setting, the poured impressions must be stored tray side down, not inverted. Inverting freshly poured impressions results in a cast with a rough and grainy surface.[8] Stone is added to create a sufficient base that provides adequate retention for mounting on the articulator. To achieve maximum strength and surface detail, the poured impression should be covered with wet paper and stored in a humidor for 1 hour. This minimizes distortion of the irreversible hydrocolloid during the setting period. The setting gypsum cast should *never* be immersed in water. If this is done, setting expansion of plaster, stone, or die stone doubles or even triples through the phenomenon of hygroscopic expansion (see Chapter 22). For best results, the cast should be separated 1 hour after pouring.

Evaluation

Although it is apparently a simple procedure, diagnostic cast fabrication is often mishandled. Seemingly minor inaccuracies can lead to serious



Fig. 2-3
A to **D**, Making an alginate impression for diagnostic casts.

diagnostic errors. Questionable impressions and casts should be discarded and the process repeated (Fig. 2-4). Voids in the impression create nodules on the poured cast. These can prevent proper articulation and effectively render useless a subsequent occlusal analysis or other diagnostic procedure.

Articulator selection

Handheld casts can provide information concerning alignment of the individual arches but do not enable analysis of functional relationships. For an analysis, the diagnostic casts need to be attached to an articulator, a mechanical device that simulates mandibular movement. Articulators can simulate the movement of the condyles in their corresponding fossae. They are classified according to how closely they can reproduce mandibular border movements. Because the movements are governed by the bones and ligaments of the temporomandibular joints, they are relatively constant and reproducible. With most articulators, mechanically adjustable posterior controls are used to simulate these movements; in some, plastic premilled or customized fossa analogs are used. If an articulator closely reproduces the actual border movements of a given patient, chair time is significantly reduced because the dental laboratory can then design the prosthesis to be in functional harmony with the patient's movements. In addition, less time is needed for adjustments at delivery.

On some instruments, the upper and lower members are permanently attached to each other, whereas on others they can be readily separated. The latter instruments may have a latch or clamplike feature that locks the two components together in the hinge position. Instrument selection depends on the type and complexity of treatment needs, the demands for procedural accuracy, and general expediency. For instance, when a fixed dental prosthesis is waxed, it is advantageous to be able to separate the instrument into two more easily handled parts. Use



Fig. 2-4
Diagnostic casts must be accurate if they are to articulate properly. **A,** Occlusal nodules may make proper occlusal analysis impossible. **B,** Proper technique ensures a satisfactory cast.



Fig. 2-5
A small nonadjustable articulator.

of the proper instrument for a given procedure can translate into significant time saving during subsequent stages of treatment.

Small Nonadjustable Articulators

Many cast restorations are made on small nonadjustable articulators (Fig. 2-5). Their use often leads to restorations with occlusal discrepancies, because these instruments do not have the capacity to reproduce the full range of mandibular movement. Some discrepancies can be corrected intraorally, but this is often time consuming and leads to increased inaccuracy. If discrepancies are left uncorrected, occlusal interferences and associated neuromuscular disorders may result.

Of practical significance are differences between the hinge closure of a small articulator and that of the patient. The distance between the hinge and the tooth to be restored is significantly less on most nonadjustable articulators than in the patient. This can lead to restorations with premature tooth contacts because cusp position is affected. This type of arcing motion on the nonadjustable articulator results in steeper travel than occurs clinically, which subsequently results in premature contacts on fabricated restorations between the distal mandibular inclines and the mesial maxillary inclines of posterior teeth (Fig. 2-6).

Depending on the specific design of the articulator, ridge and groove direction may be affected in accordance with the same principle. This is important to note, because resulting prematurities are likely on the nonworking side (see Chapters 1, 4, and 6).

Semiadjustable Articulators

For most routine fixed prostheses, the use of a semiadjustable articulator (Fig. 2-7) is a practical approach to providing the necessary diagnostic information while minimizing the need for clinical adjustment during treatment. The use of semiadjustable instruments does not require an inordinate amount of time or expertise. They are about the same size as the anatomic structures they represent. Therefore, the articulated casts can be positioned with sufficient accuracy so that arcing errors are minimal and usually of minimal clinical significance (i.e., minimal time should be required for chairside adjustments of fabricated prostheses).

There are two basic designs of the semiadjustable articulator: the **arcon** (for **ar**ticulator and **con**dyle) (Fig. 2-8*A,C*) and the **nonarcon** (Fig. 2-8*B,D*). Nonarcon instruments gained considerable popularity in complete denture prosthodontics because the upper and lower members are rigidly attached, enabling easier control when artificial teeth are positioned. As a consequence of their design, however, certain inaccuracies occur in cast restora-

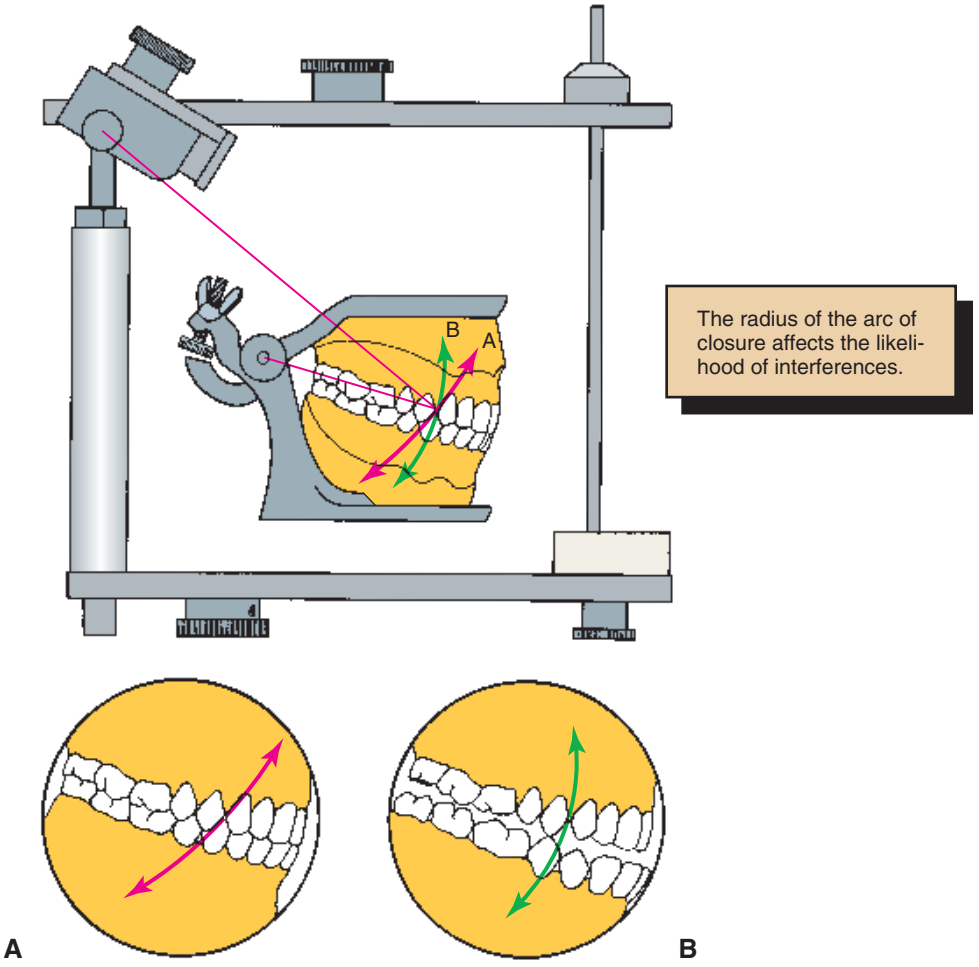


Fig. 2-6

Discrepancies in the path of closure when using a small nonadjustable articulator can lead to restorations with premature occlusal contacts. **A,** Path of closure of an anatomically accurate articulator. **B,** The small nonadjustable instrument has a smaller radius closure path, which results in premature contact at the clinical try-in between the premolars during hinge closure.

tions, which led to the development of the arcon-type instrument.

In an arcon articulator, the condylar spheres are attached to the lower component of the articulator, and the mechanical fossae are attached to the upper member of the instrument. Thus, the arcon articulator is anatomically "correct," which makes understanding of mandibular movements easier, as opposed to the nonarcon articulator (whose movements are confusingly "backwards"). The angulation of the mechanical fossae of an arcon instrument is fixed in relation to the occlusal plane of the maxillary cast; in the nonarcon design, it is fixed in relation to the occlusal plane of the mandibular cast.

Most semiadjustable articulators permit adjustments to the condylar inclination and progressive and/or immediate side shift. Some have straight condylar inclined paths, although more recent instruments have curved condylar housings, which are more anatomically correct.

The mechanical fossae on semiadjustable articulators can be adjusted to mimic the movements of the patient through the use of interocclusal records. These consist of several thicknesses of wax or another suitable material in which the patient has closed into. Because these records can be several millimeters thick, an error is introduced when nonarcon articulators are set with protrusive wax records, because the condylar path is not fixed in relation to the maxillary occlusal plane. As the protrusive record used to adjust the instrument is removed from the arcon articulator, the maxillary occlusal plane and the condylar inclination become more parallel, which leads to reduced cuspal heights in subsequently fabricated prostheses (see Table 4-3).



Fig. 2-7
Semiadjustable arcon articulators. A, The Denar Anamark. B, The Whip Mix model 2240. C, The Hanau Wide-Vue. *(**A** and **C**, Courtesy of Waterpik Technologies, Inc., Fort Collins, Colorado. **B**, Courtesy of Whip Mix Corporation, Louisville, Kentucky.)*

Fully Adjustable Articulators

A fully (or highly) adjustable articulator (Fig. 2-9) has a wide range of positions and can be set to follow a patient's border movements. The accuracy of reproduction of movement depends on the care and skill of the operator, the errors inherent in the articulator and recording device, and any malalignments resulting from slight flexing of the mandible and the nonrigid nature of the temporomandibular joints.

Rather than relying on wax records to adjust the instrument, special pantographic tracings are used to record the patient's border movements in a series of tracings. The armamentarium used to generate these tracings is then transferred to the articulator, and the instrument is adjusted so that the articulator replicates the tracings, essentially reproducing the border movements of the patient. The ability of fully adjustable instruments to track irregular pathways of movement throughout entire trajectories

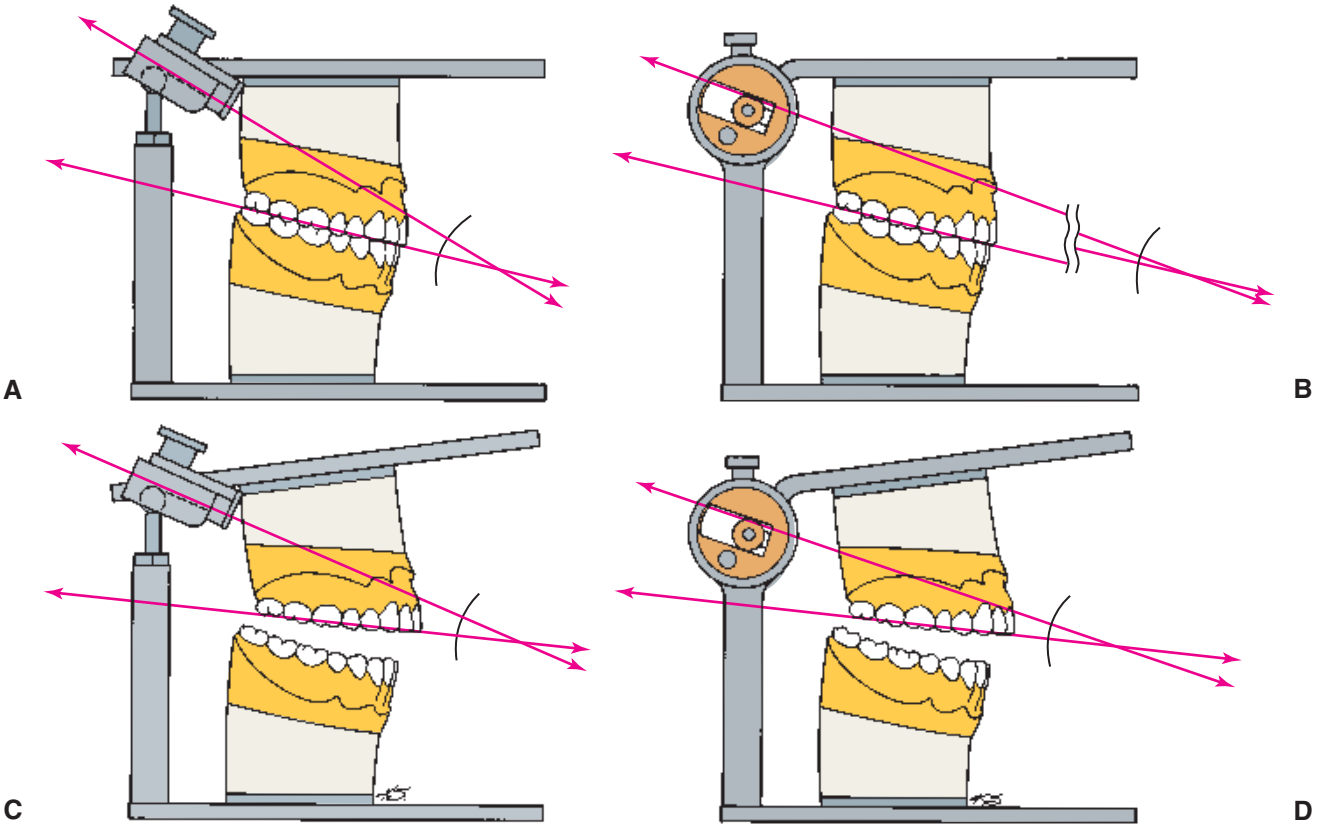


Fig. 2-8

Articulators. A and C show an arcon articulator; B and D show a nonarcon articulator. An advantage of the arcon design is that the condylar inclination of the mechanical fossae is at a fixed angle to the maxillary occlusal plane. With the nonarcon design, the angle changes as the articulator is opened, which can lead to errors when a protrusive record is being used to program the articulator. *(Redrawn from Shillingburg HT, et al: Fundamentals of Fixed Prosthodontics, 2nd ed. Chicago, Quintessence Publishing, 1981.)*

enables the fabrication of complex prostheses, which require minimal adjustment at the evaluation and delivery appointment.

Fully adjustable articulators are not often required in general practice. Using and adjusting them can be time consuming and require a high level of skill and understanding of the dentist and the technician. Once this skill has been acquired, however, the detailed information they convey can save considerable chairside time. They can be very useful as treatment complexity increases (e.g., when all four posterior quadrants are to be restored simultaneously or when it is necessary to restore an entire dentition, especially in the presence of atypical mandibular movement).

FACEBOWS

Transverse Horizontal Axis

The mandibular hinging movement around the transverse horizontal axis is repeatable. Therefore, this imaginary **hinge axis** around which the mandible may rotate in the sagittal plane is of considerable importance when fixed prostheses are fabricated. Facebows are used to record the anteroposterior and mediolateral spatial position of the maxillary occlusal surfaces in relation to this transverse opening and closing axis of the patient's mandible. The facebow is then attached to the articulator to transfer the recorded relationship of the maxilla by ensuring that the corresponding cast is attached in the correct position in relation to the hinge axis of the instrument. After the maxillary cast has been attached to the articulator with mounting stone or plaster, the mandibular cast is subsequently related to the maxillary cast with an interocclusal record. If the patient's casts are accurately transferred to an instrument, considerable time is saved in the fabrication and delivery of high-quality prostheses.

Most facebows are rigid, caliper-like devices that allow some adjustments. Two types of facebows are recognized: arbitrary and kinematic. **Arbitrary**



Fig. 2-9
Fully adjustable articulators. **A,** The Stuart. **B,** The Denar D5A. (***B,*** *Courtesy of Waterpik Technologies, Inc., Fort Collins, Colorado.)*

facebows are less accurate than the kinematic type, but they suffice for most routine dental procedures. **Kinematic facebows** are indicated when it is crucial to precisely reproduce the exact opening and closing movements of the patient on the articulator. For instance, when a decision to alter the occlusal vertical dimension is to be made in the dental laboratory during the fabrication of fixed prostheses, the use of a kinematic facebow transfer in conjunction with an accurate CR interocclusal record is indicated.

Kinematic Hinge Axis Facebow

Hinge axis recording

The hinge axis of the mandible can be determined to within 1 mm by observing the movement of kinematic facebow styli positioned immediately lateral to the temporomandibular joint close to the skin. A clutch, which is essentially a segmented impression-traylike device, is attached to the mandibular teeth with a suitable rigid material such as impression plaster. The kinematic facebow consists of three components: a transverse component and two adjustable side arms. The transverse rod is attached to the portion of the clutch that protrudes from the patient's mouth. The side arms are then attached to the transverse member and adjusted so that the styli are as close to the joint area as possible. The mandible is then manipulated to produce a terminal hinge movement, and the stylus locations are adjusted with thumbscrews (superiorly and inferiorly, anteriorly and posteriorly) until they make a purely rotational movement (Fig. 2-10). Because the entire assembly is rigidly attached to the mandible, a strictly rotational movement signifies that stylus position coincides with the hinge axis. When this purely rotational movement is verified, the position of the hinge axis is marked with a dot on the patient's skin, or it may be permanently tattooed if future use is anticipated or required.

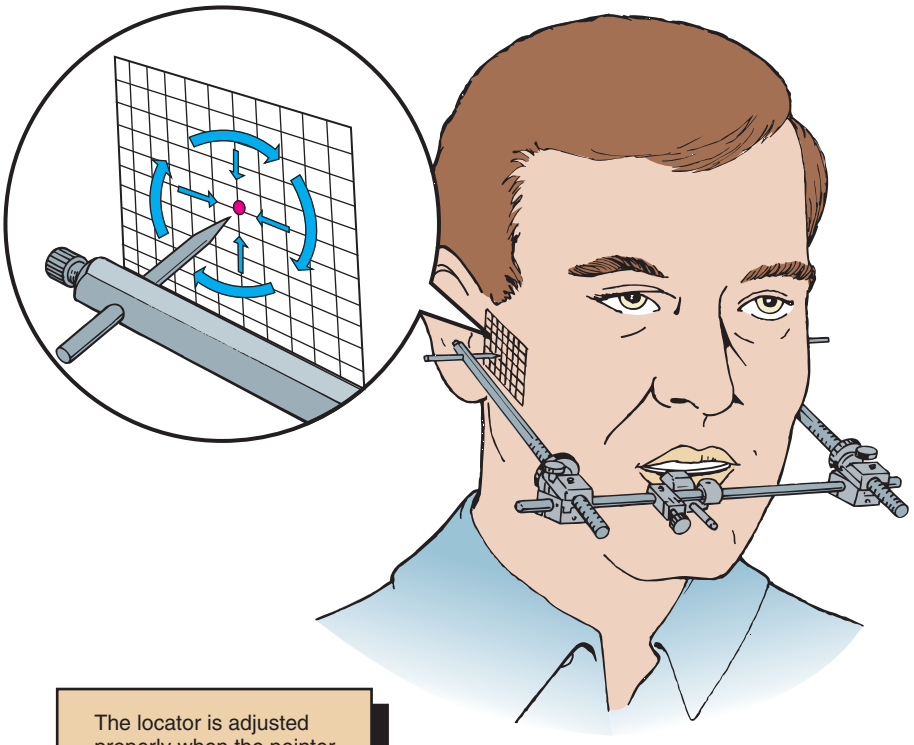
Kinematic facebow transfer

An impression of the maxillary cusp tips is obtained in a suitable recording medium on a facebow fork (Fig. 2-11). The facebow is attached to the protruding arm of the fork. The side arms are adjusted until the styli are aligned with the hinge axis marks on the patient's skin. The patient must be in the same position that was used when the axis was marked to prevent skin movement from introducing any inaccuracy. A pointer device is usually attached to the bow and adjusted to a repeatable reference point selected by the clinician. The reference point is used later for reproducibility. The kinematic facebow recording is then transferred to the articulator, and the maxillary cast is attached.

The kinematic facebow technique is time consuming, so it is generally limited to extensive prosthodontics, particularly when a change in the occlusal vertical dimension is to be made. A less precisely derived transfer would then lead to unacceptable errors and a compromised result.

Arbitrary Hinge Axis Facebow

Arbitrary hinge axis facebows (Fig. 2-12) approximate the horizontal transverse axis and rely on anatomic average values. Manufacturers design these facebows so the relationship to the true axis falls within an acceptable degree of error. Typically, an easily identifiable landmark such as the external acoustic meatus is used to stabilize the bow, which is aligned with earpieces similar to those on a stetho-



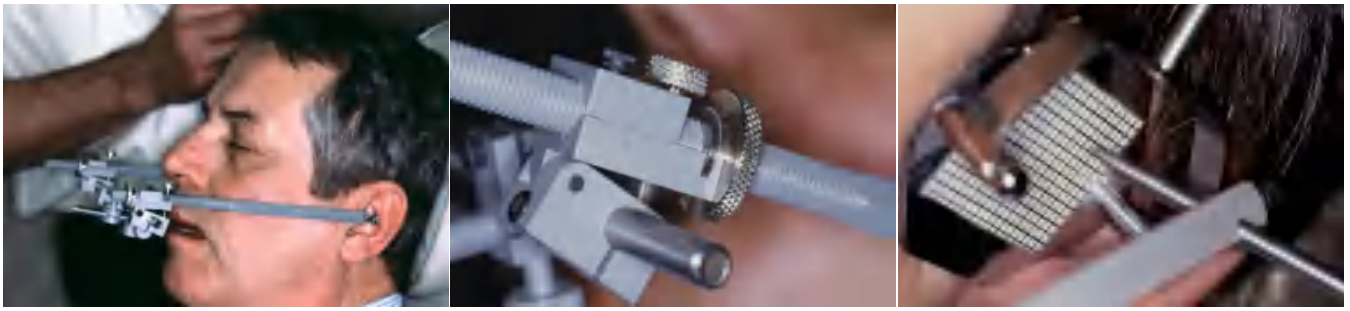


Fig. 2-10

Hinge axis recording. **A,** Left and right styli are attached via a facebow to a clutch affixed to the mandibular teeth. When the mandible makes a strictly rotational movement, the stylus remains stationary if aligned with the actual axis of rotation. If the stylus is positioned forward or backward, above or below the actual axis, it travels one of the arcs indicated by the *arrows* when the mandible makes a rotational movement. Thus, the arc indicates in what direction an adjustment should be made to the stylus position. **B,** Hinge axis locator positioned. **C,** Set screws allow side arm adjustment. **D,** Adjustment continues until no arcing of the pointer is seen.

scope. Such facebows can be used single-handedly because they are self-centering and do not require complicated assembly. They give a sufficiently accurate relationship for most diagnostic and restorative procedures. However, regardless of which arbitrary position is chosen, a minimum error of 5 mm from the axis can be expected,[9] as can errors in the steepness of the occlusal plane.[10] When coupled with the use of a thick interocclusal record made at an increased vertical dimension, this error can lead to considerable inaccuracy.

Anterior reference point

The use of an **anterior reference point** (Fig. 2-13) enables the clinician to duplicate the recorded position on the articulator at future appointments. This saves time, because previously recorded articulator settings can be used again. An anterior reference

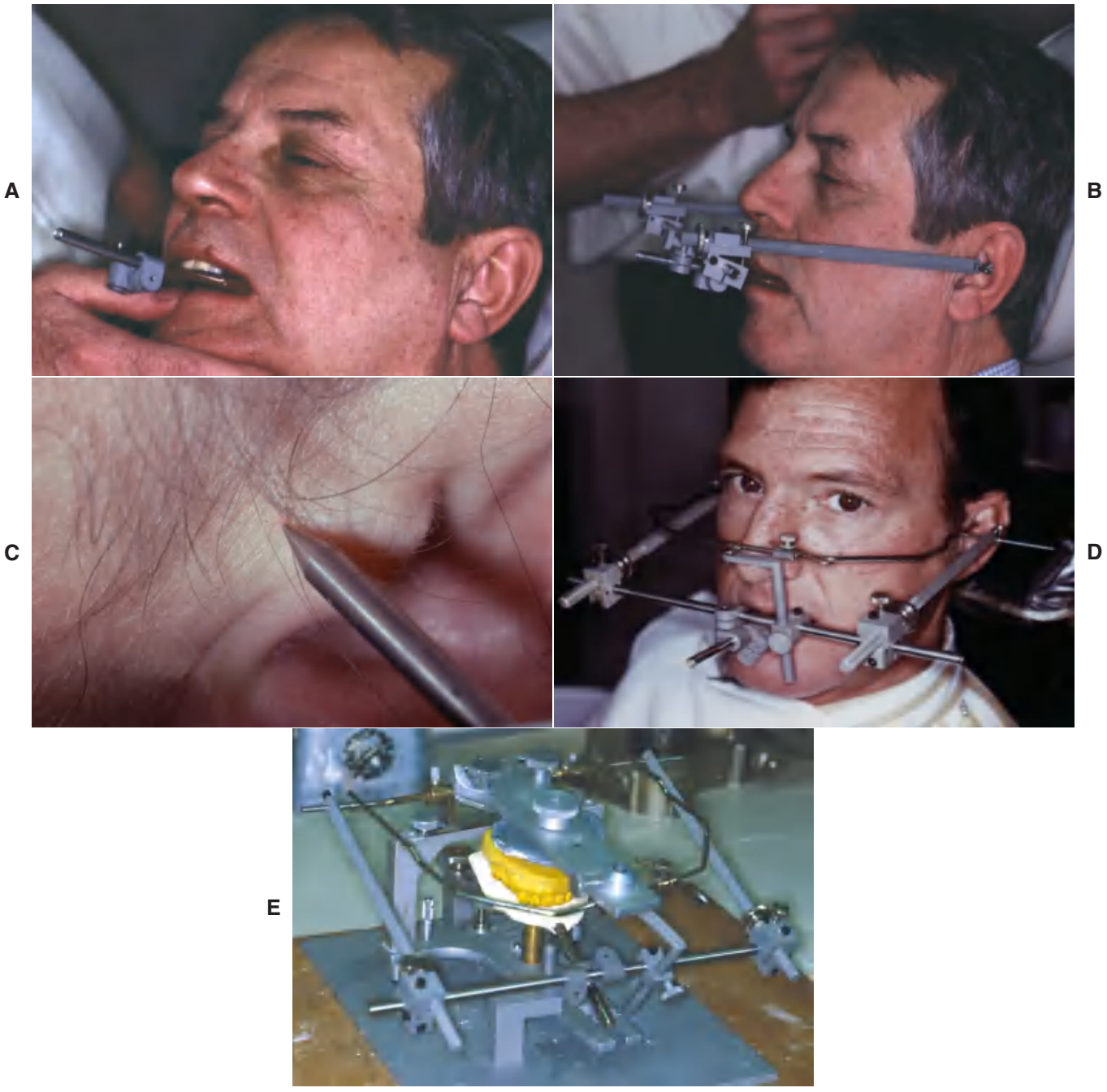


Fig. 2-11
Kinematic hinge axis facebow. **A,** Clutch seated on the mandibular teeth. The clutch separates for removal into two components by loosening the screws on left and right sides. **B,** Kinematic facebow assembly positioned. **C,** Pointers aligned with the previously marked hinge axis location. **D,** Assembled kinematic facebow. **E,** Kinematic facebow aligned on the articulator.

point, such as the inner canthus of the eye or a freckle or mole on the skin, is selected. After this has been marked, it is used, along with the two points of the hinge axis, to define the position of the maxillary cast in space. This procedure has the following advantages:

- After the posterior controls have been adjusted initially, subsequent casts can be mounted on the articulator without repeating the facebow determinations and having to reset the posterior articulator controls.
- Because the maxillary arch is properly positioned in relation to the axis, average values for posterior articulator controls can be used without having to readjust the instrument on the basis of eccentric records.

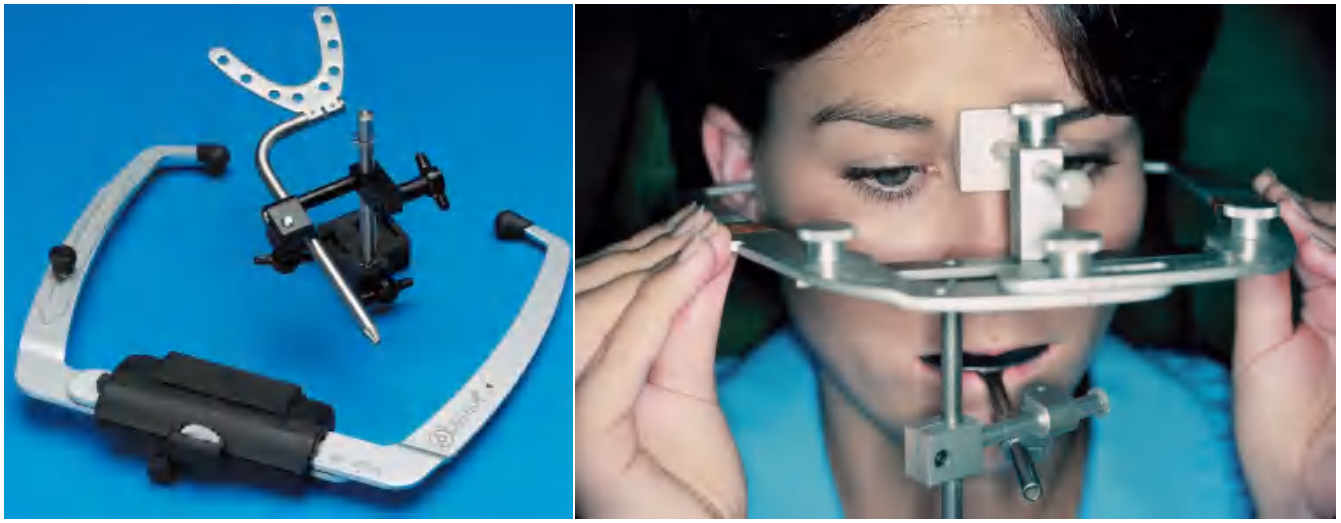


Fig. 2-12
Arbitrary hinge axis facebows. A, The Denar Slidematic. B, Whip Mix Quick Mount. Note the nasion relator as the anterior reference point. *(A, Courtesy of Waterpik Technologies, Inc., Fort Collins, Colorado.)*



Fig. 2-13
Anterior reference point. The Denar Slidematic facebow uses a mark 43 mm superior to the incisal edge of the maxillary central incisor as an anterior reference point. Other systems use the infraorbital foramen or nasion. The mark serves as a reference to average anatomic values. It also allows subsequent casts to be mounted without a repeat recording. *(Courtesy of Waterpik Technologies, Inc., Fort Collins, Colorado.)*

- When the articulator has been adjusted, the resulting numerical values for the settings can be compared with known average values to provide information about the patient's individual variations and the likelihood of encountering difficulties during restorative procedures.

Facebow transfer

Armamentarium

- Arbitrary-type hinge axis facebow
- Modeling compound
- Cotton rolls

Step-by-step procedure

1. Add modeling compound to the facebow fork (Fig. 2-14A).
2. Temper in water and seat the fork, making indentations of the maxillary cusp tips. The facebow fork is positioned in the patient's mouth, and an impression is made of the maxillary cusp tips. The impression must be deep enough to permit accurate repositioning of the maxillary cast after the facebow fork has been removed from the mouth. Only the cusp tips should be recorded. It is not necessary to get an impression of every cusp, or even an entire cusp—just one that is sufficient to position the diagnostic cast accurately. If the impression is too deep, accurate repositioning of the cast can become problematic because the diagnostic casts are not absolutely accurate reproductions of the teeth. In general, the tips are reproduced more accurately than the fossae.
3. Remove the fork from the mouth. Chill and reseat the fork, and check that no distortion has

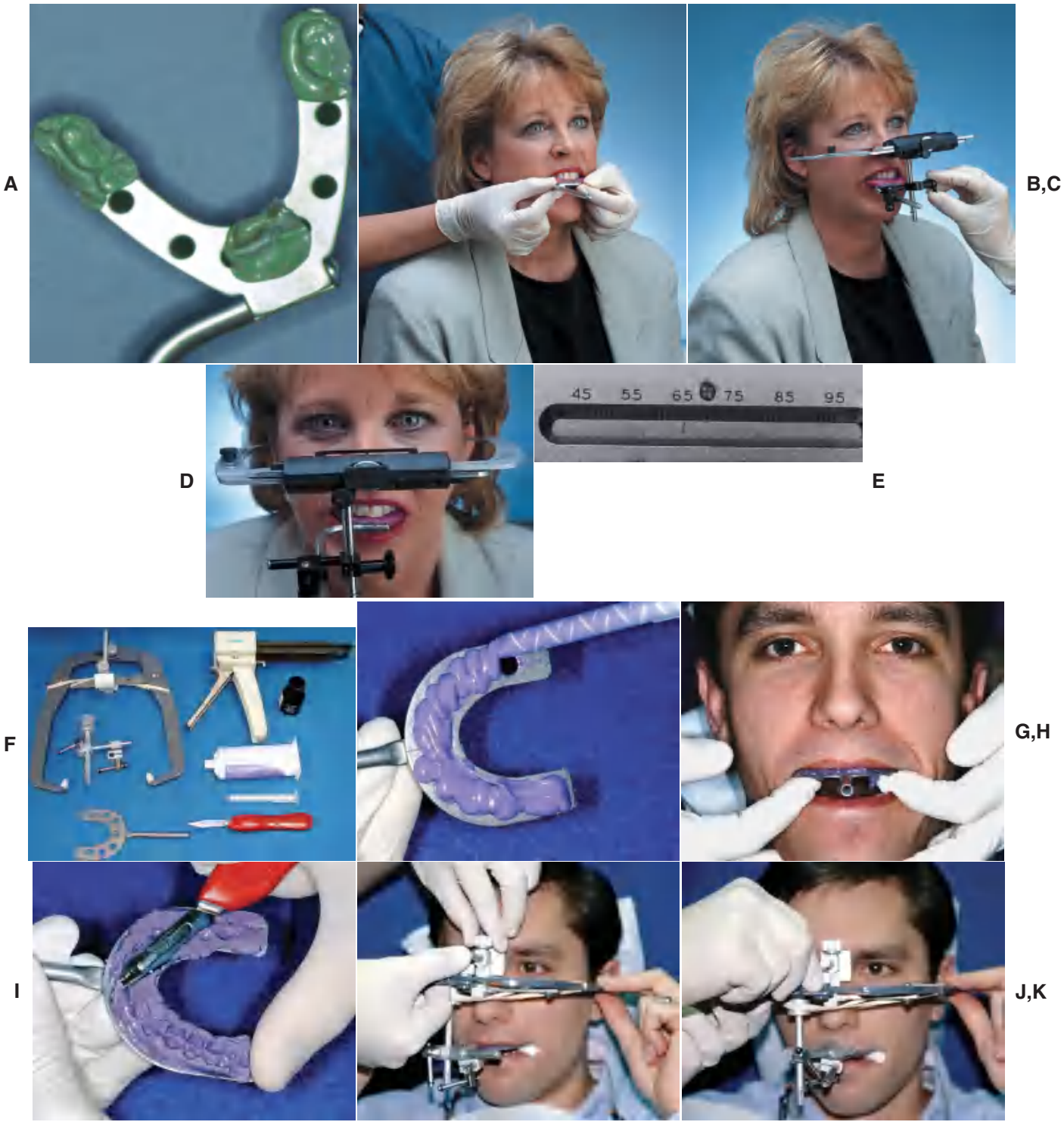


Fig. 2-14

Facebow technique. **A** to **E,** Denar Slidematic Facecow Technique. **A,** Indentations obtained in compound. **B,** Facebow fork positioned. **C,** Facebow attached to facebow fork, toggles tightened. **D,** Transfer complete. **E,** Width measurement is read from the top of the facebow. **F** to **K,** Whip Mix Quick Mount Facebow Technique. **F,** Armamentarium. **G,** Automixed elastomer is applied to the transfer fork. **H,** Adapting the facebow fork to the maxillary teeth. **I,** The obtained record is trimmed with a sharp blade to facilitate seating. **J,** Nasion relator being positioned. **K,** Knobs and toggles are tightened. *(**B** to **D,** Courtesy of Waterpik Technologies, Inc., Fort Collins, Colorado. **F, H** to **K,** Courtesy of Whip Mix Corporation, Louisville, Kentucky.)*

occurred (Fig. 2-14*B*). The inclusion of details of pits and fissures in the recording medium leads to inaccuracies in trying to seat the stone cast. Trim the recording medium as necessary before reseating. After reseating, check for stability.

4. Have the patient stabilize the facebow fork by biting on cotton rolls. As an alternative, wax can be added to the mandibular incisor region of the fork. The mandibular anterior teeth stabilize the fork as they engage the wax.
5. Slide the universal joint onto the fork and position the caliper to align with the anterior reference mark (Fig. 2-14*C*).
6. Tighten the screws securely in the correct sequence (Fig. 2-14*D*).
7. If the articulator has an adjustable intercondylar width, record this measurement (Fig. 2-14*E*). Remove the facebow from the mouth.

The technique is slightly different with other arbitrary facebows (Fig. 2-14*F* to *K*).

Centric relation record

A **centric relation record** (Fig. 2-15) provides the orientation of mandibular to maxillary teeth in CR in the terminal hinge position, in which opening and closing are purely rotational movements. *Centric relation* is defined as the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the condyle-disk complex in the anterosuperior position against the articular eminences. This position is independent of tooth contact.

MI may or may not be coincident with the CR position. The CR record is transferred to the maxillary cast on the articulator and is used to relate the mandibular cast to the maxillary cast. Once the mandibular cast is attached to the articulator with mounting stone, the record is removed. The casts then occlude in precisely the CR position as long as the maxillary cast is correctly related to the hinge axis with a facebow (see Fig. 2-14). When the articulator controls are set properly, through the use of appropriate excursive records, translated mandibular positions can be reproduced from CR. A CR/MI slide is readily reproducible on casts that have been articulated in CR. Thus, premature tooth contacts (deflective contacts) can be observed, and it can be determined whether an occlusal correction is necessary or appropriate before fixed prosthodontic treatment. Casts articulated in the MI position do not enable the evaluation of CR and retruded contact relationships. Therefore, the articulation of diagnostic casts in CR is of greater diagnostic value.

In theory, when a kinematic facebow is used, the thickness of a terminal hinge record is unimportant; a thicker record merely increases the amount of rotation. When an arbitrary facebow is used, any arcing movement results in some degree of inaccuracy. Both techniques are subject to small errors, which can be minimized by keeping the record thin.[11,12] However, it is essential that the teeth not perforate the record. Any tooth contact during record fabrication can cause mandibular translation because of

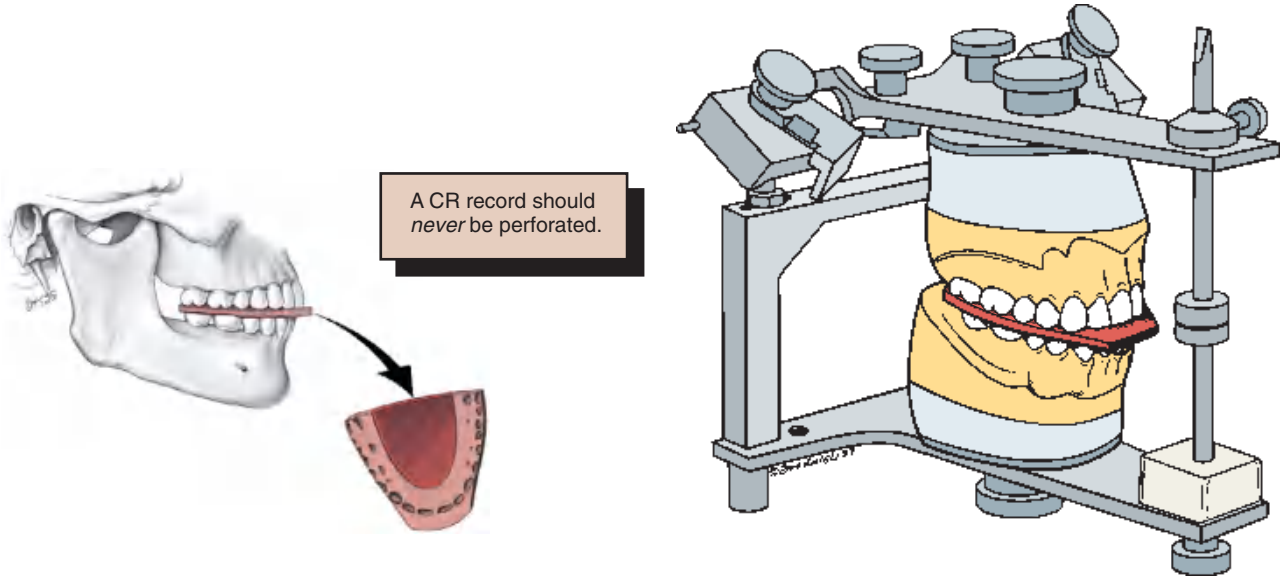


Fig. 2-15
A centric relation (CR) record transfers the tooth relationships at CR from the patient to the articulator.

neuromuscular protective reflexes governed by mechanoreceptors in the periodontium, rendering the resulting articulation useless.

Jaw manipulation

Accurate mounting of casts depends on precise manipulation of the patient's mandible by the dentist. The condyles should remain in the same place throughout the opening-closing arc. Trying to force the mandible backwards leads to downward translation of the condyles, and restorations made to such a mandibular position are in supraclusion at the evaluation stage (Fig. 2-16).

The load-bearing surfaces of the condylar processes, which face anteriorly, should be manipulated into apposition with the mandibular fossae of the temporal bones, with the disk properly interposed. The ease with which this can be accomplished depends on the degree of the patient's neuromuscular relaxation and on sound technique. The latter, in turn, depends on the patient's permitting the dentist to control the mandible. Attempts to force or shake the mandible lead to a protective muscle response by the patient.

The bimanual manipulation technique described by Dawson[13] is recommended as a reproducible technique[14] that can be reliably learned.[15] In this technique, the dental chair is reclined and the patient's head is cradled by the dentist. With both thumbs on the chin and the fingers resting firmly on the inferior border of the mandible (Fig. 2-17*A*), the dentist exerts gentle downward pressure on the thumbs and upward pressure on the fingers, manipulating the condyle-disk assemblies into their fully seated positions in the mandibular fossae. Next, the mandible is carefully hinged along the arc of terminal hinge closure. *Note:* It is more difficult to ensure that the condyles are properly located when the single-handed approach (Fig 2-17*B*) is used with the fingers exerting upward pressure, although this technique does allow the other hand to hold the record.

Anterior programming device (Fig. 2-18)

In some patients in whom CR does not coincide with MI, resistance may be encountered when hingeing the mandible. Because of well-established protective reflexes that are reinforced every time the teeth come together, such patients do not allow their mandibles to be manipulated and hinged easily. If tooth contact can be prevented, they "forget" these reflexes, and manipulation becomes easier. The teeth can be kept apart with cotton rolls, a plastic leaf gauge, or a small anterior **programming device** made of autopolymerizing acrylic resin (also known as a *Lucia jig*).[16]

If the mandible cannot be manipulated satisfactorily after an anterior programming device has been

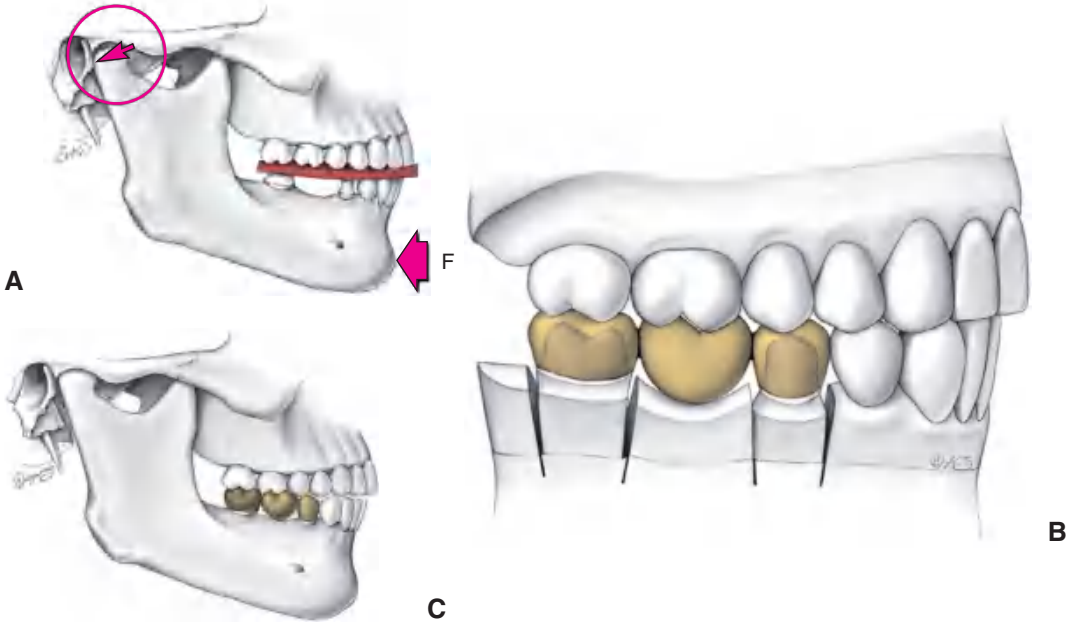


Fig. 2-16

Incorrect centric relation recording. **A,** If the mandible is forced backward (*F*), the condyles are not in their most superior position but are moved backward and downward (*arrow*). **B,** Any restorations made on casts related with this CR record are in supraclusion when tried in the mouth. **C,** Note the relationship of the anterior teeth.

in place for 30 minutes, marked neuromuscular dysfunction is likely. Normally, this is relieved by providing an occlusal device (whose fabrication and adjustment are described in Chapter 4).

Centric relation recording technique

Different techniques can be used to make a CR record. The choice of recording medium is, to some degree, a function of the casts to be articulated. For instance, very accurate casts made from elastomeric impression materials can be articulated with a high-accuracy interocclusal record material such as polyvinyl siloxane. However, less accurate diagnostic casts poured from irreversible hydrocolloid are better articulated with the use of a more "forgiving" material such as interocclusal wax, provided that the record is properly reinforced. Most studies have shown considerable variability among various registration materials and techniques,[17] and so particular care is needed with this procedure.

Reinforced Aluwax record

The reinforced Aluwax record is a "forgiving" method for recording the CR position. It is a reliable technique, originally described by Wirth[18] and Wirth and Aplin,[19] and has provided consistent results.[20,21]

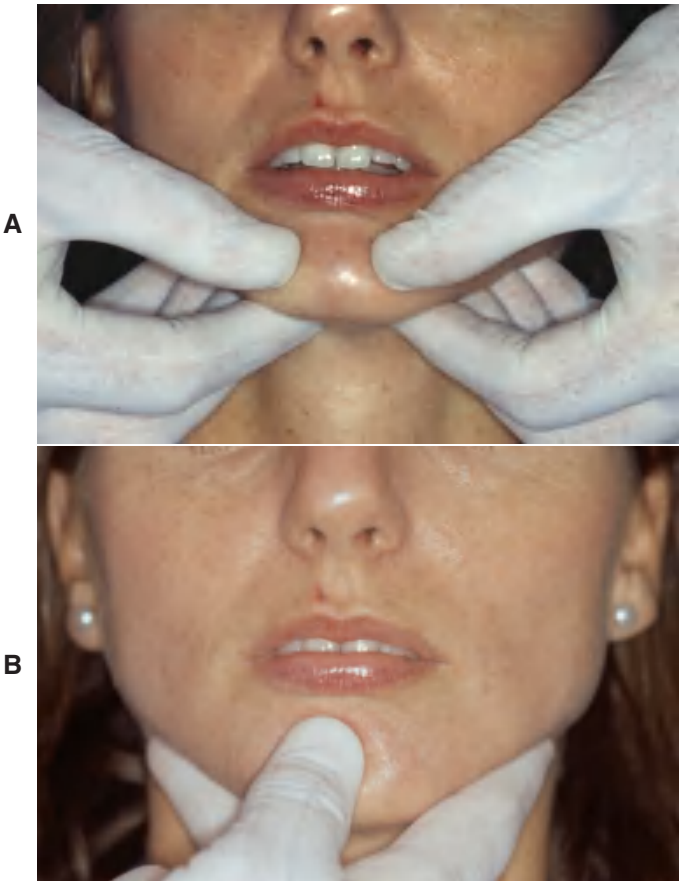


Fig. 2-17
Manipulating a patient's mandible into centric relation. Note the position of the dentist's thumbs and fingers on the mandibular border. The bimanual (**A**) and the single-handed technique (**B**).

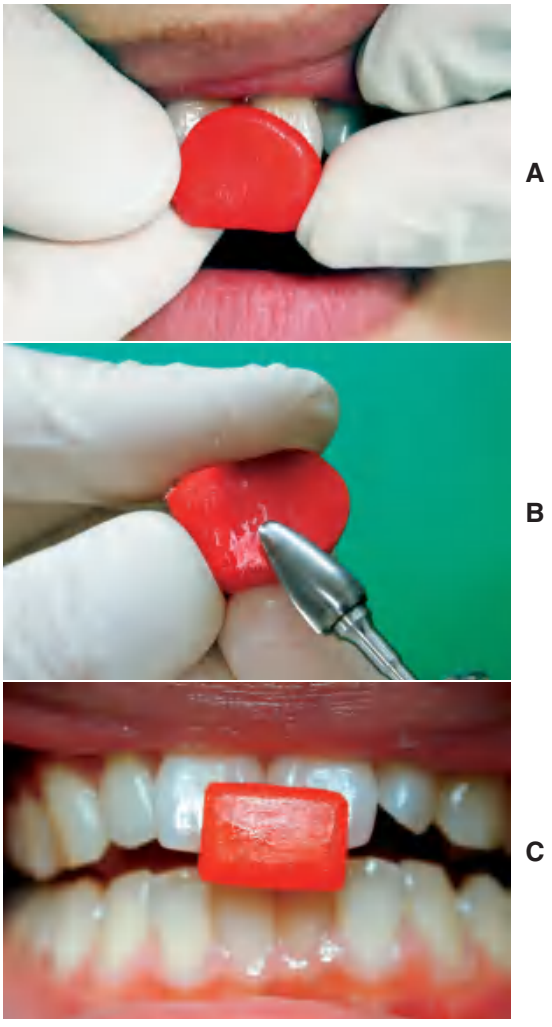


Fig. 2-18
An anterior programming device is used to facilitate centric relation recording. **A,** Autopolymerizing resin is mixed and adapted to the maxillary central incisors. The patient's mouth is guided into closure and stopped when the posterior teeth are about 1 mm apart. **B,** The indentations are used as a guide during trimming of the device. The completed device (**C**) should allow the patient to make smooth lateral and protrusive movements. An inclined contact area must be avoided, because it will tend to cause the mandible to retrude excessively.









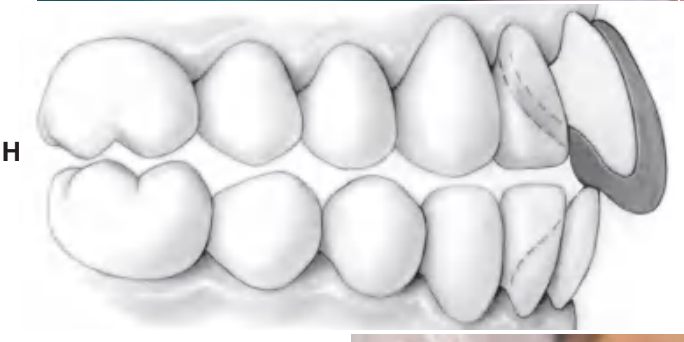






Fig. 2-18, cont'd

D, Alternatively, a thermoplastic material can be used. **E,** After softening and positioning, the mandible is guided into centric relation closure. **F,** The device is trimmed with a scalpel. **G,** Again, posterior disclusion is verified. **H,** Cross-section through device. **I** and **J,** Use of a plastic leaf gauge to prevent habitual closure into maximal intercuspation.

Armamentarium (Fig. 2-19A)
- Heat-retaining wax sheet (i.e., Aluwax)*
- Soft metal sheet (Ash's metal)*
- Sticky wax
- Scissors
- Ice water

Step-by-step procedure
1. Soften half a sheet of occlusal wax in warm water and adapt it to the maxillary cusp tips. Allow the patient to close lightly, and make cuspal indentations of the mandibular teeth (Fig. 2-19*B*). These indentations form no part of the record, but they thin the wax slightly and indicate the approximate positions of the mandibular teeth for later reference.
2. Add baseplate wax to the mandibular anterior region of the record (Fig. 2-19*C*), add soft metal sheet to reinforce the palatal area, and seal along the periphery with sticky wax (Fig. 2-19*D*).
3. Readapt the record to the maxillary teeth, resoftening if necessary. Guide the patient's mouth into centric closure, making shallow indentations in the wax. Verify that no posterior tooth contact occurs. If it does, add an additional layer of baseplate wax (Fig. 2-19*E*,*F*).
4. Remove the record carefully and verify that no distortion has occurred. Then chill it thoroughly in ice water.
5. Reseat the record on the maxillary teeth and evaluate it for stability. If the maxillary cast is available, evaluate the fit on this as well.
6. Add heat-retaining wax in the mandibular incisor region only and manipulate the mandible as previously described. Having the patient in a supine position for this manipulation allows better control.
7. Make indentations of the mandibular incisor tips in the wax, repeating several times to ensure reproducibility. Remove the wax record and rechill it in ice water until the anterior indentations are hard (Fig. 2-19*G*).
8. Add a small amount of heat-retaining wax in the mandibular posterior region (Fig. 2-19*H*) and reseat the record (Fig. 2-19*I*). Remember that when new wax is added, the record should be dried; otherwise, the wax does not adhere and may become detached. Then guide the mandibular teeth into the anterior indentations and have the patient close lightly. The baseplate wax prevents excessive closure. Excessive force may distort the record or flex the mandible.[22] The elevator muscles of the mandible ensure that the most superior position of the condylar processes is recorded.
9. Remove the record and chill it (Fig. 2-19*J*).

The advantage of this sequential technique is that the CR position is reproduced multiple times as the record is generated. The heat-retaining Aluwax is soft and distorts easily. Therefore, if the patient's mouth is not guided into exactly the same position, this problem becomes readily apparent. Once the completed record has been obtained with adequate but fairly shallow indentations for all cusps (Fig. 2-19*K*,*L*), the same arcing motion has been reproduced four times, confirming that the CR position has been accurately captured.

Anterior programming device with elastomeric or ZOE record

Armamentarium
- Self-curing resin
- Petroleum jelly
- Elastomeric material
- Syringe
- Scalpel blade

Step-by-step procedure
1. Fabricate an anterior programming device from self-curing resin. The resin should be mixed to the consistency of putty and, after lubrication of the central incisors with petroleum jelly, adapted to the teeth. The lingual aspect of the anterior programming device should follow the lingual contours of the teeth. After trimming, it should result in separation of the posterior teeth (see Fig. 2-18*H*). When the patient closes on the anterior programming device, no translation should occur.
2. Verify that no posterior contact remains and that the only occlusal contact is on the anterior programming device. The device should be stable and remain in position. If necessary, some petroleum jelly can be applied to its internal surface.
3. Rehearse the closing of the mandible with the patient until a reproducible CR position is obtained.
4. Verify that the syringe tip is large enough to permit free flow of the elastomeric material. Enlarge the opening of the syringe tip if necessary by trimming it with a scalpel blade.
5. Dispense and mix the elastomeric material according to the manufacturer's instructions (Fig. 2-20*A*). (The Automix materials are convenient.)
6. Blow the occlusal surfaces of the teeth dry, and, using a syringe, apply the material onto the occlusal surface of the mandibular arch (Fig. 2-20*B*).

*See Appendix A



Fig. 2-19

Centric relation (CR) recording technique. The reproducibility of the CR position is verified because CR has to be reproduced several times while the record is made. **A,** Armamentarium. **B,** A sheet of soft Aluwax is adapted to the maxillary arch. **C,** A piece of hard pink wax is added to the lower anterior portion of the wafer. **D,** Some Ash's Metal #7 is folded around the posterior border and luted to the wafer with sticky wax to increase rigidity. **E,** The reinforced sheet is repositioned and the mandible is guided into CR until the pink wax provides a stop for vertical closure. **F,** Note that the maxillary indentations capture only the cusp tips. Some Aluwax is added to the lower incisor indentations. The record is repositioned and the CR closure repeated. **G,** The incisor indentations are reproduced in the Aluwax. **H,** After additional wax is added to the area of the first molars, hinge closure is repeated (**I**). **J,** The molar indentations are clearly visible. The incisor indentations should have been reproduced. Any "double" indentation indicates inaccuracy. **K,** The CR closure is repeated one more time after additional Aluwax is added to the premolar regions. **L,** The completed CR record. *(Courtesy of Dr. J. N. Nelson.)*

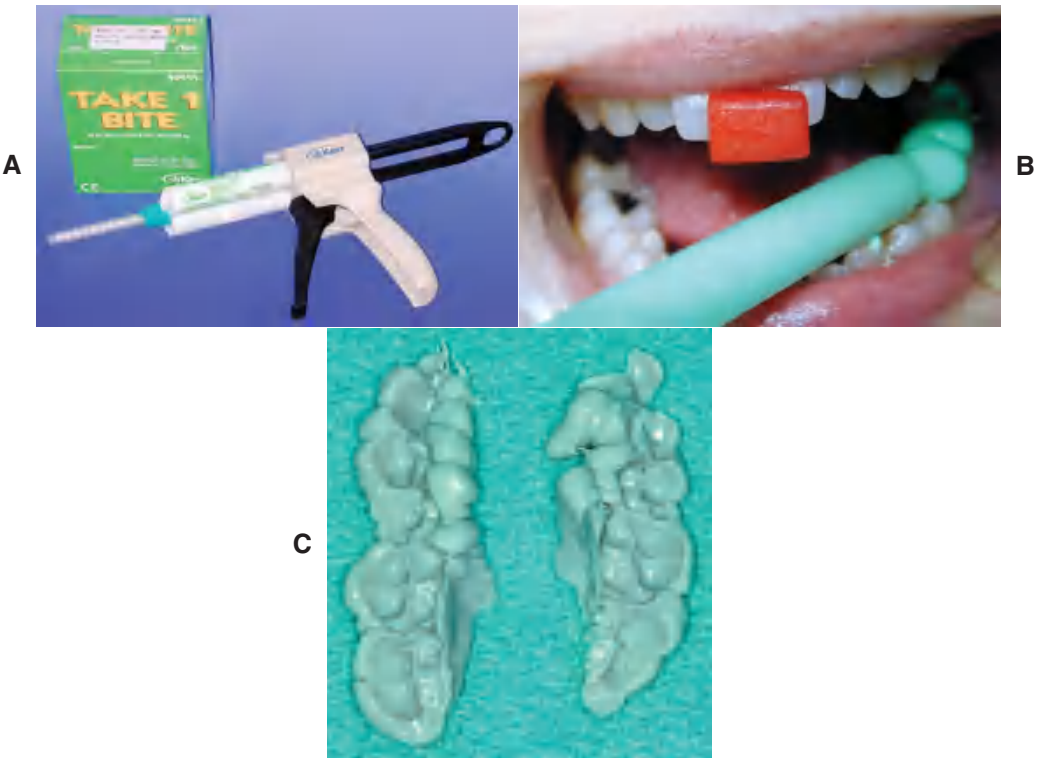


Fig. 2-20
Centric relation (CR) recording. **A,** Elastomeric material for CR recording. **B,** Mandibular quadrants coated, the dentist is using an anterior resin jig (see Fig. 2-18) to ensure a reproducible recording position is obtained. The patient's mouth remains occluded until the material has set. **C,** The record before trimming.

7. Guide the patient's mandible into hinge movement until the mandible comes to rest on the anterior programming device. Maintain this position until the material has set.
8. Remove the record from the mouth (see Fig. 2-20C) and trim with the scalpel blade following the buccal cusps.
9. Verify that the mandibular and maxillary casts seat fully in the record.

As an alternative to the use of elastomeric material, a gauze mesh with zinc oxide-eugenol occlusal registration paste can be used (Fig. 2-21). The step-by-step procedure follows the one described for the elastomeric technique. However, rather than using a syringe to apply the material onto the mandibular arch, the practitioner should coat the interocclusal cloth forms outside the mouth and interpose them, after which the patient's mouth can be guided into CR. Care must be taken, however, to position the frame that holds the cloth form so that it does not interfere with the closure movement.

Other alternative techniques include using impression plaster or autopolymerizing resin as the recording medium. In all these techniques, accuracy depends on complete seating of the casts into the recording medium. Seating is often prevented by



Fig. 2-21
Gauze mesh cloth forms with plastic holders, and ZOE paste can be used instead of elastomeric paste.

better detail reproduction in the record than in the casts, especially around the fossa. This additional detail needs to be carefully trimmed until the cast is completely seated in the record.

Recording jaw relationships in partially edentulous dentitions

When there are insufficient teeth to provide bilateral stability, obtaining a CR record as described may not be possible. As a result, acrylic resin record bases must be fabricated (Fig. 2-22). To avoid errors caused by soft tissue displacement, which prevents accurate transfer of rigid materials from one set of casts to another, these bases should be made on the casts that are to be articulated. If breakage of the casts is a concern, it may be advisable to make record bases on an accurate duplicate cast made with reversible agar hydrocolloid impression material in a flask designed for that purpose.

Articulating the diagnostic casts

Maxillary cast

The maxillary cast (Fig. 2-23) is seated in the indentations on the facebow fork after the facebow is attached to the articulator. Wedges or specially designed braces can be used to support the weight of the cast and to prevent the fork from flexing or moving. After it has been scored and wetted, the cast is attached to the mounting ring of the articulator with a low-expansion, fast-setting mounting stone or plaster.

Mandibular cast

To relate the mandibular cast properly to the maxillary cast, the incisal guide pin should be lowered sufficiently to compensate for the thickness of the CR record. The articulator is inverted, and the record is seated on the maxillary cast. The mandibular cast (Fig. 2-24) is then carefully seated in the record, and each cast is checked for stability. The maxillary and mandibular casts can be luted together with metal rods, or pieces of wooden tongue blade, and sticky wax. The mandibular member of the articulator is closed into mounting stone; the condylar balls should be fully seated in the corresponding fossae. If the articulator has a centric latch, this step is simplified. Otherwise, the articulator should be held until the stone has reached its initial set. No attempt

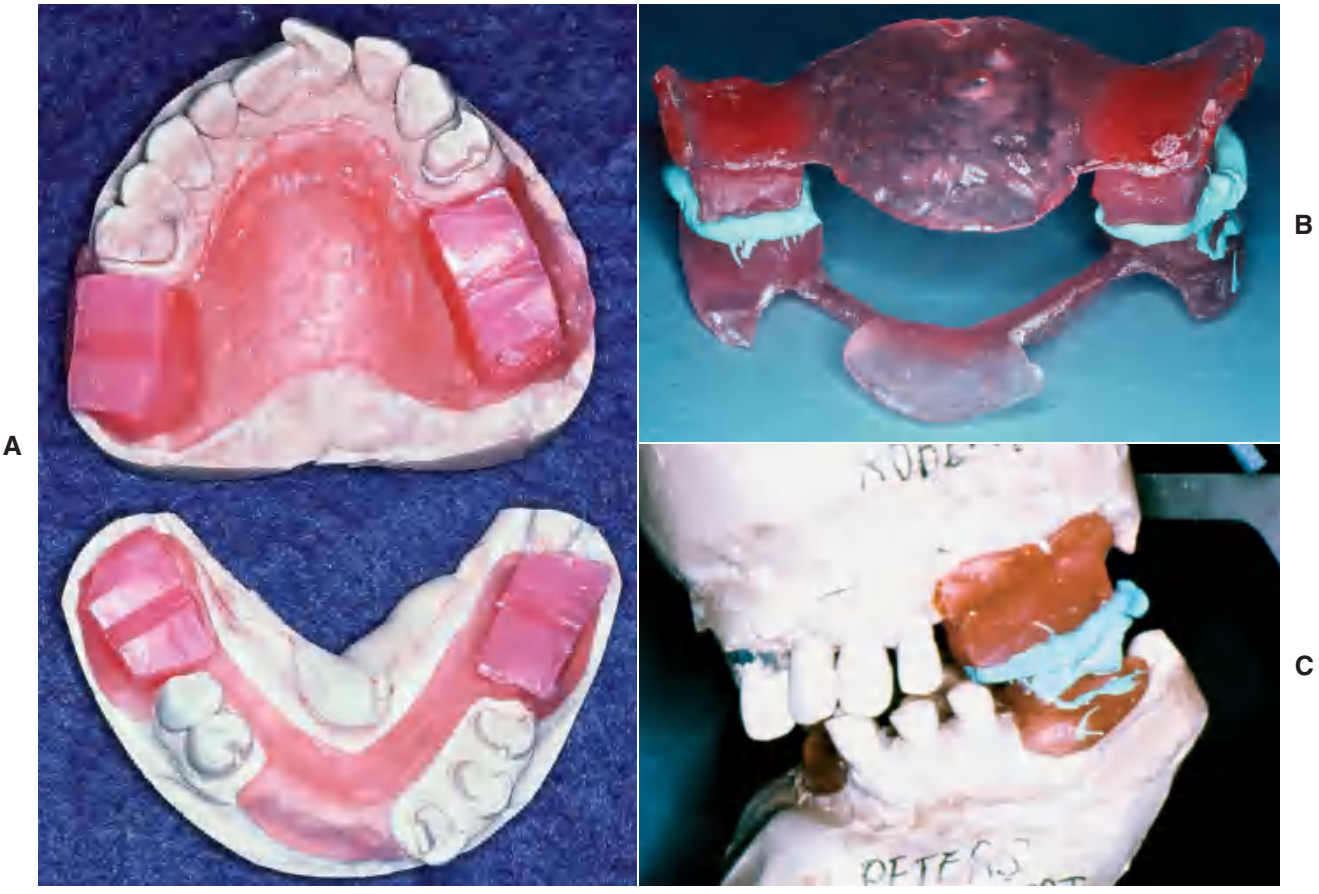


Fig. 2-22
A to **C**, Acrylic resin record base for mounting a partially edentulous cast.



Fig. 2-23
Mounting the maxillary cast on a Whip Mix articulator. A, Armamentarium. **B,** The incisal pin is removed. **C,** The condylar inclination is adjusted to the facebow setting. **D,** The side shift is set to zero. **E,** A mounting plate is attached. **F,** The facebow earpieces are attached to the condylar elements. **G,** Facebow is attached to the articulator. **H,** The scored maxillary cast is positioned on the facebow fork, and the cast is prewetted. **I,** Mounting stone is applied to the cast and the mounting plate. The upper member of the articulator is closed until it contacts the crossbar of the facebow. **J,** Additional stone is added as needed. *(Courtesy of Whip Mix Corporation, Louisville, Kentucky.)*

should be made to smooth the stone until it has fully set.

Evaluation

Accuracy is crucial in both CR and maximum intercuspation. Before the articulator controls are adjusted, the accuracy of CR must be confirmed by comparing the tooth contacts on the casts with those in the mouth (Fig. 2-25). During the clinical examination, the position of tooth contacts in CR can be marked with thin articulating film. Normally, the markings are on the mesial inclines of maxillary cusps and the distal inclines of mandibular cusps. Their exact location can be transferred by having the patient close through thin occlusal indicator wax. The articulated casts are closed, and the retruded tooth contacts marked with articulating film. When the indicator wax is transferred to the casts, the perforations should correspond exactly to these marks.

For additional verification, maximum intercuspation of the articulated casts should be examined. MI

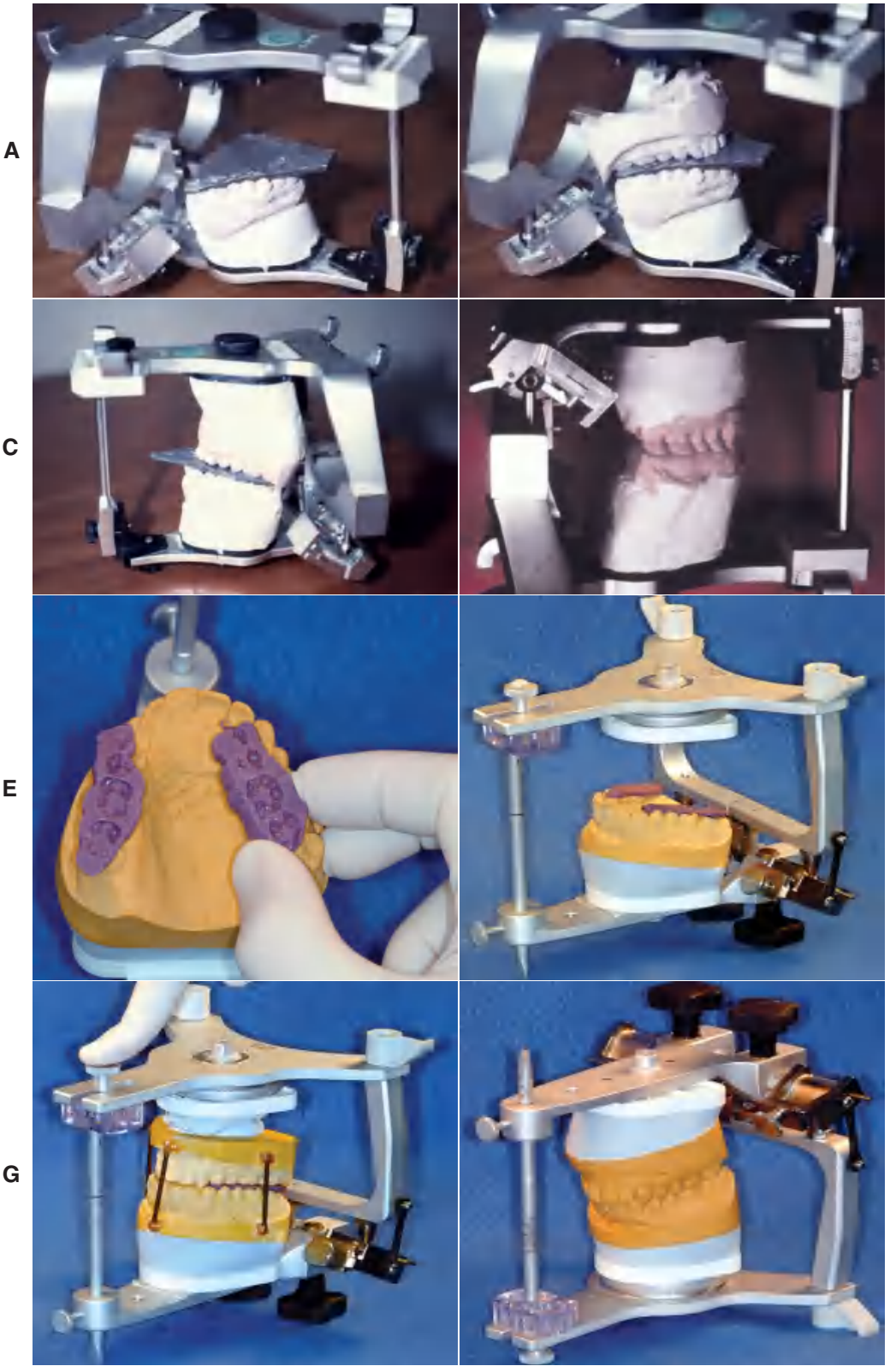


Fig. 2-24

Mounting the mandibular cast. **A** to **D,** Denar articulator. **A,** The centric relation (CR) record is positioned on the inverted maxillary cast. **B,** The incisal guide pin is adjusted, and the mandibular cast is oriented in the record. **C,** The cast is attached with mounting stone. **D,** When the pin is raised, the casts contact in CR closure. **E** to **H:** Whip Mix articulator. **E,** Trimmed elastomeric CR records. **F,** CR records positioned on the inverted articulator. **G,** The incisal guide pin is adjusted, the cast is stabilized, and plaster is applied to the prewetted cast and the mandibular mounting plate before the articulator is closed. **H,** Completed mounting. *(**E** to **H,** Courtesy of Whip Mix Corporation, Louisville, Kentucky.)*

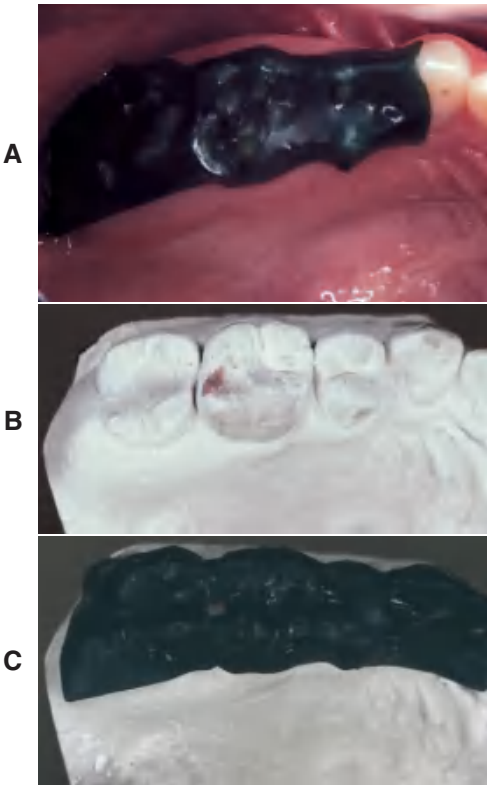


Fig. 2-25
Verifying mounting accuracy. **A,** Occlusal indicator wax is adapted to the maxillary teeth, and the patient's mouth is guided into centric relation closure. **B,** The cast contacts are marked with thin articulating film. **C,** If the mounting is accurate, the markings correspond to perforations in the wax.

is usually a translated mandibular position that may not be reproducible with absolute accuracy on a semiadjustable articulator. However, any substantive discrepancy invariably indicates an incorrect mounting. If further confirmation of mounting accuracy is required (as may be the case when definitive casts are being articulated), additional CR records can be made and compared with a split-cast mounting system or a measuring device such as the Denar Centri-Check marking system[†] (Fig. 2-26).

Posterior articulator controls

The advantages and disadvantages of the different articulators are summarized in Table 2-1. The more sophisticated (fully adjustable) articulators have a large range of adjustments that can be programmed to follow the condylar paths precisely. Their posterior controls are designed to enable simulation of movement of the condylar processes, duplicating protrusive and lateral tooth contacts. The semiadjustable instruments can be adjusted to a lesser extent. Their posterior controls are designed to

[†]Waterpik Technologies, Inc., Fort Collins, Colorado.



Fig. 2-26
The Denar Centri-Check marking system. The casts are positioned in the same relationship as on the articulator, but the condylar elements are replaced by styli. Each stylus marks graph paper attached to the maxillary half of the articulator. Successive centric relation records can be compared by examining these marks. *(Courtesy of Waterpik Technologies, Inc., Fort Collins, Colorado.)*

replicate the most clinically significant features of mandibular movement (e.g., condylar inclination and mandibular side shift). These instruments can be programmed from eccentric interocclusal records or a simplified **pantograph**. An alternative technique is to use average values for the control settings. It is important to note that no method used to program an articulator to reproduce eccentric jaw movements is without error.[23]

Arbitrary values

On the basis of clinical investigations, certain generally applicable average anatomic values have evolved for condylar inclination, both immediate and progressive side shift. These values have been described relative to the Frankfort horizontal plane and the midsagittal plane. For instance, an average value of 1.0 mm has been reported[24] for immediate side shift.

When arbitrary values are used to adjust posterior articulator controls, the actual instrument settings vary from one manufacturer to another. However, depending on the degree of adjustability of the articulator, using arbitrary values does not necessarily lead to less accuracy than do alternative techniques (e.g., eccentric interocclusal records to program a semiadjustable articulator, particularly when the instrument can execute only a straight protrusive path).

Eccentric interocclusal recordings

Eccentric interocclusal records (check bites) have been recommended[25] for setting the posterior controls of a semiadjustable articulator. These consist of

Table **2-1 ARTICULATOR SELECTION FOR FIXED PROSTHODONTICS**

Rights were not granted to include this table in electronic media.
Please refer to the printed publication.

wax or another recording material interposed between the maxillary and mandibular arches; they record the position of the condyles in eccentric mandibular positions. Static positional records are made in translated jaw positions: a protrusive record and two lateral records. The protrusive record can be used to adjust both condylar inclinations on the articulator, and the lateral records are used to adjust the side shift on semiadjustable articulators.

An articulator set by an eccentric record is accurate in only two positions: at CR and at the position recorded by the record (Fig. 2-27). This occurs because the path taken between these may differ significantly on the articulator from what is actually performed by the mandible. A semiadjustable instrument may have a protrusive and a side shift path that are straight lines, whereas the true paths are invariably curved. In an attempt to minimize errors, many contemporary semiadjustable articulators come with curved fossae.

Armamentarium

- Interocclusal wax record material

Step-by-step technique

1. Practice the three excursive positions with the patient until they can be reproduced. The patient's mandible can be guided into an anterior end-to-end position and into left and right lateral positions in which the canines are end to end when viewed from the front. We have found guiding the patient helpful in obtaining the records easily, although unguided records have been equally accurate.[26]
2. Adapt a wax record to the maxillary arch (Fig. 2-28*A*) and guide the patient's mouth into a protrusive position. Have the patient close to form indentations in the recording medium (Fig. 2-28*B*). Verify that the midline remains properly aligned and that, when viewed from the side, the maxillary and mandibular incisors are end to end.
3. For the lateral records, add additional wax to one posterior quadrant of a wax record to compensate for the additional space on the patient's nonworking side.
4. Adapt this to the patient's maxillary arch and guide the patient's mandible into an excursive position, again verifying that the canines are end to end (Fig. 2-28*C*,*D*).
5. Repeat this step for the other lateral excursion.
6. Mark each record to facilitate its identification when using it to adjust the posterior articulator controls (Fig. 2-28*E*).

Simplified pantographs

A simplified pantograph (Fig. 2-29) measures only certain components of mandibular movement thought to be of greatest clinical significance, usually the condylar inclinations and mandibular side shift. This device can be quickly assembled. Numerical values are measured directly from the recording and are used to set a semiadjustable articulator to provide useful diagnostic information.

Simplified pantographs may reveal an excessively shallow condylar inclination or an exaggerated mandibular side shift. If either of these conditions is

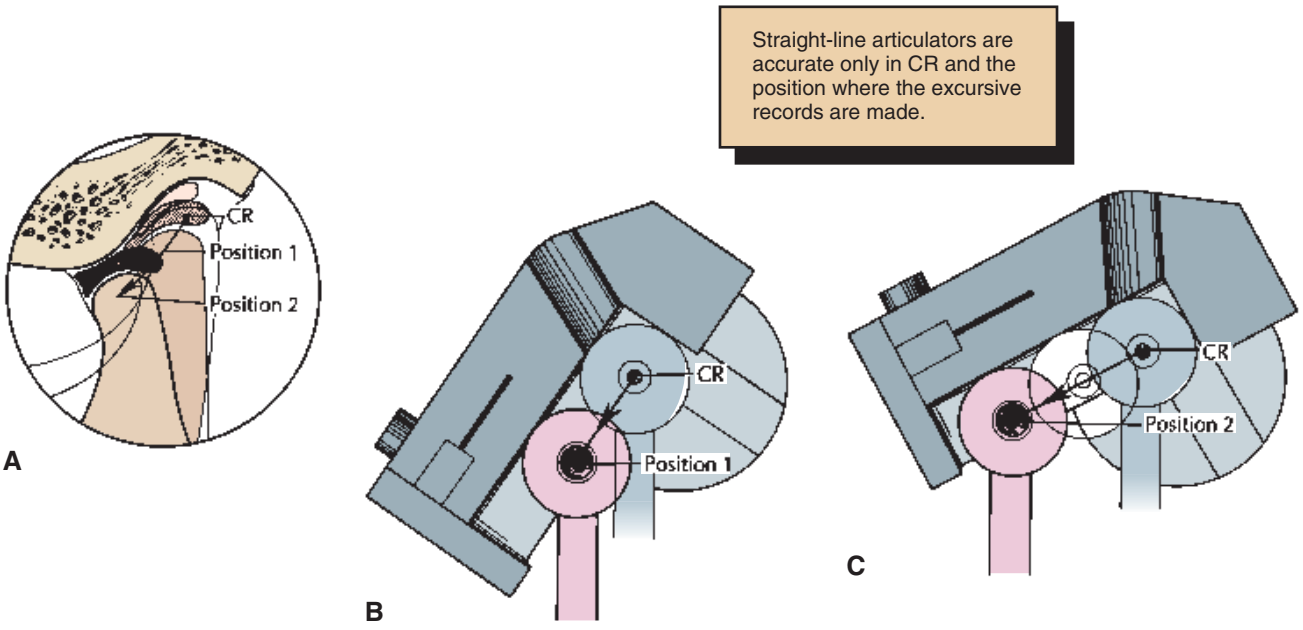


Fig. 2-27

A, The typical condylar path is curved, with its steepest inclination near centric relation (CR). If a semiadjustable articulator with a straight condylar path is programmed from an eccentric record, very different values will be obtained (depending on where the record is made) from what is actually performed by the mandible. **B,** Record made at position 1. **C,** Record made at position 2.



Fig. 2-28

Eccentric interocclusal records. **A,** Adaptation of wax to the maxillary arch. **B,** Protrusive record. **C** and **D,** The patient's mandible is guided into left and right lateral excursive movements. Records are made in the left and right canine edge-to-edge positions. **E,** The completed records.

identified, restoration of the posterior teeth is likely to be complex, and the use of a fully adjustable articulator is recommended. Some manufacturers offer inserts of standard "fossae" of varying configuration, whose selection depends on the measurements obtained with a simplified pantograph (Fig. 2-30).

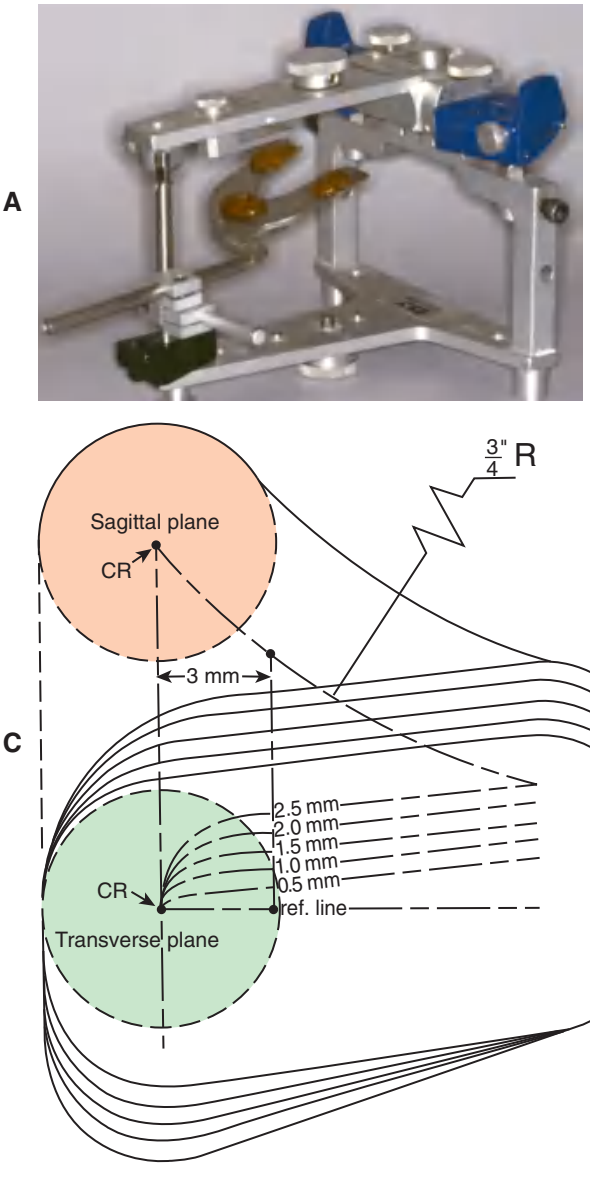
Pantographic recordings

Fully adjustable articulators are usually programmed on the basis of a pantographic recording (Fig. 2-31). Jaw movements are registered by directional tracings on recording plates. The plates are rigidly attached to one jaw, and the recording styli are attached to the other. A total of six plates are



Fig. 2-29

A, The Panadent Axi-Path Recorder. **B** and **C,** An axis stylus traces the condylar path and measures the amount of Bennett movement (B″ and B′) while the patient's mouth is guided into an eccentric border movement. (***A*** *to* **C,** *Courtesy of Panadent Corporation, Grand Terrace, California.)*



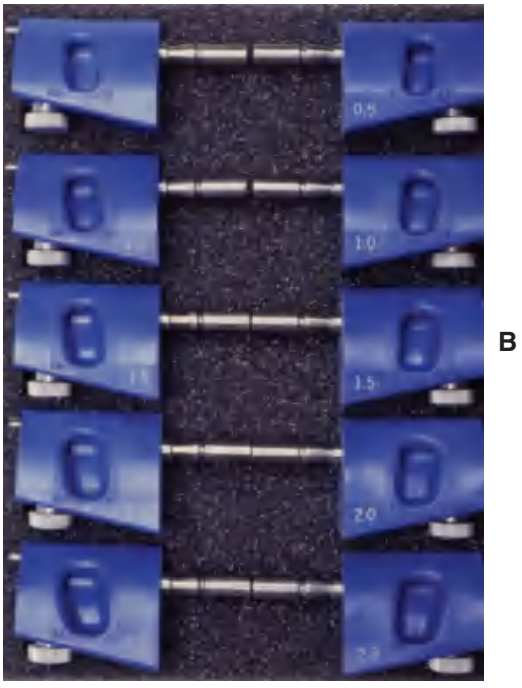


Fig. 2-30

A, The Panadent PCH Articulator with support legs. **B,** Fossa blocks (motion analogs) with different amounts of Bennett movement are selected from the simplified recorder or lateral interocclusal records. The blocks are rotated to the correct condylar inclination. **C,** Schematic showing the sagittal and transverse planes of the available motion analog blocks. CR, centric relation; $\frac{3}{4}$″R, $\frac{3}{4}$-inch radius of fossa curvature. (***A*** *to* **C,** *Courtesy of Panadent Corporation, Grand Terrace, California.)*

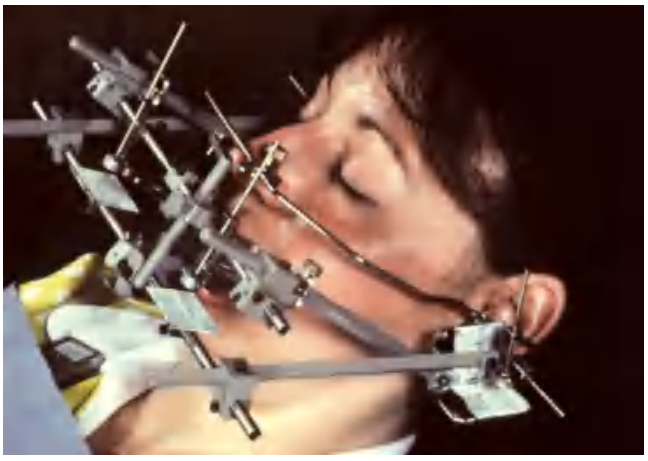


Fig. 2-31
Pantographic recording with the Stuart instrument. *(Courtesy of Drs. R. Giering and J. Petrie.)*

needed to achieve a precise movement record of the mandible. Left and right lateral border and protrusive tracings are made on each plate. The pantograph is then attached to the articulator, and the controls are adjusted and modified until the instrument can faithfully reproduce the movements of the styli on the tracings (Fig. 2-32). A simpler, although less accurate, procedure is to measure the tracings directly and adjust the condylar controls without transferring the recordings.

Electronic pantograph (the Denar Cadiax Compact*)

The Electronic Pantograph (the Denar Cadiax Compact) is designed to record and measure func-

*Waterpik Technologies, Inc. Fort Collins, Colorado.

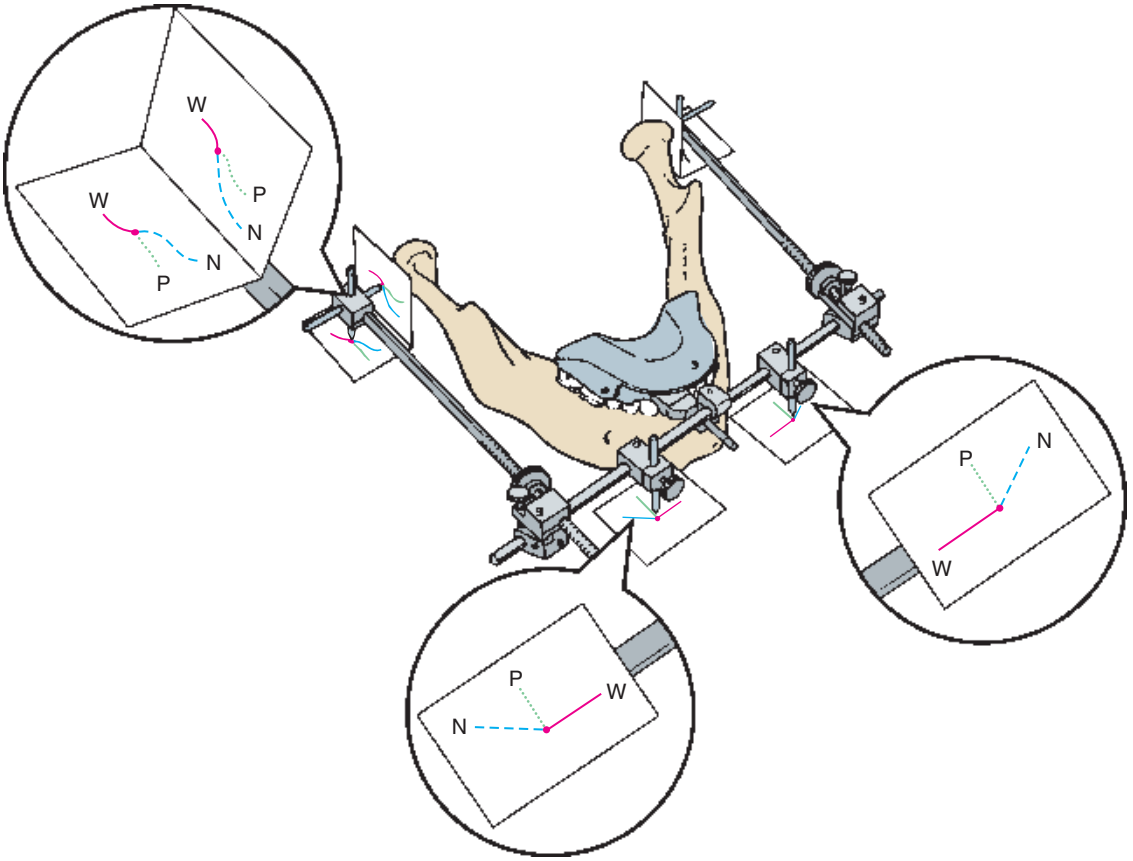


Fig. 2-32
Pantographic tracings represent information that could only be obtained with an infinite number of excursive records: This simplified schematic shows the relative orientation of six recording plates (attached to the maxillary bow, omitted for clarity) to the scribing styli, attached to the mandibular bow. N, nonworking or balancing movement; P, protrusive movement; W, working movement. The centric relation position is represented by the intersection of the paths marked by the dot.

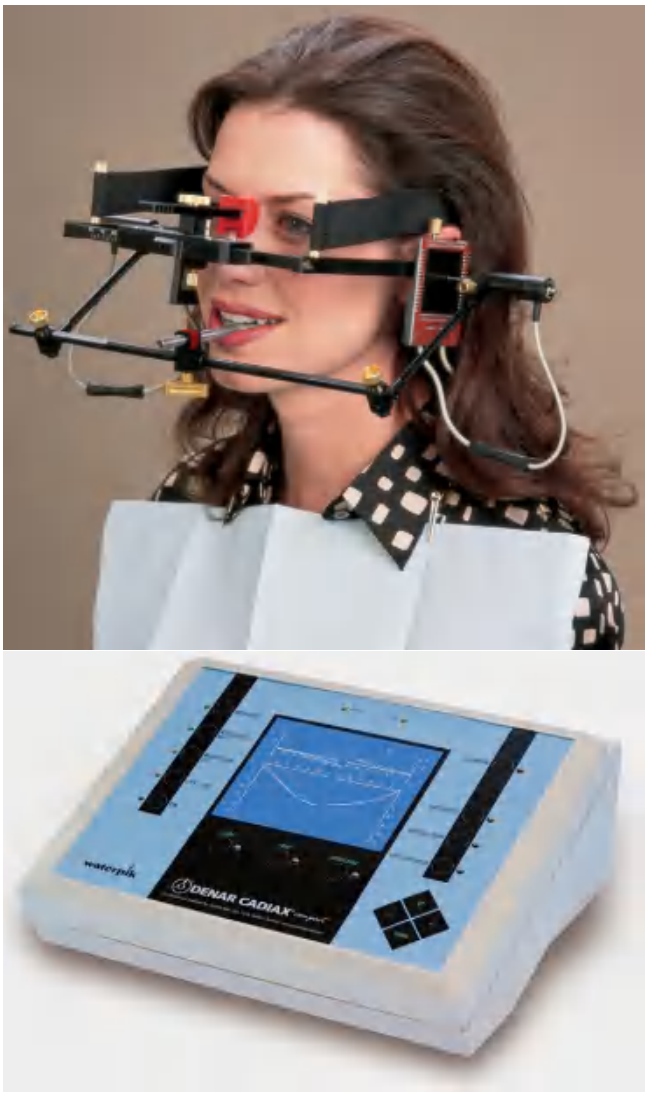


Fig. 2-33
A, B, Electronic jaw recording system. The Denar Cadiax Compact is an electronic recording system that automatically calculates articulator adjustment. *(Courtesy of Waterpik Technologies Inc., Fort Collins, Colorado.)*

tional and border movements (Fig. 2-33). It consists of upper and lower bows that record and measure mandibular movements and has been shown to provide valid and reliable measures of condylar determinants.[27]

Stereograms

Another approach to reproducing posterior condylar controls is to cut or mold a three-dimensional recording of the jaw movements. This "stereogram" (Fig. 2-34) is then used to form custom-shaped fossae for the condylar heads.

Anterior guidance

Border movements of the mandible are governed by tooth contacts and by the shape of the left and right temporomandibular joints. In patients with normal jaw relationships, the vertical and horizontal overlap of anterior teeth and the lingual concavities of the maxillary incisors are highly significant during protrusive movements. In lateral excursions, the tooth contacts normally existing between the canines are usually dominant, although the posterior teeth may also be involved (see Chapter 4). Restorative procedures that change the shape of the anterior teeth can have a profound effect on excursive tooth contacts. For this reason, when preparation of anterior teeth is contemplated, the exact nature of the anterior contacts should be transferred to the articulator, where it can be studied and stored before these teeth are prepared.

Mechanical anterior guide table

Most articulator manufacturers supply a mechanical anterior guide (incisal guidance) table (Fig. 2-35). Such tables can be pivoted anteriorly and posteriorly to simulate protrusive guidance, and they have lateral wings that can be adjusted to approximate lateral guidance. However, the sensitivity of

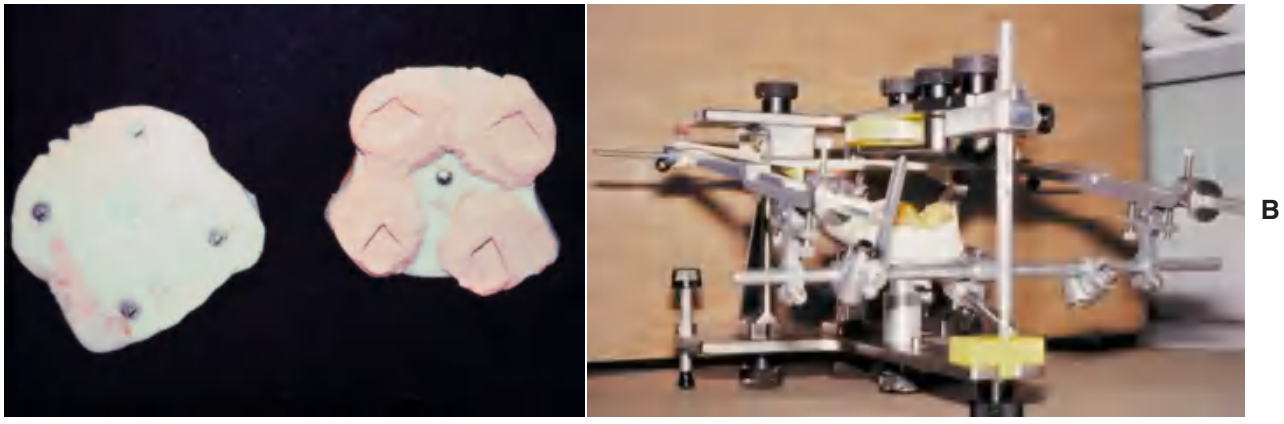


Fig. 2-34
A, B, The TMJ articulator is programmed from three-dimensional acrylic resin recordings. *(Courtesy of Dr. A. Peregrina.)*

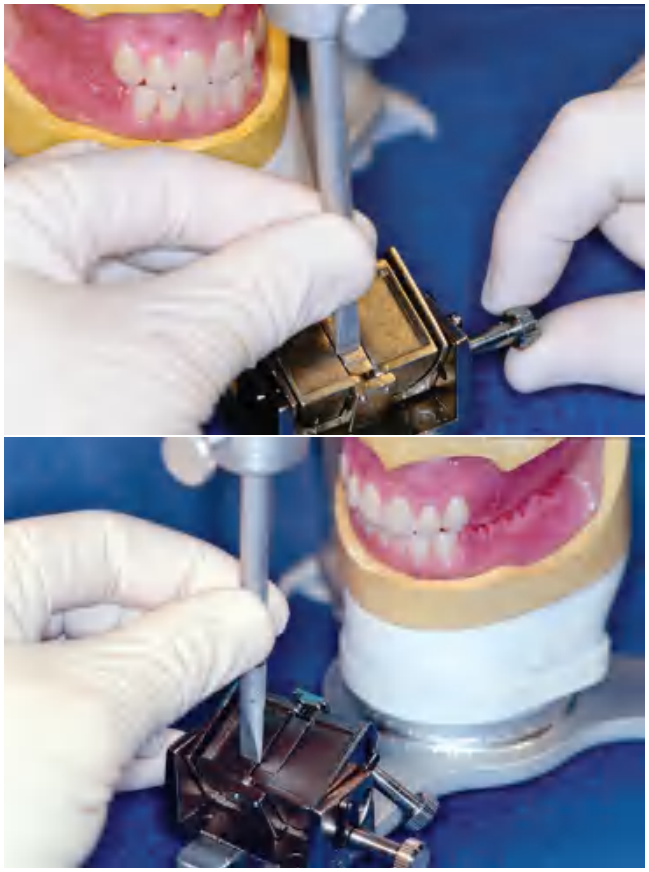


Fig. 2-35
Mechanical anterior guide table. **A,** The protrusive path has been adjusted. The side screw adjusts the lateral flange. **B,** Lateral flange adjusted to the right working movement.

these adjustments is insufficient for successfully transferring the existing lingual contours of natural teeth to newly fabricated restorations. Therefore, the principal use for these mechanical tables is in the fabrication of complete dentures and occlusal devices (see Chapter 4).

Custom acrylic anterior guide table

This simple device is used for accurately transferring to an articulator the contacts of anterior teeth when determining their influence on border movements of the mandible. Acrylic resin is used to record and preserve this information, even after the natural lingual contours of the teeth have been altered during preparation for complete coverage restorations. The technique is similar to that for stereographic recording used in setting the posterior controls of some articulators.

Custom guide table fabrication

Armamentarium (Fig. 2-36A)

- Plastic incisal table
- Tray and fossa acrylic resin
- Petrolatum

Step-by-step procedure

1. After raising and lubricating the pin, moisten the plastic incisal table with acrylic resin monomer to ensure a good bond (Fig. 2-36*B* to *D*).
2. Mix a small quantity of resin and mold it to the table (Fig. 2-36*E,F*).
3. Raise the incisal pin about 2 mm from the table, cover its tip with petrolatum, and close it into the soft resin (Fig. 2-36*G*).
4. Manipulate the articulator in hinge, lateral, and protrusive movements while the resin is in the doughy stage of polymerization (Fig. 2-36*H* to *J*). As the pin moves through these excursions, its tip pushes into and molds the doughy acrylic resin lying in its path, ultimately creating an accurate and rigid three-dimensional record of the mandibular movements and their lateral and protrusive limits through the functional range (Fig. 2-36*K*).
5. Continue these closures until the resin is no longer plastic, being careful not to abrade or damage the casts during the process. A thin film of plastic foil placed between the casts will help minimize abrasion without significantly affecting the accuracy of the guide table.

Evaluation

When the custom anterior guide table has been completed, the incisal pin should contact the table in all excursive movements. This can be checked with thin Mylar strips (shim stock). If contact is deficient, a small mix of new resin is added and the process repeated. If too much resin has been used, the table may interfere with the hinge opening-closing arc of the articulator (Fig. 2-37). Excess can be easily trimmed away.

Diagnostic cast modification

One advantage of having accurately articulated diagnostic casts is that proposed treatment procedures can be rehearsed on the stone cast before any irreversible changes are made in the patient's mouth. These diagnostic procedures are essential when the dentist attempts to solve complicated problems. Even the most experienced clinician may have difficulty deciding between different treatment plans. Even in apparently simple situations, time that the practitioner spends rehearsing diagnostic procedures on the casts is usually well rewarded.

Diagnostic cast modifications include the following:

1. Changing the arch relationship preparatory to orthognathic procedures when surgical correction of skeletal jaw discrepancy is to be performed.
2. Changing the tooth position before orthodontic procedures (Fig. 2-38).

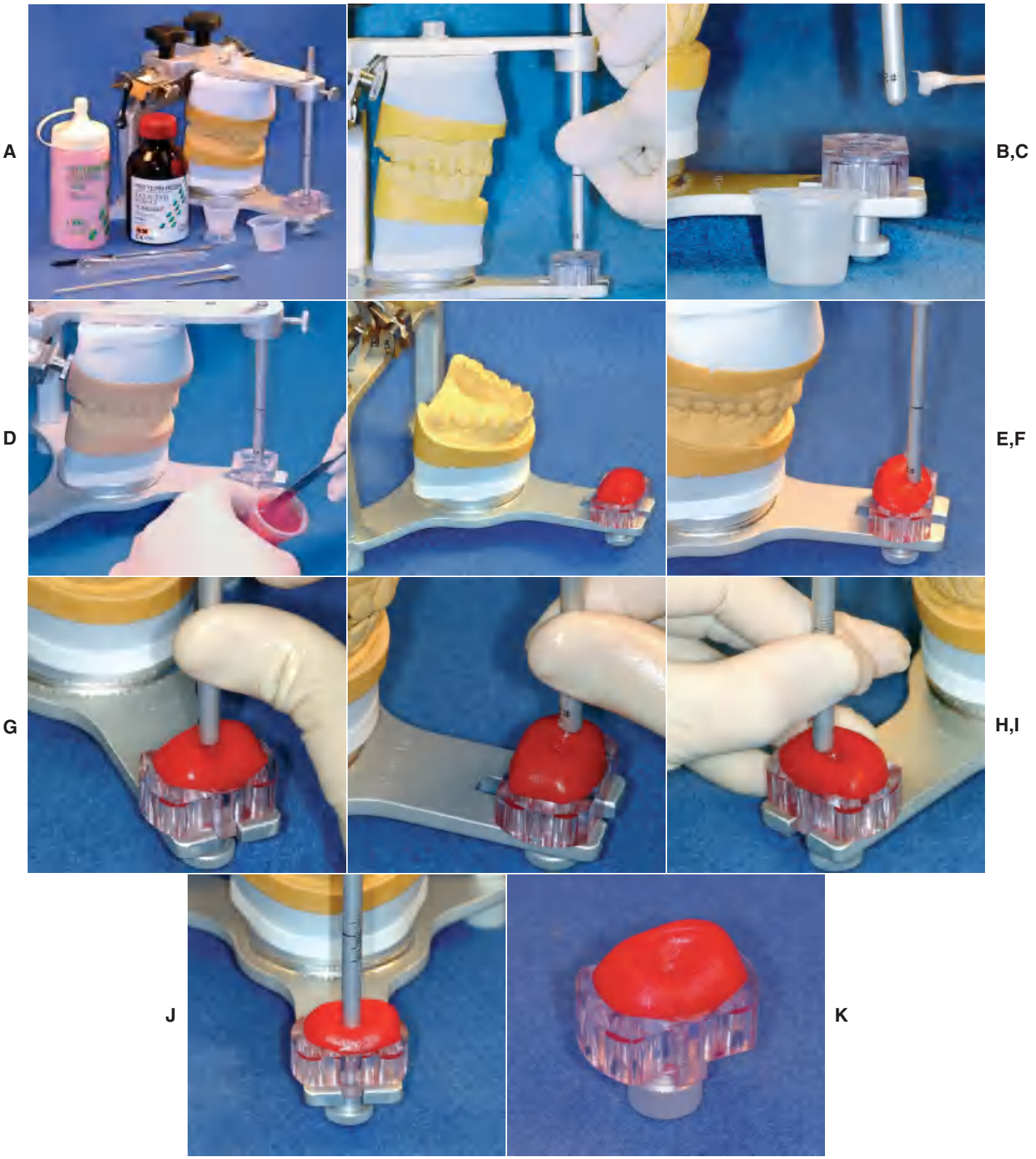


Fig. 2-36

Fabrication of a custom anterior guide table. **A,** Armamentarium. **B,** Incisal pin is raised 1 or 2 mm. **C,** The tip of the pin is lubricated. **D,** Resin is dispensed and mixed. **E,** Resin is applied to acrylic table. **F,** Pin is inserted when resin is at the doughy stage. **G,** The protrusive path is tracked. **H,** Right working movement and all intermediate laterotrusive paths. **I,** Left working movement and all intermediate laterotrusive paths. **J,** Resin is allowed to set. **K,** Excess resin still needs to be removed. *(Courtesy of Whip Mix Corporation, Louisville, Kentucky.)*



Fig. 2-37
A, A custom anterior guidance table made with excess resin. This must be trimmed if it interferes with the path of closure of the incisal pin. **B,** The completed table with excess resin ground away. Note the lateral and protrusive paths.

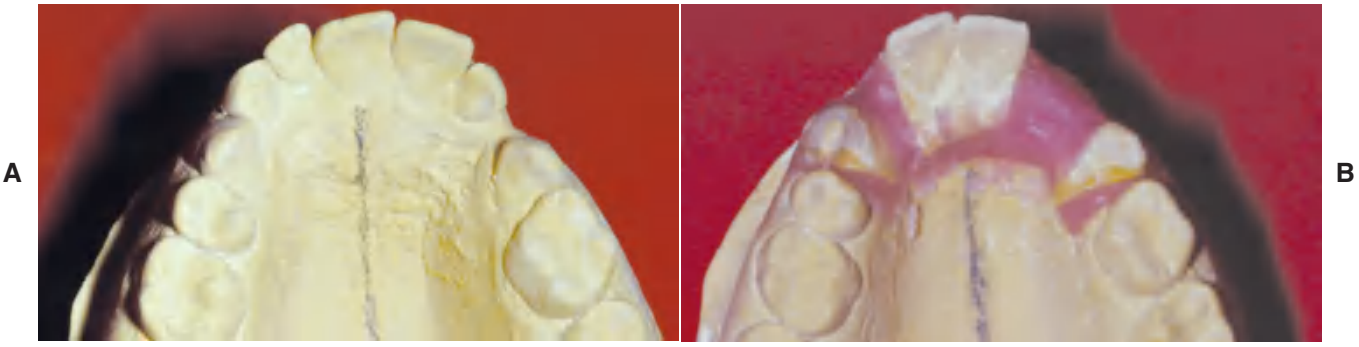


Fig. 2-38
A, B, Diagnostic cast modifications in advance of orthodontic treatment.

3. Modifying the occlusal scheme before attempting any selective occlusal adjustment.
4. Trial tooth preparation and waxing (Fig. 2-39) before fixed restorative procedures. (This is one of the most useful diagnostic techniques for patients seeking fixed prosthodontics. It enables the practitioner to rehearse a proposed restorative plan and to test it on a stone cast, providing considerable information in advance of the actual treatment and helping explain the intended procedure to the patient.)

On many occasions, it is necessary to combine two or more of these options. In fact, most treatment planning decisions (e.g., preparation design, choice of abutment teeth, selection of an optimum path of placement of a fixed dental prosthesis, or deciding to treat a patient with a fixed or removable dental prosthesis) can be simplified by adhering to these diagnostic techniques.

SUMMARY

Diagnostic casts provide valuable preliminary information and a comprehensive overview of the patient's needs that are often not apparent during the clinical examination. They are obtained from accurate irreversible hydrocolloid impressions and should be transferred to a semiadjustable articulator by using a facebow transfer and interocclusal record. For most routine fixed prosthodontic diagnostic purposes, the use of an arbitrary hinge axis facebow is sufficient. If special concerns apply, such as a change in vertical dimension, a kinematic facebow transfer is needed. Two types of articulators are recognized: arcon and nonarcon. For highly complex treatment needs, a fully adjustable articulator may be indicated. Such articulators are adjusted by using a pantographic tracing.

Diagnostic casts should be articulated in CR to enable observation of deflective tooth contact and to



Fig. 2-39

Diagnostic waxing procedure. Diagnostic tooth preparation and waxing help simplify complex prosthodontic treatment planning for predictable results. A and B, Cross-mounted diagnostic casts. A record base is used to articulate the partially edentulous mandibular cast. C and D, Diagnostic tooth preparations determine the correct reduction for esthetics and function. E to H, Diagnostic waxing, done in conjunction with diagnostic denture tooth arrangement. *(Courtesy of Dr. J. Bailey.)*

assess any slide that may be present from CR to MI. *Centric relation* is defined as the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterosuperior position against the shapes of the articular eminences. This position is independent of tooth contact. It is recorded with a suitable medium interposed between the maxillary and mandibular teeth and by guiding the patient into the CR position. This can be accomplished through bimanual manipulation. If many teeth are absent, record bases with wax rims may need to be fabricated to obtain a CR record.

If it is difficult to manipulate a patient's mandible into a reproducible hinge movement, a deprogramming device is helpful. These can be used to help minimize "muscle memory," resulting in easier replication of the rotational hinge movement of the mandible.

Posterior articulator controls can be adjusted on the basis of arbitrary values according to anatomic averages, by means of eccentric records, simplified pantographs, pantographs, or stereographs.

Anterior guidance can be approximated on articulators with a mechanical guide table. As an alternative, a custom acrylic guide table can be generated from the diagnostic casts. The latter is useful when anterior teeth are to be restored.

Diagnostic procedures such as diagnostic waxing, tooth preparation, and diagnostic cast modification can greatly enhance diagnosis and treatment planning.

STUDY QUESTIONS

1. Discuss the uses and limitations of irreversible hydrocolloid and include an overview of its material properties.
2. Why are diagnostic casts articulated in centric relation? Why are they not articulated in maximum intercuspation?
3. List five items that are easier to determine on diagnostic casts rather than intraorally.
4. What is accomplished with a facebow transfer? How do arbitrary facebows differ from kinematic facebows? When would one be selected over the other?
5. Describe the differences between arcon and nonarcon articulators. When would use of a simple hinge instrument be acceptable and when would it be contraindicated? Why?
6. What is the role of excursive records in adjusting the articulator?
7. What does a simplified pantograph record? What does a pantograph record? When would either be indicated?
8. For what purpose is a custom acrylic guide table fabricated, and when is its use necessary?
9. Give two examples when a diagnostic waxing procedure is indicated.

GLOSSARY*

acquired eccentric relation \a-kwīrd′ ĭk-sĕn′trĭk rĭ-lā′shun\: any eccentric relationship position of the mandible relative to the maxilla, whether conditioned or learned by habit, which will bring the teeth into contact

acrylic resin base \a-krĭl′ĭk rĕz′ĭn bās\: a denture base made of acrylic resin

adjustable anterior guidance \a-jŭst′a′bul ăn-tîr′ē-or gīd′ns\: an anterior guide on an articulator whose surface may be altered to provide desired guidance of the articulator's movement mechanism; the guide may be programmed (calibrated) to accept eccentric interocclusal records

adjustable articulator \a-jŭst′a′bul är-tĭk′ya-lā′tor\: an articulator that allows some limited adjustment in the sagittal and horizontal planes to replicate recorded mandibular movements–see ARTICULATOR

ala-tragus line \a′lah trā′gŭs līn\: a line running from the inferior border of the ala of the nose to some defined point on the tragus of the ear, usually considered to be the tip of the tragus. It is frequently used, with a third point on the opposing tragus, for the purpose of establishing the ala tragus plane. Ideally the ala-tragus plane is considered to be parallel to the occlusal plane. The occlusal plane is at an angle of approximately 10 degrees relative to the Frankfort horizontal plane, when viewed in the mid-sagittal plane–see CAMPER'S LINE

anterior guidance \ăn-tîr′ē-or gīd′ns\: **1:** the influence of the contacting surfaces of anterior teeth on tooth limiting mandibular movements **2:** the influence of the contacting surfaces of the guide pin and anterior guide table on articulator movements–*usage* see ANTERIOR GUIDE TABLE 3: the fabrication of a relationship of the anterior teeth preventing posterior tooth contact in all eccentric mandibular movements–see ANTERIOR PROTECTED ARTICULATION, GROUP FUNCTION, MUTUALLY PROTECTED ARTICULATION

anterior guide: see ANTERIOR GUIDE TABLE

anterior guide pin \ăn-tîr′ē-or gīd pĭn\: that component of an articulator, generally a rigid rod attached to one member, contacting the anterior guide table on the opposing member. It is used for the purpose of maintaining the established vertical separation. The anterior guide pin and table, together with the condylar elements, direct the movements of the articulators' separate members

anterior guide table \ăn-tîr′ē-or gīd tā′bl\: that component of an articulator on which the anterior guide pin rests to maintain the occlusal vertical dimension and influence articulator movements. The guide table influences the degree of separation of the casts in all relationships–see also ANTERIOR PROGRAMMING DEVICE

anterior programming device \ăn-tîr′ē-or prō′grăm′ĭng dĭ-vīs′\: an individually fabricated anterior guide table that allows mandibular motion without the influence of tooth contacts and facilitates the recording of maxillomandibular relationships; also used for deprogramming–see also *deprogrammer*

anterior reference point \ăn-tîr′ē-or rĕf′er-ens, rĕf′rens point\: any point located on the midface that, together with two posterior reference points, establishes a reference plane

ar·con \ar′kon\ *n*: a contraction of the words "ARTICULATOR" and "CONDYLE," used to describe an articulator

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containing the condylar path elements within its upper member and the condylar elements within the lower member

arcon articulator \ar'kon är-tĭk'ya-lā'tor**:** an articulator that applies the arcon design; this instrument maintains anatomic guidelines by the use of condylar analogs in the mandibular element and fossae assemblies within the maxillary element

arrow point tracer \ăr'ō point trā'ser**: 1:** a mechanical device used to trace a pattern of mandibular movement in a selected plane—usually parallel to the occlusal plane **2:** a mechanical device with a marking point attached to one jaw and a graph plate or tracing plane attached to the other jaw. It is used to record the direction and range of movements of the mandible—see GOTHIC ARCH TRACER

articulating paper \är-tĭk'ya-lāt'ing pā'per**:** ink-coated paper strips used to locate and mark occlusal contacts

ar·tic·u·la·tor \är-tĭk'ya-lā'tor\ *n***:** a mechanical instrument that represents the temporomandibular joints and jaws, to which maxillary and mandibular casts may be attached to simulate some or all mandibular movements—*usage*: articulators are divisible into four classes Class I articulator: a simple holding instrument capable of accepting a single static registration; vertical motion is possible—see NONADJUSTABLE A. Class II articulator: an instrument that permits horizontal as well as vertical motion but does not orient the motion to the temporomandibular joints. Class III articulator: an instrument that simulates condylar pathways by using averages or mechanical equivalents for all or part of the motion; these instruments allow for orientation of the casts relative to the joints and may be arcon or nonarcon instruments—see SEMI-ADJUSTABLE A. Class IV articulator: an instrument that will accept three dimensional dynamic registrations; these instruments allow for orientation of the casts to the temporomandibular joints and simulation of mandibular movements—see FULLY ADJUSTABLE A., FULLY ADJUSTABLE GNATHOLOGIC A.

average axis facebow \ăv'er-ĭj, ăv'rĭj ăk'sĭs fās bō**:** a device used to relate the maxillary cast to the condylar elements of an articulator using average anatomic landmarks to estimate the position of the transverse horizontal axis on the face.

average value articulator \ăv'rĭj văl'yōō är-tĭk'ya-lā'ter**:** an articulator that is fabricated to permit motion based on mean mandibular movements—called also *Class III articulator*

base material \bās mă-tîr'ē-al\ *obs***:** any substance of which a denture base may be made, such as acrylic resin, vulcanite, polystyrene, or metal (GPT-4)

cen·tric \sĕn'trĭk\ *adj* (1590)**: 1:** located in or at a center; central **2:** concentrated about or directed toward a center

centric occlusion \sĕn'trĭk a-klōō'zhen**:** the occlusion of opposing teeth when the mandible is in centric relation. This may or may not coincide with the maximal intercuspal position—*comp* MAXIMAL INTERCUSPAL POSITION

centric relation \sĕn'trĭk rĭ-lā'shun**: 1:** the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterior-superior position against the shapes of the articular eminencies. This position is independent of tooth contact. This position is clinically discernible when the mandible is directed superior and anteriorly. It is restricted to a purely rotary movement about the transverse horizontal axis (GPT-5) **2:** the most retruded physiologic relation of the mandible to the maxillae to and from which the individual can make lateral movements. It is a condition that can exist at various degrees of jaw separation. It occurs around the terminal hinge axis (GPT-3) **3:** the most retruded relation of the mandible to the maxillae when the condyles are in the most posterior unstrained position in the glenoid fossae from which lateral movement can be made at any given degree of jaw separation (GPT-1) **4:** The most posterior relation of the lower to the upper jaw from which lateral movements can be made at a given vertical dimension (Boucher) **5:** a maxilla to mandible relationship in which the condyles and disks are thought to be in the midmost, uppermost position. The position has been difficult to define anatomically but is determined clinically by assessing when the jaw can hinge on a fixed terminal axis (up to 25 mm). It is a clinically determined relationship of the mandible to the maxilla when the condyle disk assemblies are positioned in their most superior position in the mandibular fossae and against the distal slope of the articular eminence (Ash) **6:** the relation of the mandible to the maxillae when the condyles are in the uppermost and rearmost position in the glenoid fossae. This position may not be able to be recorded in the presence of dysfunction of the masticatory system **7:** a clinically determined position of the mandible placing both condyles into their anterior uppermost position. This can be determined in patients without pain or derangement in the TMJ (Ramsfjord)

Boucher CO. Occlusion in prosthodontics. J PROSTHET DENT 1953; 3:633-56.

Ash MM. Personal communication, July 1993.

Lang BR, Kelsey CC. International prosthodontic workshop on complete denture occlusion. Ann Arbor: The University of Michigan School of Dentistry, 1973.

Ramsfjord SP. Personal communication, July 1993.

centric relation record \sĕn'trĭk rĭ-lā'shun rĭ-kōrd**:** a registration of the relationship of the maxilla to the

mandible when the mandible is in centric relation. The registration may be obtained either intraorally or extraorally

clutch \klŭch\ *coll n*: a device placed in both the maxillary and mandibular arches for the purpose of supporting components used to record mandibular movement

[1]condylar guidance \kŏn′da-lar gīd′ns\ *vt*: mandibular guidance generated by the condyle and articular disc traversing the contour of the glenoid fossae

[2]condylar guidance \kŏn′da-lar gīd′ns\ *n*: the mechanical form located in the upper posterior region of an articulator that controls movement of its mobile member

condylar guide assembly \kŏn′da-lar gīd a-sĕm′blē\: the components of an articulator that guide movement of the condylar analogues

condylar hinge position \kŏn′da-lar hĭnj pa-zĭsh′an\ *obs*: the position of the condyles of the mandible in the glenoid fossae at which hinge axis movement is possible (GPT-4)

de·pro·gram·mer \dē-prō′grăm′er\ *n*: various types of devices or materials used to alter the proprioceptive mechanism during mandibular closure

diagnostic cast \dī′ag-nŏs′tik kăst\: a life-size reproduction of a part or parts of the oral cavity and/or facial structures for the purpose of study and treatment planning

diagnostic waxing: waxing of intended restorative contours on dental casts for the purpose of evaluation and planning restorations

earbow \îr-bō\ *n* (20c): an instrument similar to a facebow that indexes to the external auditory meatus and registers the relation of the maxillary dental arch to the external auditory meatus and a horizontal reference plane. This instrument is used to transfer the maxillary cast to the articulator. The earbow provides an average anatomic dimension between the external auditory meatus and the horizontal axis of the mandible—see FACEBOW

eccentric \ĭk-sĕn′trĭk\ *adj* (14c): **1:** not having the same center **2:** deviating from a circular path **3:** located elsewhere than at the geometric center **4:** any position of the mandible other than that which is its normal position

eccentric interocclusal record \ĭk-sĕn′trĭk ĭn′ter-a-klōō′sal rĕk′erd\: a registration of any maxillomandibular position other than centric relationship

eccentric relation \ĭk-sĕn′trik rĭ-lā′shun\: any relationship of the mandible to the maxilla other than centric relation—see ACQUIRED E.R.

facebow \fās bō\: a caliper-like instrument used to record the spatial relationship of the maxillary arch to some anatomic reference point or points and then transfer this relationship to an articulator; it orients the dental cast in the same relationship to the opening axis of the articulator. Customarily the anatomic references are the mandibular condyles transverse horizontal axis and one other selected anterior point; called also *hinge bow*—see EARBOW, KINEMATIC F.

facebow fork \fās bō fork\: that component of the facebow used to attach the occlusion rim to the facebow

facebow record \fās bō rĕk′erd\: the registration obtained by means of a facebow

Fischer's angle [Rudolf Fischer, Swiss dentist, Zurich, Switzerland]: *eponym* for the angle formed by the intersection of the protrusive and nonworking side condylar paths as viewed in the sagittal plane

Fischer R. Beziehungen zwischen den Kieferbewegungen und der Kauflachenform der Zuhne. Schweizerische Monataschrift fur Zahnheilkunde Zurich 1926;74.

Fischer R. Die Offnungsbewegungen des Unterkiefers und ibre Wiedergabe am Artikulator. Schweizerische Monateschrift fur Zahnheilkunde 1935;45:867-99.

Frankfort horizontal plane \Frăngk′fort hôr′ĭ-zŏn′tl plān\: **1:** *eponym* for a plane established by the lowest point on the margin of the right or left bony orbit and the highest point on the margin of the right or left bony auditory meatus **2:** a horizontal plane represented in profile by a line between the lowest point on the margin of the orbit to the highest point on the margin of the auditory meatus; adopted at the 13th General Congress of German Anthropologists (the "Frankfort Agreement") at Frankfort am Main, 1882, and finally by the International Agreement for the Unification of Craniometric and Cephalometric Measurements in Monaco in 1906; called also *auriculo-orbital plane, eye-ear plane, Frankfort horizontal (FH), Frankfort horizontal line*

fully adjustable articulator \fŏŏl′ē a-jŭst-a′bal är-tĭk′ya-lā′tor\: an articulator that allows replication of three dimensional movement of recorded mandibular motion —called also Class IV articulator

fully adjustable gnathologic articulator \fŏŏl′ē a-jŭst-a′bal năth′ō-lŏj′ik är-tĭk′ya-lā′tor\: an articulator that allows replication of three dimensional movement plus timing of recorded mandibular motion—called also *Class IV articulator*

guide pin \gīd pĭn\: the component of a dental implant system that is placed within the surgically prepared osseous site for an endosteal implant. It assists in deter-

mination of location and angulation of the site relative to other soft tissue or bony landmarks

hinge axis: see TRANSVERSE HORIZONTAL AXIS

hinge position \hĭnj pa-zĭsh′an\ *obs*: the orientation of parts in a manner permitting hinge movement between them (GPT-4)

horizontal plane of reference \hôr′ĭ-zŏn-tl, hŏr′- plān ŭv rĕf′er-ans, rĕf′rans\: a horizontal plane established on the face of the patient by one anterior reference point and two posterior reference points from which measurements of the posterior anatomic determinants of occlusion and mandibular motion are made

hydrocolloid \hī′dra-kŏl′oid\ *n* (1916): a colloid system in which water is the dispersion medium; those materials described as a colloid sol with water that are used in dentistry as elastic impression materials—see IRREVERSIBLE H., REVERSIBLE H.

incisal guidance \ĭn-sī′zal gīd′ans\: **1:** the influence of the contacting surfaces of the mandibular and maxillary anterior teeth on mandibular movements **2:** the influence of the contacting surfaces of the guide pin and guide table on articulator movements

instantaneous axis of rotation \ĭn′stan-tā′nē-as ăk′sĭs ŭv rō-tā′shun\: the hypothetical center of rotation of a moving body, viewed in a given plane, at any point in time; for any body that has planar motion, there exists, at any instant, some points that have zero velocity and will be fixed at a given instant. The line joining these points is the *instantaneous axis of rotation*. The intersection of this line with the plane of motion is called the *instantaneous center of rotation*

in·ter·cus·pa·tion \ĭn′ter-kŭs-pā′shun\ *n*, *obs*: the interdigitation of cusps of opposing teeth (GPT-4)

interocclusal record \ĭn′ter-a-klōō′sal rĕk′ard\: a registration of the positional relationship of the opposing teeth or arches; a record of the positional relationship of the teeth or jaws to each other

irreversible hydrocolloid \ĭr′ĭ-vûr′sa-bal hī′dra-kŏl′oid′\: a hydrocolloid consisting of a sol of alginic acid having a physical state that is changed by an irreversible chemical reaction forming insoluble calcium alginate—called also *alginate, dental alginate*

kinematic axis \kĭn′a-măt′ĭk ăk′sĭs\: the transverse horizontal axis connecting the rotational centers of the right and left condyles

kinematic facebow \kĭn′a-măt′ĭk fās-bō\: a facebow with adjustable caliper ends used to locate the transverse horizontal axis of the mandible

lateral interocclusal record \lăt′ar-al ĭn′ter-a-klōō′sal rĕk′ard′\: a registration of the positional relationship of opposing teeth or arches made in either a right or left lateral position of the mandible

leaf gauge \lēf gāj\: a set of blades or leaves of increasing thickness used to measure the distance between two points or to provide metered separation

Lucia jig [Victor O. Lucia, U.S. prosthodontist]: *eponym*—see ANTERIOR PROGRAMMING DEVICE

Lucia VO. Treatment of the edentulous patient. Chicago: Quintessence, 1986.

lu·mi·nance \lōō′ma-nans\ *n* (1880): the intensity of light per unit area

man·di·ble \măn′da-bal\ *n* (15c): the lower jawbone

man·dib·u·lar \măn-dĭb′ya-lar\ *adj*: of or pertaining to the mandible

mandibular axis: see SAGITTAL AXIS, TRANSVERSE HORIZONTAL AXIS, VERTICAL AXIS

mandibular condyle: the articular process of the mandible, called also the *head of the mandible*—see also CONDYLE

mandibular relationship record \măn-dĭb′ya-lar rĭ-lā′shun-shĭp\: any registration of the relationship of the mandible to the maxillae

me·a·tus \mē-ā′tus\ *n, pl* **me·a·tus·es** or **me·a·ti** (1665): a natural body passage; a general term for any opening or passageway in the body

[1]mount·ing \moun′tĭng\ *v*: the laboratory procedure of attaching a cast to an articulator or cast relater

[2]mount·ing \moun′tĭng\ *n*: the relationship of dental casts to each other and the instrument to which they are attached; see also—SPLIT-CAST M.

mounting plate \moun′tĭng plāt\: removable metal or resin devices that attach to the superior and inferior members of an articulator, which are used to attach casts to the articulator

muscle spasm \mŭs′al spăz′am\: a sudden involuntary contraction of a muscle or group of muscles attended by pain and interference with function. It differs from muscle splinting in that the contraction is sustained even when the muscle is at rest and the pain/dysfunction is present with passive and active movements of the affected part—called also *myospasm*

NA: *acronym* for *NAsion;* a cephalometric landmark located where the intranasal and nasofrontal sutures meet

nano·me·ter \năn′a-mē′tar\ *n* (1963): unit of length to measure the wavelength of light. It is equivalent to 1×10^{-9} M or 10 angstroms. 1 *nm* = 1/1,000,000 *mm*

nas·ion \nā′zhun\ *n*: a bony cephalometric landmark at which the nasofrontal suture is bisected by the midsagittal plane

nonadjustable articulator \nŏn-a-jŭst′ă-bal är-tĭk′ya-lā′tor\: an articulator that does not allow adjustment to replicate mandibular movements—see also CAST RELATOR

nonarcon articulator: **1:** any articulator which broadly replicates the three dimensional motions of the left and right condylar compartments **2:** any articulator design in which the condylar element (analog) is not part of the lower member of the articulator and may be used to simulate the three dimensional motions of the left and right condylar compartments

oc·clude \a-klōōd′\ *vb* **oc·clud·ed**; **oc·clud·ing** *vt* (1597): **1:** to bring together; to shut **2:** to bring or close the mandibular teeth into contact with the maxillary teeth

occluding centric relation record \a-klōōd′ĭng sĕn′trĭk rĭ-lā′shun rĕk′ard\ *obs*: a registration of centric relation made at the established occlusal vertical dimension (GPT-4)

oc·clu·sal \a-klōō′zal, -sal\ *adj* (1897): pertaining to the masticatory surfaces of the posterior teeth, prostheses, or occlusion rims

occlusal device \a-klōō′zal, -sal dĭ-vīs′\: any removable artificial occlusal surface used for diagnosis or therapy affecting the relationship of the mandible to the maxillae. It may be used for occlusal stabilization, for treatment of temporomandibular disorders, or to prevent wear of the dentition

occlusal disharmony \a-klōō′zal, -sal dĭs-hăr′ma-nē\: a phenomenon in which contacts of opposing occlusal surfaces are not in harmony with other tooth contacts and/or the anatomic and physiologic components of the craniomandibular complex

occlusion record \a-klōō′shun rĕk′ard\ *obs*: a registration of opposing occluding surfaces made at any maxillomandibular relationship (GPT-4)

occlusion rim \a-klōō′shun rĭm\: occluding surfaces fabricated on interim or final denture bases for the purpose of making maxillomandibular relation records and arranging teeth—called also *record rim*

pan·to·graph \păn′ta-gräf′\ *n* (1723): **1:** an instrument used for copying a planar figure to any desired scale **2:** in dentistry, an instrument used to graphically record in, one or more planes, paths of mandibular movement and to provide information for the programming of an articulator

pantographic tracing \păn′ta-gräf′ĭk trā′sĭng\: a graphic record of mandibular movement usually recorded in the horizontal, sagittal and frontal planes as registered by styli on the recording tables of a pantograph or by means of electronic sensors

preliminary cast \prĭ-lĭm′a-nĕr′ē\: a cast formed from a preliminary impression for use in diagnosis or the fabrication of an impression tray

preliminary impression \prĭ-lĭm′a-nĕr′ē ĭm-prĕsh′an\: a negative likeness made for the purpose of diagnosis, treatment planning, or the fabrication of a tray

preoperative record \prē-ŏp′ar-a-tĭv, -ŏp′ra-, -ŏp′a-rā-rĕk′ard\ *obs*: any record made for the purpose of study or treatment planning (GPT-4)

preoperative wax-up: a dental diagnostic procedure in which planned restorations are developed in wax on a diagnostic cast to determine optimal clinical and laboratory procedures necessary to achieve the desired esthetics and function—called also *diagnostic wax-up*, *preoperative waxing*

pretreatment records \prē-trēt′mant rĕk′ardz\: any records made for the purpose of diagnosis, recording of the patient history, or treatment planning in advance of therapy

pro·file \prō′fīl′\ *n* (ca. 1656): an outline or contour, especially one representing a side view of a human head

protrusive interocclusal record \prō-trōō′sĭv ĭn′tar-a-klōō′zal rĕk′ard\: a registration of the mandible in relation to the maxillae when both condyles are advanced in the temporal fossa

reciprocal click \rĭ-sĭp′ra-kal klĭk\: clicks emanating from the temporomandibular joint, one of which occurs during opening movement and the other during closing movement

[1]re·cord \rĭ-kōrd\ *vb* (14c): **1:** to register data relating to specific conditions that exist currently or previously **2:** to register permanently by mechanical means, i.e., jaw relationships—see CENTRIC RELATION R., ECCENTRIC INTEROCCLUSAL R., INTEROCCLUSAL R., OCCLUDING JAW R., TERMINAL JAW RELATION R.

[2]re·cord \rĭ-kōrd\ *n* (14c): **1:** an official document **2:** a body of known or recorded facts about someone or something

record base \rĕk′ard bās\: an interim denture base used to support the record rim material for recording maxillomandibular records

reg·is·tra·tion \rĕj′ĭ-strā′shun\ *n* (1566): **1:** the making of a record of the jaw relationships present, or those desired, thus allowing their transfer to an articulator to assist in proper fabrication of a dental prosthesis **2:** a record made of the desired maxillomandibular relation-

ship and used to relate casts to an articulator—see MAXILLOMANDIBULAR RELATIONSHIP RECORD

semi-adjustable articulator \sĕm′ē-a-jŭst′a-bal är-tĭk′ya-lā-tor**:** an articulator that allows adjustment to replicate average mandibular movements—called also *Class III articulator*

[1]spat·u·late \spăch′a-lĭt\ *adj* (1760)**:** shaped like a spatula

[2]spat·u·late \spăch′a-lĭt\ *vt* **-ed/-ing/-s:** to work or treat with a spatula

split-cast method \splĭt-kăst měth′ad\ *obs***: 1:** a procedure for placing indexed casts on an articulator to facilitate their removal and replacement on the instrument **2:** the procedure of checking the ability of an articulator to receive or be adjusted to a maxillomandibular relation record (GPT-4)

split-cast mounting \splĭt-kăst moun′tĭng**:** a method of mounting casts wherein the dental cast's base is sharply grooved and keyed to the mounting ring's base. The procedure allows verifying the accuracy of the mounting, ease of removal and replacement of the casts

stereographic record \stĕr′ē-a-grăf′ĭk**:** an intra or extraoral recording of mandibular movement as viewed in three planes in which the registrations are obtained by engraving, milling, or burnishing the recording medium by means of studs, rotary instruments, styli, teeth, or abrasive rims

transverse horizontal axis \trăns-vûrs′, trănz-, trăns′vûrs′, trănz′-**:** an imaginary line around which the mandible may rotate within the sagittal plane

REFERENCES

1. Mendez AJ: The influence of impression trays on the accuracy of stone casts poured from irreversible hydrocolloid impressions, J Prosthet Dent 54:383, 1985.
2. Lim PF, et al: Adaptation of finger-smoothed irreversible hydrocolloid to impression surfaces. Int J Prosthodont 8:117, 1995.
3. Khaknegar B, Ettinger RL: Removal time: a factor in the accuracy of irreversible hydrocolloid impressions. J Oral Rehabil 4:369, 1977.
4. al-Omari WM, et al: A microbiological investigation following the disinfection of alginate and addition cured silicone rubber impression materials. Eur J Prosthodont Restor Dent 6:97, 1998.
5. Hall BD, et al: Effects of a chemical disinfectant on the physical properties of dental stones. Int J Prosthodont 17:65, 2004.
6. Johnson GH, et al: Dimensional stability and detail reproduction of irreversible hydrocolloid and elastomeric impressions disinfected by immersion. J Prosthet Dent 79:446, 1998.
7. Reisbick MH, et al: Irreversible hydrocolloid and gypsum interactions. Int J Prosthodont 10:7, 1997.
8. Young JM: Surface characteristics of dental stone: impression orientation. J Prosthet Dent 33:336, 1975.
9. Palik JF, et al: Accuracy of an earpiece face-bow. J Prosthet Dent 53:800, 1985.
10. O'Malley AM, Milosevic A: Comparison of three facebow/semi-adjustable articulator systems for planning orthognathic surgery. Br J Oral Maxillofac Surg 38:185, 2000.
11. Piehslinger E, et al: Computer simulation of occlusal discrepancies resulting from different mounting techniques. J Prosthet Dent 74:279, 1995.
12. Adrien P, Schouver J: Methods for minimizing the errors in mandibular model mounting on an articulator. J Oral Rehabil 24:929, 1997.
13. Dawson PE: Temporomandibular joint pain-dysfunction problems can be solved. J Prosthet Dent 29:100, 1973.
14. Tarantola GJ, et al: The reproducibility of centric relation: a clinical approach. J Am Dent Assoc 128:1245, 1997.
15. McKee JR: Comparing condylar position repeatability for standardized versus nonstandardized methods of achieving centric relation. J Prosthet Dent 77:280, 1997.
16. Lucia VO: A technique for recording centric relation. J Prosthet Dent 14:492, 1964.
17. Gross M, et al: The effect of three different recording materials on the reproducibility of condylar guidance registrations in three semi-adjustable articulators. J Oral Rehabil 25:204, 1998.
18. Wirth CG: Interocclusal centric relation records for articulator mounted casts. Dent Clin North Am 15:627, 1971.
19. Wirth CG, Aplin AW: An improved interocclusal record of centric relation. J Prosthet Dent 25:279, 1971.
20. Lundeen HC: Centric relation records: the effect of muscle action. J Prosthet Dent 31:244, 1974.
21. Kepron D: Variations in condylar position relative to central mandibular recordings. In Lefkowitz W, ed: Proceedings of the Second International Prosthodontic Congress, p 210. St. Louis, Mosby, 1979.
22. Teo CS, Wise MD: Comparison of retruded axis articular mountings with and without applied muscular force. J Oral Rehabil 8:363, 1981.

23. Tamaki K, et al: Reproduction of excursive tooth contact in an articulator with computerized axiography data. J Prosthet Dent 78:373, 1997.
24. Lundeen HC, Wirth CG: Condylar movement patterns engraved in plastic blocks. J Prosthet Dent 30:866, 1973.
25. Bell LJ, Matich JA: A study of the acceptability of lateral records by the Whip-Mix articulator. J Prosthet Dent 38:22, 1977.
26. Celar AG, et al: Guided versus unguided mandibular movement for duplicating intraoral eccentric tooth contacts in the articulator. J Prosthet Dent 81:14, 1999.
27. Chang WSW, et al: An in vitro evaluation of the reliability and validity of an electronic pantograph by testing with five different articulators. J Prosthet Dent 92:83, 2004.

3

TREATMENT PLANNING



KEY TERMS

abutment
Ante's law
cantilever
complete dentures
crown
fixed dental prosthesis (FDP)
nonrigid connectors
partial removable dental prosthesis (RDP)
residual ridge
sequence of treatment
span length
supraclusion

Treatment planning consists of formulating a logical sequence of treatment designed to restore the patient's dentition to good health, with optimal function and appearance. The plan should be presented in written form and should be discussed in detail with the patient. Good communication with the patient is essential when the plan is formulated. Most dental disorders can be corrected with several different procedures; the patient's preferences are paramount in establishing a suitable treatment plan. An appropriate plan informs the patient about the current conditions, the extent of dental treatment proposed, the time and cost of treatment, and the level of home care and professional follow-up needed for success. In addition, before any irreversible procedures are undertaken, the patient should understand that some details may need to be altered during the course of treatment.

This chapter outlines the decisions that are necessary in planning treatment for fixed prosthodontics. Foremost among these is the identification of patients' needs and their preferences, which must be correlated with the range of treatments available. For long-term success, when a **fixed dental prosthesis (FDP)** is being considered, the **abutment** teeth must be carefully assessed. Finally, the treatment plan must be properly sequenced as part of an ongoing program of comprehensive dental care.

IDENTIFICATION OF PATIENT NEEDS

Successful treatment planning is based on proper identification of the patient's needs. If an attempt is made to have the patient conform to the "ideal" treatment plan rather than have the treatment plan conform to the patient's needs, success is unlikely. Frequently, several treatment plans are presented and discussed, each with advantages and disadvantages. Indeed, failing to explain and present alternatives may be considered legally negligent.

Treatment is necessary to accomplish one or more of the following objectives: correcting an existing disease, preventing future disease, restoring function, and improving appearance.

Correction of Existing Disease

Existing disease is revealed during the clinical examination. The disease process can usually be arrested



Fig. 3-1
Poor plaque control with dental caries.

by identification and reduction of the initiating factors, identification and improvement of the resistive factors, or both (Fig. 3-1). For example, oral hygiene instruction helps reduce the amount of residual plaque, an initiating factor, and thus helps reduce the likelihood of further dental caries. It also helps improve gingival health, and the resulting healthy tissue is more resistant to disease.

Additional fluoride intake (e.g., mouth rinses) is also recommended in a patient with a caries problem. Restorative care replaces damaged or missing tooth structure, but additional treatment is essential for controlling the disease that caused the damage.

Prevention of Future Disease

The likelihood of future disease can be predicted by evaluating the patient's disease experience and by knowing the prevalence of the disease in the general population. Treatment should be proposed if future disease seems likely in the absence of such intervention.

Restoration of Function

Although objective measurement may be difficult, the level of function is assessed during the examination. Treatment may be proposed to correct impaired function (e.g., mastication or speech).

Improvement of Appearance

Patients often seek dental treatment because they are dissatisfied with their appearance. However, it is difficult to objectively assess dental esthetics. The dentist should develop expertise in this area and should be prepared to appraise the appearance of the patient's dentition and listen carefully to the patient's views. If the appearance is far outside socially accepted values, the feasibility of corrective procedures should be brought to the patient's attention. Long-term dental health should not be compromised by unwise attempts to improve appearance. Patients should always be made aware of the possible adverse consequences of treatment.

AVAILABLE MATERIALS AND TECHNIQUES

All existing restorative materials and techniques have limitations and cannot exactly match the properties of natural tooth structure. Before the clinician selects the appropriate procedure, he or she should understand these limitations. This helps prevent an experimental approach to treatment.

Plastic Materials

Plastic materials (e.g., silver amalgam or composite resin) are the most commonly used dental restoratives. They allow simple and conservative restoration of damaged teeth. However, their mechanical properties are inferior to those of cast metal or metal-ceramic restorations. Their continued service depends on the strength and integrity of the remaining tooth structure. When the remaining tooth substance needs reinforcement, a cast metal restoration should be fabricated, usually with amalgam as the foundation or core (see Chapter 6).

Large amalgam restorations (Fig. 3-2*A*) are shaped or carved directly in the mouth. The great degree of difficulty associated with this direct approach often results in defective contours and poor occlusion. The indirect procedure, used in making cast metal **crowns** (Fig. 3-2*B*), facilitates the fabrication of more accurately shaped restorations.

Cast Metal

Cast metal crowns are fabricated outside the mouth and are cemented with a luting agent. To minimize exposure of the luting agent to oral fluids, a long-lasting restoration must have good marginal adaptation. The highly refined techniques for overcoming the problem of marginal fit also permit the manufacture of cast metal crowns with precisely shaped axial and occlusal surfaces. This ensures continued periodontal health and good occlusal function. The internal dimensions of a casting must seat without binding against the walls while remaining stable and



Fig. 3-2
A, The large amalgam restoration is hard to condense and contour accurately. **B,** The complete cast crown is stronger and can be shaped by an indirect procedure in the dental laboratory.

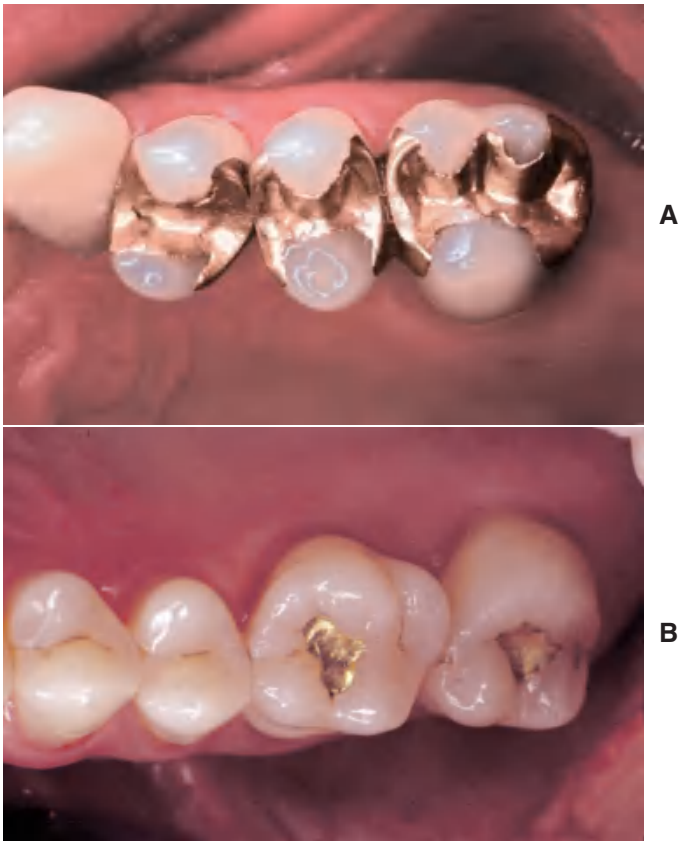


Fig. 3-3
A, The mesio-occlusal-distal (MOD) inlay is generally contraindicated because there is the risk of tooth fracture. However, it can be a very long-lasting restoration. These, placed in 1948, are still satisfactory after 58 years. **B,** These small gold foil restorations were placed in 1943.

not becoming displaced during function. Preparation design for cast metal restorations is crucial and is discussed in detail in Chapters 7 through 10.

Intracoronal restorations

An intracoronal cast metal restoration (Fig. 3-3), or inlay, relies on the strength of the remaining tooth structure for support and retention, just as a plastic restoration does. However, greater tooth bulk is needed to resist any wedging effect on the preparation walls. Therefore, this restoration is contraindicated in a significantly weakened tooth. When fabricated correctly, it is extremely durable because of the strength and corrosion resistance of the gold casting alloy; in a tooth with a minimal proximal carious lesion, however, it usually requires greater removal of tooth structure than does an amalgam preparation. Inlays do not have sufficient resistance or retention to be used as abutment retainers for FDPs.

Extracoronal restorations

An extracoronal cast metal restoration (Fig. 3-4), or crown, encircles all or part of the remaining tooth structure. As such, it can strengthen and protect a tooth weakened by caries or trauma. To provide the necessary bulk of material for strength, considerably more tooth structure must be removed than for an intracoronal restoration. The margins of an extracoronal restoration often must be near the free gingiva, which can make maintenance of tissue health difficult. Tooth preparation for an extracoronal restoration may be combined with intracoronal features (e.g., grooves and pinholes) to gain resistance and retention.

Metal-Ceramic

Metal-ceramic restorations (Fig. 3-5) consist of a tooth-colored layer of porcelain bonded to a cast metal substructure. They are used when a complete crown is needed to restore appearance as well as function. Sufficient reduction of tooth structure is necessary to provide space for the bulk of porcelain needed for a natural appearance. Thus, the preparation design for a metal-ceramic crown is among the least conservative, although tooth structure can be

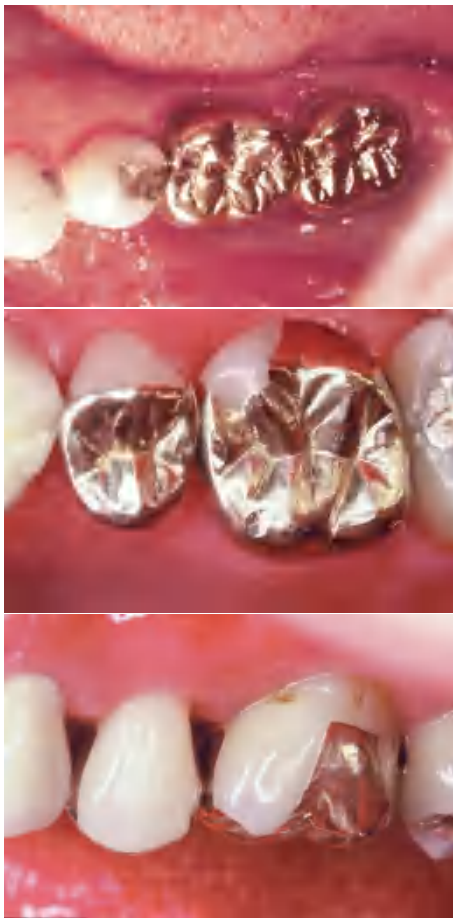


Fig. 3-4
A, Complete cast crowns. **B, C,** Partial veneer crowns.

conserved if only the most visible part of the restoration is veneered.

The labial margins of a metal-ceramic restoration are often discernible and may detract from its appearance. They can be hidden by subgingival placement, although they then have the potential for increasing gingival inflammation; this should be avoided when possible.[1] Appearance can be improved by omitting the metal shoulder and making the labial margin in porcelain. As discussed in Chapter 24, this is a more demanding laboratory procedure.

Resin-Veneered

Resin-veneered restorations were popular before the metal-ceramic technique was fully developed, but problems with wear and discoloration of the polymethyl methacrylate veneer (Fig. 3-6) limited their use to long-term interim restorations. Current resin-veneer techniques[2] incorporate bis-GMA–based



Fig. 3-5
A, B, Metal-ceramic restorations.



Fig. 3-6
Worn acrylic resin veneer.

materials (bisphenol-A glycidyl dimethacrylates), which have better physical properties than do the earlier acrylic resins, and adhesive techniques to improve the bond to the supporting metal.[3,4]

Fiber-Reinforced Resin

Advances in composite resin technology, especially the introduction of glass and polyethylene fibers,[5-7] have prompted the use of indirect composite resin restorations for inlays, crowns, and FDPs. Excellent marginal adaptation and esthetic results are achievable (Fig. 3-7), but because these are newer technologies, little is known about their longer-term performance (see Chapter 27).

Complete Ceramic

Crowns, inlays, and laminate veneers made entirely of dental porcelain can be the most esthetically pleasing of all fixed restorations (Fig. 3-8). Drawbacks include a comparative lack of strength and the difficulties associated with achieving an acceptable marginal fit. The current focus in improving strength lies with either veneering a high-strength alumina, zirconia, spinel, or lithium disilicate core[8-10] with a more translucent porcelain or using a leucite-reinforced translucent material[11-13] (see Chapter 25). Complete ceramic restorations are fabricated by an indirect technique and generally retained with composite resin. Acid etching is used to provide retention "keys."

Fixed Dental Prostheses

An FDP (Fig. 3-9) is often indicated when one or more teeth require removal or are missing. Such teeth are replaced by pontics that are designed to fulfill the functional and often the esthetic requirements of the missing teeth (see Chapter 20). Pontics are connected to retainers, which are the restorations on prepared abutment teeth.

All the components of an FDP are fabricated and assembled in the laboratory before cementation in the mouth. This requires precise alignment of tooth preparations. Because unseating forces on individual retainers can be considerable, highly retentive restorations are essential. FDPs have been demonstrated to have exceptional long-term success,[14]



Fig. 3-7
Fiber-reinforced fixed dental prosthesis.



Fig. 3-8
Complete ceramic restoration.

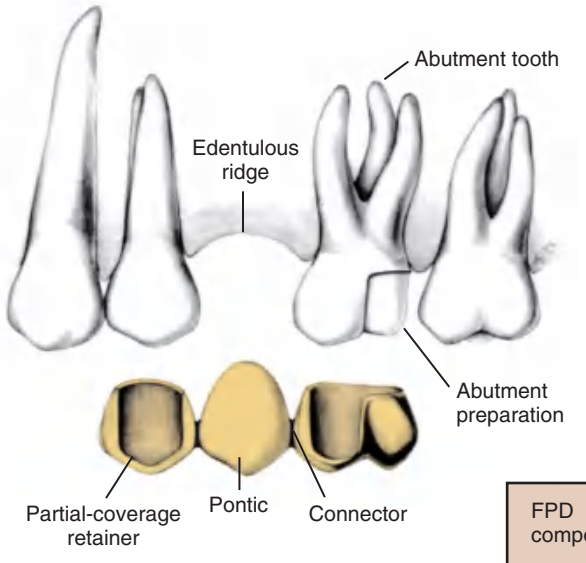


Fig. 3-9
A, A three-unit fixed dental prosthesis showing the main components. **B,** The pontic rigidly attached to crowns on the abutment teeth. The connectors should occupy the normal interproximal contact area and be large enough for strength but not so large as to impede plaque control.

which is ensured by controlling the magnitude and direction of forces and by making sure the patient practices appropriate oral hygiene measures.

Implant-Supported Prostheses

Single or multiple missing teeth can be replaced with an implant-supported prosthesis (Fig. 3-10). For the successful "osseointegrated" technique, the bone is atraumatically drilled to receive precisely fitting titanium cylinders.[15] These are left in place without loading for some months until they are invested with bone. Only then are function and esthetics restored with a prosthesis (see Chapter 13).

Partial Removable Dental Prosthesis

A **partial removable dental prosthesis** (**RDP**) (Fig. 3-11) is designed to replace missing teeth and their supporting structures. Forces applied to a well-designed prosthesis are distributed to the remaining teeth and the residual alveolar ridges. These forces are most accurately controlled if the abutment teeth are provided with fixed cast restorations that have carefully contoured guide planes and rest seats (see Chapter 21).

Complete Dentures

Some of the difficulties encountered with **complete dentures** relate to the lack of denture stability and a gradual loss of supporting bone. Stability is enhanced if the denture has a carefully designed occlusion. Problems with stability can be especially severe when the mandibular incisors are the only teeth retained, with ensuing damage to the opposing premaxilla,[16] although any treatment plan that involves a complete denture opposing fixed restorations requires careful planning of the occlusion (Fig. 3-12). For selected patients, providing an overdenture that rests on endodontically treated roots may help preserve the **residual ridge** and enhance the stability of the complete denture.[17]

TREATMENT OF TOOTH LOSS

A treatment plan involving fixed prosthodontics generally includes the replacement of missing teeth. Most teeth are lost as a result of dental caries or

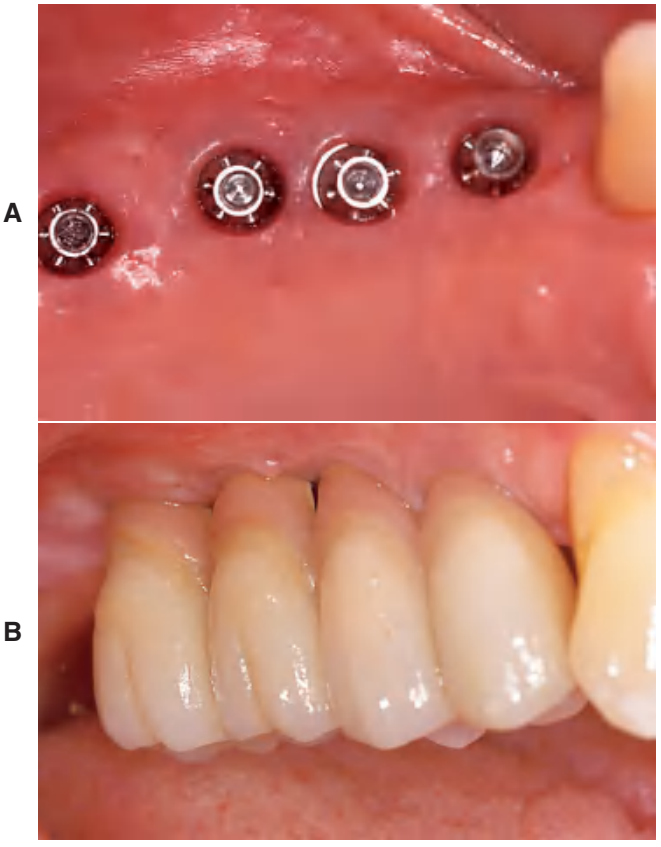


Fig. 3-10
Four-unit fixed dental prosthesis supported by four dental implants.

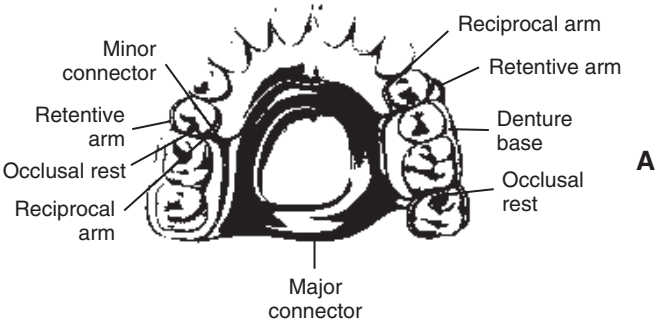




Fig. 3-11
The component parts of a partial removable dental prosthesis.



Fig. 3-12
Special planning is required when a combination of a complete maxillary denture is planned opposing a fixed mandibular prosthesis. In general, a trial maxillary denture is indicated so the fixed prosthesis can be fabricated to a well-aligned occlusal plane. A, Preoperative appearance. B to E, Completed restoration. *(Courtesy of Dr. J. A. Holloway.)*

periodontal disease. In rare cases, they may be congenitally absent or lost as a result of trauma or neoplastic disease.

Decision to Remove a Tooth

The decision to remove a tooth is part of the treatment-planning process and is made after assessing the advantages and disadvantages associated with retention of the tooth. Sometimes it is possible to retain a tooth with an apparently hopeless prognosis by using highly specialized and complex techniques. In other cases, removing the tooth is the treatment of choice (Fig. 3-13). A decision about replacing a missing tooth is best made at the time its removal is recommended, rather than months or years after the fact.



Fig. 3-13
Poor treatment planning. The displaced premolar should never have been restored under these circumstances. *(Courtesy of Dr. P. B. Robinson.)*

Consequences of Removal without Replacement

The decision to replace or not replace missing teeth requires a careful analysis of the costs and benefits of the action. The loss of posterior occlusion may lead to excessive forces on the remaining dentition with consequent damage and poor function. However, studies have demonstrated that adequate function is possible with reduced posterior occlusion.[18] Deciding not to replace a tooth may lead to a situation in which the balance of the forces exerted on that tooth by the adjacent and opposing teeth and supporting tissues and by the soft tissues of the cheeks, lips, and tongue is upset (Fig. 3-14). The con-

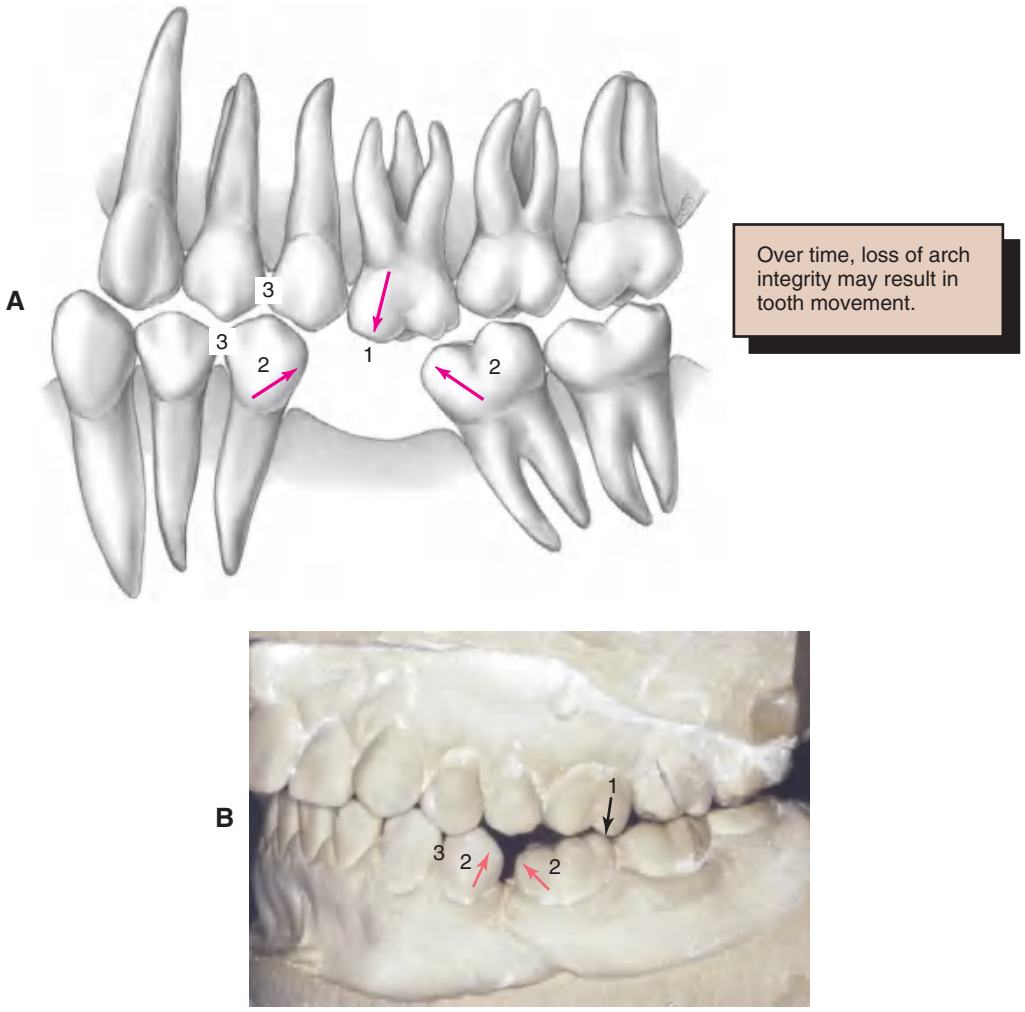


Fig. 3-14
Loss of a mandibular first molar not replaced with a fixed dental prosthesis. The typical consequences are supraclusion of opposing teeth (1), tilting of adjacent teeth (2), and loss of proximal contacts (3). *(A, Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment, London, Kluwer Publishing, 1983.)*

sequences may be **supraclusion** of the opposing tooth or teeth, tilting of the adjacent teeth, and loss of proximal contact (with resulting disturbances in the health of the supporting structures and the occlusion). However, the teeth adjacent to an edentulous space have not been shown to be at greater risk of damage,[19] and the rate of change of teeth adjacent to an edentulous space is usually slow.[20]

However, if the situation is not carefully monitored and significant movement of adjacent teeth has occurred, simple replacement of the missing tooth at this late stage may prevent further disruption, although it may be insufficient to return the dentition to full health. Extended treatment plans, including orthodontic repositioning and additional cast restorations (to correct the disturbed occlusal plane), may be needed to compensate for the lack of treatment at the time of tooth removal.

SELECTION OF ABUTMENT TEETH

Whenever possible, FDPs should be designed as simply as possible, with a single well-anchored retainer fixed rigidly at each end of the pontic. The use of multiple splinted abutment teeth, **nonrigid connectors,** or intermediate abutments makes the procedure much more difficult, and often the result compromises the long-term prognosis (Fig. 3-15).

Replacement of a Single Missing Tooth

Unless bone support has been weakened by advanced periodontal disease, a single missing tooth can almost always be replaced by a three-unit FDP that includes one mesial and one distal abutment tooth. An exception is when the FDP is replacing a maxillary or mandibular canine. Under these cir-



Fig. 3-15
A to **C,** Congenitally missing lateral incisors replaced with two simple three-unit fixed dental prostheses. **D** to **F,** This patient had a missing canine as well as two congenitally missing laterals. Here, there is a much greater restorative challenge than in part A, necessitating an eight-unit prosthesis.

cumstances, the small anterior abutment tooth needs to be splinted to the central incisor to prevent lateral drift of the FDP.

Cantilever fixed dental prostheses

FDPs in which only one side of the pontic is attached to a retainer are referred to as *cantilevered.* An example would be a lateral incisor pontic attached only to an extracoronal metal-ceramic retainer on a canine. Cantilevered FDPs remain popular because some of the difficulties encountered in making a three-unit FDP are lessened. Also, many clinicians are reluctant to prepare an intact central incisor, preferring instead to use a **cantilever.**

However, the long-term prognosis of the single-abutment cantilever is poor.[21] Forces are best tolerated by the periodontal supporting structures when directed in the long axes of the teeth.[22] This is the case when a simple three-unit FDP is used. A cantilever induces lateral forces on the supporting tissues, which may be harmful and lead to tipping, rotation, or drifting of the abutment (Fig. 3-16). Laboratory analysis[23,24] has confirmed the potential harmful nature of such FDPs. However, clinical experience with resin-retained FDPs has suggested that cantilever designs may be preferred, especially because re-adhesion after failure is greatly facilitated[25] (see Chapter 26).

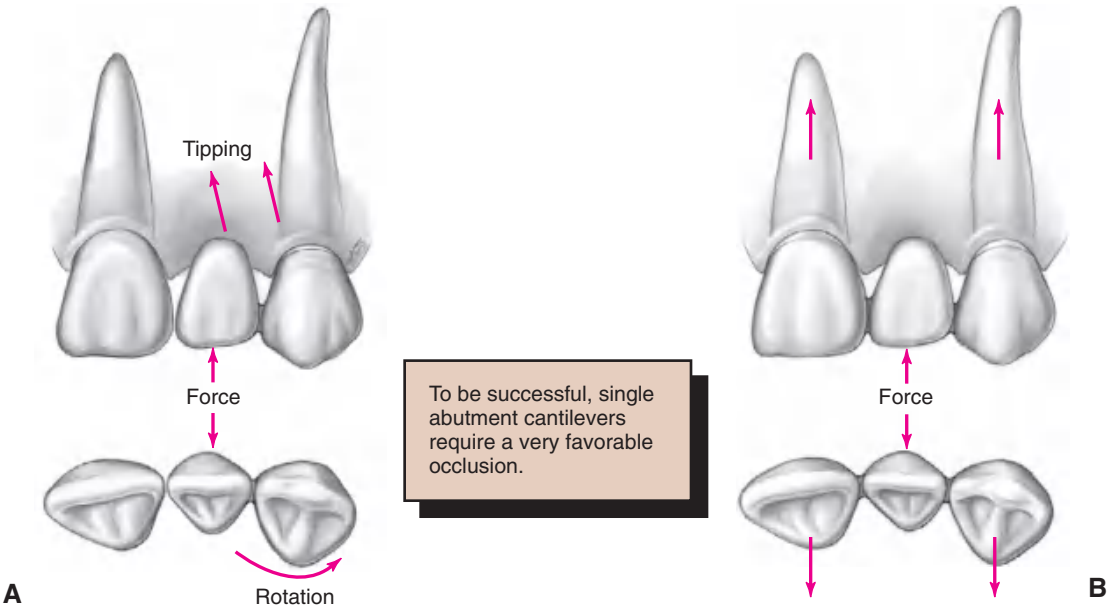


Fig. 3-16

A, Forces applied to a cantilever fixed dental prosthesis are resisted on only one side, leading to imbalance. Vertical forces can cause tipping, and horizontal forces, rotation, of abutment teeth. **B,** By including both adjacent teeth in the prosthesis, it is possible to resist forces much better since the teeth have to be moved bodily rather than merely rotated or tipped. *(Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment, London, Kluwer Publishing, 1983.)*

When multiple missing teeth are replaced, cantilever FDPs have considerable application (see Fig. 3-20). The harmful tipping forces are resisted by multiple abutment teeth, and movement of the abutments is unlikely. Cantilevers are also successfully used with implant-supported prostheses (see Chapter 13).

Assessment of abutment teeth

Considerable time and expense are spared, and loss of a patient's confidence can be avoided, by thoroughly investigating each abutment tooth before proceeding with tooth preparation. Radiographs are made, and pulpal health is assessed by evaluating the response to thermal and electrical stimulation. Existing restorations, cavity liners, and residual caries are removed[26] (preferably under a rubber dam), and a careful check is made for possible pulpal exposure. Teeth in which pulpal health is doubtful should be endodontically treated before the initiation of fixed prosthodontics. Although a direct pulp cap may be an acceptable risk for a simple amalgam or composite resin, conventional endodontic treatment is normally preferred for cast restorations, especially when the later need for endodontic treatment would jeopardize the overall success of treatment.

Endodontically treated abutments

If a tooth is properly treated endodontically, it can serve well as an abutment with a post and core foundation for retention and strength (see Chapter 12). Failures occur, however, particularly on teeth with short roots or little remaining coronal tooth structure. Care is needed to obtain maximum retention for the post and core. Sometimes it is better to recommend removal of a badly damaged tooth rather than to attempt endodontic treatment.

Unrestored abutments

An unrestored, caries-free tooth is an ideal abutment. It can be prepared conservatively for a strong retentive restoration with optimum esthetics (Fig. 3-17). The margin of the retainer can be placed without modifications to accommodate existing restorations or caries. In an adult patient, an unrestored tooth can be safely prepared without jeopardizing the pulp as long as the design and technique of tooth preparation are wisely chosen. Certain patients are reluctant to have a perfectly sound tooth cut down to provide anchorage for an FDP. In these cases, the overall dental health of the patient, rather than the condition of each individual tooth, should be emphasized.

Mesially tilted second molar

Loss of a permanent mandibular first molar to caries early in life is still relatively common (Fig. 3-18). If the space is ignored, the second molar may tilt mesially, especially with eruption of the third molar.



Fig. 3-17
A, B, Unrestored abutment teeth can be prepared for conservative retainers. **C,** An esthetic fixed dental prosthesis replacing a maxillary incisor.

It then becomes difficult or impossible to make a satisfactory FDP, because the positional relationship no longer allows for parallel paths of insertion without interference from the adjacent teeth.

In such circumstances, an FDP is sometimes made with modified preparation designs or with a nonrigid connector, or a straightforward solution[27] may be considered: uprighting the tilted abutment orthodontically with a simple fixed appliance. However, the problem can be avoided altogether if a space-maintainer appliance (Fig. 3-19) is fabricated when the first molar is removed. This device may be as simple as a square section of orthodontic wire bent to follow the edentulous ridge and anchored with small restorations in adjacent teeth.

Replacement of Several Missing Teeth

Fixed prosthodontics becomes more difficult when several teeth must be replaced. Problems are encountered in restoring a single long, uninterrupted edentulous area or multiple edentulous areas with intermediate abutment teeth (Fig. 3-20), especially when anterior and posterior teeth are to be replaced with a single fixed prosthesis. Underestimation of the problems involved in extensive prosthodontics can lead to failure. One key to ensuring a successful result is to plan the prostheses by waxing the intended restorations on articulated diagnostic casts. This is essential for complex fixed prosthodontic treatments, particularly when an irregular occlusal plane is to be corrected, the occlusal vertical dimension is to be altered, an implant-supported prosthesis is recommended, or a combination of fixed and removable prostheses are to be used. The precise end point of such complicated treatments can be far from evident, even to an experienced prosthodontist (see Fig. 2-39).

Overloading of abutment teeth

The ability of the abutment teeth to accept applied forces without drifting or becoming mobile must be estimated and has a direct influence on the prosthodontic treatment plan. These forces can be particularly severe during parafunctional grinding and clenching (see Chapter 4), and the need to eliminate them becomes obvious during the restoration of such a damaged dentition. Although it is hoped that a well-reconstructed occlusion will reduce the duration and strength of any parafunctional activity, there is little scientific evidence to support this. It is unwise to initiate treatment on the assumption that new restorations will reduce parafunctional activity, unless this has been demonstrated with treatment appliances over a significant period.[28]

Direction of forces

Whereas the magnitude of any applied force is difficult to regulate, a well-fabricated FDP can distribute these forces in the most favorable way, directing them in the long axis of the abutment teeth. Potentially damaging lateral forces can be confined to the anterior teeth, where they are reduced by the longer lever arm (see Chapter 4).

Root surface area

The root surface area of potential abutment teeth must be assessed when treatment for fixed prosthodontics is planned. Ante[29] suggested in 1926 that it was unwise to provide an FDP when the root surface

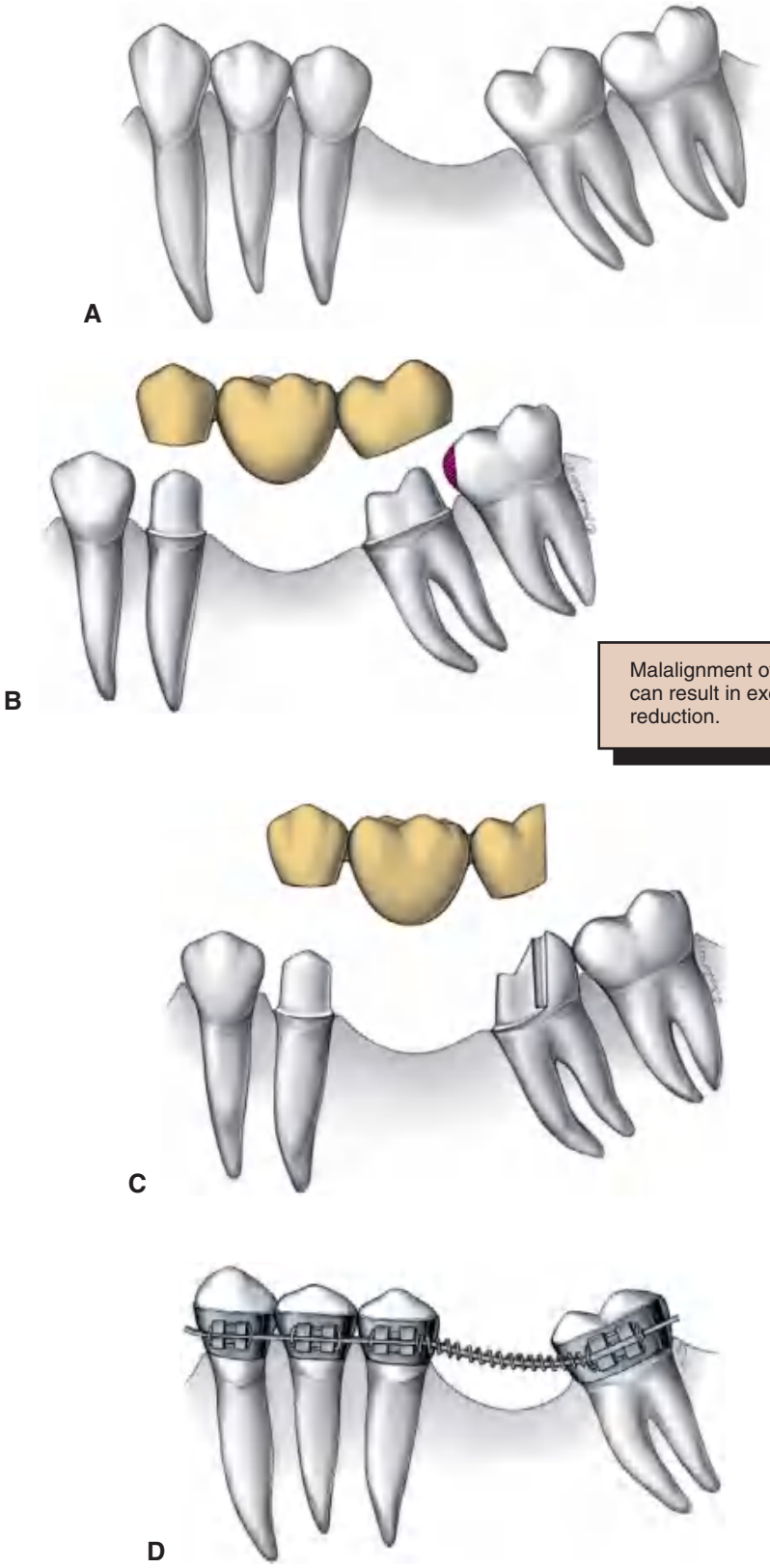


Fig. 3-18

A, Early loss of a mandibular first molar with mesial tilting and drifting of the second and third molars. **B,** A conventional three-unit fixed dental prosthesis will fail because its seating is prevented by the third molar. **C,** A modified preparation design can be used on the distal abutment. **D,** A better treatment plan would be to remove the third molar and upright the second molar orthodontically before fabricating a fixed dental prosthesis. *(Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment, London, Kluwer Publishing, 1983.)*

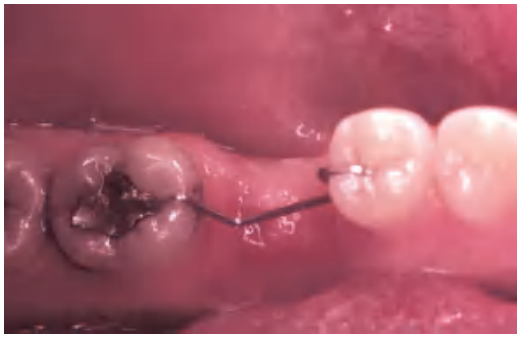


Fig. 3-19
Square section orthodontic wire can be used as a simple stabilizing appliance to prevent drifting of abutment teeth after exodontia. The wire is retained by placing small restorations. As an alternative, orthodontic bands can be used as the retainer. Note that these simple stabilizers do not prevent supraeruption of opposing teeth; in areas where this is anticipated, a provisional fixed dental prosthesis is needed.

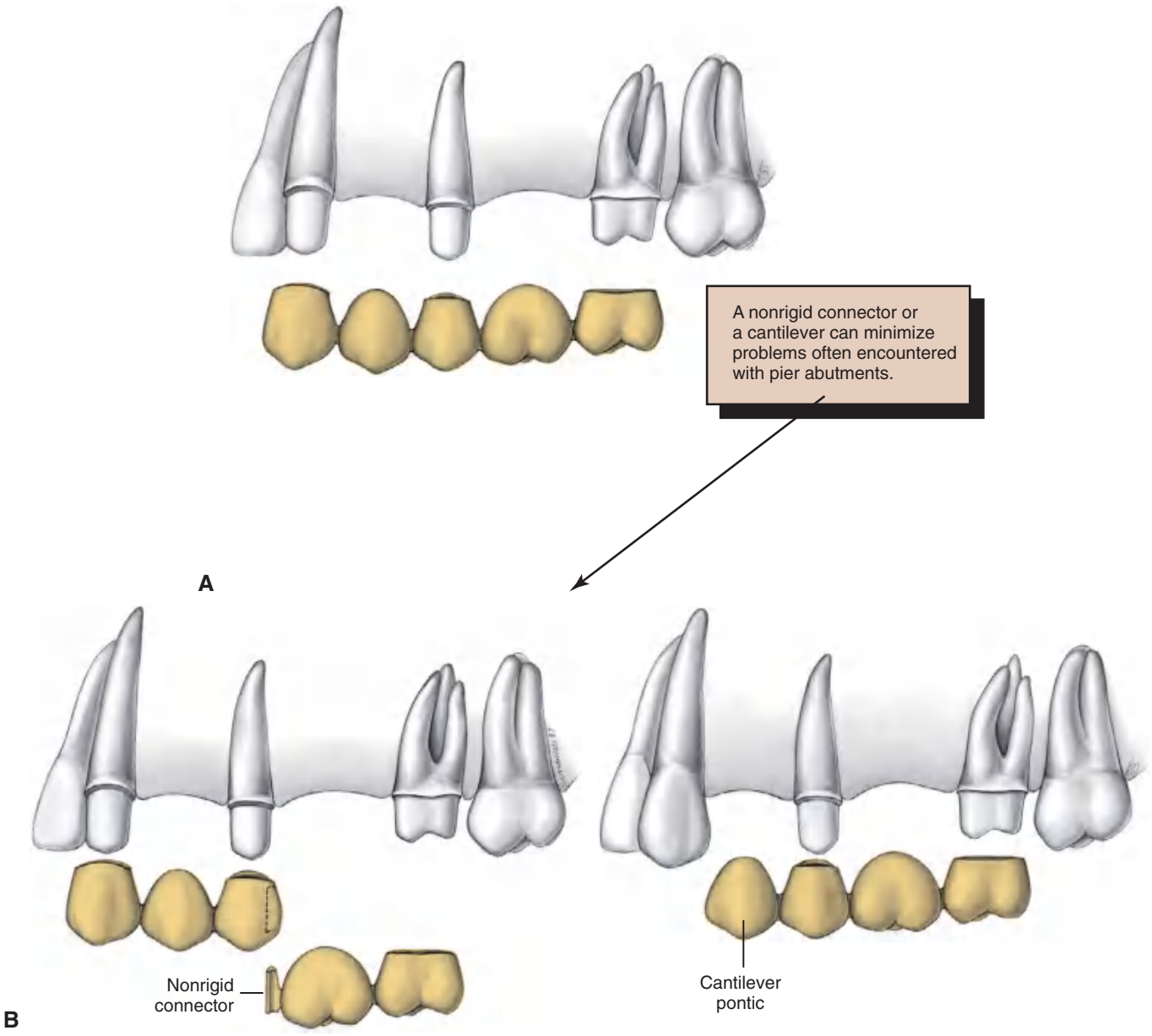


Fig. 3-20
A, A five-unit fixed dental prosthesis (FDP) replacing the maxillary first molar and first premolar. The middle abutment can act as a fulcrum during function, with possible unseating of one of the other retainers. To be successful, this type of FDP needs extremely retentive retainers. **B,** An alternative approach is a nonrigid dovetail connector between the molar pontic and the second premolar. **C,** Where periodontal support is adequate, a much simpler approach would be to cantilever the first premolar pontic. *(Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment, London, Kluwer Publishing, 1983.)*

Table 3-1 ROOT SURFACE AREA OF ABUTMENT

	Root Surface Area (mm^2)	Percentage Root Surface Area in Quadrant
MAXILLARY		
Central	204	10
Lateral	179	9
Canine	273	14
First premolar	234	12
Second premolar	220	11
First molar	433	22
Second molar	431	22
MANDIBULAR		
Central	154	8
Lateral	168	9
Canine	268	15
First premolar	180	10
Second premolar	207	11
First molar	431	24
Second molar	426	23

Data from Jepsen A: Root surface measurement and a method for x-ray determination of root surface area. Acta Odontol Scand 21:35, 1963.

area of the abutment was less than the root surface area of the teeth being replaced; this has been adopted and reinforced by other authors[30-32] as **Ante's law.** Average values for the root surface area of permanent teeth are given in Table 3-1.[33] As an example of Ante's law, consider the patient who has lost a first molar and second premolar (Fig. 3-21). In this situation, a four-unit FDP is an acceptable risk, as long as there has been no bone loss from periodontal disease, because the second molar and first premolar abutments have root surface areas approximately equal to those of the missing teeth. If the first molar and both premolars are missing, however, an FDP is not considered a good risk because the missing teeth have a greater total root surface area than the potential abutments.

Nyman and Ericsson,[34] however, cast doubt on the validity of Ante's law by demonstrating that teeth with considerably reduced bone support can be successfully used as FDP abutments. In the majority of the treatments discussed by these authors, the abutment root surface area was less than half that of the replaced teeth, and there was no loss of attachment after 8 to 11 years. The authors attributed this success to meticulous root planing during the active phase of treatment, proper plaque control during the observed period, and the occlusal design of the prostheses. Other authors have confirmed that abutment teeth with limited periodontal bone can successfully support fixed prostheses.[35,36]

Ante's law is useful for determining the prognosis of fixed dental prostheses.

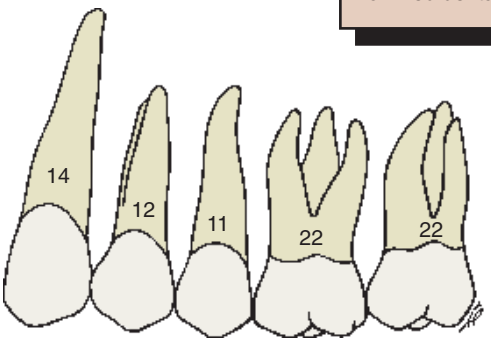


Fig. 3-21

To assess the support of a fixed dental prosthesis (FDP), Ante's law has been invoked.

It proposes a relationship between the root surface areas of the missing teeth and those of the potential abutment teeth. (The numbers represent root surface area percentages.) If the first molar (22) and second premolar (11) are missing, the abutments for a four-unit FDP have a slightly greater total root surface area (34) than do the teeth being replaced. In that case, in the absence of other detrimental factors, an FDP's prognosis is favorable. However, if the first premolar (12) is also missing, the loss of potential abutment root surface area comprises 45, whereas the remaining abutments have only 36, which is much less favorable.

Root shape and angulation

When tooth support is borderline adequate, the shape of the roots and their angulation should be considered. A molar with divergent roots provides better support than a molar with conical roots and little or no interradicular bone. A single-rooted tooth with an elliptic cross-section offers better support than a tooth with similar root surface area but a circular cross-section. Similarly, a well-aligned tooth provides better support than a tilted one. Alignment can be improved with orthodontic uprighting (Fig. 3-22).

Periodontal disease

After horizontal bone loss from periodontal disease, the periodontal ligament–supported root surface area can be dramatically reduced.[37] Because of the conical shape of most roots (Fig. 3-23), when one third of the root length has been exposed, half the supporting area is lost. In addition, the forces applied to the supporting bone are magnified because of the greater leverage associated with the lengthened clinical crown. Thus, potential abutment teeth need very careful assessment when significant bone loss has occurred.

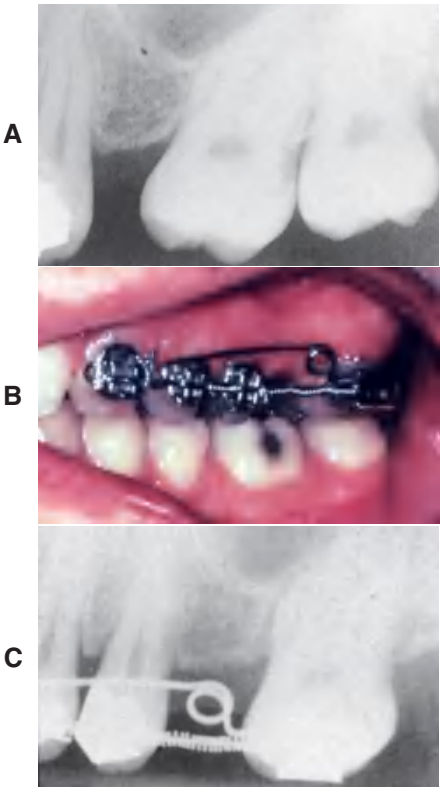


Fig. 3-22

A, A misaligned abutment tooth may be difficult or impossible to prepare for a fixed dental prosthesis abutment and provides poor support. **B** and **C,** When possible, this should be corrected with orthodontic treatment before restoration. *(Courtesy of Dr. G. Gruendeman.)*

In general, successful fixed prostheses can be fabricated on teeth with severely reduced periodontal support if the periodontal tissues have been returned to excellent health and long-term maintenance has been ensured[38,39] (Fig. 3-24). When extensive reconstruction is attempted without complete control over the health of the periodontal tissues, the results can be disastrous.

Healthy periodontal tissues are a prerequisite for all fixed restorations. If the abutment teeth have normal bone support, an occasional lapse in plaque removal by the patient is unlikely to affect the long-term prognosis. However, when teeth with severe bone loss resulting from periodontal disease are used as abutments, there is very little tolerance. It then becomes imperative that excellent plaque-removal technique be implemented and maintained at all times.

Span length

Excessive flexing under occlusal loads may cause failure of a long-span FDP (Fig. 3-25). It can lead to fracture of a porcelain veneer, breakage of a connector, loosening of a retainer, or an unfavorable soft tissue response and thus render a prosthesis useless. All FDPs flex slightly when subjected to a load; the longer the span, the greater the flexing. The relationship between deflection and length of span is not simply linear but varies with the cube of the length of the span. Thus, other factors being equal, if a span of a single pontic is deflected a certain amount, a span of two similar pontics will move 8 times as much, and three will move 27 times as much[40] (Fig. 3-26).

Replacing three posterior teeth with an FDP rarely has a favorable prognosis, especially in the mandibular arch.[41] Under such circumstances, it is usually better to recommend an implant-supported prosthesis or a partial RDP.

When a long-span FDP is fabricated, pontics and connectors should be made as bulky as possible to ensure optimum rigidity without jeopardizing gingival health. In addition, the prosthesis should be made of a material that has high strength and rigidity (see Chapter 19).

Replacing multiple anterior teeth

Special considerations in this situation include problems with appearance and the need to resist laterally directed tipping forces.

The four mandibular incisors can usually be replaced by a simple FDP with retainers on each canine. It is not usually necessary to include the first

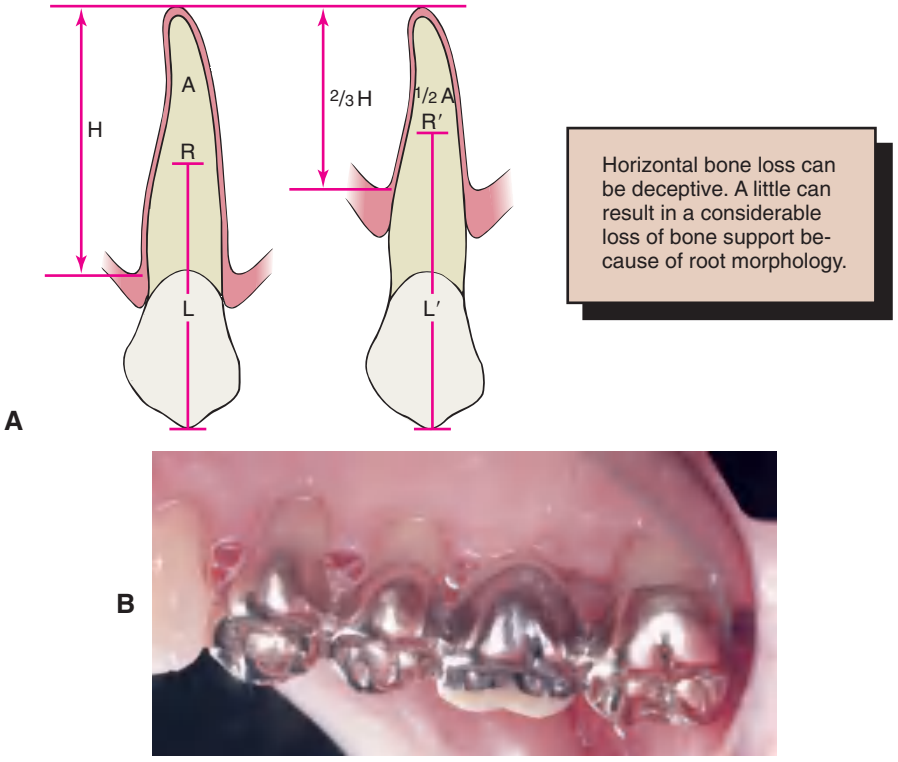


Fig. 3-23

A, Because of the conical shape of most roots, the actual area of support (*A*) diminishes more than might be expected from the height of the bone (*H*). In addition, the center of rotation (*R*) moves apically (*R′*) and the lever arm (*L′*) increases, magnifying the forces on the supportive structure. **B,** A fixed dental prosthesis (FDP) replacing a maxillary first molar. The first premolar is an abutment providing additional stabilization for this FDP on abutment teeth with compromised bone support. (**A,** *Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment, London, Kluwer Publishing, 1983.)*

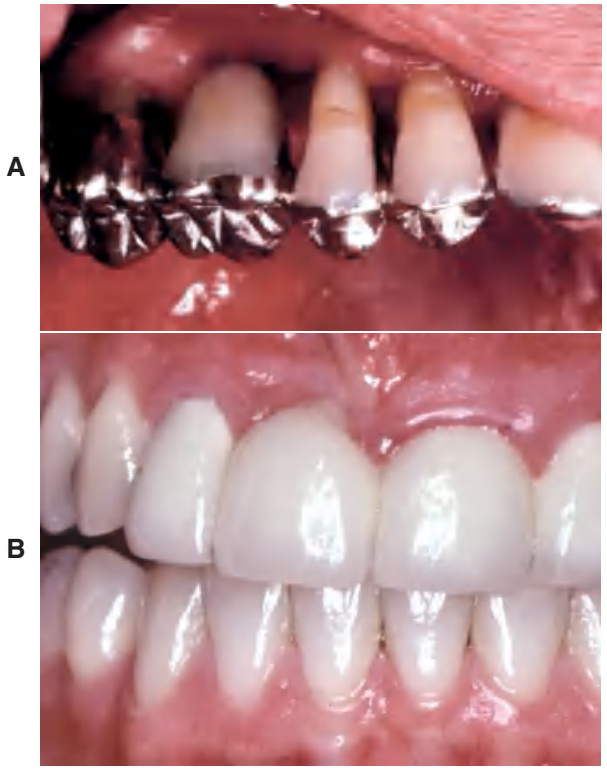


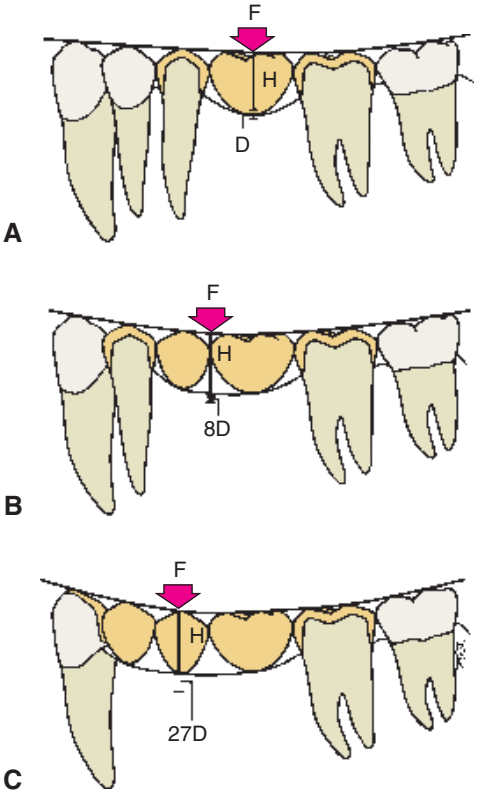
Fig. 3-24

A, Supragingival margins and large gingival embrasures facilitate plaque control in a periodontally compromised patient. **B,** Poor prosthetic contours and margins have contributed to this failure.



Fig. 3-25

Failure of a long-span fixed dental prosthesis.



Excessive span length is a common contraindication for fixed dental prostheses.

Fig. 3-26

The deflection of a fixed dental prosthesis is proportional to the cube of the length of its span. **A,** A single pontic deflects a small amount (*D*) when subjected to a certain force (*F*). **B,** Two pontics deflect 2^3 times as much (8*D*) to the same force. **C,** Three pontics deflect 3^3 times as much (27*D*).

premolars. If a lone incisor remains, it should be removed because its retention unnecessarily complicates the design and fabrication of the FDP and can jeopardize the long-term result. Mandibular incisors, because of their small size, generally are poor abutment teeth. It is particularly important not to have overcontoured restorations on these teeth, because plaque control is nearly impossible. Thus, the clinician may have to make a choice between (1) compromised esthetics from too thin a ceramic veneer and (2) pulpal exposure during tooth preparation. A third alternative would be selective tooth removal.

The loss of several maxillary incisors presents a much greater problem in terms of restoring appearance and providing support. Because of the curvature of the arch, forces directed against a maxillary incisor pontic tend to tip the abutment teeth. Unlike the mandibular incisors, the maxillary incisors are not positioned in a straight line (particularly in patients with narrow or pointed dental arches). Tipping forces must be resisted by means of two abutment teeth at each end of a long span anterior FDP. Thus, when replacing the four maxillary incisors, the clinician should generally use the canines and first premolars as abutment teeth.[42]

There may be considerable difficulty in achieving a good appearance when several maxillary incisors are being replaced with an FDP. Obtaining the best tooth contours and position for appearance and phonetics can be a challenge. A good attempt can be made with the diagnostic waxing procedure, evaluating any esthetic problems. As treatment progresses, an interim restoration is provided (see Chapter 15). This may be used to test appearance and phonetics. It may also be readily shaped and modified to suit the patient, and the final restoration can be made as a copy of it, thereby avoiding any embarrassing misunderstandings when the finished fixed prosthesis is delivered.

If anterior bone loss has been severe, as can happen when teeth are lost as a result of trauma or periodontal disease, there may be a ridge defect (Fig. 3-27). In these patients, a partial RDP should be considered, especially when the person has



Fig. 3-27
This patient lost two incisors in an accident. Considerable alveolar bone has also been lost. An aesthetic fixed prosthesis would be very difficult or impossible to fabricate without surgical ridge augmentation. *(Courtesy of Dr. N. Archambo.)*



Fig. 3-28
A partial removable dental prosthesis replacing the mandibular right first and second molars. *(Courtesy of Dr. J. A. Holloway.)*

a high smile line, since an FDP generally replaces only the missing tooth structure, not the supporting tissues. Again, an interim restoration may help the patient determine the most appropriate treatment. A surgical ridge augmentation procedure[43] may also be an option, although the results can be unpredictable.

Indications for Partial Removable Dental Prostheses

Whenever possible, edentulous spaces should be restored with FDPs rather than partial RDPs. A well-fabricated FDP provides better health and better function than does a partial RDP[44] and is preferred by most patients. Under the following circumstances, however, a partial RDP is indicated:

1. Where vertical support from the edentulous ridge is needed; for example, in the absence of a distal abutment tooth (Fig. 3-28).
2. Where resistance to lateral movement is needed from contralateral teeth and soft tissues; for example, to ensure stability with a long edentulous space.
3. When there is considerable bone loss in the visible anterior region and an FDP would have an unacceptable appearance (Fig. 3-29).

Multiple edentulous spaces often are best restored with a combination of FDPs and partial RDPs (Fig. 3-30).



Fig. 3-29
Where there has been considerable bone loss, a partial removable dental prosthesis has a more natural appearance than a fixed dental prosthesis.

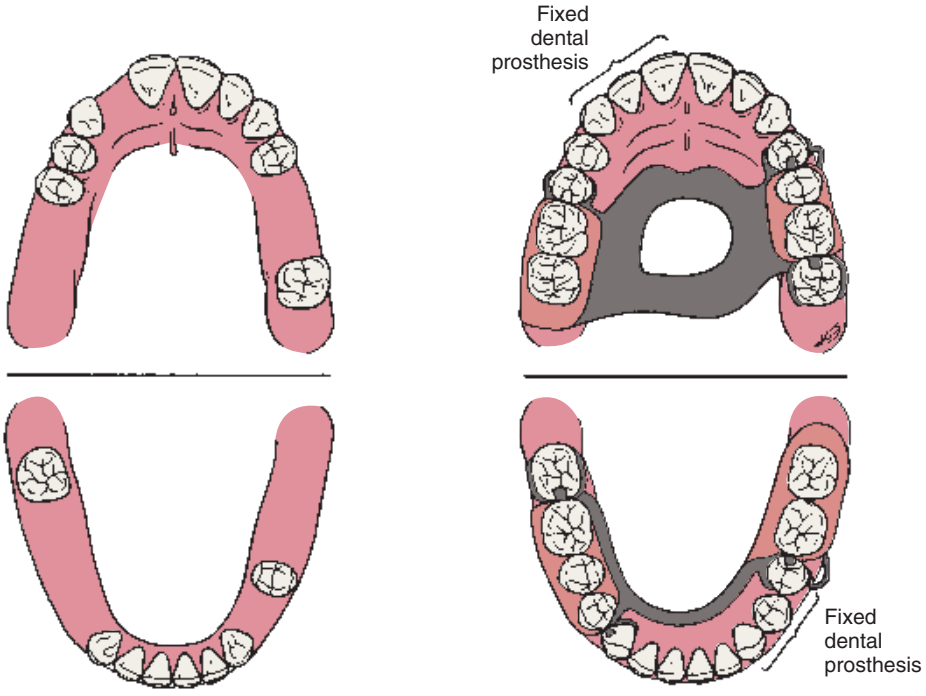
TREATMENT SEQUENCE

When patient needs have been identified and the appropriate corrective measures have been determined, a logical sequence of steps must be decided on, including the treatment of symptoms, stabilization of deteriorating conditions, definitive therapy, and a program of follow-up care. The importance of proper sequencing is emphasized, because mistakes can lead to compromised effort or unnecessary and expensive remakes.

Treatment of Symptoms

The relief of discomfort accompanying an acute condition is a priority in planning treatment (Fig. 3-31). Discomfort can result from one or more of the following: a fractured tooth or teeth, acute pulpitis, acute exacerbation of chronic pulpitis, a dental abscess, acute pericoronitis or gingivitis, and myofascial pain dysfunction.

The clinician needs only sufficient diagnostic information to ascertain the nature of a particular



Minimizing the number of modification spaces in a removable partial dental prosthesis is often helpful.

Fig. 3-30
Treatment planning for multiple edentulous spaces. A combination of fixed and removable prostheses may provide the best replacement when several teeth are missing. In the maxillary arch, the missing lateral incisor has been restored with a simple three-unit fixed dental prosthesis (FDP), which is more easily cleaned than is a partial removable dental prosthesis (RDP). In the mandibular arch, the single remaining premolar is splinted to the canine with a three-unit FDP. A partial RDP that fits around a lone-standing premolar usually does not have a good prognosis. *(Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment, London, Kluwer Publishing, 1983.)*



Fig. 3-31
Swelling from an acute periapical abscess. *(Courtesy of Dr. P. B. Robinson.)*

condition and to form a diagnosis; treatment is instituted without delay. A full examination is neither desirable nor generally possible until the symptoms of the acute condition have been addressed.

Urgent treatment of nonacute problems

Fortunately, most potential candidates for fixed prosthodontics do not seek treatment for acute conditions; however, they may have a specific problem that should receive immediate attention, such as a lost anterior crown, a cracked or broken porcelain veneer, or a fractured removable prosthesis (Fig. 3-32).

Stabilization of Deteriorating Conditions

The second phase of treatment involves stabilizing conditions such as dental caries or periodontal



Fig. 3-32
For both appearance and comfort, fractured porcelain often necessitates urgent treatment.

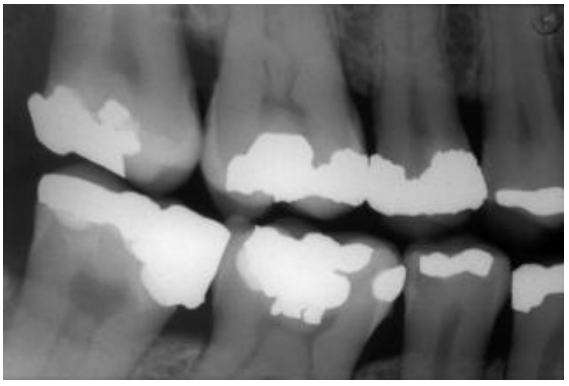


Fig. 3-33
Overhangs and defective restorations impede proper plaque control and should be corrected as part of the stabilization process.

disease by removing the etiologic factors, increasing the patient's resistance, or doing both.

Dental caries

Treatment of carious lesions is approached in a conventional manner, and the teeth are restored with properly contoured plastic materials. These may serve as a foundation for fixed castings during a subsequent phase of treatment (see Chapter 6). However, cast restorations are best avoided in a patient with active caries, because the results of such extensive treatment would be jeopardized by recurrence of the disease. This can be prevented by a combination of dietary advice, oral hygiene measures, and fluoride treatment.

Periodontal disease

Chronic periodontitis with continuing irreversible bone loss should be treated as early as possible by effective daily plaque control. The proper removal of plaque is possible only if the teeth are smooth and their contours allow unimpeded access to the gingival sulci. Therefore, the following procedures are essential (Fig. 3-33):

- Replacement of defective restorations
- Removal of carious lesions
- Recontouring of overcontoured crowns (especially near furcation areas)
- Proper oral hygiene instruction adequately implemented at home

Definitive Therapy

When the stabilization phase has been completed, successful elective long-term treatment aimed at promoting dental health, restoring function, and improving appearance can begin. On occasion, this takes considerable time. Several therapeutic proposals may be applicable to a single patient and may range in complexity from minimum restorative treatment with regular maintenance to full mouth prosthodontic reconstruction preceded by orthognathic surgery and orthodontic treatment. The advantages and disadvantages of each should be thoroughly explained to the patient, with diagnostic casts and waxings used as guides. When a definitive plan is established, it should attempt to minimize the possibility of having to repeat earlier treatment if problems later occur. Usually oral surgical procedures are scheduled first, followed by periodontics, endodontics, orthodontics, fixed prosthodontics, and finally, removable prosthodontics.

Oral surgery

The treatment plan should allow time for healing and ridge remodeling. Therefore, teeth with a hopeless prognosis, unerupted teeth, and residual roots and root tips should be removed early. All preprosthetic surgical procedures (e.g., ridge contouring) should be undertaken during the early phase of treatment.

Periodontics

Most periodontal procedures should (or will) have been accomplished as part of the stabilization phase of treatment. Any surgery, pocket elimination, mucogingival procedure, guided tissue regeneration, or root resection is performed at this time (see Chapter 5).

Endodontics

Some endodontic treatment may have been accomplished as part of the relief of discomfort and stabilization of conditions. Elective endodontics may be needed to provide adequate space for a cast restoration or to provide retention for a badly damaged or worn tooth.

If a tooth with doubtful pulpal health is to be used as an abutment for an FDP, it should be endodonti-

cally treated prophylactically, despite the consideration that periodic recall may be more appropriate treatment if a single restoration is planned.

Orthodontics

Minor orthodontic tooth movement is a common adjunct to fixed prosthodontics. A tooth can be uprighted, rotated, moved laterally, intruded, or extruded to improve its relationship before fixed prosthodontic treatment. Orthodontics should always be considered when a treatment plan is being proposed, especially if tooth loss has been neglected and drifting has occurred.

Fixed prosthodontics

Fixed prosthodontic treatment is initiated only after the preceding modalities have been completed. This allows modification of the original plan if unforeseen difficulties surface during treatment. For example, a tooth scheduled for endodontic treatment might prove to be untreatable, necessitating considerable modification of the restorative treatment plan.

Occlusal adjustment

Occlusal adjustments are often necessary before the initiation of fixed prosthodontics. When extensive fixed prosthodontics is to be provided, an accurate and well-tolerated occlusal relationship may be obtainable only if a discrepancy between maximal intercuspation and centric relation is eliminated first (see Chapter 4). When less extensive treatment is planned, it may be acceptable to modify the fixed prosthesis to conform to the existing occlusion, provided the patient is functioning satisfactorily. However, any supraeruption or drifting should be corrected rather than be allowed to compromise the patient's occlusal scheme.

Anterior restorations

If both anterior and posterior teeth are to be restored, the anterior teeth are usually restored first because they influence the border movements of the mandible and thus the shape of the occlusal surfaces of the posterior teeth (see Chapter 4). If the posterior teeth are restored first, a subsequent change in the lingual contour of the anterior teeth could require considerable adjustment of the posterior restorations.

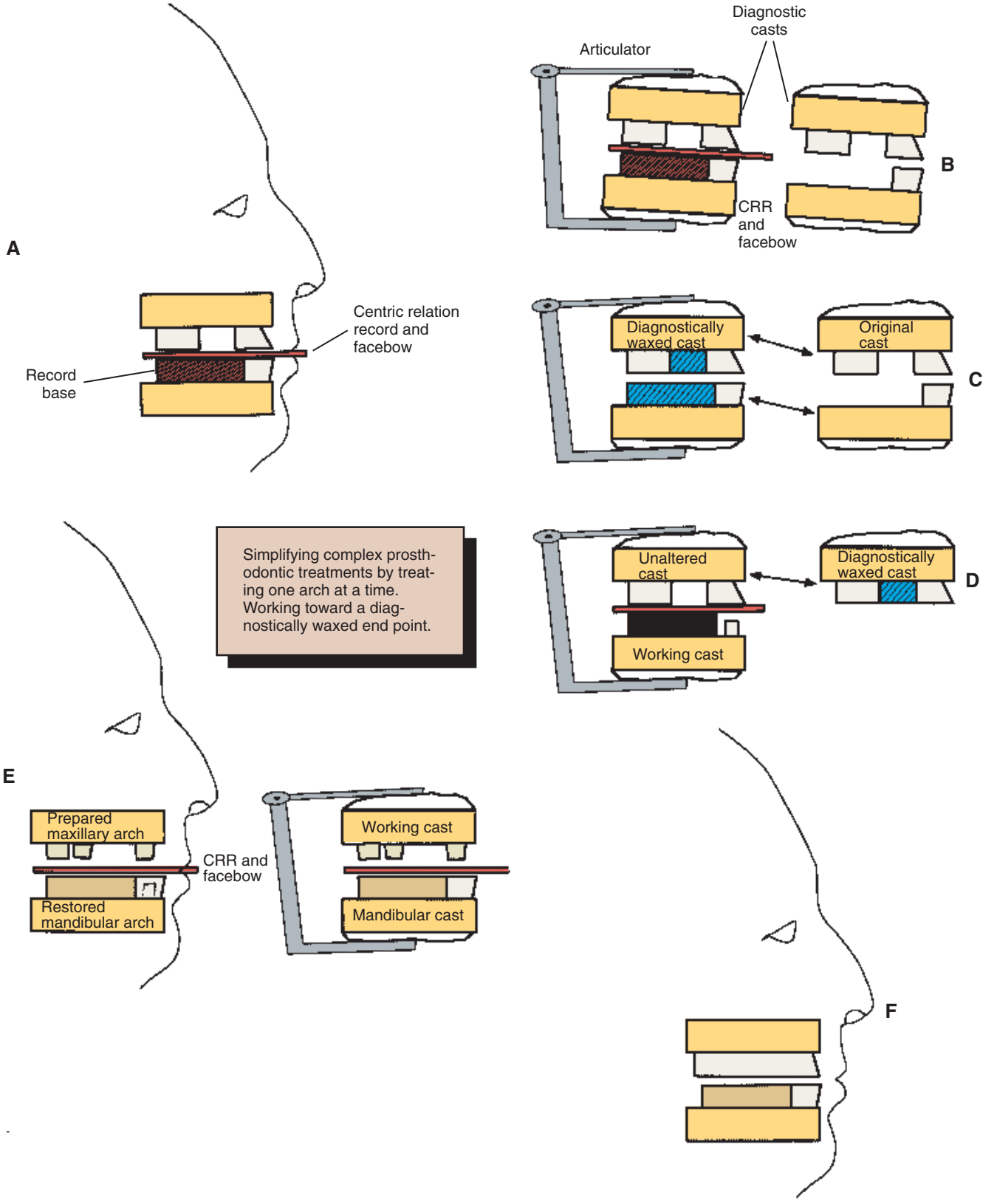
Posterior restorations

Restoring opposing posterior segments at the same time is often advantageous. This allows the development of an efficient occlusal scheme through the application of an additive wax technique (see Chapter 18). Treatment of one side of the mouth should be completed before the other side is treated; restoring all four posterior segments at the same time might lead to considerably more complications for the patient and dentist, including fracture or breaking of interim restorations, discomfort with bilateral local anesthesia, and difficulties in confirming the accuracy of jaw relationship recordings.

Complex prosthodontics

Carefully planned treatment sequencing is particularly important when complex prosthodontic treatments involving alteration of the vertical dimension or a combination of fixed and removable prostheses is required. One recommended approach is illustrated in Figure 3-34. Two sets of diagnostic casts are accurately mounted so they can be precisely interchanged on the articulator. One set is prepared and waxed to the intended end point of treatment, with denture teeth inserted where removable prostheses are to be used. The waxing is carefully evaluated on the articulator in relation to occlusion and appearance. When anterior teeth are to be replaced, they can be assessed for appearance and phonetics directly in the mouth if they are mounted on a removable record base. Definitive tooth preparation starts in one arch only, so that the occlusal surfaces of the opposing arch are preserved to act as an essential reference for mounting the definitive cast. The definitive restorations are waxed against the diagnostically waxed cast, which establishes optimal occlusion. When one arch has been completed, the

Fig. 3-34 Complex prosthodontic treatment sequence using cross-mounted diagnostic cases. **A,** Diagnostic impressions, facebow, and centric relation records are made for a patient requiring complex prosthodontic treatment. In this schematic, a record base is needed for mounting the mandibular cast. **B,** The diagnostic casts are duplicated, and each set is mounted in the identical orientation of an articulator through the use of the facebow and centric record. **C,** One pair of diagnostic casts is waxed to the proposed end point of treatment. If a removable prosthesis is planned, denture teeth are set for this step. The other pair of casts is left unaltered. **D,** One arch is treated at a time. For this patient, the mandibular arch has been prepared for crowns. The definitive cast is mounted on the articulator with a centric record made against the (unaltered) maxillary teeth. This record is used to mount the definitive cast against the (unaltered) maxillary cast. Then the maxillary cast is removed and replaced with the cross-mounted diagnostically waxed cast. The mandibular restorations are fabricated against this cast to ensure an optimal occlusal plane. **E,** Once the mandibular arch has been restored, the maxillary teeth are prepared and mounted against a cast of the newly restored mandibular arch. CRR, centric relation record. **F,** The completed restoration conforms to the diagnostic waxing.


A
Centric relation record and facebow
Record base
Articulator
Diagnostic casts
CRR and facebow
B
Diagnostically waxed cast
Original cast
C
Simplifying complex prosthodontic treatments by treating one arch at a time. Working toward a diagnostically waxed end point.
Unaltered cast
Diagnostically waxed cast
Working cast
D
E
Prepared maxillary arch
Restored mandibular arch
CRR and facebow
Working cast
Mandibular cast
F

STUDY QUESTIONS

1. Discuss 12 considerations that affect the design of a fixed dental prosthesis and their general impact on FDP design.
2. Discuss at least four different indications for a partial removable dental prosthesis, as opposed to a fixed dental prosthesis.
3. When would a nonrigid connector be indicated in a fixed dental prosthesis? When would it be contraindicated?
4. If a patient has a multitude of needs involving all clinical disciplines, in what typical sequence would treatment be conducted? Why? How are the various stages of occlusal therapy sequenced? Why?
5. Contrast the replacement of all the maxillary incisors by an FDP with the replacement of all the mandibular incisors by an FDP. How would you treat each situation?
6. Which occlusal forces are of least concern? Why? Which forces/loading should be avoided? Why?
7. How do span length and FDP design influence flexure? When is rigidity essential? Why?
8. List the steps in treating a patient with extensive restorative needs, using the cross-mounted cast method of treating complex prosthodontic patients. Explain briefly the importance of treatment sequence.

opposing cast can be restored and the predicted result thus achieved.

Follow-Up

A specific program of follow-up care and regular recall is an essential part of the treatment plan. The aim is to monitor dental health, identify the signs of disease early, and initiate prompt corrective measures as necessary (see Chapter 32). Restorations do not last forever, are subject to wear, and may need replacement. Adequate follow-up will help maintain long-term health.

SUMMARY

The basis of logical treatment planning consists of identifying the patient's needs, eliciting his or her expectations and wishes, and comparing these with the available corrective materials and techniques. It also involves evaluating whether a technique has a good prognosis. Then a rational sequence of treatment may be initiated for symptomatic relief, stabilization, definitive therapy, and follow-up care. The extent of treatment is modified throughout and is dictated by the patient's attitude and by the objectives for that patient.

GLOSSARY*

ab·frac·tion \ăb frăk′shun\ *n* (1991)**:** the pathologic loss of hard tooth substance caused by biomechanical loading forces. Such loss is thought to be due to flexure and chemical fatigue degradation of enamel and/or dentin at some location distant from the actual point of loading–*comp* ABLATION, ABRASION, ATTRITION, and EROSION

abut·ment \a-bŭt′ment\ *n* (1634)**: 1:** that part of a structure that directly receives thrust or pressure; an anchorage **2:** a tooth, a portion of a tooth, or that portion of a dental implant that serves to support and/or retain a prosthesis–*usage* see ANGULATED A., HEALING A., DENTAL IMPLANT A., INTERMEDIATE A., ONE PIECE A., PREPARATION PIECE A., STANDARD A., TWO PIECE A.

acrylic resin veneer: usually referring to fixed dental prosthesis, the veneering or lamination of the facial and/or buccal surfaces of a crown or fixed dental prosthesis using acrylic resin. The intention of such veneering is to provide a natural tooth color to the viewable portions of the restoration

acute pain: pain having a brief and relatively severe course

Ante's Law [Irwin H: Ante, Toronto, Ontario Canada, dentist]**:** *eponym,* in fixed partial prosthodontics for the observation that the combined pericemental area of all abutment teeth supporting a fixed dental prosthesis should be equal to or greater in pericemental area than the tooth or teeth to be replaced; as formulated for removable dental prosthodontics, the combined pericemental area of the abutment teeth plus the mucosa area of the denture base should be equal to or greater than the pericemental area of the missing teeth

Ante IH. The fundamental principles, design and construction of crown and bridge prosthesis. Dent Item Int 1928;50:215-32.

artificial crown \ăr′ti-fish′al kroun**:** a metal, plastic, or ceramic restoration that covers three or more axial

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surfaces and the occlusal surface or incisal edge of a tooth

bi·op·sy *n, pl* **-sies** (1895): the removal of tissue for histologic examination and diagnosis

buccolingual relationship \bŭk′o-lĭng′gwal rĭ-lā′shun-shĭp\: any position of reference relative to the tongue and cheeks

can·ti·lever \kăn′tl-ē′ver\ *n* (1667): a projecting beam or member supported on one end

cantilever fixed dental prosthesis \kăn′tl-ē′ver fĭkst dĕn′tl prŏs-thē′sis\: a fixed dental prosthesis in which the pontic is cantilevered, i.e., is retained and supported only on one end by one or more abutments

clinical crown \klĭn′ĭ-kel kroun\: the portion of a tooth that extends from the occlusal table or incisal edge to the free gingival margin

complete crown \kŏm-plēt kroun\: a restoration that covers all the coronal tooth surfaces (mesial, distal, facial, lingual, and occlusal)

complete denture \kŏm-plēt dĕn′chur\: a removable dental prosthesis that replaces the entire dentition and associated structures of the maxillae or mandible; called a *complete removable dental prosthesis*

[1]crown \kroun\ *n* (12c): **1:** the highest part, as the topmost part of the skull, head or tooth; the summit; that portion of a tooth occlusal to the dentinoenamel junction or an artificial substitute for this **2:** an artificial replacement that restores missing tooth structure by surrounding part or all of the remaining structure with a material such as cast metal, porcelain, or a combination of materials such as metal and porcelain

[2]crown \kroun\ *vt* (12c): to place on the head, as to place a crown on a tooth, dental implant or tooth substitute—*usage:* implies fabrication of a restoration for a tooth on a natural tooth, dental implant and/or dental implant abutment

crown fracture \kroun frăk′chur\: micro or macroscopic cleavage in the coronal portion of a tooth

crown-root ratio \kroun-rōōt rā′shō, rā′shē-ō′\: the physical relationship between the portion of the tooth within alveolar bone compared with the portion not within the alveolar bone, as determined by radiograph

de·min·er·al·iza·tion \dē-mĭn′er-ă-lī-zā′shun\ *n* (ca. 1903): **1:** loss of minerals (as salts of calcium) from the body **2:** in dentistry, decalcification, usually related to the dental caries process

dental prosthesis \dĕn′tl prŏs-thē′sis\: an artificial replacement (prosthesis) of one or more teeth (up to the entire dentition in either arch) and associated dental/alveolar structures. Dental prostheses usually are subcatagoried as either *fixed dental prostheses* or *removable dental prosthses*—see also FIXED DENTAL PROSTHESIS, REMOVABLE DENTAL PROSTHESIS; *comp* to MAXILLOFACIAL PROSTHESIS, ANCILLARY PROSTHESIS

differential diagnosis \dĭf′a-rĕn′shal dī′ag-nō′sĭs\: the process of identifying a condition by comparing the signs and symptoms of all pathologic processes that may produce similar signs and symptoms

e·ti·ol·o·gy \ē′tē-ŏl′a-jē\ *n* (1555): **1:** the factors implicated in the cause or origin of a disease or disorder **2:** the study or theory of the factors causing disease

extracoronal retainer \ĕk′stra-kôr′a-nal, kŏr′-, ka-rō′nal rĭ-tā′ner\: that part of a fixed dental prosthesis uniting the abutment to the other elements of a prosthesis that surrounds all or part of the prepared crown

fixed partial denture \fĭkst pär′shal dĕn′chur\: see FIXED DENTAL PROSTHESIS

fixed dental prosthesis \fĭkst dĕn′tl prŏs-thē′sĭs\: any dental prosthesis that is luted, screwed or mechanically attached or otherwise securely retained to natual teeth, tooth roots, and/or dental implant abutments that furnish the primary support for the dental prosthesis. This may include replacement of one to sixteen teeth in each dental arch. If a metallic or ceramic component is included within the fixed dental prosthesis, that component is termed the *framework*. *Ed note:* Dental prostheses (fixed dental prostheses, removable dental prostheses) as well as maxillofacial prostheses can be supported and retained in part or whole by dental implants. Terminology to assist in describing the means of retention, support and dental materials should be limited to concatenation of three and no more than four adjectives to provide clarity. Descriptive terminology (modifiers) expressed as adejectives to each fixed dental prosthesis may include such items as the *method of retention, composition, nature of support, design characteristics,* and/or *form of anchorage*

Simon H, Yanase RT. Terminology for Implant Prostheses. Int J Oral Maxillofac Implants 2003; 18:539-543.

fren·u·lum \frĕn′ya-lem\ *n, pl* **-la** \lă\ (1706): a connecting fold of membrane serving to support or retain a part

high lip line \hī lĭp līn\: the greatest height to which the inferior border of the upper lip is capable of being raised by muscle function

horizontal overlap \hôr′ĭ-zŏn-tl, hŏr′- ō′ver-lăp′\: the projection of teeth beyond their antagonists in the horizontal plane

hydroxyapatite ceramic \hī-drŏk′sē-ăp′a-tīt sa-răm′ĭk\: a composition of calcium and phosphate in physiologic ratios to provide a dense, non-resorbable, biocompatible ceramic used for dental implants and residual ridge augmentation

id·io·path·ic \ĭd′ē-ō-păth′ĭk\ *adj* (1669): self-originated; of unknown causation

immediate denture \ĭ-mē′dē-ĭt dĕn′chur\: any removable dental prosthesis fabricated for placement immediately following the removal of a natural tooth/teeth

indirect retainer \ĭn′dĭ-rĕkt′, -dī- rĭ-tā′ner\: the component of a removable dental prosthesis that assists the direct retainer(s) in preventing displacement of the distal extension denture base by functioning through lever action on the opposite side of the fulcrum line when the denture base moves away from the tissues in pure rotation around the fulcrum line

indirect retention \ĭn′dĭ-rĕkt′, -dī- rĭ-tĕn′shun\: the effect achieved by one or more indirect retainers of a removable partial denture that reduces the tendency for a denture base to move in an occlusal direction or rotate about the fulcrum line

interim denture: see INTERIM PROSTHESIS

interim prosthesis \ĭn′ter-ĭ prŏs-thē′sĭs\: a fixed or removable dental prosthesis, or maxillofacial prosthesis, designed to enhance esthetics, stabilization and/or function for a limited period of time, after which it is to be replaced by a definitive dental or maxillofacial prosthesis. Often such prostheses are used to assist in determination of the therapeutic effectiveness of a specific treatment plan or the form and function of the planned for definitive prosthesis—***syn*** PROVISIONAL PROSTHESIS, PROVISIONAL RESTORATION

intermediate abutment \ĭn′ter-mē′dē-ĭt a-bŭt′ment\: a natural tooth located between terminal abutments that serve to support a fixed or removable dental prosthesis

interproximal contact \ĭn′ter-prŏk′sa-mal kŏn′tăkt\: the area of a tooth that is in close association, connection, or touch with an adjacent tooth in the same arch

key·way \kē′wā′\ *n*: an interlock using a matrix and patrix between the units of a fixed dental prosthesis. It may serve two functions: 1) to hold the pontic in the proper relationship to the edentulous ridge and the opposing teeth during occlusal adjustment on the working cast (during application of any veneering material) and 2) to reinforce the connector after soldering

low lip line \lō lĭp līn\: **1:** the lowest position of the inferior border of the upper lip when it is at rest **2:** the lowest position of the superior border of the lower lip during smiling or voluntary retraction

lu·mi·nance \lōō′ma-nans\ *n* (1880): the intensity of light per unit area

masticatory force \măs′tĭ-ka-tôr′ē fôrs, fōrs\: the force applied by the muscles of mastication during chewing

mesial drift \mē′zē-al drĭft\: movement of teeth toward the midline

mesioversion \mē′zē-ō-vûr′zhun, -shun\: with reference to a tooth, nearer than normal in its position toward the median line of the face, along the dental arch

nano·me·ter \năn′a-mē′tar\ *n* (1963): unit of length to measure the wavelength of light. It is equivalent to 1×10^{-9} M or 10 angstroms. 1 *nm* = 1/1,000,000 *mm*

nonrigid connector \nŏn-rĭj′ĭd ka-nĕk′tor\: any connector that permits limited movement between otherwise independent members of a fixed dental prosthesis

occlusal analysis \a-klōō′zal,-sal a-năl′ĭ-sĭs\: an examination of the occlusion in which the interocclusal relations of mounted casts are evaluated

occlusal equilibration \a-klōō′zal, -sal ĭ-kwĭl′a-brā′shun\: the modification of the occlusal form of the teeth with the intent of equalizing occlusal stress, producing simultaneous occlusal contacts or harmonizing cuspal relations

occlusal interference \a-klōō′zal, -sal ĭn′tur-fîr′ans\: any tooth contact that inhibits the remaining occluding surfaces from achieving stable and harmonious contacts

occlusal prematurity \a-klōō′zal, -sal prē′ma-tyōōr′ĭ-tē, -tōōr′-, -chōōr′-\: any contact of opposing teeth that occurs before the planned intercuspation

occlusal reshaping \a-klōō′zal, -sal rē-shāp′ĭng\: the intentional alteration of the occlusal surfaces of teeth to change their form

occlusal stability \a-klōō′zal, -sal sta-bĭl′ĭ-tē\: the equalization of contacts that prevents tooth movement after closure

occlusion analysis \a-klōō′shun a-năl′ĭ-sĭs\ *obs*: a systematic examination of the masticatory system with special consideration to the effect of tooth occlusion on the teeth and their related structures (GPT-4)

pal·lia·tive \păl′ē-ā′tĭv\ *adj* (1543): affording relief but not a cure

pier abutment: see INTERMEDIATE ABUTMENT

plunger cusp \plŭn′jer kŭsp\: a cusp that tends to force food into interproximal areas

prog·no·sis \prŏg-nō′sĭs\ *n* (1655): a forecast as to the probable result of a disease or a course of therapy

pros·the·sis \prŏs-thē'sĭs\ *n*, *pl*-ses (1900) **1:** an artificial replacement of an absent part of the human body **2:** a therapeutic device to improve or alter function **3:** a device used to aid in accomplishing a desired surgical result *Editorial note:* The taxonomy of the word *prostheses* is as complex as are the varieties of items made by humans for any utilitarian purpose. While classification of botanical or zoological species can be relatively precise due to the common nature of genetic derivation (including descriptions of genetic alterations), such is not the case with respect to many things made by humans. One has only to think about the range of forms used in the course of human history classified as "items of transportation" to be convinced of the complexity and frequently transient nature of such a mode as the automobile! With respect to dentistry, the noun *prosthesis* generally is described first by a *type* adjective (dental, maxillofacial or ancillary) and frequently second by use of one or more additional adjectives (termed *modifiers*) to clarify such matters as anatomic location, form, materials, means of retention, support, time of usage, or other items. Using coordinate adjectives (two or more adjectives separated by a comma, instead of by coordinating conjunctions) to assist in further description of the prosthesis is helpful but should generally be limited to three or at most four for convenience in maintaining understanding of the noun *prosthesis*. Frequently, an adjective clause ⟨*descriptor*⟩ can be used following the word *prosthesis* to help clarify such issues as the nature of the support [i.e. tooth number(s), dental implant number(s)] available for the prosthesis. A *descriptor* is something (a word, phrase or characteristic feature) that serves to identify or describe; especially a word or phrase (as an index term) used to identify an item in an information retrieval system. Use of acronyms to describe a prosthesis is to be discouraged since such descriptors do not transfer between languages and thus can be easily misunderstood.

Modifier: {anatomic location} i.e. maxillary, mandibular, inferior, superior
{form} i.e. complete, partial, splint, stent, carrier, bar, ovoid, round
{material} i.e. ceramic, metal, resin
{retention} i.e. cement, screw, friction, tissue, fixed, removable
{support} i.e. tooth, implant, tissue
{time} i.e. surgical, temporary, interim, definitive
{other} i.e. soft, zirconium

Type: (dental, maxillofacial, ancillary)

Descriptor: ⟨support⟩ tissue borne, implant borne, tooth/implant borne

Examples . . .
dental prosthesis
maxillary, removable, partial, dental prosthesis
surgical, obturator, maxillofacial prosthesis
mandibular, fixed, partial, dental prosthesis on dental implants # 28, 30 and 31
cemented, fixed, partial, dental prosthesis on teeth # 12 and 14
cemented, fixed, partial, dental prosthesis on dental # 12 and tooth # 14
ceramic, fixed, partial, dental prosthesis on dental implants # 3 and 5

To be avoided examples . . .
rigid, interim, mandibular, removable, partial, dental prosthesis replacing teeth # 23-30
hybrid prosthesis
hybrid denture prosthesis
interim plate

see also DEFINITIVE P., DENTAL P., INTERIM P., MAXILLOFACIAL P., PROVISIONAL P., SUPPLEMENTARY P., and SURGICAL P.

pulp \pŭlp\ *n*: the richly vascularized connective tissue of mesodermal origin with much innervation contained in the central cavity of the tooth

removable partial denture prosthesis \rĭ-mōō'va-bal păr'shal dēn'chur\: any prosthesis that replaces some teeth in a partially dentate arch. It can be removed from the mouth and replaced at will—also called *partial removable dental prosthesis*

residual bone \rĭ-zĭj'ōō-al bōn\: that component of maxillary or mandibular bone that remains after the teeth are lost

residual ridge \rĭ-zĭj'ōō-al rĭj\: the portion of the residual bone and its soft tissue covering that remains after the removal of teeth

res·to·ra·tion \rĕs'ta-rā'shun\ *n* (1660): a broad term applied to any material or prosthesis that restores or replaces lost tooth structure, teeth, or oral tissues

span length \spăn lĕngkth\: the length of a beam between two supports

splint·ing \splĭn'tĭng\ *v*: **1:** in dentistry, the joining of two or more teeth into a rigid unit by means of fixed or removable restorations or devices **2:** in physiology, prolonged muscle spasms that inhibit or prevent movement

stress breaker: see STRESS DIRECTOR

stress director \strĕs dĭ-rĕk'tar, dī-\: a device or system that relieves specific dental structures of part or all of the occlusal forces and redirects those forces to other bearing structures or regions

su·pra·erup·tion \sōō'pra-ĭ-rŭp'shun\ *n*: movement of a tooth or teeth above the normal occlusal plane

su·pra·oc·clus·ion \sōō′pra-a-klōō′zhun\ *n*: malocclusion in which the occluding surfaces of teeth extend beyond the normal occlusal plane—called also *overeruption*

sympathetic nervous system \sĭm′pa-thĕt′ĭk nûr′vas sĭs′tum\: the part of the autonomic nervous system that responds to dangerous or threatening situations by preparing a person physiologically for "fight or flight"—see PARASYMPATHETIC NERVOUS SYSTEM

symp·tom \sĭm′tum, sĭmp-\ *n* (14c): subjective evidence of disease or physical disturbance; something that indicates the presence of a bodily disorder

systemic etiologic factors \sĭ-stĕm′ĭk ē′tē-ō-lŏj′ĭk făk′turs\: generalized biologic factors that are implicated in the causation, modification, and/or perpetuation of a disease entity

tooth supported \tōōth sa-pôr′tĭd\: a term used to describe a prosthesis or part of a prosthesis that depends entirely on the natural teeth for support

transitional prosthesis: see INTERIM PROSTHESIS, TRANSITIONAL DENTURE

trau·ma \trou′ma, trô′-\ *n, pl* **trau·ma·ta** \trou′ma-ta\ or **trau·mas** \trou′mas\, **traumatic** \trou′măt-ik\ *adj*-**traumatically** \trou′măt-ĭ-kă-lē\ *adv* (1693): an injury or wound, whether physical or psychic

up·right \ŭp′rīt\ *adj*: the movement of a tooth into an erect or normal position

working articulation \wûr′kĭng ăr-tĭk′ya-lā′shun\: the occlusal contacts of teeth on the side toward which the mandible is moved

REFERENCES

1. Palomo F, Peden J: Periodontal considerations of restorative procedures. J Prosthet Dent 36:387, 1976.
2. Jones RM, et al: A comparison of the physical properties of four prosthetic veneering materials. J Prosthet Dent 61:38, 1989.
3. Vojvodic D, et al: The bond strength of polymers and metal surfaces using the "silicoater" technique. J Oral Rehabil 22:493, 1995.
4. Rothfuss LG, et al: Resin to metal bond strengths using two commercial systems. J Prosthet Dent 79:270, 1998.
5. Karmaker AC, et al: Continuous fiber reinforced composite materials as alternatives for metal alloys used for dental appliances. J Biomater Appl 11:318, 1997.
6. Rosenthal L, et al: A new system for posterior restorations: a combination of ceramic optimized polymer and fiber-reinforced composite. Pract Periodontics Aesthet Dent 9(5 suppl):6, 1997.
7. Zanghellini G: Fiber-reinforced framework and Ceromer restorations: a technical review. Signature 4(1):1, 1997.
8. Claus H: Vita In-Ceram, a new procedure for preparation of oxide-ceramic crown and bridge framework. Quintessenz Zahntech 16:35, 1990.
9. Magne P, Belser U: Esthetic improvements and in vitro testing of In-Ceram Alumina and Spinell ceramic. Int J Prosthodont 10:459, 1997.
10. Zimmer D, et al: Survival rate of IPS-Empress 2 all-ceramic crowns and bridges: three years' results. Schweiz Monatsschr Zahnmed 114:115, 2004.
11. Denry IL: Recent advances in ceramics for dentistry. Crit Rev Oral Biol Med 7:134, 1996.
12. Sorensen JA, et al: IPS Empress crown system: three-year clinical trial results. J Calif Dent Assoc 26:130, 1998.
13. Denry IL, et al: Effect of cubic leucite stabilization on the flexural strength of feldspathic dental porcelain. J Dent Res 75:1928, 1996.
14. Walton TR: An up to 15-year longitudinal study of 515 metal-ceramic FPDs: Part 1. Outcome. Int J Prosthodont 15:439, 2002.
15. Adell R, et al: A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 10:387, 1981.
16. Saunders TR, et al: The maxillary complete denture opposing the mandibular bilateral distal-extension partial denture: treatment considerations. J Prosthet Dent 41:124, 1979.
17. Brewer AA, Morrow RM: Overdentures, 2nd ed. St. Louis, Mosby, 1980.
18. Sarita PTN, et al: Chewing ability of subjects with shortened dental arches. Community Dent Oral Epidemiol 31:328, 2003.
19. Shugars DA, et al: Survival rates of teeth adjacent to treated and untreated posterior bounded edentulous spaces. J Am Dent Assoc 129:1089, 1998.
20. Gragg KL, et al: Movement of teeth adjacent to posterior bounded edentulous spaces. J Dent Res 80:2021, 2001.
21. Cheung GS, et al: A clinical evaluation of conventional bridgework. J Oral Rehabil 17:131, 1990.
22. Glickman I, et al: Photoelastic analysis of internal stresses in the periodontium created by occlusal forces. J Periodontol 41:30, 1970.
23. Wright KWJ, Yettram AL: Reactive force distributions for teeth when loaded singly and when used

as fixed partial denture abutments. J Prosthet Dent 42:411, 1979.
24. Yang HS, et al: Stress analysis of a cantilevered fixed partial denture with normal and reduced bone support. J Prosthet Dent 76:424, 1996.
25. Briggs P, et al: The single unit, single retainer, cantilever resin-bonded bridge. Br Dent J 181:373, 1996.
26. Christensen GJ: When to use fillers, build-ups or posts and cores. J Am Dent Assoc 127:1397, 1996.
27. Miller TE: Orthodontic therapy for the restorative patient. I. The biomechanic aspects. J Prosthet Dent 61:268, 1989.
28. Holmgren K, et al: The effects of an occlusal splint on the electromyographic activities of the temporal and masseter muscles during maximal clenching in patients with a habit of nocturnal bruxism and signs and symptoms of craniomandibular disorders. J Oral Rehabil 17:447, 1990.
29. Ante IH: The fundamental principles of abutments. Mich State Dent Soc Bull 8:14, 1926.
30. Dykema RW, et al, eds: Johnston's Modern Practice in Fixed Prosthodontics, 4th ed, p 4. Philadelphia, WB Saunders, 1986.
31. Tylman SD, Malone WFP: Tylman's Theory and Practice of Fixed Prosthodontics, 7th ed, p 15. St Louis, Mosby, 1978.
32. Shillingburg HT, et al: Fundamentals of Fixed Prosthodontics, 2nd ed, p 20. Chicago, Quintessence Publishing, 1981.
33. Jepsen A: Root surface measurement and a method for x-ray determination of root surface area. Acta Odontol Scand 21:35, 1963.
34. Nyman S, Ericsson I: The capacity of reduced periodontal tissues to support fixed bridgework. J Clin Periodontol 9:409, 1982.
35. Freilich MA, et al: Fixed partial dentures supported by periodontally compromised teeth. J Prosthet Dent 65:607, 1991.
36. Decock V, et al: 18-Year longitudinal study of cantilevered fixed restorations. Int J Prosthodont 9:331, 1996.
37. Penny RE, Kraal JH: Crown-to-root ratio: its significance in restorative dentistry. J Prosthet Dent 42:34, 1979.
38. Nyman S, et al: The role of occlusion for the stability of fixed bridges in patients with reduced periodontal tissue support. J Clin Periodontol 2(2):53, 1975.
39. Laurell L, et al: Long-term prognosis of extensive polyunit cantilevered fixed partial dentures. J Prosthet Dent 66:545, 1991.
40. Smyd ES: Dental engineering. J Dent Res 27:649, 1948.
41. Napankangas R, et al: Longevity of fixed metal ceramic bridge prostheses: a clinical follow-up study. J Oral Rehabil 29:140, 2002.
42. Dykema RW: Fixed partial prosthodontics. J Tenn Dent Assoc 42:309, 1962.
43. Olin PS, et al: Improved pontic/tissue relationships using porous coralline hydroxyapatite block. J Prosthet Dent 66:234, 1991.
44. Aquilino SA, et al: Ten-year survival rates of teeth adjacent to treated and untreated posterior bounded edentulous spaces. J Prosthet Dent 85:455, 2001.

4

PRINCIPLES OF OCCLUSION



KEY TERMS

anterior guidance
articular disk
attrition
Bennett movement
border movement
bruxism
capsule
centric relation
clenching
determinants of occlusion
disocclusion
eccentric
excursion
group function
guidance
horizontal overlap
intercondylar distance
interference
malocclusion
mandibular movement
mandibular side shift
mutual protection
nonworking side
occlusal device
parafunction
pathogenic occlusion
Posselt
speaking space
temporomandibular joint
terminal hinge axis
translation
vertical overlap
working side

Most restorative procedures affect the shape of the occlusal surfaces. Proper dental care ensures that functional contact relationships are restored in harmony with both dynamic and static conditions. Maxillary and mandibular teeth should contact to allow optimum function, minimize trauma to the supporting structures, and allow an even load distribution throughout the dentition. Positional stability of the teeth is crucial if arch integrity and proper function are to be maintained over time.

As an aid to the diagnosis of occlusal dysfunction, it is helpful to evaluate the condition of specific anatomic features and functional aspects of a patient's occlusion with reference to a concept of "optimum" or "ideal" occlusion. Deviation from this concept can then be measured objectively and may prove to be a useful guide during treatment planning and active treatment phases.

Over time, many concepts of "ideal" occlusion have been proposed. In the literature, the concept of what is "ideal," "acceptable," and "harmful" continues to evolve.

This chapter reviews the anatomic structures important to the study of occlusion and includes a discussion of **mandibular movement** (movement of the lower jaw). The concepts of ideal versus pathologic occlusion are introduced, as is the history of occlusal theory. The chapter concludes with guidelines for the initial phase of occlusal treatment.

ANATOMY

Temporomandibular Joints

The major components of the **temporomandibular joints** (TMJs) are the cranial base, the mandible, and the muscles of mastication with their innervation and vascular supply. Each joint can be described as ginglymoarthrodial, which means that it is capable

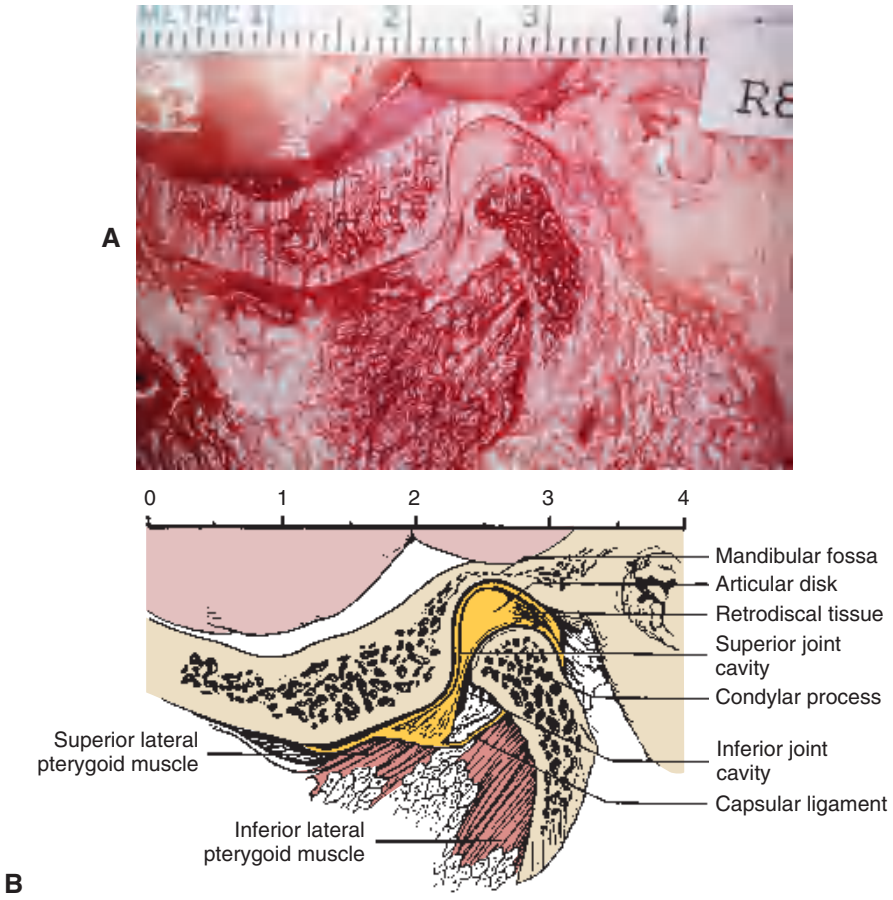


Fig. 4-1
Temporomandibular joint (lateral section). The mandible is open. (***A*** *courtesy Dr. K. A. Laurell.*)

of both a hinging and a gliding articulation. An **articular disk** separates the mandibular fossa and articular tubercle of the temporal bone from the condylar process of the mandible.

The articulating surfaces of the condylar processes and fossae are covered with avascular fibrous tissue (in contrast to most other joints, which have hyaline cartilage). The articular disk consists of dense connective tissue; it also is avascular and devoid of nerves in the area where articulation normally occurs. Posteriorly, it is attached to loose highly vascularized and innervated connective tissue, the retrodiscal pad or bilaminar zone,* which connects to the posterior wall of the articular **capsule** surrounding the joint (Fig. 4-1). Medially and laterally, the disk is attached firmly to the poles of the condylar process. Anteriorly, it fuses with the capsule and with the superior lateral pterygoid muscle. Superior and inferior to the articular disk are two spaces: the superior and inferior synovial cavities. These are bordered peripherally by the capsule and the synovial membranes and are filled with synovial fluid. Because of its firm attachment to the poles of each condylar process, the disk follows condylar movement during both hinging and **translation,** which is made possible by the loose attachment of the posterior connective tissues.

*Called *bilaminar* because it consists of two layers: an elastic superior layer and a collagenous inelastic inferior layer.

Ligaments

The body of the mandible is attached to the base of the skull by muscles and also by three paired ligaments (Table 4-1): the temporomandibular (also called the lateral), the sphenomandibular, and the stylomandibular. Ligaments cannot be stretched significantly, and so they limit the movement of joints. The temporomandibular ligaments limit the amount of rotation of the mandible and protect the structures of the joint, limiting **border movements**.[1] The sphenomandibular and stylomandibular ligaments (Fig. 4-2) limit separation between the condylar process and the disk; the stylomandibular ligaments also limit protrusive movement of the mandible.

Table **4-1** **MANDIBULAR LIGAMENTS**

	Origin	Insertion	Function
Temporomandibular			
Superficial	Outer surface of articular eminence	Posterior aspect of neck of condylar process	Limits mandibular rotation on opening
Medial	Crest of articular eminence	Lateral aspect of neck of condylar process	Limits posterior movement
Sphenomandibular	Spine of sphenoid	Inferior to lingula	Accessory to temporomandibular articulation: influence on mandibular movement disputed
Stylomandibular	Styloid process	Mandibular angle and fascia of medial pterygoid muscle	Limits extreme protrusion of the mandible; influence on mandibular movement disputed

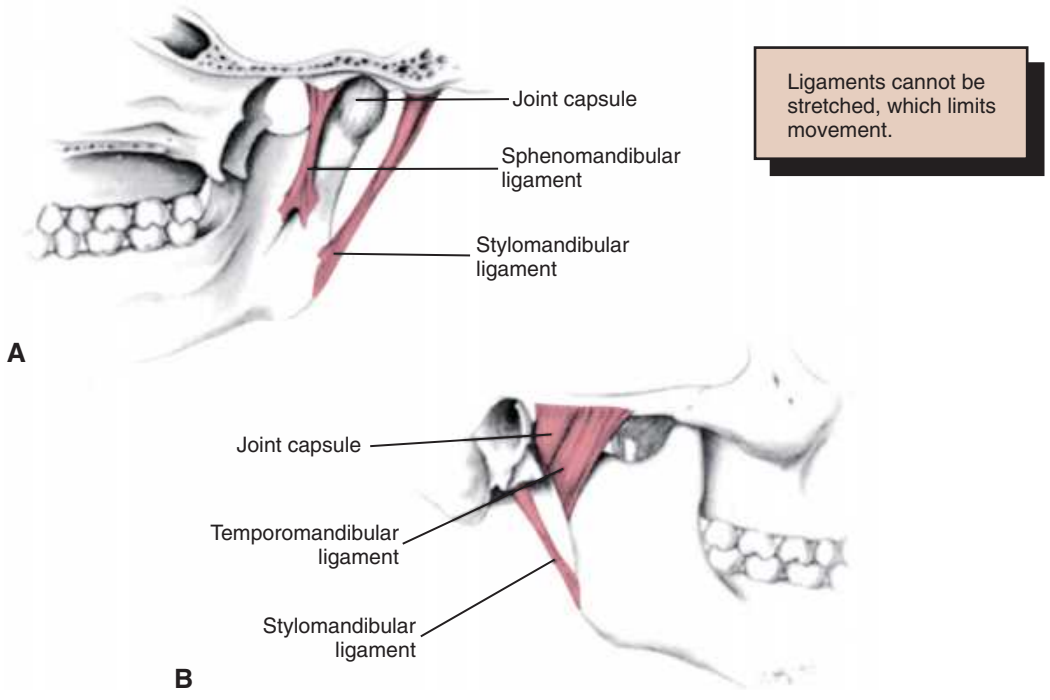


Fig. 4-2
Ligaments of the temporomandibular joint. A, Medial view. B, Lateral view.

Musculature

Several muscles are responsible for mandibular movements. These can be grouped into the muscles of mastication and the suprahyoid muscles (Fig. 4-3). The former include the temporal, the masseter, and the medial and lateral pterygoid muscles; the latter are the geniohyoid, the mylohyoid, and the digastric muscles. Their respective origins, insertions, and innervation and vascular supply are summarized in Table 4-2.

Muscular function

The functions of the mandibular muscles are well-coordinated, complex events.

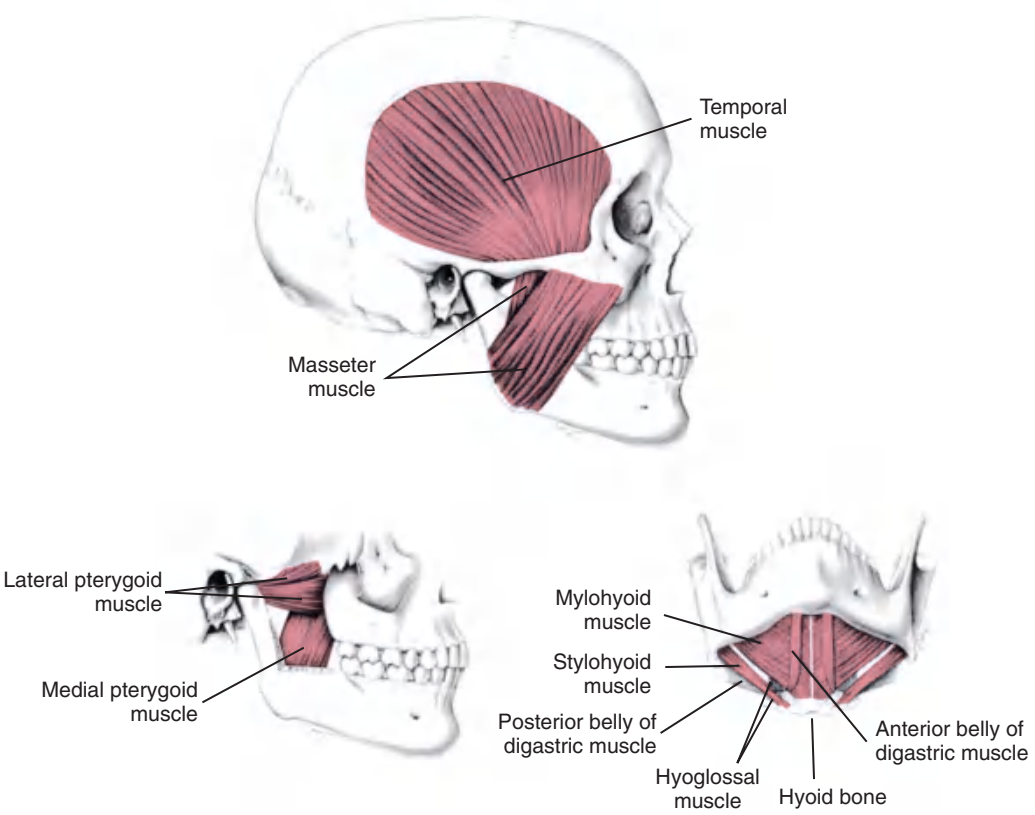


Fig. 4-3
The muscles of mastication and the suprahyoid muscles.

The three paired muscles of mastication provide elevation and lateral movement of the mandible. These are the temporal, the masseter, and the medial pterygoid muscles. The lateral pterygoid muscles, each with two bellies (which probably should be considered as two separate muscles), function horizontally during opening and closing; the inferior belly (or inferior lateral pterygoid) is active during protrusion, depression, and lateral movement; the superior belly (or superior lateral pterygoid) is active during closure. The latter muscle is thought to assist in maintaining the integrity of the condyle-disk assembly by pulling the condylar process firmly against the disk, because the superior belly has been shown to attach to the disk and the neck of the condyle.

The muscles of the suprahyoid group have a dual function. They can elevate the hyoid bone or depress the mandible. The movement that results when they contract depends on the state of contraction of the other muscles of the neck and jaw region. When the muscles of mastication are in a state of contraction, the suprahyoid muscles elevate the hyoid bone. However, if the infrahyoid muscles (which anchor the hyoid bone to the sternum and clavicle) are contracted, the suprahyoid muscles depress and retract the mandible. The geniohyoid and mylohyoid initiate the opening movements, and the anterior belly of the digastric muscle completes mandibular depression. Although the stylohyoid muscle (which also belongs to the suprahyoid group) may contribute indirectly to mandibular movement through fixation of the hyoid bone, it does not play a significant role in mandibular movement.

Dentition

The relative positions of the maxillary and mandibular teeth influence mandibular movement. Many "ideal" occlusions have been described.[2] In most of these, the maxillary and mandibular teeth contact simultaneously when the condylar processes are fully seated in the mandibular fossae and the teeth do not interfere with harmonious movement of the mandible during function. Ideally, in the fully bilateral seated position of the condyle-disk assemblies, the maxillary and mandibular teeth exhibit maximum intercuspation. This means that the maxillary lingual and mandibular buccal cusps of the posterior teeth are evenly distributed and in stable contact with the opposing occlusal fossae. These functional cusps can then act as stops for vertical

Table **4-2** **MUSCLES OF MASTICATION**

	Origin	Insertion	Innervation	Vascular supply	Function
Temporal	Lateral surface of skull	Coronoid process and anterior border of ramus	Temporal nerve (branch of mandibular)	Middle and deep temporal arteries (branches of superficial temporal and maxillary)	Elevates and retracts jaw, assists in rotation, active in clenching
Masseter	Zygomatic arch	Angle of mandible	Masseteric nerve (division of trigeminal)	Masseteric artery (branch of maxillary)	Elevates and protracts jaw, assists in lateral movement, active in clenching
Medial pterygoid	Pterygoid fossa and medial surface of lateral pterygoid plate	Medial surface of angle of mandible	Medial pterygoid nerve (division of trigeminal)	Branch of maxillary artery	Elevates jaw, causes lateral movement and protrusion
Superior lateral pterygoid	Infratemporal surface of greater wing of sphenoid	Articular capsule and disk, neck of condyle	Branch of masseteric or buccal nerve	Branch of maxillary artery	Positions disk in closing
Inferior lateral pterygoid	Lateral surface of lateral pterygoid plate	Neck of condyle	Branch of masseteric or buccal nerve	Branch of maxillary artery	Protrudes and depresses jaw, causes lateral movement
Mylohyoid	Inner surface of mandible	Hyoid and mylohyoid raphe	Branches of mylohyoid nerve (division of trigeminal)	Submental artery	Elevates and stabilizes hyoid
Geniohyoid	Genial tubercle	Hyoid	First cervical via hypoglossal nerve	Branch of lingual artery	Elevates and draws hyoid forward
Anterior belly of digastric	Tendon linked to hyoid by fascia	Digastric fossa (lower border of mandible)	Branch of mylohyoid nerve (division of trigeminal)	Branch of facial artery	Elevates hyoid, depresses jaw

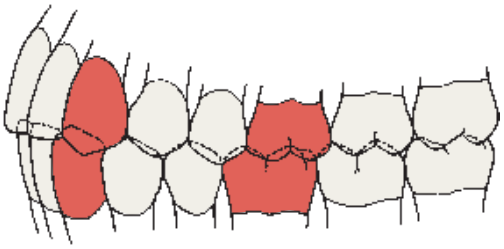


Fig. 4-4
The Angle Class I occlusal relationship.

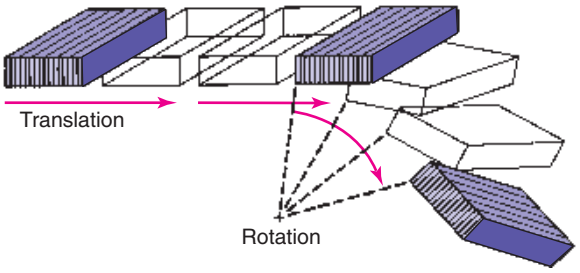


Fig. 4-5
Three-dimensional movement of a body can be defined by a combination of translation (all points within the body having identical movement) and rotation (all points turning around an axis).

closure without excessively loading any one tooth, while left and right TMJs are simultaneously in an unstrained position.

However, in many patients, maximal intercuspal contact occurs with the condyles in a slightly translated position. This position is referred to as maximum intercuspation which is defined as the complete intercuspation of the opposing teeth independent of condylar position, sometimes referred to as the best fit of the teeth regardless of the condylar position. If the mesiobuccal cusp of the maxillary first molar is aligned with the buccal groove of the mandibular first molar, an Angle Class I orthodontic relationship (Fig. 4-4) exists; this is considered normal (see glossary). In such a relationship, the anterior teeth overlap both horizontally and vertically. This position is defined as the dental relationship in which there is normal anteroposterior relationship of the jaws, as indicated by correct intercuspation of maxillary and mandibular molars, but, when a **malocclusion** is present, there are crowding and rotation of teeth elsewhere (i.e., a dental dysplasia or arch length deficiency). Orthodontic textbooks[3] have traditionally described an arbitrary 2 mm for **horizontal overlap** and **vertical overlap** as being ideal. For most patients, however, greater vertical overlap of the anterior teeth is desirable, to prevent undesirable posterior tooth contact as a result of flexing of the mandible during mastication. Empirically, dentitions with greater vertical overlap of the anterior teeth appear to have a better long-term prognosis than do dentitions with minimal vertical overlap.

CENTRIC RELATION

Centric relation is defined as the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterosuperior position against the shapes of the articular eminences. This position is independent of tooth contact. It is also clinically discernible when the mandible is directed superior and anteriorly and is restricted to a purely rotary movement about the transverse horizontal axis.

Centric relation is considered a reliable and reproducible reference position. If maximum intercuspation coincides with the centric relation position, restorative treatment is often straightforward. When maximum intercuspation does not coincide with centric relation, it is necessary to determine whether corrective occlusal therapy is needed before restorative treatment.

MANDIBULAR MOVEMENT

As for any other movement in space, complex three-dimensional mandibular movement can be broken down into two basic components: translation, when all points within a body have identical motion, and rotation, when the body is turning about an axis (Fig. 4-5). Every possible three-dimensional movement can be described in terms of these two components. It is easier to understand mandibular movement when the components are described as projections in three perpendicular planes: sagittal, horizontal, and frontal (Fig. 4-6).

Reference Planes

Sagittal plane

In the sagittal plane (Fig. 4-7), the mandible is capable of a purely rotational movement as well as translation. Rotation occurs around the **terminal hinge axis,** an imaginary horizontal line through the rotational centers of the left and right condylar processes. The rotational movement is limited to about 12 mm of incisor separation before the temporomandibular ligaments and structures anterior to the mastoid process force the mandible to translate. The initial rotation or hingeing motion is

between the condyle and the articular disk. During translation, the lateral pterygoid muscle contracts and moves the condyle-disk assembly forward along the posterior incline of the tubercle. Condylar movement is similar during protrusive mandibular movement.

Horizontal plane

In the horizontal plane, the mandible is capable of rotation around several vertical axes. For example, lateral movement consists of rotation around an axis situated in the working (laterotrusive) condylar process (Fig. 4-8) with relatively little concurrent translation. A slight lateral translation of the condyle on the **working side** in the horizontal plane—known as *laterotrusion*, **Bennett movement,**[4] or **mandibular side shift** (Fig. 4-9)—is frequently present. This may be slightly forward or slightly backward (lateroprotrusion or lateroretrusion). The orbiting (nonworking) condyle travels forward and medially as limited by the medial aspect of the mandibular fossa and the temporomandibular ligament. Finally, the mandible can make a straight protrusive (anterior) movement (Fig. 4-10).

Frontal plane

In a lateral movement in the frontal plane, the mediotrusive (or nonworking) condyle moves down and medially, whereas the laterotrusive (or working) condyle rotates around the sagittal axis perpendicular to this plane (Fig. 4-11). Again, as determined by the anatomy of the medial wall of the mandibular fossa on the mediotrusive side, transtrusion may be observed; as determined by the anatomy of the mandibular fossa on the laterotrusive side, this may be lateral and upward or lateral and downward (laterosurtrusion and laterodetrusion). A straight protrusive movement observed in the frontal plane, with both condylar processes moving downward as they slide along the tubercular eminences, is shown in Figure 4-12.

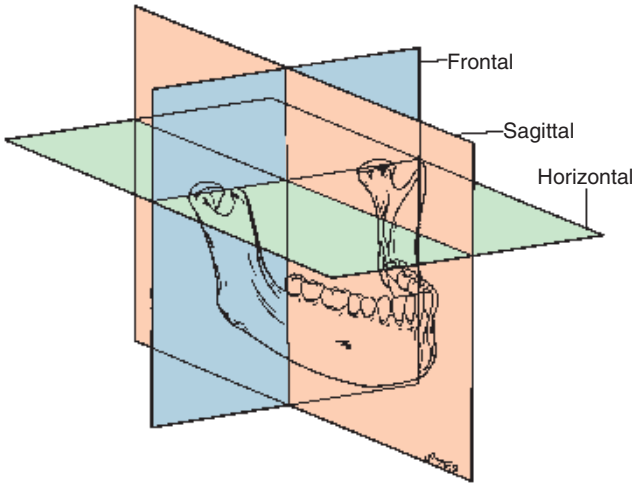
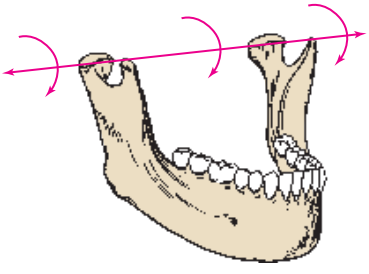


Fig. 4-6
Reference planes.

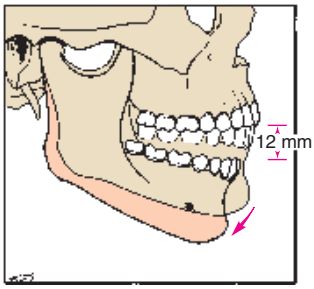
Border Movements

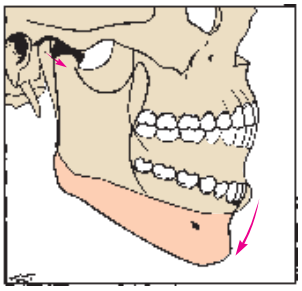
Mandibular movements are limited by the TMJs and ligaments, the neuromuscular system, and the teeth. **Posselt**[5] was the first to describe mandibular movement at the limits dictated by anatomic structures, as viewed in a given plane which he called *border movements* (Fig. 4-13). His classic work is well worth reviewing in the attempt to understand how the determinants control the extent to which movement can occur.

Posselt used a three-dimensional representation of the extreme movements that the mandible is capable of (see Fig. 4-13*B*). All possible mandibular movements occur within its boundaries. At the top of both illustrations, a horizontal tracing represents the protrusive movement of the incisal edge of the mandibular incisors (solid numbered line in Fig. 4-13*B*).



Border movements comprise pure rotation and translatory movement.





A B,C

Fig. 4-7
A, Rotation of the mandible in a sagittal plane can be made around the terminal hinge axis. **B,** After about 12 mm of incisal opening, the mandible is forced to translate. **C,** Maximum opening; the condyles have translated forward.

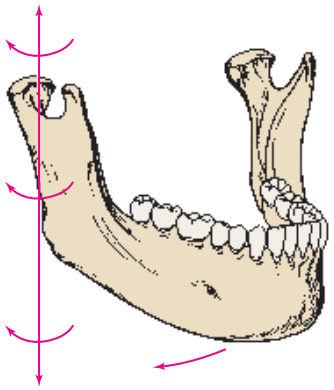


Fig. 4-8
Rotation in the horizontal plane occurs during lateral movement of the mandible. (The vertical axis is situated in the condylar process.) Normally there is relatively little translation (side shift).

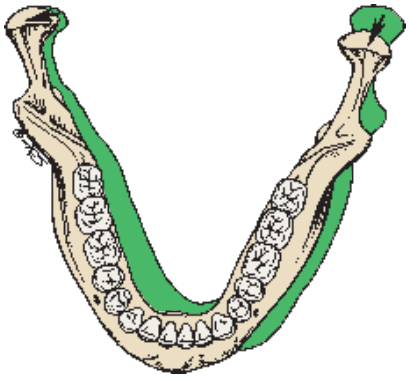


Fig. 4-9
Right lateral mandibular movement in the horizontal plane.

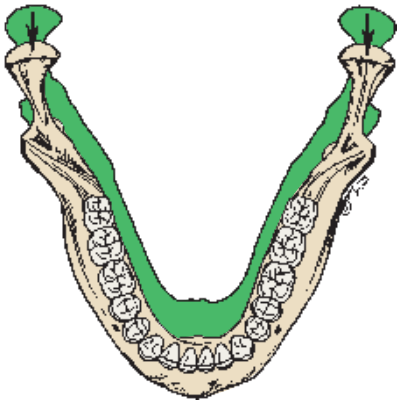


Fig. 4-10
Protrusive mandibular movement in the horizontal plane.

Starting from the maximum intercuspation position, in the protrusive pathway, the lower incisors are initially guided by the lingual concavity of the maxillary anterior teeth. This leads to gradual loss of posterior tooth contact as the incisors reach the edge-to-edge position. This is represented in Posselt's diagram by the initial downward slope. As the mandible moves farther protrusively, the incisors slide over a horizontal trajectory representing the edge-to-edge position (the flat portion in the diagram), after which the lower incisors move upward until new posterior tooth contact occurs. Further protrusive movement of the mandible typically takes place without significant tooth contact.

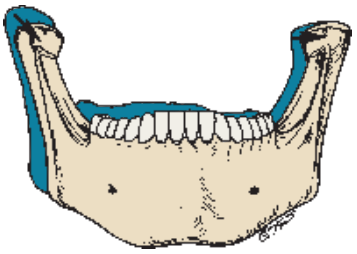


Fig. 4-11
Lateral movement in the frontal plane.

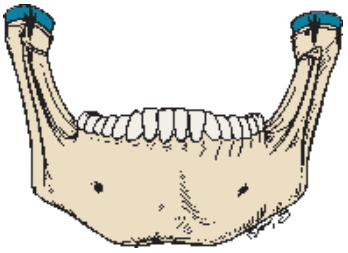


Fig. 4-12
Protrusive movement in the frontal plane.

The border farthest to the right of Posselt's solid (see Fig. 4-13*B*) represents the most protruded opening and closing stroke. The maximal open position of the mandible is represented by the lowest point in the diagram. The left border of the diagram represents the most retruded closing stroke. This movement occurs in two phases: The lower portion consists of a combined rotation and translation, until the condylar processes return to the fossae. The second portion of the most retruded closing stroke is represented by the top portion of the border that is farthest to the left in Posselt's diagram. It is strictly rotational.

Posterior and anterior determinants of mandibular movement

These determinants (Table 4-3) are the anatomic structures that dictate or limit the movements of the mandible. The anterior determinant of mandibular movement is the dental articulation. The posterior determinants of mandibular movement are the temporomandibular articulations and their associated

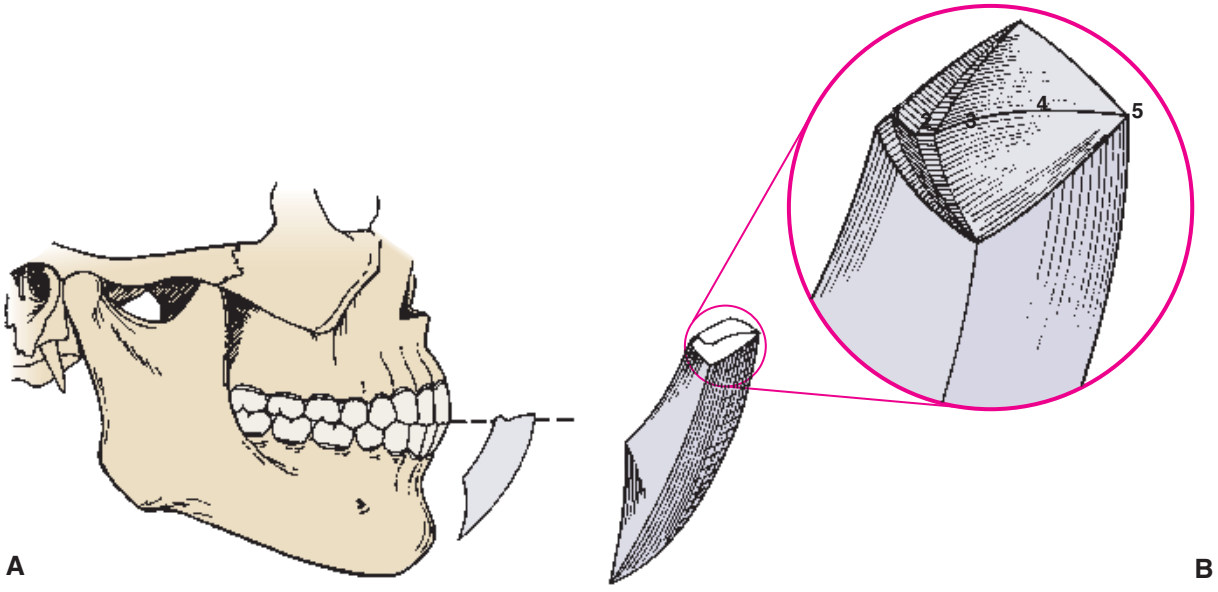


Fig. 4-13

A, Mandibular border movement in the sagittal plane. **B,** Posselt's three-dimensional representation of the total envelope of mandibular movement. *1,* Mandibular incisors track along the lingual concavity of the maxillary anterior teeth. *2,* Edge-to-edge position. *3,* Incisors move superiorly until posterior tooth contact recurs. *4,* Protrusive path. *5,* Most protrusive mandibular position.

Table **4-3** **IMPACT OF SELECTED VARIABLES ON OCCLUSAL FORM OF RESTORATIONS**

	Variation	Impact on Restoration
POSTERIOR DETERMINANTS		
Inclination of articular eminence	Steeper	Posterior cusps may be taller
	Flatter	Posterior cusps must be shorter
Medial wall of glenoid fossa	Allows more lateral translation	Posterior cusps must be shorter
	Allows minimal lateral translation	Posterior cusps may be taller
Intercondylar distance	Greater	Smaller angle between laterotrusive and mediotrusive movement
	Lesser	Increased angle between laterotrusive and mediotrusive movement
ANTERIOR DETERMINANTS		
Horizontal overlap of anterior teeth	Increased	Posterior cusps must be shorter
	Reduced	Posterior cusps may be taller
Vertical overlap of anterior teeth	Increased	Posterior cusps may be taller
	Reduced	Posterior cusps must be shorter
OTHER		
Occlusal plane	More parallel to condylar guidance	Posterior cusps must be shorter
	Less parallel to condylar guidance	Posterior cusps may be longer
Anteroposterior curve	More convex (shorter radius)	The most posterior cusps must be shorter
	Less convex (larger radius)	The most posterior cusps may be longer

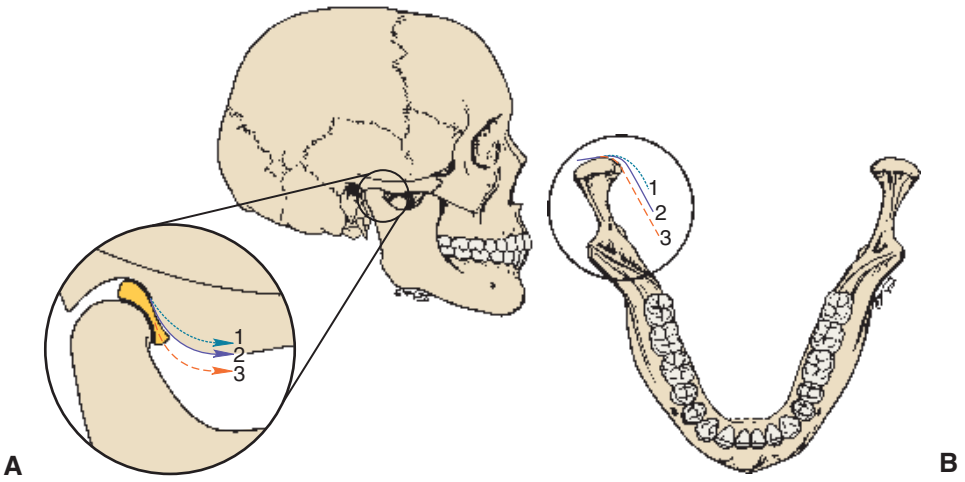


Fig. 4-14

Posterior determinants of occlusion. A, Angle of the articular eminence (condylar guidance angle). *1*, Flat; *2*, average; *3*, steep. B, Anatomy of the medial walls of the mandibular fossae. *1*, Greater than average; *2*, average; *3*, minimal side shift.

structures The *posterior determinants* (Fig. 4-14)–shape of the articular eminences, anatomy of the medial walls of the mandibular fossae, configuration of the mandibular condylar processes–cannot be controlled, and it is not possible to influence the neuromuscular responses of the patient unless it is done by indirect means (e.g., through changes in the configuration of the contacting teeth or by the provision of an occlusal appliance). If a patient has steeply sloped eminences, there is a large downward component of condylar movement during lateral and protrusive **excursions.** Similarly, the anatomy of the medial wall of each fossa normally allows the condyle to move slightly medially as it travels forward (mandibular side shift, or transtrusion). The side shift becomes greater as the extent of medial movement increases. However, the anatomy of the joint dictates the actual path and timing of condylar movement. Movement of the laterotrusive or working condylar process is influenced predominantly by the anatomy of the lateral wall of the mandibular fossa. The amount of the side shift is, of course, a function of the mediotrusive or nonworking condyle; on the working side, however, it is the anatomy of the lateral aspect of the fossa that guides the working condyle straight out or upward and downward. The amount of side shift does not appear to increase as the result of a loss of occlusion.[6]

The *anterior determinants* (Fig. 4-15) are the vertical and horizontal overlaps and the maxillary lingual concavities of the anterior teeth. These can be altered by restorative and orthodontic treatment. A greater vertical overlap causes the direction of mandibular opening to be more vertical during the early phase of protrusive movement and creates a more vertical pathway at the end of the chewing stroke. Increased horizontal overlap allows a more horizontal jaw movement.

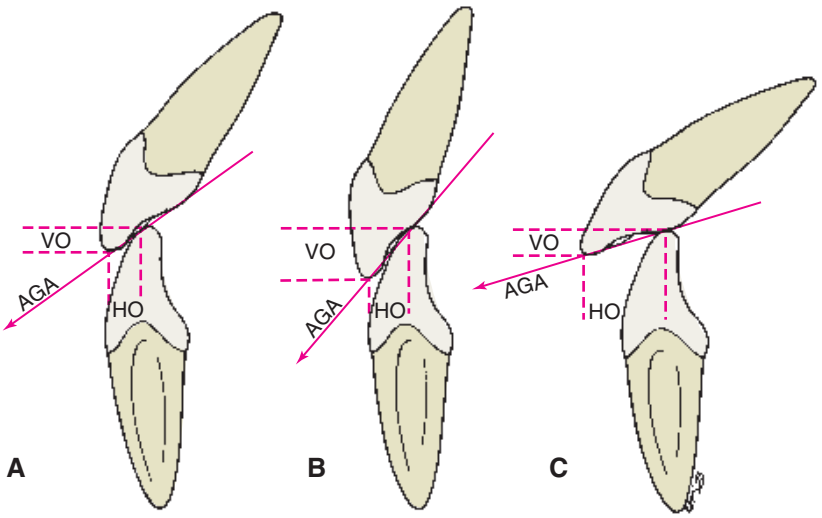
Although the posterior and anterior determinants combine to affect mandibular movement, no correlation has been established[7]; that is, patients with steep **anterior guidance** angles do not necessarily have a steep posterior disclusion, and those with a steep posterior disclusion do not necessarily have steep guidance angles.

Functional Movements

Functional mandibular movement is defined as all normal, proper, or characteristic movements of the mandible made during speech, mastication, yawning, swallowing, and other associated movements. Most functional movement of the mandible (as occurs during mastication and speech) takes place inside the physiologic limits established by the teeth, the TMJs, and the muscles and ligaments of mastication; therefore, these movements are rarely coincident with border movements.

Chewing

When incising food, adults open their mouths a comfortable distance and move the mandible forward until they incise, with the anterior teeth meeting approximately edge to edge. The food bolus is then transported to the center of the mouth as the mandible returns to its starting position, with the incisal edges of the mandibular anterior teeth tracking along the lingual concavities of the maxillary anterior teeth (Fig. 4-16). The mouth then opens slightly, the tongue pushes the food onto the occlusal



The anterior guidance between the maxillary and mandibular anterior teeth has a direct influence on the direction of mandibular movement.

Fig. 4-15
Anterior determinants of occlusion. Different incisor relationships with differing horizontal and vertical overlaps (*HO* and *VO*) produce different anterior guidance angles (*AGA*). A, Class I. B, Class II, Division 2 (increased VO; steep AGA). C, Class II, Division 1 (increased HO; flat AGA).

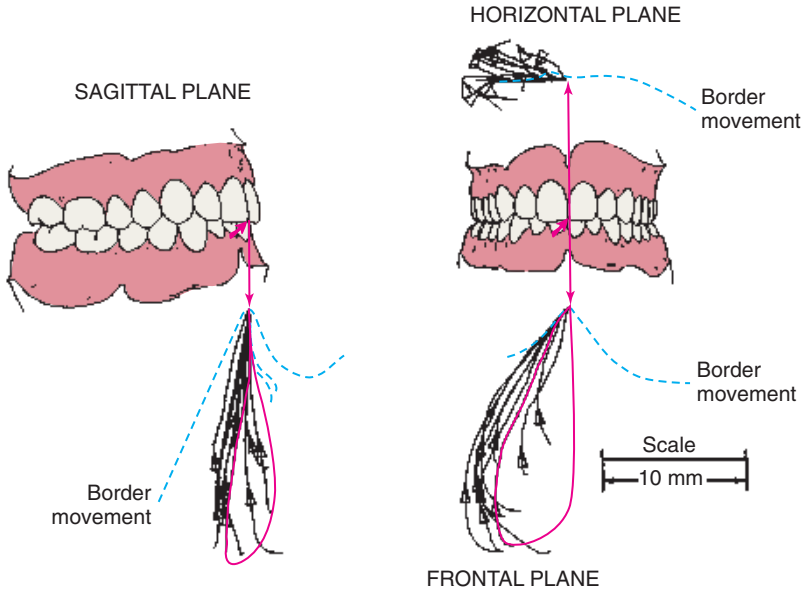


Fig. 4-16
Comparison of border and chewing movements for soft food at the central incisor. Sagittal, frontal, and horizontal views in an orthographic projection. *(From Gibbs CH, et al: Chewing movements in relation to border movements at the first molar. J Prosthet Dent 46:308, 1981.)*

table, and, after moving sideways, the mandible closes into the food until the guiding teeth (typically the canines) contact.[8] The cycle is completed as the mandible returns to its starting position.[9] This pattern repeats itself until the food bolus has been reduced to particles that are small enough to be swallowed, at which point the process can start over. The direction of the mandibular path of closure is influenced by the inclination of the occlusal plane with the teeth apart and by the occlusal guidance as the jaw approaches maximum intercuspation.[10]

The chewing pattern observed in children differs from that found in adults. Until about age 10, children begin the chewing stroke with a lateral movement. After the age of 10, they start to chew increasingly like adults, with a more vertical stroke[11] (Fig. 4-17). Stimuli from the pressoreceptors play an important role in the development of functional chewing cycles.[12]

Mastication is a learned process. At birth, no occlusal plane exists, and only after the first teeth have erupted far enough to contact each other is a message sent from the receptors to the cerebral cortex, which controls the stimuli to the masticatory musculature. Stimuli from the tongue and cheeks, and perhaps from the musculature itself and from the periodontium, may influence this feedback pattern.

Speaking

The teeth, tongue, lips, floor of the mouth, and soft palate form the resonance chamber that affects pronunciation. During speech, the teeth are generally not in contact, although the anterior teeth may come very close together during soft "c," "ch," "s," and "z" sounds, forming the "**speaking space:** the space that occurs between the incisal and/or occlusal surfaces of the maxillary and mandibular teeth during speech."[13] When pronouncing the fricative "f," the inner vermilion border of the lower lip traps air against the incisal edges of the maxillary incisors. Phonetics is a useful diagnostic guide for correcting vertical dimension and tooth position during fixed and removable prosthodontic treatment.[14-17]

Parafunctional Movements

Parafunctional movements of the mandible may be described as sustained activities that occur beyond the normal functions of mastication, swallowing, and

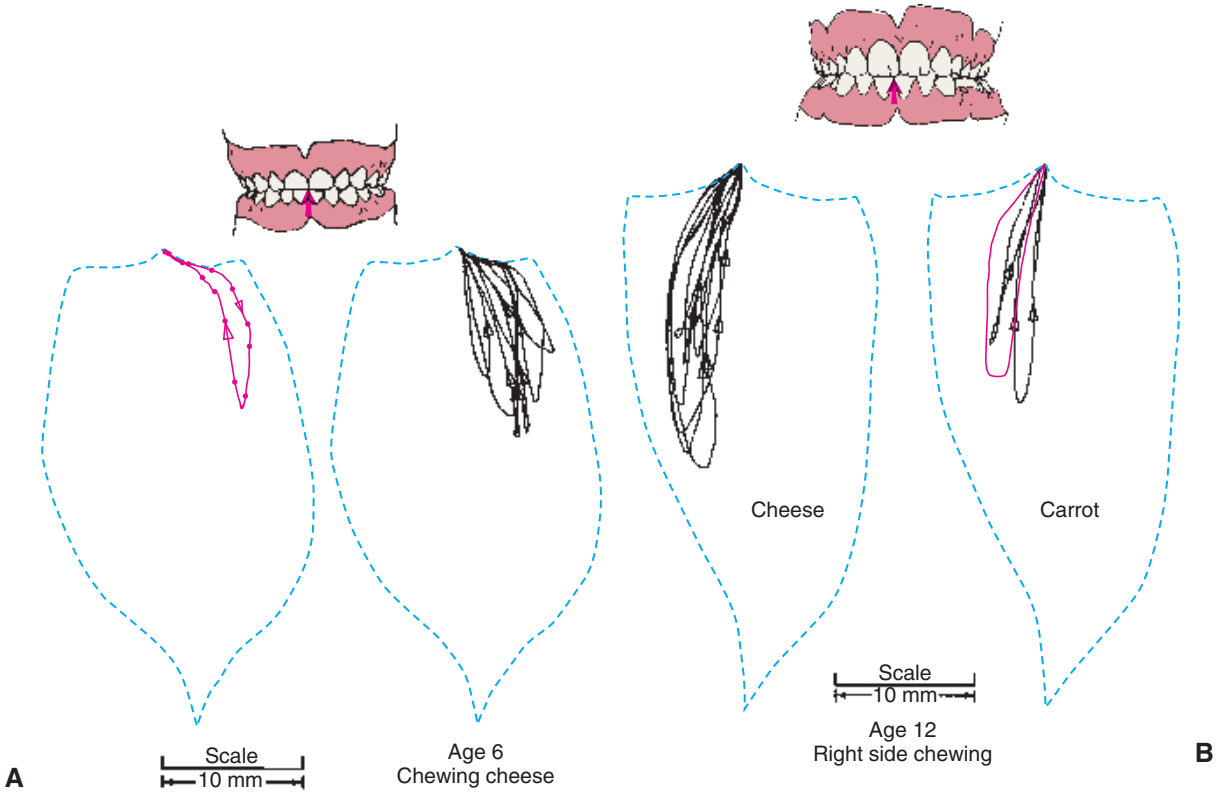


Fig. 4-17

Frontal views of chewing. The *dashed lines* are border movements. A, Chewing in a young person, characterized by a wide lateral movement on opening and decreased lateral movement on closing. B, In an older child, the chewing pattern resembles that of an adult. *(From Wickwire NA, et al: Chewing patterns in normal children. Angle Orthod 51:48, 1981.)*

speech. There are many forms of parafunctional activities, including **bruxism, clenching,** nail biting, and pencil chewing, among others. Typically, **parafunction** is manifested by long periods of increased muscle contraction and hyperactivity. Concurrently, excessive occlusal pressure and prolonged tooth contact occur, which is inconsistent with the normal chewing cycle. Over a protracted period, this can result in excessive wear; widening of the periodontal ligament; and mobility, migration, or fracture of the teeth. Muscle dysfunction such as myospasms, myositis, myalgia, and referred pain (headaches) from trigger point tenderness may also occur. The degree of symptoms varies considerably among individuals. The two most common forms of parafunctional activities are bruxism and clenching. Increased radiographic bone density is often seen in patients with a history of sustained parafunctional activity.

Bruxism

Oral habits consisting of involuntary rhythmic or spasmodic nonfunctional gnashing, grinding, or clenching of teeth, in other than chewing movements of the mandible, that may lead to occlusal trauma is known as *bruxism* (Fig. 4-18). This activity may be diurnal, nocturnal, or both. Although bruxism is initiated on a subconscious level, nocturnal bruxism is potentially more harmful because the patient is not aware of it while sleeping. Therefore, it can be difficult to detect, but it should be suspected in any patient exhibiting abnormal tooth wear or pain. The prevalence of bruxism is about 10% and is less common with age.[18] The etiology of bruxism is often unclear. Some theories relate bruxism to malocclusion, neuromuscular disturbances, responses to emotional distress, or a combination of these factors.[19] A study on cohort twins has demonstrated substantial genetic effects[20]; the condition has been related to sleep disturbance[21]; and the symptoms of bruxism are three times more common in smokers.[22] Altered mastication has been observed in subjects who brux[23,24] and may result from an attempt to avoid premature occlusal contacts (occlusal **interferences**). There may also be a neuromuscular attempt to "rub out" an interfering cusp. The fulcrum effect of rubbing on posterior interferences creates a protrusive or laterotrusive movement that can cause overloading of the anterior teeth, with resultant excessive anterior wear. It is common for wear on anterior teeth to progress from initial faceting on the canines to the central and lateral incisors. Once vertical overlap diminishes as the result of wear, posterior wear facets are commonly observed. However, the chewing patterns of normal subjects can be quite varied, and the relationship, if any, between altered mastication and occlusal dysfunction is not clear.[25]



Fig. 4-18
Extensive abrasion (tooth wear) resulting from parafunctional grinding. *(Courtesy of Dr. M. Padilla.)*

The causes of bruxism are difficult to determine. One theory[26] states that bruxism is performed on a subconscious reflex-controlled level and is related to emotional responses and occlusal interferences. In certain malocclusions, the neuromuscular system exerts fine control during chewing to avoid particular occlusal interferences. As the degree of muscle activity necessary to avoid the interferences becomes greater, an increase in muscle tone may result, with subsequent pain in the hyperactive musculature, which in turn can lead to restricted movement. The relationship, if any, between bruxism and temporomandibular disorders is still unclear.[27]

Patients who brux can exert considerable forces on their teeth, and much of this may have a lateral component. Posterior teeth do not tolerate lateral forces as well as vertical forces in their long axes. Buccolingual forces, in particular, appear to cause rapid widening of the periodontal ligament space and increased mobility.

Clenching

Clenching is defined as the pressing and clamping of the jaws and teeth together frequently associated with acute nervous tension or physical effort. The pressure thus created can be maintained over a considerable time with short periods of relaxation in between. The etiology can be associated with stress, anger, physical exertion, or intense concentration on a given task, rather than an occlusal disorder. In contrast to bruxism, clenching does not necessarily result in damage to the teeth because the concentration of pressure is directed more or less through the long axes of the posterior teeth without the involvement of detrimental lateral forces. Abfractions—cervical defects at the cementoenamel junction—may result from sustained clenching.[28,29] Also, the increased load may result in damage to the periodontium, TMJs, and muscles of mastication. Typically, the elevator muscles become overdeveloped. Muscle splinting, myospasm, and myositis may progress, causing the patient to seek treatment. As with bruxism, clenching can be difficult to diagnose and difficult if not impossible for the patient to voluntarily control.

HISTORY OF OCCLUSAL STUDIES

Historically, the study of occlusion and articulation has undergone an evolution of concepts. These can be broadly categorized as concepts of bilaterally balanced,[30] unilaterally balanced, and **mutually protected articulation**. Current emphasis in teaching fixed prosthodontics and restorative dentistry has been on the concept of mutual protection (Fig. 4-19). However, because restorative treatment requirements vary, the clinician should understand possible combinations of occlusal schemes and their advantages, disadvantages, and indications.

In most patients, maximum tooth contact occurs anterior to the centric relation position of the mandible. Often, this maximum intercuspation position anterior to centric relation is referred to as *centric occlusion,* although the term is also used to refer to occlusal contact in centric relation. To avoid confusion, *maximum intercuspation* and *centric relation* are the terms used in this text.



Fig. 4-19
Canine-guided or mutually protected articulation. During lateral excursions, there are no contacts on the mediotrusive (nonworking) side; all contacts are between the laterotrusive (working side) canines.

Bilaterally Balanced Articulation

Early work in removable prosthodontics centered on the concept of a bilaterally balanced articulation. This requires having a maximum number of teeth in contact in maximum intercuspation and all excursive positions. In complete denture fabrication, this tooth arrangement helps maintain denture stability because the nonworking contact prevents the denture from being dislodged. However, as the principles of bilateral balance were applied to the natural dentition and in fixed prosthodontics, it proved to be extremely difficult to accomplish, even with great attention to detail and with the use of sophisticated articulators. In addition, high rates of failure resulted. An increased rate of occlusal wear, increased or accelerated periodontal breakdown, and neuromuscular disturbances were commonly observed. The last were often relieved when posterior contacts on the mediotrusive side were eliminated in an attempt to eliminate unfavorable loading. Thus, the concept of a unilaterally balanced occlusion **(group function)** evolved[31] (Fig. 4-20).

Unilaterally Balanced Articulation (Group Function)

In a unilaterally balanced articulation, excursive contact occurs between all opposing posterior teeth on the laterotrusive (working) side only. On the mediotrusive (nonworking) side, no contact occurs until the mandible has reached centric relation. Thus, in this occlusal arrangement, the load is distributed among the periodontal support of all posterior teeth on the working side. This can be advantageous if, for instance, the periodontal support of the canine is compromised. While on the working side, occlusal load is distributed during excursive movement, and the posterior teeth on the **nonworking side** do not contact. In the protrusive movement, no posterior tooth contact occurs.



Fig. 4-20
Group function or unilaterally balanced occlusion. A, During lateral excursions, there are no contacts between teeth on the mediotrusive (nonworking) side, but even excursive contacts occur on the laterotrusive (working) side (B).

Long centric

As the concept of unilateral balance evolved, it was suggested that allowing some freedom of movement in an anteroposterior direction is advantageous. This concept is known as *long centric*. Schuyler[32] was one of the first to advocate such an occlusal arrangement. He thought that it was important for the posterior teeth to be in harmonious gliding contact when the mandible translates from centric relation forward to make anterior tooth contact. Others[33] have advocated long centric because centric relation only rarely coincides with the maximum intercuspation position in healthy natural dentitions. However, its length is arbitrary. At given vertical dimensions, long centric ranges from 0.5 to 1.5 mm in length have been advocated. This theory presupposes that the condyles can translate horizontally in the fossae over a commensurate trajectory before beginning to move downward. It also necessitates a greater horizontal space between the maxillary and mandibular anterior teeth (deeper lingual concavity), allowing horizontal movement before posterior **disocclusion** (separation of opposing teeth during **eccentric** movements of the mandible).

Mutually Protected Articulation

During the early 1960s, an occlusal scheme called *mutually protected articulation* was advocated by Stuart and Stallard,[34] based on earlier work by D'Amico.[35] In this arrangement, centric relation coincides with the maximum intercuspation position. The six anterior maxillary teeth, together with the six anterior mandibular teeth, guide excursive movements of the mandible, and no posterior occlusal contacts occur during any lateral or protrusive excursions.

The relationship of the anterior teeth, or anterior guidance, is critical to the success of this occlusal scheme. In a mutually protected articulation, the posterior teeth come into contact only at the very end of each chewing stroke, minimizing horizontal loading on the teeth. Concurrently, the posterior teeth act as stops for vertical closure when the mandible returns to its maximum intercuspation position. Posterior cusps should be sharp and should pass each other closely without contacting to maximize occlusal function. Investigations of the neuromuscular physiology of the masticatory apparatus indicate advantages associated with a mutually protected occlusal scheme.[8] However, in studies involving unrestored dentitions, relatively few occlusions can be classified as mutually protected.[36]

Optimum occlusion

In an ideal occlusal arrangement, the load exerted on the dentition should be distributed optimally. Occlusal contact has been shown[37] to influence muscle activity during mastication. Any restorative procedures that adversely affect occlusal stability may affect the timing and intensity of elevator muscle activity. Horizontal forces on any teeth should be avoided or at least minimized, and loading should be predominantly parallel to the long axes of the teeth. This is facilitated when the tips of the functional cusps are located centrally over the roots and when loading of the teeth occurs in the fossae of the occlusal surfaces rather than on the marginal ridges. Horizontal forces are also minimized if posterior tooth contact during excursive movements is avoided. Nevertheless, to enhance masticatory efficiency, the cusps of the posterior teeth should have adequate height. Stabilizing contacts involves primarily the mandibular buccal cusps, and it has been suggested that maintenance or improvement of the number of such contacts should be among occlusal treatment objectives.[38]

The chewing and grinding action of the teeth is enhanced if opposing cusps on the laterotrusive side interdigitate at the end of the chewing stroke. The mutually protected occlusal scheme probably meets

this criterion better than the other occlusal arrangements. The features of a mutually protected articulation are as follows[39]:

1. Uniform contact of all teeth around the arch when the mandibular condylar processes are in their most superior position.
2. Stable posterior tooth contacts with vertically directed resultant forces.
3. Centric relation coincident with maximum intercuspation (intercuspal position).
4. No contact of posterior teeth in lateral or protrusive movements.
5. Anterior tooth contacts harmonizing with functional jaw movements.

In achieving these criteria, it is assumed that (1) a full complement of teeth exists, (2) the supporting tissues are healthy, (3) there is no reverse articulation (crossbite) and (4) the occlusion is Angle Class I.

Rationale

At first glance, it might seem illogical to load the single-rooted anterior teeth as opposed to the multirooted posterior teeth during chewing. However, the canines and incisors have a distinct mechanical advantage over the posterior teeth[40]: The effectiveness of the force exerted by the muscles of mastication is notably less when the loading contact occurs farther anteriorly.

The mandible is a lever of the class III type (Fig. 4-21), which is the least efficient of lever systems. An example of another class III lever would be a fishing pole. The longer the pole, the more effort it takes to pull a fish out of the water. The same holds true for the muscles of mastication and the teeth: the farther anteriorly initial tooth-to-tooth contact occurs (i.e., the longer the lever arm), the less effective the forces exerted by the musculature are and the smaller the load to which the teeth are subjected is. The canine—with its long root, significant amount of periodontal surface area, and strategic position in the dental arch—is well adapted to guiding excursive movements. This function is governed by pressoreceptors in the periodontal ligament, receptors that are very sensitive to mechanical stimulation.[41]

The elimination of posterior contacts during excursions reduces the amount of lateral force to which posterior teeth are subjected. Therefore, molars and premolars in group function are subjected to greater horizontal and potentially more pathologic force than the same teeth in a mutually protected articulation.

PATIENT ADAPTABILITY

There are significant differences in the adaptive response of patients to occlusal abnormalities. Some individuals are unable to tolerate seemingly trivial occlusal deficiencies, whereas others are able to tolerate distinct malocclusions without obvious symp-

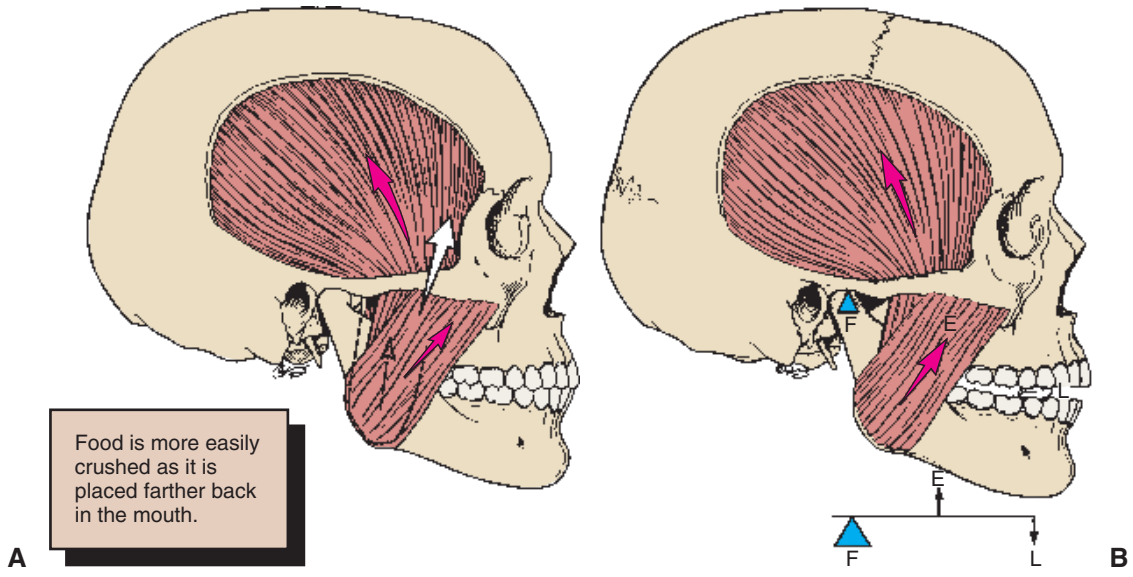


Fig. 4-21

Lever system of the mandible. **A,** The elevator muscles of the mandible insert anterior to the temporomandibular joints (TMJs) and posterior to the teeth, forming a class III lever system. **B,** The fulcrum (*F*) is the TMJ, the force or effort (*E*) is applied by the muscles of mastication, and the resistance or load (*L*) is food placed between the teeth. The load diminishes as the lever arm increases. Therefore, less load is placed on the anterior teeth than on the posterior teeth.



Fig. 4-22

Patient adaptability: None of the four patients described here expressed any concern about their occlusion. **A**, Anterior esthetics motivated a 45-year-old woman to seek treatment, although loss of posterior occlusal contact probably contributed to the development of her anterior diastema. **B**, A 26-year-old woman had no complaints or neuromuscular symptoms, despite contacting only on her second and first molars. **C**, A patient with amelogenesis imperfecta sought care for esthetic reasons rather than functional complaints. **D**, A 21-year-old man with congenitally missing lateral incisors had neither functional nor pain complaints when he was referred for fixed prosthodontic care after orthodontic treatment.

toms (Fig. 4-22). Most patients seem able to adapt to small occlusal deficiencies without exhibiting acute symptoms.

Lowered Threshold

Patients with a low pain threshold generally do not present much difficulty in diagnosis. They readily identify every pain. A lowered threshold, however, is not to be confused with hypochondria; it is merely an indication of poor adaptability to occlusal discrepancies. The tolerance or adaptability of an individual patient is likely to vary: It is lower at times of emotional stress and general malaise, when clinical symptoms such as severe headaches, muscle spasm, and pain may surface.

Raised Threshold

Individuals who have adapted to existing malocclusions may report being quite comfortable with their dentition, although a number of signs are evident. Even in the absence of pain, however, occlusal treatment may be advised so as to prevent or minimize wear on the teeth and damage to the musculature or TMJs.

PATHOGENIC OCCLUSION

A **pathogenic occlusion** is defined as an occlusal relationship capable of producing pathologic changes in the stomatognathic system. In such occlusions, sufficient disharmony exists between the teeth and the TMJs to result in symptoms that necessitate intervention.

Signs and Symptoms

There are many indications that a pathogenic occlusion may be present. Diagnosis is often complicated because patients almost always have a combination of symptoms. Although it is often not possible to

prove a direct correlation between specific symptoms and malocclusion, the following symptoms can help confirm this diagnosis.

Teeth

The teeth may exhibit hypermobility, open contacts, or abnormal wear. Hypermobility of an individual tooth or an opposing pair of teeth is often an indication of excessive occlusal force. This may result from premature contact in centric relation or during excursive movements. Such contacts frequently can be detected by placing the tip of the index finger on the crown portion of the mobile tooth and asking the patient to repeatedly tap the teeth together. Small amounts of movement (fremitus) that otherwise might not be readily seen can often be felt this way.

Open proximal contacts may be the result of tooth migration because of an unstable occlusion and should prompt further investigation (Fig. 4-23). Diagnostic casts made during previous treatment help assess any changes in the stability of the occlusion. Abnormal tooth wear, cusp fracture, or chipping of incisal edges may be signs of parafunctional activity.[42,43] However, extensive tooth destruction is often caused by a combination of acid erosion and **attrition.**[44-46] In these cases, the acid may be present in the diet (e.g., excessive citrus fruit consumption) or endogenous (caused by regurgitation or frequent vomiting).

Periodontium

There is no convincing evidence that chronic periodontal disease is caused directly by occlusal overload. However, a widened periodontal ligament space (detected radiographically) may indicate premature occlusal contact and is often associated with tooth mobility (Fig. 4-24). Similarly, isolated or circumferential periodontal defects are often associated with occlusal trauma. In patients with advanced periodontal disease who have extensive bone loss, rapid tooth migration may occur with even minor occlusal discrepancies. Tooth movement may make it difficult for these patients to institute proper oral hygiene measures, and the result may be a recurrence of periodontal disease. Precise adjustment of the occlusion is probably more crucial in patients with a compromised crown/root ratio than in those with better periodontal support (see Chapter 32).

Musculature

Acute or chronic muscular pain on palpation can indicate habits associated with tension such as bruxism or clenching. Chronic muscle fatigue can lead to muscle spasm and pain. In one study,[47] subjects were instructed to grind their teeth for approximately 30 minutes. They experienced muscle pain that typically peaked 2 hours after parafunctioning and lasted as long as 7 days. Asymmetric muscle activity can be diagnosed by observing a patient's opening and closing movements in the frontal plane. A deviation of a few millimeters is quite common, but any deviation larger than this may be a sign of dysfunction and mandates further examination (Fig. 4-25).[48] Restricted opening, or trismus, may be a result of the fact that the mandibular elevator muscles are not relaxing.

Temporomandibular joints

Pain, clicking, or popping in the TMJs can indicate temporomandibular disorders. Clicking and popping may be present without the patient's awareness. A stethoscope is a useful diagnostic aid; one study revealed that joint sounds are generally



Fig. 4-23
Unstable occlusion. Removal of a tooth without replacement has led to tilting and drifting.



Fig. 4-24
Widened periodontal ligament space and increased mobility of mandibular molars. Occlusal premature contacts were noted in lateral and protrusive movements.

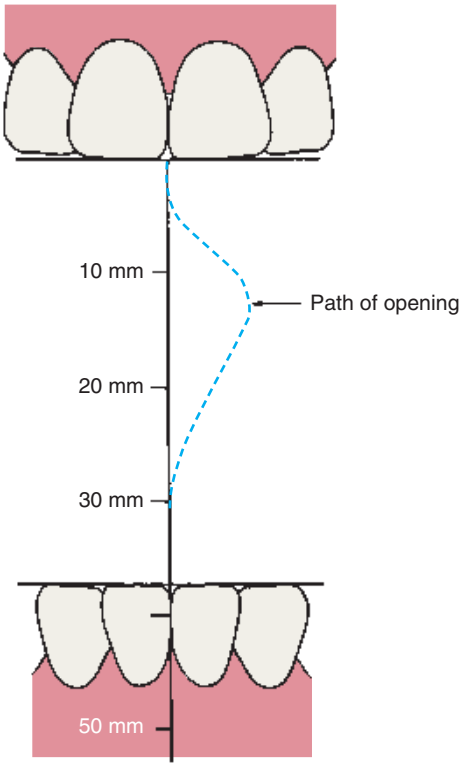


Fig. 4-25
Midline deviation during opening and closing movements can be indicative of asymmetric muscle activity or joint derangement. Here, during opening, less than optimal translation occurs on the patient's left side.

reliable indicators of temporomandibular disorders.[49] The patient may complain of TMJ pain that is actually of muscular origin and is referred to the joints.

Clicking may also be associated with internal derangements of the joint. A patient with unilateral clicking when opening and closing (reciprocal click) in conjunction with a midline deviation may have a displaced disk. The midline deviation typically occurs toward the side of the affected joint because the displaced disk can prevent (or slow down) the normal anterior translatory movement of the condyle.

Myofascial pain dysfunction

The myofascial pain dysfunction (MPD) syndrome manifests as diffuse unilateral pain in the preauricular area, with muscle tenderness, clicking, or popping noises in the contralateral TMJ and limitation of jaw function. Often the muscles, and not the TMJ, are the primary site, but over time the functional problem may lead to organic changes in the joint. Three major theories about the cause of MPD are recognized: (1) According to the psychophysiologic theory,[50] MPD results from bruxing and clenching, with chronic muscle fatigue leading to muscle spasm and altered mandibular movement. Tooth movement may follow, and the malocclusion becomes apparent when spasm is relieved. According to this theory, treatment should focus on emotional rather than physical therapy. (2) According to the muscle theory,[51] continuous muscle hyperactivity is responsible for MPD, with pain referred to the TMJ and other areas of the head and neck region. (3) According to the mechanical displacement theory,[52] malocclusion of the teeth displaces the condyles, and the feedback from the dentition is altered, which results in muscle spasm.

Correct diagnosis and management is often complicated by the concurrent presence of multiple etiologies. Patients with MPD may require multidisciplinary treatment involving occlusal therapy, medications, biofeedback, and physical therapy. Extensive fixed prosthodontic treatment should be postponed until the patient's conditions have been stabilized at acceptable levels.

OCCLUSAL TREATMENT

When a patient exhibits signs and symptoms that appear correlated to occlusal interferences (see also p. 195), occlusal treatment should be considered.[53] Such treatment can include tooth movement through orthodontics, elimination of deflective occlusal contacts through selective reshaping of the occlusal surfaces of teeth, or the restoration and replacement of missing teeth that result in more favorable distribution of occlusal force.

The objectives of occlusal treatment are as follows:

1. To direct the occlusal forces along the long axes of the teeth.
2. To attain simultaneous contact of all teeth in centric relation.
3. To eliminate any occlusal contact on inclined planes to enhance the positional stability of the teeth.
4. To have centric relation coincide with the maximum intercuspation position.
5. To arrive at the occlusal scheme selected for the patient (e.g., unilateral balanced versus mutually protected).

In the short term, these objectives can be accomplished with a removable **occlusal device** (Fig. 4-26) fabricated from clear acrylic resin that overlies the occlusal surfaces of one arch. On a more permanent basis, this can be accomplished through selective occlusal reshaping, tooth movement, the



Fig. 4-26
Occlusal device. *(Courtesy of Dr. W. V. Campagni.)*

placement of restorations, or a combination of these. Definitive occlusal treatment involves accurate manipulation of the mandible, particularly in centric relation. Because the patient may resist such manipulation as a result of protective muscular reflexes, some type of deprogramming device may be needed (e.g., an occlusal device).

Occlusal Device Therapy

Occlusal devices (sometimes referred to as *occlusal splints, occlusal appliances,* or *orthotics*) are used extensively in the management of temporomandibular disorders and bruxism.[54] In controlled clinical trials, they have effectively controlled myofascial pain (i.e., the patient perceives positive changes as a result of the device therapy). However, no clear hypothesis about the mechanism of action has been proved, and none of the various hypotheses (repositioning of condyle and/or the articular disk, reduction in masticatory muscle activity, modification of "harmful" oral behavior, and changes in the patient's occlusion) has been consistently supported by scientific studies.[55] Occlusal devices are particularly helpful in determining whether a proposed change in a patient's occlusal scheme will be tolerated. The proposed scheme is created in an acrylic resin overlay, which allows testing of the scheme through reversible means, although at a slightly increased vertical dimension. If a patient responds favorably to an occlusal device, the response to restorative treatment should be positive as well. Thus, occlusal device therapy can serve as an important diagnostic procedure before initiation of fixed prosthodontic treatment. The device can be made for either maxillary or mandibular teeth. Some clinicians express a preference for one or the other and cite advantages; however, both maxillary and mandibular devices have proved satisfactory.

Fabrication of Device

There are several satisfactory methods for making an occlusal device.[45] One made from heat-polymerized acrylic resin has the advantage of durability, but autopolymerizing resin used alone or in conjunction with a vacuum-formed matrix can serve equally well. Box 4-1 compares the indirect and direct techniques.

Direct procedure with a vacuum-formed matrix

1. Adapt a sheet of clear thermoplastic resin to a diagnostic cast, using a vacuum-forming machine. Hard resin (1 mm thick) is suitable. Be sure that excessive undercuts have been blocked out. Trim the excess resin so that all facial soft tissues are exposed. On the facial surfaces of the

Box **4-1** **Comparison of Occlusal Devices**

INDIRECT TECHNIQUE (HEAT POLYMERIZED)	DIRECT TECHNIQUE (AUTOPOLYMERIZED)
• More esthetic—plastic is crystal clear • More dense, less subject to breakage, warping, or wear • More precise occlusal contacts with use of articulator • Less chair time at delivery • Better adaptation to teeth and soft tissues • Increased laboratory cost (waxing, flasking, finishing) • Better control of bulk • Less coverage needed for stability • Use of ball clasps for retention	• Can be done in one appointment • Uses the mouth as an articulator, introducing errors • Vacuum-formed matrix is thin and flexible, requiring more coverage for stability • Chipping and breaking—need for chairside repairs • Stain, odors, and excess wear because of porosity of acrylic • Device can be duplicated in heat-polymerized resin for greater durability

Courtesy of Dr. J. E. Petrie.

teeth, the device must be kept well clear of the gingival margins (Fig. 4-27*A*). On the lingual surface of maxillary devices, the matrix should cover the anterior third of the hard palate for rigidity.

2. Try in the matrix for fit and stability. Add a small amount of autopolymerizing acrylic resin in the incisal region. Guide the mandible into centric relation, using the bimanual manipulation technique (see Chapter 2). Hinge the mandible to make shallow indentations in the resin (see Fig. 4-27*B*).
3. Add more resin to the incisor and canine regions, and guide the patient's mouth to retrusive, protrusive, and lateral closures in the soft resin. Allow the resin to polymerize. Note that the resin should be allowed to polymerize on the cast or with the appliance in place in the mouth. Otherwise, the heat generated by polymerization may distort the thermoplastic matrix.
4. With the help of marking ribbon, adjust the resin to give smooth, even contacts during protrusive and lateral excursions as well as a defi-

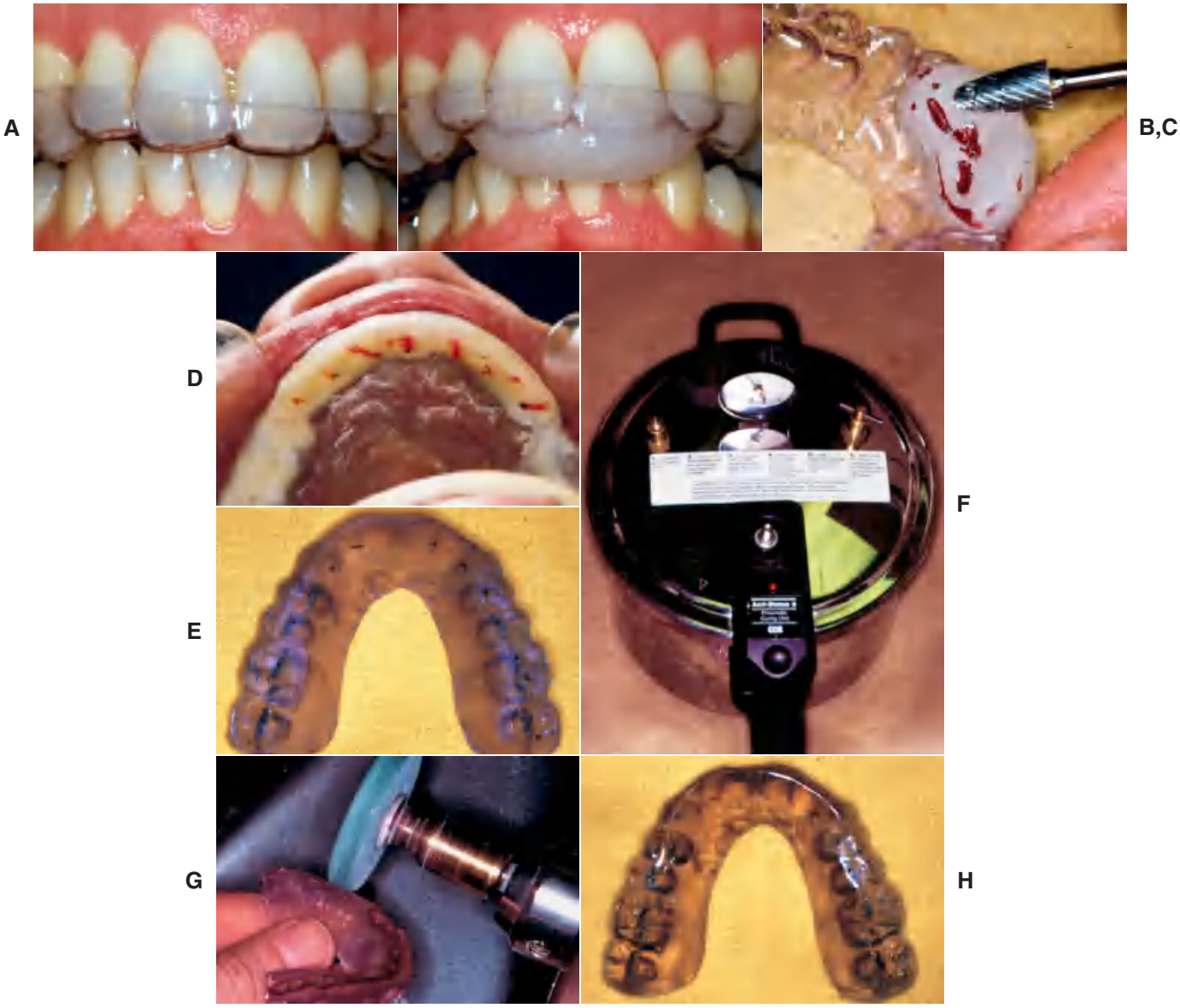


Fig. 4-27
Direct procedure for the fabrication of an occlusal device.

nite occlusal stop for each incisor in centric relation (see Fig. 4-27*C*). Confine protrusive contacts to the incisors and lateral contacts to the laterotrusive canines (Fig. 4-27*D*). All posterior contacts should be relieved at this stage.

5. Have the patient wear the device for a few minutes in the office. Repeated protrusive and lateral movements overcome most problems in jaw manipulation. On occasion, it is necessary for the patient to wear the device overnight before the acquired protective muscle patterns are overcome. In such cases, if posterior tooth eruption is to be avoided, the patient must be seen again within 24 to 48 hours.
6. Add autopolymerizing acrylic resin to the posterior region of the device and guide the patient's mouth into centric relation. Hold centric relation until the acrylic resin has polymerized.
7. Remove the device and examine the impressions of the opposing arch in the resin (Fig. 4-27*E*). Polymerization can be accelerated by placing the device on the cast in warm water in a pressure pot (Fig. 4-27*F*).
8. Place pencil marks in the depressions formed by the opposing functional cusps. If a cusp registration is missing, new resin can be added and the device reseated.
9. Remove excess resin with a bur or wheel to leave only the pencil marks (Fig. 4-27*G*). All other contacts must be eliminated if posterior disclusion is to be achieved.
10. Check the device in the patient's mouth for centric relation contacts, marking them with a ribbon. Relieve heavy contacts by continued adjustment until each functional cusp has an even mark.
11. Identify protrusive and lateral excursions with different-colored tape. Adjust excursive contacts as necessary, being careful not to remove the functional cusp stops.
12. Smooth and polish the device, again being careful not to alter the functional surfaces (Fig. 4-27*H*).
13. After a period of satisfactory use, the device can be duplicated in heat-polymerized resin with the careful use of a standard denture reline technique.

Indirect procedure with autopolymerizing acrylic resin

Accurately mounted diagnostic casts are essential for this procedure. A relatively small mounting error can lead to considerable loss of time at try-in. Particular attention must be given to occlusal defects or interfering soft tissue projections on the casts, which could cause errors during mounting.

1. Be sure that the device is made at the same occlusal vertical dimension as the centric relation record. This reduces mounting errors derived from the use of an arbitrary facebow.
2. Fit the articulator with a mechanical incisal guidance table initially set flat.
3. Lower the incisal guide pin until there is approximately 1 mm of clearance between the posterior teeth (Fig. 4-28*A*). This should be the same occlusal vertical dimension as the one at which the centric relation record was made.
4. Depending on the type of articulator used, it may be necessary to reposition the incisal guide table after step 3.
5. Check the clearance between opposing casts during protrusive movement of the articulator. Where this is less than 1 mm, increase it by tilting the incisal guidance table.
6. Raise the platform wings of the incisal guidance table so there is at least 1 mm of clearance in all lateral excursions (Fig. 4-28*B*). It may be necessary to raise the incisal pin occasionally to ensure adequate clearance.
7. Mark the height of contour of each tooth on the cast, and block out undercuts with wax (Fig. 4-28*C*).
8. Form wire clasps to engage facial undercuts, seal the cast with a separating medium (e.g., Al-Cote), and allow it to dry (Fig. 4-28*D*). The opposing cast can be soaked in water to prevent the acrylic resin from sticking to it.
9. Fabricate the device with autopolymerizing clear acrylic resin (Fig. 4-28*E*), applied by alternating liquid and powder (Fig. 4-28*F*). To avoid porosities, the resin should always be kept wet with monomer and added in small increments (Fig. 4-28*G*).
10. While the resin is still soft, close the articulator (Fig. 4-28*H*). Add resin where necessary until a slight depression is formed by each functional cusp.
11. Again, while the resin is still soft, close the articulator into protrusive and lateral excursions. Add or remove resin until it is in constant contact with the anterior teeth when the incisal guide pin contacts the incisal guidance table. This adjustment need only be approximate because the working time of the acrylic resin is

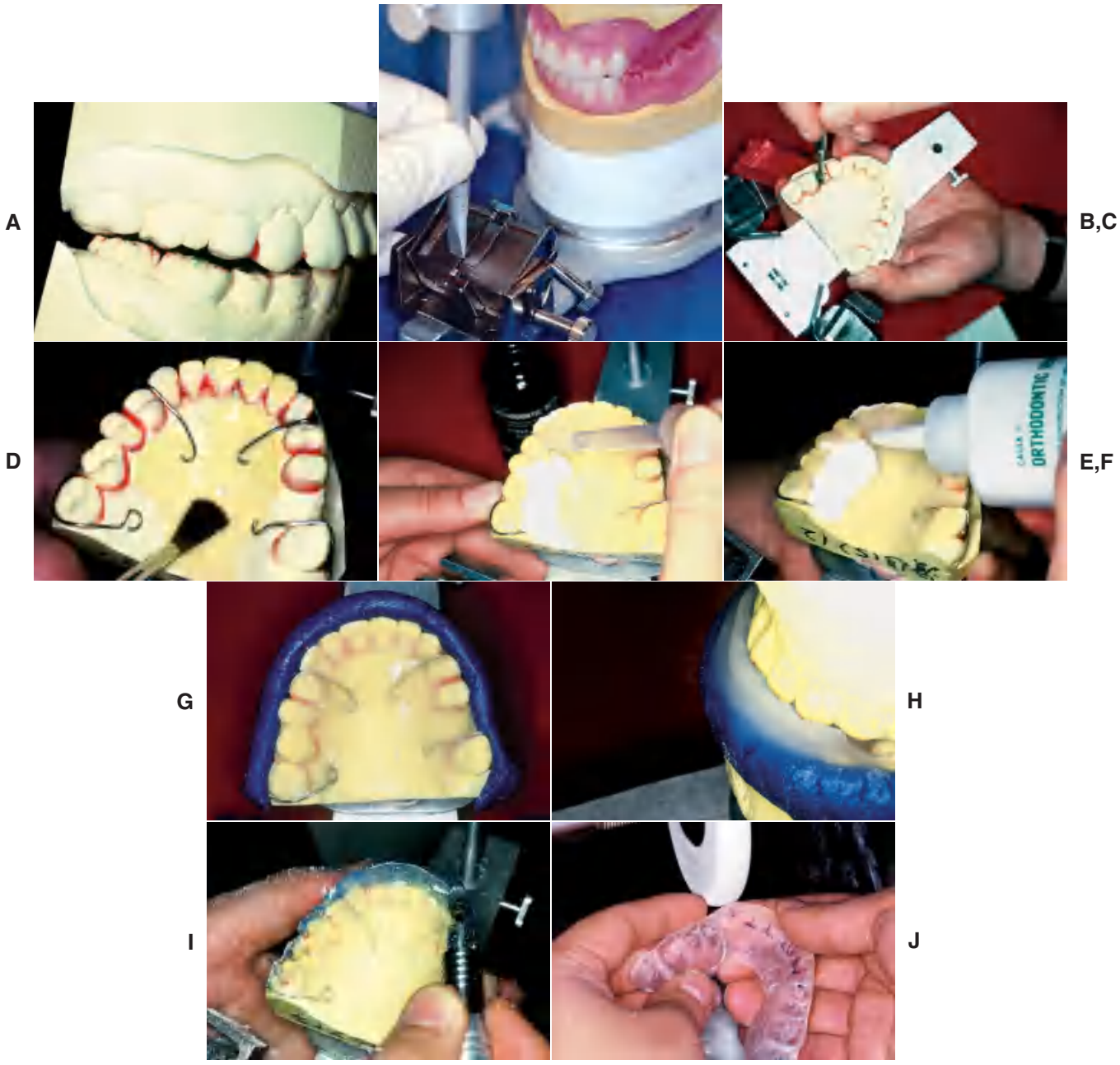


Fig. 4-28
A to **J**, Indirect procedure with autopolymerizing resin for the fabrication of an occlusal device.

limited and the occlusal contacts will be refined after the resin has polymerized.

12. Place the device and cast in warm water in a pressure vessel to polymerize. When this is complete, flush wax from the cast with boiling water.
13. Refine the occlusion on the articulator (Fig. 4-28*I*).
    a. There should be even contact for each functional cusp in centric relation.
    b. A stop should exist for each anterior tooth in centric relation.
    c. Protrusive contact on the incisors should be smooth and even.
    d. There should also be smooth and even lateral contact on the laterotrusive (working side) canines.
14. Remove the device from the cast, and smooth and polish it, taking care not to alter the functional surfaces (Fig. 4-28*J*).



Fig. 4-29
A to **U**, Alternative technique for occlusal device fabrication with autopolymerizing resin.

15. At try-in, check for fit and stability. Also check the occlusal contacts and adjust as necessary, using different-colored marking ribbon for centric and eccentric contacts.

Indirect procedure with autopolymerizing resin (alternative technique)

1. Obtain accurate casts and an interocclusal record (Fig. 4-29*A* and *B*).
2. Articulate the casts in centric relation, and adjust the setting of the articulator pin until approximately 2 mm of interocclusal clearance results (Fig. 4-29*C* to *E*).
3. Stainless wire clasps (Fig. 4-29*F*) and two sheets of baseplate wax are adapted to the maxillary cast (Fig. 4-29*G*).
4. Develop an anterior ramp (Fig. 4-29*H*), and establish evenly distributed occlusal contact with the mandibular teeth (Fig. 4-29*I*).
5. Wax sprues are added to the posterior aspect of the completed waxed device (Fig. 4-29*J*).
6. Laboratory Silicone is adapted over the waxup (Fig. 4-29*K* and *L*).
7. After the wax is boiled off the cast, reposition the clasps and lute them in place with some sticky wax (Fig. 4-29*M* and *N*).



Fig. 4-29, cont'd

8. Apply a separating agent to the cast (Fig. 4-29*O*).
9. Autopolymerizing resin is then mixed in accordance with manufacturer's instructions; fill the mold cavity between the cast and the repositioned silicone external surface form with the liquid resin (Fig. 4-29*P* and *Q*).
10. Place the model in a pressure pot and allow the resin to cure (Figure 4-29*R*).
11. After the cast is reattached to the articulator, mark and adjust occlusal contacts until a mutually protected articulation is established (Fig. 4-29*S* and *T*)
12. The completed occlusal device (Fig. 4-29*U*) is then removed from the cast and polished prior to clinical try-in and delivery.

Indirect procedure with heat-polymerized acrylic resin

A more durable device can be made with heat-polymerized acrylic resin. The desired occlusal surface is shaped in wax on articulated diagnostic casts, or the direct device made with a vacuum-formed matrix can be used as a pattern. This is flasked and processed in a manner similar to that for a complete denture. Because of processing errors, it is important to remount the cast and make necessary adjustments before finishing and polishing are completed.

1. Articulate the casts in centric relation. Allow for a remount procedure by notching the base of the cast on which the device will be processed.
2. Create the desired configuration of the device in wax, obtaining centric stops and anterior guidance. Use the mechanical anterior guidance table as for an autopolymerizing resin device.
3. Separate the cast from its mounting and flask as for conventional processing of complete dentures.
4. Process in clear, heat-cured resin.
5. Rearticulate and adjust the occlusion.
6. Remove the stone cast with a shell blaster. Polish the external surfaces on a lathe with pumice and an appropriate polishing compound.
7. Store in 100% humidity.

Attention to detail

Regardless of the device chosen, success depends very much on meticulous attention to detail during the fabrication. When making a direct device, a well-adapted and stable vacuum-formed base should be used and the procedure followed exactly. For example, the clinician must be sure that the anterior guidance is properly established and that the patient's jaw can be easily manipulated before adding resin to the posterior region. When the indirect procedure is used, the casts must articulate to an accurate centric relation record made at the correct occlusal vertical dimension. Inaccurate mounting is probably the most common cause for frustration and results in excessive adjustments at delivery.

Follow-Up

After delivery to the patient, the occlusion must be verified and corrected as necessary. The patient is instructed to wear the device 24 hours a day, removing it only for oral hygiene, and to return at regular weekly and biweekly intervals (or sooner if a problem is anticipated) for modification. A reduction in discomfort suggests that definitive occlusal adjustment (see Chapter 6) or restorative dentistry, or both, will probably be successful. If device therapy fails to relieve the discomfort, further evaluation and diagnosis of the etiology and parameters of the chief complaint should be pursued.

SUMMARY

Mandibular movement depends on certain anatomic limitations. The extremes, called *border movements*, are subject to restriction by the TMJs and ligaments and the teeth. Speech and mastication are examples of *functional movements*. Bruxism and clenching are examples of *parafunctional movements*. These accomplish no purposeful objective and are potentially harmful.

A balanced occlusion provides complete denture patients with stability, because there is even contact between all the teeth in each excursion. This is potentially destructive in dentate patients and is not indicated for fixed prosthodontic treatment. In a unilaterally balanced occlusion (group function), eccentric occlusal contact occurs only between posterior teeth on the laterotrusive (working) side. This may be indicated when it is important to distribute the occlusal load over multiple teeth. Mutually protected articulation offers the most desirable distribution of occlusal load. Centric relation coincides with the maximum intercuspation position, and the relationship of the maxillary and mandibular anterior teeth (the anterior guidance) is instrumental to its success.

In the presence of pathology that is potentially related to malocclusion, occlusal therapy may be indicated. Occlusal devices can serve as useful diagnostic and therapeutic adjuncts to treatment. For such patients, occlusal therapy should be initiated and completed before any substantial restorative care is undertaken.

STUDY QUESTIONS

1. Discuss the various functions of the mandibular ligaments, and relate them to their respective origins and insertions.
2. Discuss the various functions of the mandibular muscles, and relate them to their respective origins and insertions.
3. What are border movements? Draw and label Posselt's solid.
4. What are the determinants of occlusion, and what do they determine?
5. Give examples of pathologic occlusion, and list five categories with multiple associated symptoms for each category.
6. Describe a mutually protected occlusal scheme, its advantages, and indications. When is a mutually protected articulation undesirable? Why?
7. Discuss typical mandibular movement during normal function and during parafunction. What is the influence of age on chewing patterns?
8. What is the difference between a bilateral balanced occlusion, a unilateral balanced occlusion, and mutual protection?
9. What are the purposes of an occlusal device? Describe a scenario justifying its use, and explain how the device should be designed. Explain your rationale for this design.

GLOSSARY*

ab·duct \ăb dŭkt′\ *vt* (1834): to draw away from the median plane—*comp* ADDUCT

abrade \uh-brād′*vt* (1677): to rub away the external covering or layer of a part—*comp* ATTRITION, EROSION

abra·sion \ă-brā′ shun\ *n* (1656): **1:** the wearing away of a substance or structure (such as the skin or the teeth) through some unusual or abnormal mechanical process **2:** an abnormal wearing away of the tooth substance by causes other than mastication—*comp* ATTRITION, EROSION

acquired eccentric relation \a-kwīrd′ ĭk-sĕn′trĭk rĭ-lā′shun\: any eccentric relationship position of the mandible relative to the maxilla, whether conditioned or learned by habit, which will bring the teeth into contact

adaptation \ăd′ăp-tā′shun\ *n* (1610): **1:** the act or process of adapting; the state of being adapted **2:** the act of purposefully adapting two surfaces to provide intimate contact **3:** the progressive adjustive changes in sensitivity that regularly accompany continuous sensory stimulation or lack of stimulation **4:** in dentistry, (**a**) the degree of fit between a prosthesis and supporting structures, (**b**) the degree of proximity of a restorative material to a tooth preparation, (**c**) the adjustment of orthodontic bands to teeth

ad·duct \a-dŭkt′,-ă-\ *vt* (1836): to draw toward the median plane or toward the axial line—*comp* ABDUCT

ag·o·nist \ăg′a-nĭst\ *n* (ca. 1626): **1:** in physiology, a muscle that is controlled by the action of an antagonist with which it is paired **2:** in anatomy, a prime mover **3:** in pharmacology, a drug that has an affinity for and stimulates physiologic activity in cell receptors normally stimulated by naturally occurring substances

Angle's classification of occlusion \ăng′gulz klăs′a-fĭ-kā′shun ŭv a-klōō′shun\ [Edward Harley Angle, American orthodontist, 1855-1930]: *eponym* for a classification system of occlusion based on the interdigitation of the first molar teeth originally described by Angle as four major groups depending on the anteroposterior jaw relationship. Class IV is no longer used. Class I (normal occlusion or *neutrooocclusion*): the dental relationship in which there is normal anteroposterior relationship of the jaws, as indicated by correct interdigitation of maxillary and mandibular molars, but with crowding and rotation of teeth elsewhere, i.e., a dental dysplasia or arch length deficiency. Class II *(distocclusion)*: the dental relationship in which the mandibular dental arch is posterior to the maxillary dental arch in one or both lateral segments; the mandibular first molar is distal to the maxillary first molar. Class II can be further subdivided into two divisions. Division 1: bilateral distal retrusion with a narrow maxillary arch and protruding maxillary incisors. Subdivisions include right or left (unilaterally distal with other characteristics being the same). Division 2: bilateral distal with a normal or square-shaped maxillary arch, retruded maxillary central incisors, labially malposed maxillary lateral incisors, and an excessive vertical overlap. Subdivisions include right or left (unilaterally distal with other characteristics the same). Class III (*mesiooocclusion*): the dental relationship in which the mandibular arch is anterior to the maxillary arch in one or both lateral segments; the mandibular first molar is mesial to the maxillary first molar. The mandibular incisors are usually in anterior cross bite. Subdivisions include right or left (unilaterally mesial with other characteristics the same). Class IV: the dental relationship in which the occlusal relations of the dental arches present the peculiar condition of being in distal occlusion in one lateral half and in mesial occlusion in the other (no longer used).

Angle EM. Classification of malocclusion. Dental Cosmos 1899; 41:248-64, 350-7.

an·tag·on·ist \ăn-tăg′a-nĭst\ *n* (1599): **1:** a tooth in one jaw that articulates with a tooth in the other jaw—called also *dental antagonist* **2:** a substance that tends to nullify the actions of another, as a drug that binds to cell receptors without eliciting a biologic response **3:** a muscle whose action is the direct opposite of another muscle

anterior guidance \ăn-tîr′ē-or gīd′ns\: **1:** the influence of the contacting surfaces of anterior teeth on tooth limiting mandibular movements **2:** the influence of the contacting surfaces of the guide pin and anterior guide table on articulator movements—*usage* see ANTERIOR GUIDE TABLE **3:** the fabrication of a relationship of the anterior teeth preventing posterior tooth contact in all eccentric mandibular movements—see ANTERIOR PROTECTED ARTICULATION, GROUP FUNCTION, MUTUALLY PROTECTED ARTICULATION

anterior open occlusal relationship \ăn-tîr′ē-or ō′pen a-klōō′zal rĭ-lā′shen-shĭp′\: the lack of anterior tooth contact in any occluding position of the posterior teeth

arc of closure \ărk ŭv klō′zhur\: the circular or elliptic arc created by closure of the mandible, most often viewed in the mid-sagittal plane, using a reference point on the mandible (frequently either mandibular central incisors' mesial incisal edge)

arthrodial joint \är-thrō′dē al joint\: a joint that allows gliding motion of the surfaces

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ar·tic·u·lar \är tĭk′ya-ler\ *adj* (15c)**:** of or relating to a joint

articular capsule \är tĭk′ya-ler kăp′sel**:** the fibrous ligament that encloses a joint and limits its motion. It is lined with the synovial membrane

articular cartilage \är tĭk′ya-ler kär′tl-ĭj**:** a thin layer of hyaline cartilage located on the joint surfaces of some bones not found on the articular surfaces of the temporomandibular joints which is covered with an avascular fibrous tissue

attrition \a-trĭsh′un\ *n* (14c)**: 1:** the act of wearing or grinding down by friction **2:** the mechanical wear resulting from mastication or parafunction, limited to contacting surfaces of the teeth—*comp* ABRASION, EROSION

balanced articulation \băl ansd är-tĭk′ya-lā′shun**:** the bilateral, simultaneous, anterior, and posterior occlusal contact of teeth in centric and eccentric positions—see CROSS ARCH B.A., CROSS TOOTH B.A.

balancing interference \băl′ans ĭng ĭn′ter-fear′ans**:** undesirable contact(s) of opposing occlusal surfaces on the nonworking side

Bennett angle \Bĕn′ĕt ăng′gal\ *obs***:** the angle formed between the sagittal plane and the average path of the advancing condyle as viewed in the horizontal plane during lateral mandibular movements (GPT-4)

Bennett's movement [Sir Norman Godfrey Bennett, British dental surgeon, 1870-1947]: see LATEROTRUSION

Bennett NG. A contribution to the study of the movements of the mandible. Proc Roy Soc Med (Lond) 1908;1:79-88 (Odont Section)

bilateral balanced articulation: also termed *balanced articulation*, the bilateral, simultaneous anterior and posterior occlusal contact of teeth in centric and excentric positions

bo·lus \bō′lus\ *n* (1562)**:** a rounded mass, as a large pill or soft mass of chewed food

border movement \bôr′der mōōv′ment**:** mandibular movement at the limits dictated by anatomic structures, as viewed in a given plane

brux·ism \brŭk-sĭz′em\ *n* (ca. 1940)**: 1:** the parafunctional grinding of teeth **2:** an oral habit consisting of involuntary rhythmic or spasmodic nonfunctional gnashing, grinding, or clenching of teeth, in other than chewing movements of the mandible, which may lead to occlusal trauma—called also *tooth grinding*, *occlusal neurosis*

canine protected articulation \kā′nīn pra-tĕk′tid är-tĭk′ya-lā′shun**:** a form of mutually protected articulation in which the vertical and horizontal overlap of the canine teeth disengage the posterior teeth in the excursive movements of the mandible—*comp* ANTERIOR PROTECTED ARTICULATION

cap·su·lar \kăp′su-ler\ *adj* (ca. 1730)**:** pertaining to a capsule

capsular fibrosis \kăp′su-ler fī-brō′sĭs**:** fibrotic contracture of the capsular ligament of the temporomandibular joint

capsular ligament \kăp′su-ler lĭg′a-ment**:** as it relates to the temporomandibular joint, a fibrous structure that separately encapsulates the superior and inferior synovial cavities of the temporomandibular articulation

cap·sule \kăp′sal,-sōōl\ *n* (1693)**:** a fibrous sac or ligament that encloses a joint and limits its motion. It is lined with synovial membrane

centric relation \sĕn′trĭk rĭ-lā′shun**: 1:** the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterior-superior position against the shapes of the articular eminencies. This position is independent of tooth contact. This position is clinically discernible when the mandible is directed superior and anteriorly. It is restricted to a purely rotary movement about the transverse horizontal axis (GPT-5) **2:** the most retruded physiologic relation of the mandible to the maxillae to and from which the individual can make lateral movements. It is a condition that can exist at various degrees of jaw separation. It occurs around the terminal hinge axis (GPT-3) **3:** the most retruded relation of the mandible to the maxillae when the condyles are in the most posterior unstrained position in the glenoid fossae from which lateral movement can be made at any given degree of jaw separation (GPT-1) **4:** The most posterior relation of the lower to the upper jaw from which lateral movements can be made at a given vertical dimension (Boucher) **5:** a maxilla to mandible relationship in which the condyles and disks are thought to be in the midmost, uppermost position. The position has been difficult to define anatomically but is determined clinically by assessing when the jaw can hinge on a fixed terminal axis (up to 25 mm). It is a clinically determined relationship of the mandible to the maxilla when the condyle disk assemblies are positioned in their most superior position in the mandibular fossae and against the distal slope of the articular eminence (Ash) **6:** the relation of the mandible to the maxillae when the condyles are in the uppermost and rearmost position in the glenoid fossae. This position may not be able to be recorded in the presence of dysfunction of the masticatory system **7:** a clinically determined position of the mandible placing both condyles into their anterior uppermost position. This can be determined in patients without pain or derangement in the TMJ (Ramsfjord)

Boucher CO. Occlusion in prosthodontics. J PROSTHET DENT 1953; 3:633-56. Ash MM. Personal communication, July 1993.

Lang BR, Kelsey CC. International prosthodontic workshop on complete denture occlusion. Ann Arbor: The University of Michigan School of Dentistry, 1973.

Ramsfjord SP. Personal communication, July 1993.

Christensen's phenomenon \Krĭs′chen-senz fĭ-nŏm′a-nŏn′, -nen\ [Carl Christensen, Danish dentist and educator]: *eponym* for the space that occurs between opposing occlusal surfaces during mandibular protrusion

Christensen C. The problem of the bite. D Cosmos 1905;47:1184-95.

clench·ing \klĕn′chĭng\ *vt* (13c): the pressing and clamping of the jaws and teeth together frequently associated with acute nervous tension or physical effort

click·ing \klĭ′kĭng\ *n* (611): a series of clicks, such as the snapping, cracking, or noise evident on excursions of the mandible; a distinct snapping sound or sensation, usually audible (or by stethoscope) or on palpation, which emanates from the temporomandibular joint(s) during jaw movement. It may or may not be associated with internal derangements of the temporomandibular joint

condylar path \kŏn′da-lar păth\: that path traveled by the mandibular condyle in the temporomandibular joint during various mandibular movements

condylar path element \kŏn′da-lar păth ĕl′a-ment\: the member of a dental articulator that controls the direction of condylar movement

coronoid process \kôr′a-noid′, kŏr′- pro-sĕs\: the thin triangular rounded eminence originating from the anterosuperior surface of the ramus of the mandible—see HYPERPLASIA OF THE C.P.

defective occlusal contact \dĭ-fĕk′tĭv a-klōō′sal kŏn′tăkt′\ *obs*: contact that is capable of guiding the mandible from its original path of action into a different path of motion or capable of disturbing the relation between a denture base and its supporting tissues (GPT-1)

delayed disclusion \dĭ-lād′ dĭs-klōō′shun\: deferred separation of the posterior teeth due to the anterior guidance

dental articulation \dĕn′tl är-tĭk′ya-lā′shun\: the contact relationships of maxillary and mandibular teeth as they move against each other—*usage:* this is a *dynamic* process

determinants of mandibular movement \dĭ-tûr′ma-nent\: those anatomic structures that dictate or limit the movements of the mandible. The anterior determinant of mandibular movement is the dental articulation. The posterior determinants of mandibular movement are the temporomandibular articulations and their associated structures

de·tru·sion \dē-trōō′shun\ *n*: downward movement of the mandibular condyle

de·vi·a·tion \dē′vē-ā′shun\ *n* (15c): with respect to movement of the mandible, a discursive movement that ends in the centered position and is indicative of interference during movement

disk-condyle complex \dĭsk-kŏn′dīl, -dl kŏm′plĕks′\: the condyle and its disk articulation that functions as a simple hinge joint

disk \dĭsk\ *n* (1664): with respect to the temporomandibular joint, the avascular intraarticular tissue—spelled also *disc*

dis·oc·clu·sion \dĭs′a-kiōō′zhen\ *vb*: separation of opposing teeth during eccentric movemets of the mandible—see DELAYED D., IMMEDIATE D.

dynamic relations \dī-năm′ĭk rĭ-lā′shunz\ *obs*: relations of two objects involving the element of relative movement of one object to another, as the relationship of the mandible to the maxillae (GPT-4)

dys·func·tion \dĭs-fŭngk′shun\ *n* (ca. 1916): the presence of functional disharmony between the morphologic form (teeth, occlusion, bones, joints) and function (muscles, nerves) that may result in pathologic changes in the tissues or produce a functional disturbance

eccentric \ĭk-sĕn′trĭk\ *adj* (14c): **1:** not having the same center **2:** deviating from a circular path **3:** located elsewhere than at the geometric center **4:** any position of the mandible other than that which is its normal position

edge to edge articulation \ĕj tōō ĕj är-tĭk′ya-lā′shun\: articulation in which the opposing anterior teeth meet along their incisal edges when the teeth are in maximum intercuspation

elevator muscle \ĕl′a-vā′ter mŭs′el\: one of the muscles that, on contracting, elevates or closes the mandible

envelope of function \ĕn′va-lōp ŭv fŭngk′shun\: the three-dimensional space contained within the envelope of motion that defines mandibular movement during masticatory function and/or phonation

envelope of motion \ĕn′va-lōp ŭv mō′shun\: the three-dimensional space circumscribed by mandibular border movements within which all unstrained mandibular movement occurs

e·ro·sion \ĭ-rō′zhun\ *n* (1541): **1:** an eating away; a type of ulceration **2:** in dentistry, the progressive loss of tooth substance by chemical processes that do not involve bacterial action producing defects that are sharply defined, wedge-shaped depressions often in facial and cervical areas—*comp* ABFRACTION, ABRASION, ATTRITION

ex·cur·sion \ĭk-skûr′shun\ *n* (1577)**: 1:** a movement outward and back or from a mean position or axis; also, the distance traversed **2:** in dentistry, the movement occurring when the mandible moves away from maximum intercuspation

excursive movement \ĭk-skûr′sĭv mōōv′ment**:** movement occurring when the mandible moves away from maximum intercuspation

excursive movement \ĭk-skûr′sĭv mōōv′ment**:** movement occurring when the mandible moves away from maximum intercuspation

FGP: *acronym* for *Functionally Generated Path*

frontal plane \frŭn′tl**:** any plane parallel with the long axis of the body and at right angles to the median plane, thus dividing the body into front and back parts. So called because this plane roughly parallels the frontal suture of the skull

functional mandibular movements' \fŭngk′sha-nal măn-dĭb′ū-lar mōōv′ments**:** all normal, proper, or characteristic movements of the mandible made during speech, mastication, yawning, swallowing, and other associated movements

gnath·ol·o·gy \năth′ŏl-a-gē\ *n***:** the science that treats the biology of the masticatory mechanism as a whole: that is, the morphology, anatomy, histology, physiology, pathology, and the therapeutics of the jaws or masticatory system and the teeth as they relate to the health of the whole body, including applicable diagnostic, therapeutic, and rehabilitation procedures

group function \grōōp fŭngk′shun**:** multiple contact relations between the maxillary and mandibular teeth in lateral movements on the working side whereby simultaneous contact of several teeth acts as a group to distribute occlusal forces

Hanau's Quint [Rudolph L. Hanau, (1881-1930) Buffalo, New York, U.S. engineer, born Capetown, South Africa]**:** rules for balanced denture articulation including incisal guidance, condylar guidance, cusp length, the plane of occlusion, and the compensating curve described by Rudolph Hanau in 1926

Hanau R. Articulation defined, analyzed, and formulated. J Am Dent Assoc 1926;13:1694-709.

horizontal plane \hôr′ĭ-zŏn′tl, hŏr- plān**:** any plane passing through the body at right angles to both the median and frontal planes, thus dividing the body into upper and lower parts; in dentistry, the plane passing through a tooth at right angles to its long axis

horizontal overlap \hôr′ĭ-zŏn-tl, hŏr′- ō′ver-lăp′**:** the projection of teeth beyond their antagonists in the horizontal plane

immediate mandibular lateral translation \ĭ-mē′dē-ĭt măn-dĭb′ya-lar lăt′ar-al trăns-lā′shun**:** the translatory portion of lateral movement in which the nonworking side condyle moves essentially straight and medially as it leaves the centric relation position—see also EARLY MANDIBULAR LATERAL TRANSLATION; PROGRESSIVE MANDIBULAR LATERAL TRANSLATION

incisal guidance \ĭn-sī′zal gīd′ans**: 1:** the influence of the contacting surfaces of the mandibular and maxillary anterior teeth on mandibular movements **2:** the influence of the contacting surfaces of the guide pin and guide table on articulator movements

incisal guide angle \ĭn-sī′zal gīd ăng′gal**: 1:** anatomically, the angle formed by the intersection of the plane of occlusion and a line within the sagittal plane determined by the incisal edges of the maxillary and mandibular central incisors when the teeth are in maximum intercuspation **2:** on an articulator, that angle formed, in the sagittal plane, between the plane of reference and the slope of the anterior guide table, as viewed in the sagittal plane

instantaneous axis of rotation \ĭn′stan-tā′nē-as ăk′sĭs ŭv rō-tā′shun**:** the hypothetical center of rotation of a moving body, viewed in a given plane, at any point in time; for any body that has planar motion, there exists, at any instant, some points that have zero velocity and will be fixed at a given instant. The line joining these points is the *instantaneous axis of rotation*. The intersection of this line with the plane of motion is called the *instantaneous center of rotation*

intercondylar distance \ĭn′ter-kŏn′da-lar dĭs′tans**:** the distance between the occluding surfaces of the maxillary and mandibular teeth when the mandible is in a specific position

in·ter·fer·ence \ĭn′ter-fîr′ans\ *n* (1783)**:** in dentistry, any tooth contacts that interfere with or hinder harmonious mandibular movement

isometric contraction \ī′sa-mĕt′rĭk kon-trăk′shun**:** muscular contraction in which there is no change in the length of the muscle during contraction

lateral condylar path \lăt′ar-al kŏn′da-lar păth**:** the path of movement of the condyle-disk assembly in the joint cavity when a lateral mandibular movement is made

lateral mandibular relation \lăt′ar-al măn-dĭb′ya-lar rĭ-lā′shun**:** the relationship of the mandible to the maxillae in a position to the left or right of the midsagittal plane

lateral movement \lăt′ar-al mōōv′ment\ *obs***:** a movement from either right or left of the midsagittal plane (GPT-4)

lat·ero·de·tru·sion \lăt′ar-ō-de-trōō′zhun\ *n*: lateral and downward movement of the condyle on the working side—see LATEROTRUSION

lat·ero·pro·tru·sion \lăt′ar-al-prō-trōō′zhun\ *n*: a protrusive movement of the mandibular condyle in which there is a lateral component

lat·ero·re·tru·sion \lăt-ar-ō-rĭ-trōō′shun\ *n*: lateral and backward movement of the condyle on the working side

lat·ero·sur·tru·sion \lăt-ar-ō-sûr-trōō′shun\ *n*: lateral and upward movement of the condyle on the working side—see LATEROTRUSION

lat·ero·tru·sion \lăt-ar-ō-trōō′shun\ *n*: condylar movement on the working side in the horizontal plane. This term may be used in combination with terms describing condylar movement in other planes, for example, *laterodetrusion, lateroprotrusion, lateroretrusion,* and *laterosurtrusion*

mal·oc·clu·sion \măl′a-klōō′shun\ *n* (1888): **1:** any deviation from a physiologically acceptable contact between the opposing dental arches **2:** any deviation from a normal occlusion—see ANGLE'S CLASSIFICATION OF OCCLUSION

man·di·ble \măn′da-bal\ *n* (15c): the lower jawbone

mandibular condyle: the articular process of the mandible, called also the *head of the mandible*—see also CONDYLE

mandibular hinge position \măn-dĭb′ya-lar hĭnj pa-zish′an\ *obs*: the position of the mandible in relation to the maxilla at which opening and closing movements can be made on the hinge axis (GPT-4)

mandibular movement \măn-dĭb′ya-lar mōōv′ment\: any movement of the lower jaw

mandibular side shift: see MANDIBULAR TRANSLATION

mandibular translation \măn-dĭb′ya-lar trăns-lā′shun\: the translatory (medio-lateral) movement of the mandible when viewed in the frontal plane. While this has not been demonstrated to occur as an immediate horizontal movement when viewed in the frontal plane, it could theoretically occur in an essentially pure translatory form in the early part of the motion or in combination with rotation in the latter part of the motion or both—see also EARLY MANDIBULAR LATERAL TRANSLATION, IMMEDIATE MANDIBULAR LATERAL TRANSLATION, PROGRESSIVE MANDIBULAR LATERAL TRANSLATION

mas·ti·ca·tion \măs′tĭ-kā′shun\ *n* (1649): the process of chewing food for swallowing and digestion

masticatory cycle \măs′tĭ-ka-tôr′ē, -tōr′ē sī′kal\: a three dimensional representation of mandibular movement produced during the chewing of food

masticatory performance \măs′tĭ-ka-tôr′ē par-fôr′mans\: a measure of the comminution of food attainable under standardized testing conditions

maximal intercuspal contacts \măk′sa-mal ĭn′ter-kŭs′pal′ kŏn′tăkts′\: tooth contact in the maximum intercuspal position

maximal intercuspal position \măk′sa-mal ĭn′ter-kŭs′pal′ pa-zĭsh′an\: the complete intercuspation of the opposing teeth independent of condylar position, sometimes referred to as the best fit of the teeth regardless of the condylar position—called also *maximal intercuspation*—*comp* CENTRIC OCCLUSION

median line \mē′dē-an līn\: the centerline dividing a body into the right and left

me·di·o·tru·sion \mē′dē-ō-trōō′shun\ *n*: a movement of the condyle medially—see NONWORKING SIDE

me·nis·cus \ma-nĭs′kas\ *n, pl* **me·nis·ci** \ma-nĭs′ī\: see DISK

mus·cle \mŭs′al\ *n* (14c): an organ that by contraction produces movements of an animal; a tissue composed of contractile cells or fibers that effect movement of an organ or part of the body

muscle hyperalgesia \mŭs′al hī′par-ăl-gē′sha\: increased sensitivity to pain in a muscle evoked by stimulation at the site of pain in the muscle

muscle marking: see BORDER MOLDING

muscular splinting \mŭs-kya′lar splĭnt′ĭng\: contraction of a muscle or group of muscles attended by interference with function and producing involuntary movement and distortion; differs from *muscle spasm* in that the contraction is not sustained when the muscle is at rest

musculoskeletal pain \mŭs′kya-lō-skĕl′ĭ-tl pān\: deep, somatic pain that originates in skeletal muscles, facial sheaths, and tendons (myogenous pain), bone and periosteum (osseous pain), joint, joint capsules, and ligaments (arthralgic pain), and in soft connective tissues

mutually protected articulation \myōō′chōō-al-lē pratĕk′tĭd är-tĭk′ya-lā′shun\: an occlusal scheme in which the posterior teeth prevent excessive contact of the anterior teeth in maximum intercuspation, and the anterior teeth disengage the posterior teeth in all mandibular excursive movements. Alternatively, an occlusal scheme in which the anterior teeth disengage the posterior teeth in all mandibular excursive movements, and the posterior teeth prevent excessive contact of the anterior teeth in maximum intercuspation

mutually protected occlusion: see MUTUALLY PROTECTED ARTICULATION

my·al·gia \mī-ăl′jē-a\ *n* (1860): pain in a muscle or muscles

mylohyoid concavity \mī′la-hoid kŏn-kăv′ĭ-tē\: the fossa in the mandible below the mylohyoid line in the molar region

my·o·cen·tric \mī′a-sĕn′trĭk\ *adj*: that terminal point in space in which, with the mandible in rest position, subsequent colonic muscle contraction will raise the mandible through the interocclusal space along the myocentric (muscle balanced) trajectory. Also described as the initial occlusal contact along the myocentric trajectory (isotonic closure of the mandible from rest position)

Jankelson B. Dent Clin North Am 1979;23:157-68.

Jankelson BR, Polley ML. Electromyography in clinical dentistry. Seattle: Myotronica Research Inc, 1984:52.

myogenous pain \mī′a-jēn′ŭs\: deep somatic musculoskeletal pain originating in skeletal muscles, fascial sheaths, or tendons

neck of the condylar process \nĕk ŭv tha kŏn′dah lĕr prŏ sĕs\: the constricted inferior portion of the mandibular condylar process that is continuous with the ramus of the mandible; that portion of the condylar process that connects the mandibular ramus to the condyle

nonworking side \nŏn-wûr′kĭng sīd\: that side of the mandible that moves toward the median line in a lateral excursion. The condyle on that side is referred to as the *nonworking side condyle*

nonworking side condyle \nŏn-wûr′kĭng sīd kŏn′dĭl\: the condyle on the nonworking side

nonworking side interference \nŏn-wûr′kĭng sīd ĭn′tar-fîr′ans\: undesirable contacts of the opposing occlusal surfaces on the nonworking side

noxious stimulus \nŏk′shas stĭm′ya-las\: a tissue damaging stimulus

oc·clu·sal \a-klōō′zal, -sal\ *adj* (1897): pertaining to the masticatory surfaces of the posterior teeth, prostheses, or occlusion rims

occlusal balance \a-klōō′zal, -sal băl′ans\: a condition in which there are simultaneous contacts of opposing teeth or tooth analogues (i.e., occlusion rims) on both sides of the opposing dental arches during eccentric movements within the functional range

occlusal contact \a-klōō′zal, -sal kŏn′tăkt′\: **1:** the touching of opposing teeth on elevation of the mandible **2:** any contact relation of opposing teeth—see DEFLECTIVE O.C, INITIAL O.C

occlusal device \a-klōō′zal, -sal dĭ-vīs′\: any removable artificial occlusal surface used for diagnosis or therapy affecting the relationship of the mandible to the maxillae. It may be used for occlusal stabilization, for treatment of temporomandibular disorders, or to prevent wear of the dentition

occlusal disharmony \a-klōō′zal, -sal dĭs-hăr′ma-nē\: a phenomenon in which contacts of opposing occlusal surfaces are not in harmony with other tooth contacts and/or the anatomic and physiologic components of the craniomandibular complex

occlusal wear \a-klōō′zal, -sal wâr\: loss of substance on opposing occlusal units or surfaces as the result of attrition or abrasion

occlusion \a-klōō′shun\ *n* (1645): **1:** the act or process of closure or of being closed or shut off **2:** the static relationship between the incising or masticating surfaces of the maxillary or mandibular teeth or tooth analogues—see CENTRIC O., COMPONENTS OF O., ECCENTRIC O., LINE OF O., LINEAR O., MONOPLANE O., PATHOGENIC O., SPHERICAL FORM OF O.—*comp* ARTICULATION

open occlusal relationship \ō′pan a-klōō′zal, -sal rĭ-lā′shun-shĭp′\: the lack of tooth contact in an occluding position—see ANTERIOR O.O.R., POSTERIOR O.O.R.

opening movement \ō′pa-nĭng\ *obs*: movement of the mandible executed during jaw separation; movement executed during jaw separation (GPT-1)—see ENVELOPE OF MOTION

para·func·tion \păr′a-fŭngk′shun\ *adj*: disordered or perverted function

pathogenic occlusion \păth′a-jĕn′ĭk\: an occlusal relationship capable of producing pathologic changes in the stomatognathic system

posterior \pŏ-stîr′ē-ar, pō-\ *adj* (1534): **1:** situated behind or in back of; caudal **2:** in human anatomy, dorsal

posterior border movement \pŏ-stîr′ē-ar, pō- bôr′dar mōōv′mant\: movements of the mandible along the posterior limit of the envelope of motion

posterior determinants of mandibular movement \pŏ-stîr′ē-ar, pō- dĭ-tûr′ma-nant ŭv măn′dĭb-ū-lar mōōv′mant\: the temporomandibular articulations and associated structures—see DETERMINANTS OF MANDIBULAR MOVEMENT

posterior determinants of occlusion: see DETERMINANTS OF MANDIBULAR MOVEMENT

progressive mandibular lateral translation \pra-grĕs′ĭv măn-dĭb′ya-lar lăt′ar-al trăns-lā′shun\: **1:** the translatory portion of mandibular movement when viewed in a specified body plane **2:** the translatory portion of mandibular movement as viewed in a specific body plane that occurs at a rate or amount that is directly proportional to the forward movement of the nonworking condyle—see MANDIBULAR TRANSLATION

proprioception \prō′prē-ō-sĕp′shun\ *n* (1906): the reception of stimulation of sensory nerve terminals within the tissues of the body that give information concerning

movements and the position of the body; perception mediated by proprioceptors

pro·tru·sion \prō-trōō′zhan\ *n* (1646)**:** a position of the mandible anterior to centric relation—see LATEROPROTRUSION

protrusive condyle path \prō-trōō′sĭv kŏn′dīl′, -dl păth**:** the path the condyle travels when the mandible is moved forward from its initial position

pterygoid plates \tĕr′ĭ-goid′ plāts**:** broad, thin, wing-shaped processes of the spheroid bone separated by the pterygoid fossa. The inferior end of the medial plate terminates in a long curved process or hook for the tendon of the tensor veli palatini muscle. The lateral plate gives attachment to the medial and lateral pterygoid muscles

retrodiscal tissue \rĕt′rō-dĭs′kal tĭsh′ōō**:** a mass of loose, highly vascular and highly innervated, connective tissue attached to the posterior edge of the articular disk and extending to and filling the loose folds of the posterior capsule of the temporomandibular joint—called also *bilaminar zone*

retruded contact position \rĭ-trōō′dĭd kŏn′tăkt pa-zĭsh′an**:** that guided occlusal relationship occurring at the most retruded position of the condyles in the joint cavities. A position that may be more retruded than the centric relation position

re·tru·sion \rĭ-trōō′shun\ *vb***:** movement toward the posterior

re·tru·sive \rĭ-trōō′sĭv\ *adj***:** denotes a posterior location

ro·ta·tion \rō-tā′shun\ *n* (1555)**: 1:** the action or process of rotating on or as if on an axis or center **2:** the movement of a rigid body in which the parts move in circular paths with their centers on a fixed line called the axis of rotation. The plane of the circle in which the body moves is perpendicular to the axis of rotation

sag·it·tal \săj′ĭ-tl\ *adj* (1541)**:** situated in the plane of the cranial sagittal suture or parallel to that plane—*usage:* see SAGITTAL PLANE

sagittal plane \săj′ĭ-tl plān**:** any vertical plane or section parallel to the median plane of the body that divides a body into right and left portions

silent period \sī′lant pĭr′ē-ad**:** a momentary electromyographic decrease in elevator muscle activity on initial tooth contact presumably due to the inhibitory effect of stimulated periodontal membrane receptors

speaking space \spē′kĭng spās**:** the space that occurs between the incisal or/and occlusal surfaces of the maxillary and mandibular teeth during speech

[1]splint \splĭnt\ *n* (14c)**: 1:** a rigid or flexible device that maintains in position a displaced or movable part; also used to keep in place and protect an injured part **2:** a rigid or flexible material used to protect, immobilize, or restrict motion in a part—see ANDERSON S., CAP S., ESSIG S., FUNCTIONAL OCCLUSAL S., GUNNING'S S., INTERDENTAL S., KINGSLEY S., LABIAL S., LINGUAL S., PROVISIONAL S., RESIN-BONDED S., SOFT S., SURGICAL S., WIRE S.

static relation \stăt′ĭk rĭ-lā′shun**:** the relationship between two parts that are not in motion

stomatognathic system \stō-măt′a-nā′thĭk sĭs′tum**:** the combination of structures involved in speech, receiving, mastication, and deglutition as well as parafunctional actions

synovial fluid \sĭ-nō′vē-al flōō′ĭd**:** a viscid fluid contained in joint cavities and secreted by the synovial membrane

temporomandibular disorders \tĕm′pa-rō′măn-dĭb′ya-lar dĭs-ôr′derz**: 1:** conditions producing abnormal, incomplete, or impaired function of the temporomandibular joint(s) **2:** *(obs)* a collection of symptoms frequently observed in various combinations first described by Costen (1934, 1937), which he claimed to be reflexes due to irritation of the auriculotemporal and/or chorda tympanic nerves as they emerged from the tympanic plate caused by altered anatomic relations and derangements of the temporomandibular joint associated with loss of occlusal vertical dimension, loss of posterior tooth support, and/or other malocclusions. The symptoms can include headache about the vertex and occiput, tinnitus, pain about the ear, impaired hearing and pain about the tongue—*acronym* TMD

temporomandibular joint \tĕm′pa-rō′măn-dĭb′ya-lar joint**: 1.** the articulation between the temporal bone and the mandible. It is a bilateral diarthrodial, bilateral ginglymoid joint **2:** the articulation of the condylar process of the mandible and the intraarticular disk with the mandibular fossa of the squamous portion of the temporal bone; a diarthrodial, sliding hinge (ginglymus) joint. Movement in the upper joint compartment is mostly translational, whereas that in the lower joint compartment is mostly rotational. The joint connects the mandibular condyle to the articular fossa of the temporal bone with the *temporomandibular disk* interposed

terminal hinge axis: see TRANSVERSE HORIZONTAL AXIS

TMD: *acronym* for *TemporoMandibular Disorders*—see TEMPOROMANDIBULAR DISORDERS

trans·la·tion \trăn-zĭsh′an, -sĭsh′-\ *n* (14c)**:** that motion of a rigid body in which a straight line passing through any two points always remains parallel to its initial position. The motion may be described as a sliding or gliding motion

translatory movement \trănz-lă′tōr-ē\ *obs*: the motion of a body at any instant when all points within the body are moving at the same velocity and in the same direction (GPT-1)

transverse horizontal axis \trănz-vûrs′, trănz-, trănz′vûrs′, trănz′-\: an imaginary line around which the mandible may rotate within the sagittal plane

traumatogenic occlusion \trou′ma-ta-jĕn′ĭk a-klōō′zhun\ *obs*: an occluding of the teeth that is capable of producing injury to oral structures (GPT-4)

vertical axis of the mandible \vûr′tĭ-kul ăk′sĭs ŭv tha măn′dĭ-bal\: an imaginary line around which the mandible may rotate through the horizontal plane

vertical overlap \vûr′tĭ-kal ō′var-lăp\: **1:** the distance teeth lap over their antagonists as measured vertically; especially the distance the maxillary incisal edges extend below those of the mandibular teeth. It may also be used to describe the vertical relations of opposing cusps **2:** the vertical relationship of the incisal edges of the maxillary incisors to the mandibular incisors when the teeth are in maximum intercuspation

wear facet \wâr făs′ĭt\: any wear line or plane on a tooth surface caused by attrition

working side \wûr′kĭng sīd\: the side toward which the mandible moves in a lateral excursion

working side contacts \wûr′kĭng sīd kŏn′tăkts\: contacts of teeth made on the side of the articulation toward which the mandible is moved during working movements

REFERENCES

1. Okeson JP: Management of Temporomandibular Disorders and Occlusion, 5th ed, St. Louis, Mosby, 2003.
2. Schweitzer JM: Concepts of occlusion: a discussion. Dent Clin North Am 7:649, 1963.
3. Proffit WR, Fields HW Jr: Contemporary Orthodontics, 3rd ed. St. Louis, Mosby, 1999.
4. Bennett NG: A contribution to the study of the movements of the mandible. Odontol Sec R Soc Med Trans 1:79, 1908. (Reprinted in J Prosthet Dent 8:41, 1958.)
5. Posselt U: Movement areas of the mandible, J Prosthet Dent 7:375, 1957.
6. Goldenberg BS, et al: The loss of occlusion and its effect on mandibular immediate side shift. J Prosthet Dent 63:163, 1990.
7. Pelletier LB, Campbell SD: Evaluation of the relationship between anterior and posterior functionally disclusive angles. II. Study of a population. J Prosthet Dent 63:536, 1990.
8. Hayasaki H, et al: A calculation method for the range of occluding phase at the lower incisal point during chewing movements using the curved mesh diagram of mandibular excursion (CMDME). J Oral Rehabil 26:236, 1999.
9. Lundeen HC, Gibbs CH: Advances in Occlusion. Boston, John Wright PSG, 1982.
10. Ogawa T, et al: Inclination of the occlusal plane and occlusal guidance as contributing factors in mastication. J Dent 26:641, 1998.
11. Wickwire NA, et al: Chewing patterns in normal children. Angle Orthod 51:48, 1981.
12. Lavigne G, et al: Evidence that periodontal pressoreceptors provide positive feedback to jaw closing muscles during mastication. J Neurophysiol 58:342, 1987.
13. Burnett CA, Clifford TJ: Closest speaking space during the production of sibilant sounds and its value in establishing the vertical dimension of occlusion. J Dent Res 72:964, 1993.
14. Pound E: The mandibular movements of speech and their seven related values. J Prosthet Dent 16:835, 1966.
15. Pound E: Let /S/ be your guide. J Prosthet Dent 38: 482, 1977.
16. Howell PG: Incisal relationships during speech. J Prosthet Dent 56:93, 1986.
17. Rivera-Morales WC, Mohl ND: Variability of closest speaking space compared with interocclusal distance in dentulous subjects. J Prosthet Dent 65:228, 1991.
18. Duckro PN, et al: Prevalence of temporomandibular symptoms in a large United States metropolitan area. Cranio 8:131, 1990.
19. Hathaway KM: Bruxism. Definition, measurement, and treatment. In Fricton JR, Dubner RB, eds: Orofacial Pain and Temporomandibular Disorders, New York, Raven Press, 1995.
20. Hublin C, et al: Sleep bruxism based on self-report in a nationwide twin cohort. J Sleep Res 7:61, 1998.
21. Macaluso GM, et al: Sleep bruxism is a disorder related to periodic arousals during sleep. J Dent Res 77:565, 1998.
22. Madrid G, et al: Cigarette smoking and bruxism. Percept Mot Skills 87:898, 1998.
23. Mongini F, Tempia-Valenta G: A graphic and statistical analysis of the chewing movements in function and dysfunction. J Craniomandib Pract 2:125, 1984.
24. Faulkner KD: Preliminary studies of some masticatory characteristics of bruxism. J Oral Rehabil 16:221, 1989.
25. Mohl ND, et al: Devices for the diagnosis and treatment of temporomandibular disorders. Part I:

introduction, scientific evidence, and jaw tracking. J Prosthet Dent 63:198, 1990.
26. Rugh JD, Solberg WK: Electromyographic studies of bruxist behavior before and during treatment. J Calif Dent Assoc 3(9):56, 1975.
27. Lobbezoo F, Lavigne GJ: Do bruxism and temporomandibular disorders have a cause-and-effect relationship? J Orofac Pain 11:15, 1997.
28. Grippo JO: Abfractions: a new classification of hard tissue lesions of teeth. J Esthet Dent 3:14, 1991.
29. Owens BM, Gallien GS: Noncarious dental "abfraction" lesions in an aging population. Compend Contin Educ Dent 16:552, 1995.
30. Sears VH: Balanced occlusions. J Am Dent Assoc 12:1448, 1925.
31. Schuyler CH: Considerations of occlusion in fixed partial dentures. Dent Clin North Am 3:175, 1959.
32. Schuyler CH: An evaluation of incisal guidance and its influence in restorative dentistry. J Prosthet Dent 9:374, 1959.
33. Mann AW, Pankey LD: Concepts of occlusion: the P.M. philosophy of occlusal rehabilitation. Dent Clin North Am 7:621, 1963.
34. Stuart C, Stallard H: Concepts of occlusion. Dent Clin North Am 7:591, 1963.
35. D'Amico A: Functional occlusion of the natural teeth of man. J Prosthet Dent 11:899, 1961.
36. Ogawa T, et al: Pattern of occlusal contacts in lateral positions: canine protection and group function validity in classifying guidance patterns. J Prosthet Dent 80:67, 1998.
37. Bakke M, et al: Occlusal control of mandibular elevator muscles. Scand J Dent Res 100:284, 1992.
38. McDevitt WE, Warreth AA: Occlusal contacts in maximum intercuspation in normal dentitions. J Oral Rehab 24:725, 1997.
39. Dawson PE: Evaluation, Diagnosis, and Treatment of Occlusal Problems, 2nd ed, St. Louis, Mosby, 1989.
40. Stuart CE, Stallard H: Diagnosis and treatment of occlusal relations of the teeth. Texas Dent J 75:430, 1957.
41. Ramfjord S, Ash MM: Occlusion, 4th ed. Philadelphia, WB Saunders, 1994.
42. Ekfeldt A: Incisal and occlusal tooth wear and wear of some prosthodontic materials: an epidemiological and clinical study. Swed Dent J Suppl 65:1, 1989.
43. Imfeld T: Dental erosion. Definition, classification and links. Eur J Oral Sci 104:151, 1996.
44. Lewis KJ, Smith BGN: The relationship of erosion and attrition in extensive tooth loss. Case reports. Br Dent J 135:400, 1973.
45. Rytomaa I, et al: Bulimia and tooth erosion. Acta Odontol Scand 56:36, 1998.
46. Simmons JJ 3rd, Hirsh M: Role of chemical erosion in generalized attrition. Quintessence Int 29:793, 1998.
47. Christensen LV: Facial pain and internal pressure of masseter muscle in experimental bruxism in man. Arch Oral Biol 16:1021, 1971.
48. Ishigaki S, et al: Clinical classification of maximal opening and closing movements. Int J Prosthod 2:148, 1989.
49. Leader JK, et al: The influence of mandibular movements on joint sounds in patients with temporomandibular disorders. J Prosthet Dent 81:186, 1999.
50. Mikami DB: A review of psychogenic aspects and treatment of bruxism. J Prosthet Dent 37:411, 1977.
51. Schwartz LL: A temporomandibular joint pain-dysfunction syndrome. J Chron Dis 3:284, 1956.
52. Gelb H: An orthopedic approach to occlusal imbalance and temporomandibular dysfunction. Dent Clin North Am 23:181, 1979.
53. Dawson PE: Position paper regarding diagnosis, management, and treatment of temporomandibular disorders. J Prosthet Dent 81:174, 1999.
54. Okeson JP: Management of Temporomandibular Disorders and Occlusion, 5th ed, chap 15. St. Louis, Mosby, 1998.
55. Dao TT, Lavigne GJ: Oral splints: the crutches for temporomandibular disorders and bruxism? Crit Rev Oral Biol Med 9:345, 1998.

5

PERIODONTAL CONSIDERATIONS



Robert F. Baima

KEY TERMS

attached gingiva
bifurcation
débridement
gingiva
guided tissue regeneration
hemisection
interdental papillae
marginal gingiva
mucogingival junction (MGJ)
reflection
Sharpey's fibers

In the fabrication of any fixed prosthesis, the practitioner must determine the periodontal status of the involved abutment teeth. This allows a reliable and accurate prognosis for the restoration. Because periodontal disease is a major cause of tooth loss in adults, the dentist must be aware of the basic concepts and clinical modes of therapy available in periodontics to be able to develop an appropriate diagnosis and treatment plan.

This chapter reviews those concepts and treatment modalities and gives the practitioner a better understanding of periodontics and how it relates to restorative dentistry.

ANATOMY

The lining of the oral cavity consists of three types of mucosa, each with a different function[1]:

1. Masticatory (keratinized) mucosa, covering the **gingiva** and hard palate.
2. Lining or reflecting mucosa, covering the lips, cheeks, vestibule, alveoli, floor of the mouth, and soft palate.
3. Specialized (sensory) mucosa, covering the dorsum of the tongue and taste buds.

Gingiva

Normal gingiva (Fig. 5-1)—exhibiting no fluid exudate or inflammation caused by bacterial plaque—is pink and stippled. It varies in width from 1 to 9 mm and extends from the free margin of the gingiva to the alveolar mucosa. The gingiva and alveolar mucosa are separated by a demarcation called the ***mucogingival junction (MGJ),*** which marks the differentiation between stippled keratinized tissue and smooth, shiny mucosa; the latter contains more elastic fibers in its connective tissue. Apical to the MGJ, the alveolar mucosa then forms the vestibule and attaches to the muscles and fascia of the lips and cheeks.

The gingiva (Fig. 5-2) consists of three parts:

1. Free **(marginal) gingiva,** which extends from the most coronal aspect of the gingiva to the epithelial attachment with the tooth.
2. **Attached gingiva,** which extends from the level of the epithelial attachment to the junction between the gingiva and the alveolar mucosa (the MGJ).
3. **Interdental papillae,** which are triangular projections of gingivae filling the area between



Fig. 5-1
Normal gingiva.

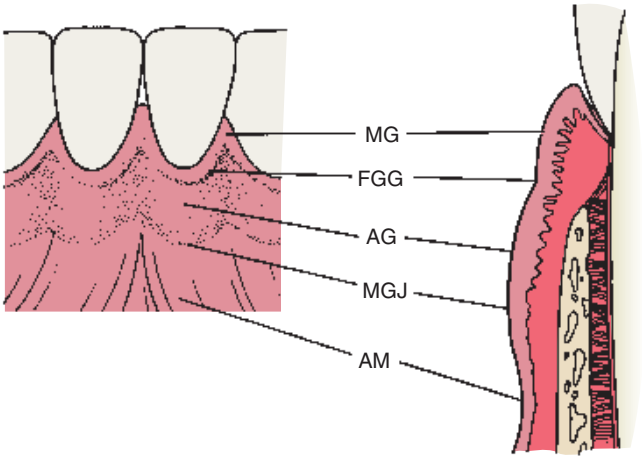


Fig. 5-2
Normal gingival structure and anatomic landmarks. *MG*, Marginal gingiva; *FGG*, free gingival groove; *AG*, attached gingiva; *MGJ*, mucogingival junction; *AM*, alveolar mucosa. *(Redrawn from Schluger S, et al: Periodontal Disease: Basic Phenomena, Clinical Management, and Occlusal and Restorative Interrelationships, 2nd ed. Philadelphia, Lea & Febiger, 1990.)*

adjacent teeth and consisting of a buccal and a lingual component separated by a central concavity (the col).

A V-shaped depression on the labial or buccal surface of the gingiva at or somewhat apical to the level of the epithelial attachment to the tooth is called the *free gingival groove*. It is not always readily apparent clinically but can be seen histologically and may serve as a reference point for dividing the free gingiva from the labially or buccally attached gingiva.[2,3]

The gingiva consists of dense collagen fibers, sometimes referred to as the *gingivodental ligament*, which can be divided into alveologingival, dentogingival, circular, dentoperiosteal, and transseptal groups. These fibers firmly bind the gingiva to the teeth and are continuous with the underlying alveolar periosteum. A more detailed description can be found in standard periodontal texts.[4-8]

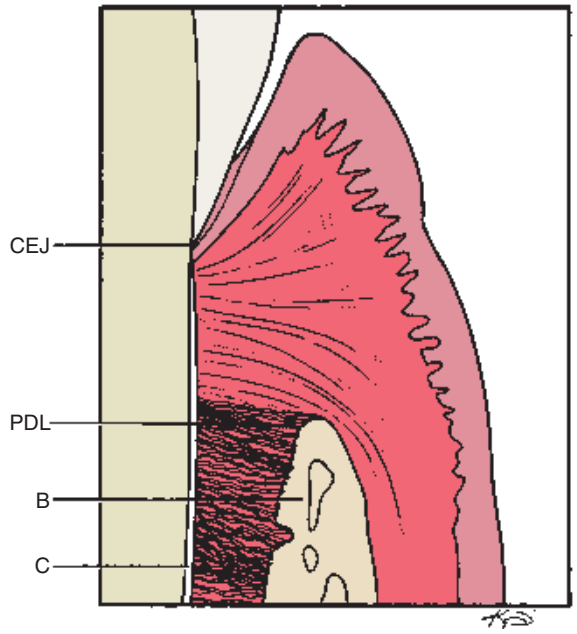


Fig. 5-3
Normal tooth-gingival interface and coronal periodontium. *CEJ*, cementoenamel junction; *PDL*, periodontal ligament. *B*, bone; C, cementum.

Periodontium

The periodontium is a connective tissue structure attached to the periosteum of both the mandible and the maxilla that anchors the teeth in the mandibular and maxillary alveolar processes. It provides attachment and support, nutrition, synthesis and resorption, and mechanoreception. The main element of the periodontium is the periodontal ligament (PDL), which consists of collagenous fibers embedded in bone and cementum, giving support to the tooth in function (Fig. 5-3). These fibers, also known as **Sharpey's fibers,** follow a wavy course and terminate in either cementum or bone. There are five principal fiber groups in the PDL that traverse the space between the tooth root and alveolar bone, providing attachment and support[4]:

1. Transseptal fibers, which extend interproximally between adjacent teeth. (Their ends are embedded in cementum.)
2. Alveolar crest fibers, which begin just apical to the epithelial attachment and extend from cementum to the alveolar crest.
3. Horizontal fibers, which course at right angles from cementum to the alveolar bone.

4. Oblique fibers, which extend in an oblique direction apically, attaching cementum to the alveolar bone. (They are the most numerous fibers.)
5. Apical fibers, which radiate from cementum into the alveolar bone at the apex of the root.

There are also smaller, irregularly arranged collagen fibers interspersed between the principal fiber groups. In addition, the PDL contains elastic fibers[9] as well as oxytalan fibers.[10]

Cellular elements found in the PDL include fibroblasts (the main synthetic cells, which produce collagen and other proteoglycans), cementoblasts and cementoclasts, osteoblasts and osteoclasts (which maintain the viability of their respective tissues), and mast cells and epithelial rests (which play a role in pathologic conditions of the periodontium).[1]

Dentogingival Junction

At the base of the gingival sulcus (crevice) is the epithelium-tooth interface, also known as the *dentogingival junction (DGJ)*. This structural relationship between hard and soft tissues is unique in the body. At the ultrastructural level, it is made up of hemidesmosomes and a basal lamina, which anchor the epithelial cells to the enamel and cemental surfaces.[4,11]

The depth of the sulcus varies in healthy individuals, averaging 1.8 mm.[12] In general, the shallower it is, the more likely the gingiva is to be in a state of health. Sulcular depths up to 3 mm are considered maintainable. The continued maintenance of the gingiva in a state of health depends on tight, shallow sulci, which in turn depend on optimal plaque control and ensure the success of periodontal therapy, as well as affording a good prognosis for subsequent restorative treatment.

DISEASES OF THE PERIODONTIUM

The general term *periodontal disease* is used to describe any condition of the periodontium other than normal. It covers such pathologic states as gingival hyperplasia, juvenile periodontitis (also known as *periodontosis*), and acute necrotizing ulcerative gingivitis—all distinct clinical entities that warrant specific treatment. Information concerning these disease states is available in any of the standard periodontal texts.[4-8] Periodontal disease must be recognized and treated before fixed prosthodontics so that the gingival tissue levels can be determined for proper margin placement, esthetics, and gingival displacement (with an $AlCl_3$-impregnated or plain cord; see Chapter 14). Only when the gingiva and periodontium are in an optimal state of health can these determinations be made with ease or predictability.

This discussion is limited to the etiology and progression of the inflammatory gingivitis-periodontitis lesion, which affects the majority of adults[13] and constitutes the bulk of pathologic disorders necessitating treatment before restorative dentistry.

Etiology

Most gingival and periodontal diseases result from microbial plaque, which causes inflammation and its subsequent pathologic processes. Other contributors to inflammation include calculus, acquired pellicle, materia alba, and food debris.[5,14]

Terminology

Microbial plaque

Microbial plaque (Fig. 5-4) is a sticky substance composed of bacteria and their byproducts in an extracellular matrix; it also contains substances from the saliva, diet, and serum. It is basically a product of the growth of bacterial colonies and is the initiating factor in gingival and periodontal disease. If left undisturbed, it gradually covers an entire tooth surface and can be removed only by mechanical means.

Calculus

Dental calculus is a chalky or dark deposit attached to the tooth structure. It is essentially microbial plaque that has undergone mineralization over time. Calculus can be found on tooth structure in a supragingival and/or a subgingival location.

Acquired pellicle

Pellicle is a thin brown or gray film of salivary proteins that develops on teeth after they have been



Fig. 5-4
Gross plaque and calculus accumulation on the mandibular anterior teeth.

cleaned. It frequently forms the interface between the tooth surface and dental deposits.

Materia alba

Materia alba is a white coating composed of microorganisms, dead epithelial cells, and leukocytes that adheres loosely to the tooth. It can be removed from the tooth surface by water spray or by rinsing.

Structure of the dental plaque

Dental plaque consists mainly of microorganisms, scattered leukocytes, enzymes, food debris, epithelial cells, and macrophages in an intracellular matrix. Bacteria make up 70% of the solid portion of the mass. The remainder is an intracellular matrix consisting of carbohydrates, proteins, and calcium and phosphate ions.[15-17]

As the plaque mass increases and matures, the flora progresses apically from a supragingival position, facilitated by the presence of gingival crevicular fluid. The flora also change from a predominantly gram-positive, aerobic, and facultatively anaerobic population of coccoid morphology to a mix relatively high in gram-negative, anaerobic, and rodlike or filamentous organisms, along with increasing numbers of spirochetes.[18,19] There is evidence[5] that an increase in gram-negative organisms leads to an increase in disease activity within the periodontium and causes both direct and indirect tissue damage.

As the plaque colony matures and increases its mineral content, calculus forms within the plaque mass. Although gingival inflammation is often most severe in areas where calculus is present, the calculus itself is not the most significant source of inflammation; rather, it provides a nidus for plaque accumulation and retains the plaque in proximity to the gingiva. Dental plaque is the etiologic agent of the inflammation.[20]

Pathogenesis

The pathogenesis or sequence of events in the development of a gingivitis-periodontitis lesion is very complex. It involves not only local phenomena in the gingiva, PDL, tooth surface, and alveolar bone but also a number of complex host response mechanisms modified by the bacterial infection and behavioral factors.[21] Implicated in the pathogenic mechanism are phagocytic cells, the lymphoid system, antibodies and immune complexes, complement and clotting cascades, immune reactions, and the microcirculation. Detailed descriptions of host response in the gingivitis-periodontitis lesion are available in standard periodontal texts and reviews.[5-7]

The chronic plaque-induced lesion has been investigated[5,22] in great detail clinically, histopathologically, and ultrastructurally, and the model of disease activity has remained consistent over time. From these analyses, an indistinct division into initial, early, established, and advanced stages has been put forth. The salient features and approximate time frame for each stage are presented here.

Initial lesion

The initial lesion (Fig. 5-5) is localized in the region of the gingival sulcus and is evident after approximately 2 to 4 days of undisturbed plaque accumulation from a baseline of gingival health. The vessels of the gingiva become enlarged, and vasculitis occurs, allowing a fluid exudate of polymorphonuclear leukocytes to form in the sulcus. Collagen is lost perivascularly, and the resultant space is filled with proteins and inflammatory cells. The most coronal portion of the junctional epithelium becomes altered.

Early lesion

Although there is no distinct division between the stages of lesion formation, the early lesion (Fig. 5-6) generally appears within 4 to 7 days of plaque accumulation. This stage of development exhibits further loss of collagen from the marginal gingiva. In addition, an increase in gingival sulcular fluid flow occurs with increased inflammatory cells and the accumulation of lymphoid cells subjacent to the junctional epithelium. The basal cells of the junctional epithelium begin to proliferate, and significant alterations are seen in the connective tissue fibroblasts.

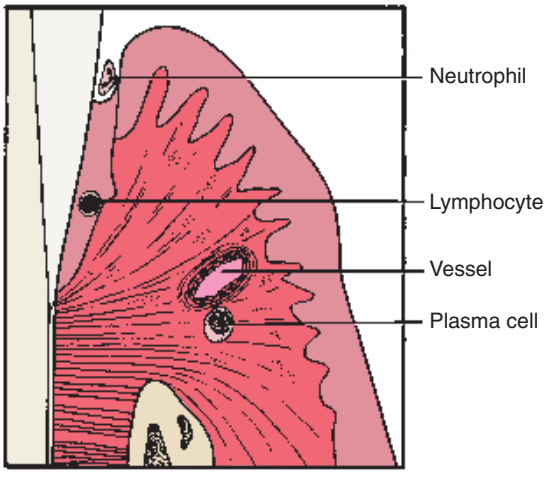


Fig. 5-5

Initial lesion of gingivitis-periodontitis. There is a predominance of polymorphonuclear leukocytes in the beginning stages of inflammation.

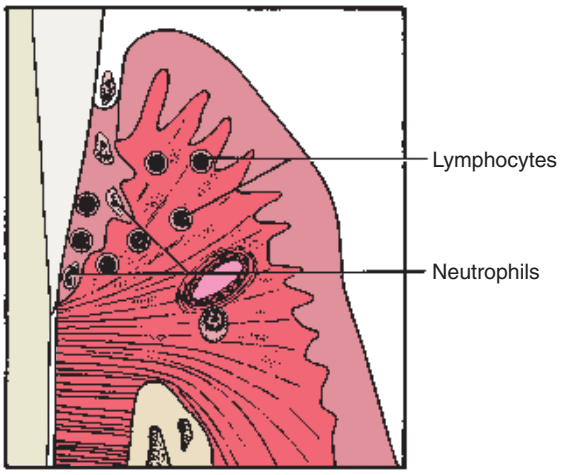


Fig. 5-6
Early lesion of gingivitis-periodontitis. The predominant inflammatory cells are lymphocytes subjacent to the junctional epithelium. The epithelium is beginning to proliferate into rete ridges. *(Redrawn from Schluger S, et al: Periodontal Disease: Basic Phenomena, Clinical Management, and Occlusal and Restorative Interrelationships, 2nd ed. Philadelphia, Lea & Febiger, 1990.)*

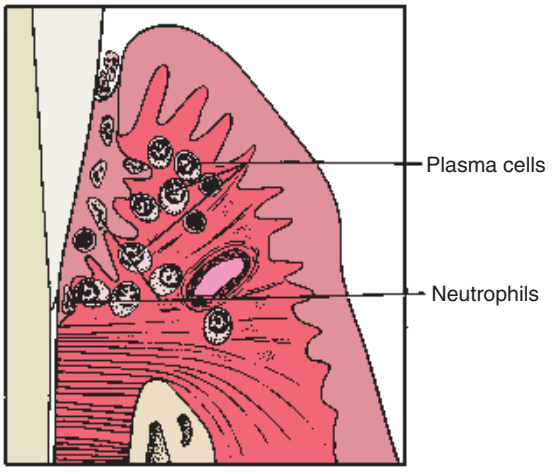


Fig. 5-7
Established lesion of gingivitis-periodontitis. The junctional epithelium is converted into pocket epithelium. Pocket formation may begin. The predominant inflammatory cells are plasma cells. *(Redrawn from Schluger S, et al: Periodontal Disease: Basic Phenomena, Clinical Management, and Occlusal and Restorative Interrelationships, 2nd ed. Philadelphia, Lea & Febiger, 1990.)*

Established lesion

Within 7 to 21 days, the lesion enters the established stage (Fig. 5-7). It is still located at the apical portion of the gingival sulcus, and the inflammation is centered in a relatively small area. There is continuing loss of connective tissue, with persistence of the features of the early lesion. This stage exhibits a predominance of plasma cells, the presence of immunoglobulins in the connective tissue, and a

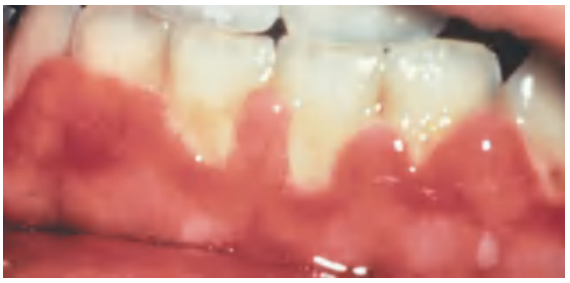


Fig. 5-8
Gingivitis. The interproximal gingiva is bulbous and inflamed. Note the erythematous and edematous tissue extending onto the labial portions of the lateral incisors.

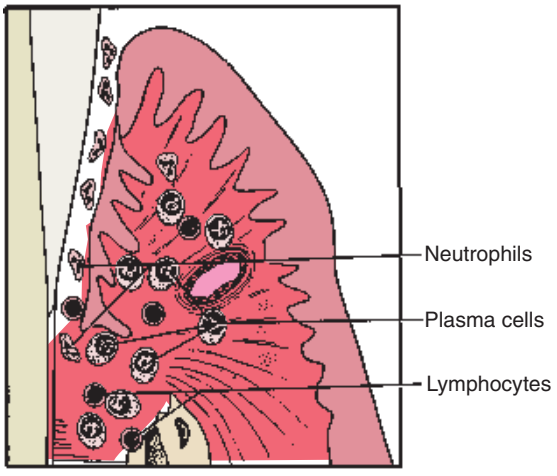


Fig. 5-9
Advanced lesion of gingivitis-periodontitis. Pocket formation has begun, with a loss of connective tissue attachment apical to the cementoenamel junction. Bone is converted into fibrous connective tissue and is subsequently lost. The predominant inflammatory cells are plasma cells, and there are scattered lymphocytes present.

proliferation of the junctional epithelium (Fig. 5-8). Pocket formation, however, does not necessarily occur.

Advanced lesion

It is difficult to pinpoint the time at which the established lesion of gingivitis results in a loss of connective tissue attachment to the tooth structure and becomes an advanced lesion or overt periodontitis (Fig. 5-9). Upon conversion to the advanced stage, the features of an established lesion persist. The connective tissue continues to lose collagen content, and fibroblasts are further altered. Periodontal pockets are formed, with increased probing depths, and the lesion extends into alveolar bone. The bone marrow converts to fibrous connective tissue, with a significant loss of connective tissue attachment to the root



Fig. 5-10
Periodontitis. Plaque and calculus accumulation has resulted in a loss of connective tissue attachment apical to the cementoenamel junction.

of the tooth. This is accompanied by the manifestations of immunopathologic tissue reactions and inflammatory responses in the gingiva.

Periodontitis

When a loss of connective tissue attachment occurs, the lesion transforms from gingivitis into periodontitis (Fig. 5-10), a disease that may be characterized by alternating periods of quiescence and exacerbation. The extent to which the lesion progresses before it is treated will determine the amount of bone and connective tissue attachment loss that occurs. It subsequently affects the prognosis of the tooth with regard to restorative demands.

EXAMINATION, DIAGNOSIS, AND TREATMENT PLANNING

Before treatment is rendered, all facts and findings related to the patient's disease state should be recorded.[23,24] These data can then be used to formulate a precise working blueprint for the proposed treatment. The diagnosis and treatment planning stages should be completed before therapy is initiated. In general practice, the data collection, diagnosis, and treatment planning for a patient's restorative needs are accomplished at approximately the same time. Although laboratory assessments of gingival microflora and gingival crevicular fluid,[24] as well as genetic tests for susceptibility to periodontal diseases, are available,[25] traditional clinical assessments are most often employed to arrive at a periodontal diagnosis. These include such factors as probing depths, bleeding upon probing, clinical attachment levels, radiographic evidence of bone loss, and the presence or absence of the patient's signs and symptoms.[26,27] Once the diagnosis has been determined, a treatment plan is presented to the patient.

The treatment plan should be concise, logical, and rational—a realistic approach to therapy. It should not be a rigid or inflexible sequence of events, because often it must be emended as new information or changing circumstances dictate. The timing and sequencing of treatment are important in correcting the patient's dental problems as efficiently as possible.

The following is a viable working model for periodontal treatment:

Initial Therapy
- Control of microbial plaque
  Toothbrushing
  Flossing
  Other aids
- Scaling and polishing
- Correction of defective and/or overhanging restorations
- Root planing
- Strategic tooth removal
- Stabilization of mobile teeth
- Minor tooth movement

Evaluation of Initial Therapy

Surgical Therapy
- Soft tissue procedures
  Gingivectomy
  Open **débridement**
  Mucosal repair (see Chapter 6)
- Hard tissue procedures
  Bone induction
  Osseous resection
- Treatment of furcation involvement
  Odontoplasty-osteoplasty
  Root amputation
  Hemisection
  Provisionalization
  Restoration

Evaluation of Surgical Therapy

Guided Tissue Regeneration (Hard and Soft Tissue Procedures)
- Technique
- Restoration

Maintenance

Prognosis

Initial Therapy

Initial therapy consists of all treatment carried out before evaluation for the surgical phases of periodontal therapy. A number of procedures in each patient's treatment regimen may be accomplished

before more definitive or invasive approaches are undertaken.

Control of microbial plaque

The most crucial aspect of periodontal therapy is the control of microbial flora in the sulcular area. If the patient does not maintain excellent oral hygiene and thereby the optimum condition of soft and hard tissues, the success of subsequent periodontal and restorative treatments will be jeopardized.

Bacterial plaque occurs on all surfaces of the teeth but is especially prevalent on the gingival third.[28] It is strongly adherent to the tooth structure, which means that it is not removed by the chewing of fibrous foods.[29] The prevention of plaque accumulation, by either mechanical or chemical means, is crucial in the prevention of hard and soft tissue pathosis. Although there are chemical means for removing plaque accumulation, only mechanical methods are considered in this text. Excellent reviews of the subject of chemical plaque removal are contained in standard periodontal texts.[5,7]

Toothbrushing

Plaque removal is accomplished with a toothbrush and other orophysiotherapy aids. Many types of toothbrushes can be used and are classified according to their size, shape, length, bristle arrangement, and whether they are manually or electrically powered. The many types of brushes and alternate techniques are reviewed in standard periodontal textbooks.[4-7] The soft-bristle brush is particularly effective for cleaning in the gingival sulci and at buccal and lingual surfaces of interproximal areas[30,31] without causing gingival damage and tooth abrasion, which can result from a hard-bristle brush.[32]

Technique

In toothbrushing, effective placement of the bristles is more important than the amount of energy expended. The Bass sulcular method of brushing is preferred for most fixed prosthodontics patients because it cleans the sulci, where the margins of restorations are often placed.

The bristles are placed in the sulci at an angle of approximately 45 degrees to the tooth surface, directed gingivally, and moved back and forth with short scrubbing motions under light pressure. The brush is applied in a similar manner throughout the mouth on all buccal and lingual or palatal surfaces of the teeth. In the anterior area, where interproximal spaces are small and where it may seem impossible to place the brush horizontally against the gingiva, the brush can be turned vertically for better access. After the sulcular areas have been cleansed, the occlusal surfaces are brushed, as is the dorsal surface of the tongue. Excellent descriptions and illustrations of toothbrush placement appear in standard periodontal texts.[5-7]

Flossing

Interproximal plaque can be controlled with dental floss.[33,34] Both waxed and unwaxed types clean proximal surfaces, but the unwaxed floss has several advantages[35]:

1. It is smaller in diameter and thus more easily passed through interproximal contact areas.
2. It flattens out under tension, and thus each separate thread effectively covers a larger surface area.
3. It makes a squeaking noise when applied to a clean tooth surface, which can be used as a guide to effective performance.

Other Aids

Plaque may also be controlled effectively by orophysiotherapy aids such as dental tape, yarn, rubber and wooden tips, toothpicks, interdental stimulators, interproximal brushes, and electric toothbrushes.

When plaque is removed around a fixed dental prosthesis or a restoration involving splinted teeth, a floss threader may be needed. Alternatively, special lengths of floss with stiffened ends are available and have been shown to be quite effective.

Disclosing agents may be used to provide better visualization of areas where plaque control is difficult or deficient. Erythrosin dye in tablet or liquid form stains plaque, rendering it readily observable. Ultraviolet light has been used in combination with fluorescein dye to reveal plaque deposits, precluding the undesirable red stain that remains after erythrosin use.

All the previously mentioned items are useful in removing and controlling inflammation-inducing microbial plaque. However, the most important aspect of plaque control is *patient motivation*. Without motivation, all orophysiotherapy aids and the knowledge to apply them are useless.

Scaling and polishing

Removal of supragingival calculus (scaling) and polishing of the coronal portion of the tooth are the first definitive steps in débridement of the teeth. Scaling consists of the removal of deposits and accretions from the crowns of teeth and from tooth surfaces slightly subgingival. This is accomplished with the use of sharp scalers or curettes. The gingiva responds to this removal of supragingival and slightly subgingival calculus with a decrease in inflammation and bleeding. Thus, the patient is able to observe the first signs of therapeutic gain, especially when part or half of the mouth is instrumented at one appoint-



Fig. 5-11
Overhanging splinted restoration connecting the mandibular right and left central incisors, with obliteration of the interproximal space by the castings. The patient's inability to clean this area properly has resulted in iatrogenic loss of attachment.



Fig. 5-12
Recontouring of the interproximal space of the castings seen in Figure 5-11 allows the patient to clean the area. Note the excellent gingival health between the central incisors as a result of good oral hygiene techniques.

ment and the remainder is done after a short time has elapsed.

Correction of defective and/or overhanging restorations

Overhanging restorations, open interproximal contacts, and areas of food impaction contribute to local irritation of the gingiva and, of greater importance, impede proper plaque control. These deficiencies (Fig. 5-11) should be corrected during the initial therapy phase of treatment by either replacement or reshaping and/or removal of the overhang (Fig. 5-12). Close cooperation and communication between the periodontist and the restorative dentist are essential during this treatment phase.

Root planing

Root planing (Fig. 5-13) is the process of débriding the root surface with a curette. It is a more deliberate and more delicately executed procedure than scaling and necessitates the administration of a local anesthetic for most patients. At present, it constitutes the primary mode of initial therapy in periodontics, and there is evidence that tooth loss is substantially reduced over time when root surfaces are débrided on a continuing basis.[36] Other work has also demonstrated that disease progression continues without root planing, even with effective oral hygiene.[37]

Oral hygiene instruction and calculus removal are prerequisite to fixed prosthodontic treatment.

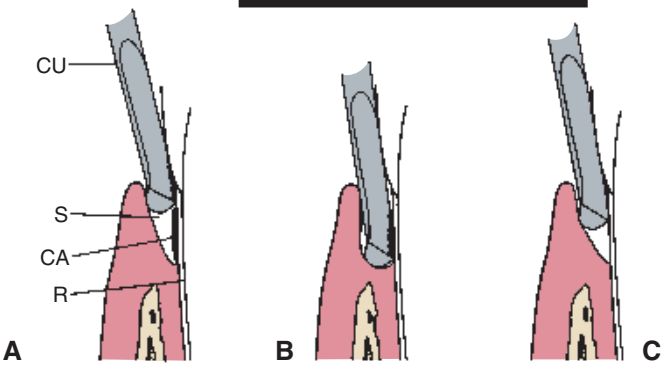


Fig. 5-13
Root planing. **A,** Curette placed in the sulcus to address calculus. **B,** The curette, initially placed apical to the calculus, moves coronally to dislodge the calculus. **C,** Accretions removed and the root planed to a smooth finish. *CA,* calculus; *CU,* Curette; *R,* root surface; *S,* sulcus. (Redrawn from Carranza FA Jr: Glickman's Clinical Periodontology, 7th ed. Philadelphia, WB Saunders, 1990.)

The curette is a spoon-shaped instrument well suited to cleaning and smoothing root surfaces. It is applied apically on the root with regard to the accretion and is moved coronally to lift deposits off the root surface and to plane it to a glasslike smoothness. As the patient's plaque-control techniques improve, the changes observed when root planing is completed may necessitate changing or modifying the treatment plan, and further therapy may not be indicated.

Root planing and the incidental curettage of soft tissue that accompanies it may be an end point of active periodontal therapy. In many cases, the combination of root planing and improved oral hygiene on the part of the patient leads to manageable probing depths, and no further treatment is necessary. For this reason, the initial therapy requires careful evaluation.

Strategic tooth removal

An important part of treatment sequencing is the elimination of teeth that are hopelessly involved periodontally or are nonrestorable. Although no hard-and-fast rules exist regarding the timing of such extractions, removing teeth early in therapy is often more advantageous, when the patient has recently been informed of the prognosis and is prepared for treatment.

Extractions can be accomplished during initial therapy when the quadrant being instrumented is anesthetized. The operator can make an excellent determination of questionable teeth at this time by "sounding" the periodontium and can inform the patient of the verdict immediately. The patient is thus prepared psychologically (and also pharmacologically) for the removal. Teeth can also be removed during periodontal surgery, when the same conditions exist.

Early extraction of teeth and/or roots allows the socket areas to heal and can provide better access for plaque control of adjacent tooth surfaces. A transitional or provisional partial removable dental prosthesis or fixed dental prosthesis can also be fabricated; this stabilizes the arch and potentially maintains or improves occlusion, function, and esthetics.[5,7]

Stabilization of mobile teeth

Tooth mobility occurs when a tooth is subjected to excessive forces, especially when bony support is lacking. It is not necessarily a sign of disease, because it may be a normal response to abnormal forces, and it does not always need corrective treatment. However, it is sometimes a source of discomfort to the patient, and in these cases it should be treated by reduction of the abnormal forces after occlusal evaluation. Depending on the patient's need, the teeth may also be treated by splinting with provisional restorations (see Chapter 15) or an acid-etch resin technique (see Chapter 26) in conjunction with occlusal adjustment (see Chapter 6). Such restorations should be carefully designed so they do not impede plaque control or future periodontal treatment. Close communication between the periodontist and the restorative dentist is crucial in this phase of treatment.

Minor tooth movement

Orthodontics can be of major benefit to periodontal therapy. Malposed teeth may be realigned to make them more receptive to periodontal treatment and to improve the efficacy of plaque-control measures. As described in Chapter 6, restorative procedures can also be aided by minor tooth movement. Thus, for the best treatment of a patient with complex dental problems, good communication among consulting dentists is essential.

Evaluation of Initial Therapy

The periodontium recovering from active disease should be regularly reexamined and reevaluated to determine the efficacy of treatment. Soft tissue responses to the initial therapy are observed along with the patient's motivation and ability to maintain a relatively inflammation-free state. Probing depths should be recorded again, and the location of the MGJ noted in relation to the teeth. Changes must be assessed in regard to the necessity of further periodontal treatment.

Reevaluation gives the practitioner a firmer grasp on the progress of treatment, and if necessary, it allows revision of the initial treatment plan. At this time, the gingiva is healthier, probing depths may have decreased because of better plaque control and root planing, and the working knowledge of the patient's abilities and desires should have improved. The combination of these factors facilitates decisions regarding further treatment of the periodontium and allows a more informed prognosis.

Surgical Therapy

There are a number of surgical procedures for the improvement of plaque removal aimed primarily at reducing or eliminating probing depths. Accurately diagnosing and choosing the most appropriate surgical regimen is crucial for maximum results.

Soft tissue procedures

Gingivectomy

Gingivectomy is the removal of diseased or hypertrophied gingiva. Introduced by G. V. Black,[38,39] it was the first periodontal surgical approach to gain widespread acceptance. Gingivectomy is essentially the resection of keratinized gingiva only, and it may be applied to the treatment of suprabony pockets[40] and to fibrous or enlarged gingiva, particularly when they result from diphenylhydantoin (Dilantin) therapy[41] (see Fig. 1-4). However, it is unsuitable for the treatment of infrabony defects.

Technique

The surgical technique consists of establishing bleeding points (Fig. 5-14*A*) at the base of the gingival sulcus with a pocket marker or periodontal probe to serve as a guide for the gingival excision. The initial incision (Fig. 5-14*B*) is made at these points in



Fig. 5-14
A, Demarcation of pocket depth before the initial incision of a gingivectomy. **B,** Initial incision for the gingivectomy. **C,** Final gingival contours after removal of the coronal tissue and beveling of the incised area. **D,** Result of the gingivectomy, 6 months after surgery. Note the excellent gingival health and contours.

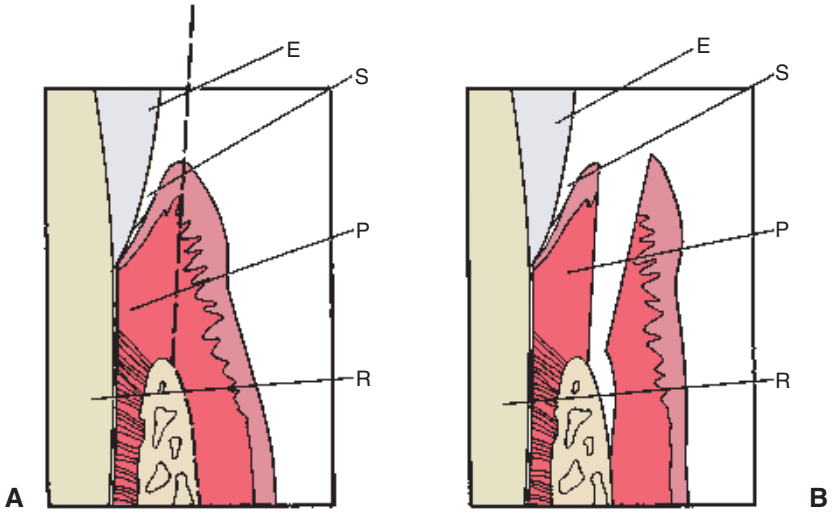


Fig. 5-15
Internal bevel incision. **A,** Ending on the bone, to allow reflection of the flap. **B,** Flap reflected. The supracrestal connective tissue and epithelium are to be removed. *E,* Enamel; *P,* supracrestal periodontium; *R,* root; *S,* sulcus. (Redrawn from Carranza FA Jr: Glickman's Clinical Periodontology, 7th ed. Philadelphia, WB Saunders, 1990.)

a beveled manner with firm, continuous strokes from the gingivectomy knife. The interproximal tissue is freed by sharp excision and is removed from the site. The resulting ledge of tissue at the buccal and lingual or palatal terminations of the incision (Fig. 5-14*C*) is then smoothed with the knife or a rotary instrument to a margin continuous with the remaining tissue.

After vigorous débridement of the newly accessible tooth surfaces, a surgical dressing is applied for protection and hemostasis; it remains in place for 7 to 10 days. When it is removed, oral hygiene procedures are immediately resumed (Fig. 5-14*D*).

Contraindications

The major contraindication to gingivectomy-gingivoplasty is the absence of attached keratinized tissue.

The procedure should be confined to areas of keratinized tissue to prevent leaving gingival margins that consist of alveolar mucosa (which is ill suited to resisting the trauma of restorative procedures and mastication).

Open débridement (modified Widman procedure)

Open débridement or curettage is a surgical procedure designed to gain better access to root surfaces for complete débridement and root planing. The modified Widman approach[42] has been advocated because it allows good soft tissue flap control, minimum surgical trauma, and good postoperative integrity without excessive loss of osseous tissue or connective tissue attachment.

Technique

A sulcular or minimal internal bevel incision (Fig. 5-15) is made on the buccal or the lingual surfaces of the mandibular teeth. Next, a scalloped internal bevel incision is made on the palatal surfaces of maxillary teeth. The palatal flap is then thinned and the underlying connective tissue removed. The resulting flaps are reflected minimally yet sufficiently to allow access for complete débridement of the root surfaces and degranulation of any osseous lesions in the field. No osseous resection is accomplished, except where necessary for proper flap placement. The flaps are then carefully coapted and sutured to promote healing by primary intention (see Fig. 5-16).

Mucosal repair

Mucosal reparative surgery is used to increase the width of the band of keratinized gingiva. It is particularly useful when complete-coverage restorations are planned (see Chapter 6 for a more detailed discussion).

Hard tissue procedures

Hard tissue therapy is aimed at modifying the topography of areas where plaque control is difficult or impossible. Two examples are obvious:

1. In areas where an irregular pattern of bone loss has led to intrabony pockets.
2. Around root furcations (hard tissue procedures may include techniques for the induction of new



Fig. 5-16

Open débridement (modified Widman procedure). **A,** Initial thinning incision on the buccal surface for open débridement. **B,** Lingual flap thinned. **C,** Roots planed to remove subgingival accretions. **D,** Roots débrided and planed. **E** and **F,** Flaps coapted and sutured. **G** and **H,** The completed restoration, with a healthy periodontium.

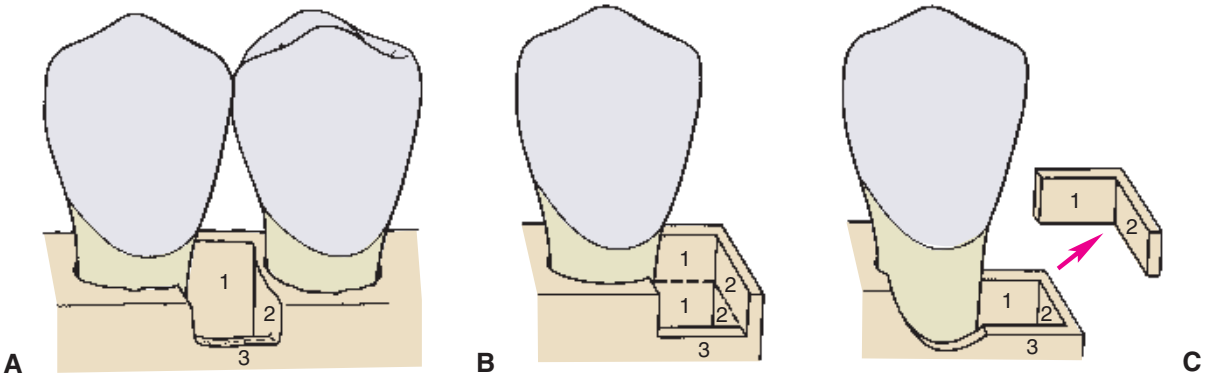


Fig. 5-17

Osseous defects. **A,** Three walls of bone present: at the lingual (*1*), distal (*2*), and buccal (*3*). **B,** Two walls of bone (*1* and *2*) in the coronal portion of the defect and three walls (*1*, *2*, and *3*) in the apical portion. **C,** The two coronal walls have been removed and the buccal surface of the bone recontoured, leaving the apical three-walled defect to fill with bone after degranulation. *(Redrawn from Carranza FA Jr: Glickman's Clinical Periodontology, 7th ed. Philadelphia, WB Saunders, 1990.)*

bone formation, for the judicious removal of bone by surgery, and for tooth modification or root resection).

Bone induction

Intrabony lesions (Fig. 5-17) are categorized as one-walled, two-walled, or three-walled, depending on the remaining osseous topography. The three-walled defect responds best to inductive or degranulation procedures, with resulting new attachment and resolution of all or part of the lesion. The one-walled and two-walled (crater) defects respond better to pocket elimination procedures.[43]

Many materials have been used to fill osseous defects: ceramic,[44] sclera,[45] cartilage,[46] bone chips,[47] cementum and dentin,[48] osseous coagulum,[49] freeze-dried bone,[50] iliac crest marrow,[51,52] hydroxylapatite,[53] tricalcium phosphate,[54] and bioactive glass materials.[55,56] Laboratory and clinical studies with enamel matrix protein derivative have shown promising results in regenerating lost periodontium.[57,58] Overall, results with these materials have been mixed, and no currently available alloplastic grafting material is clearly superior to any other in the regeneration of periodontal defects.

Technique

After the flaps have been reflected and the lesion has been thoroughly degranulated, the grafting material is packed firmly into the lesion until it is slightly overfilled. The flaps are then coapted, and interrupted sutures are placed (Fig. 5-18). A surgical dressing is applied and removed after 7 to 10 days.

Osseous resection with apically positioned flaps

Chronic inflammatory periodontitis results in the loss of osseous tissue, destruction of osseous architecture, and creation of an intrabony lesion. The osseous tissue has no predictable or simple pattern of loss; the resorption may take the form of craters, hemiseptal defects, or well-like (troughlike) shapes. Craters in the interproximal areas (Fig. 5-19) are the most common type of lesion.[4]

The objective of osseous resection is to shape the bone to form even contours. This is accomplished by leveling interproximal lesions, reducing osseous recontour lesions that are too wide and/or shallow for predictable repair or bony fill, thinning bony ledges, and eliminating or ramping crater defects. The result is intended to be a sound osseous base for gingival attachment and the elimination of pockets and excessive sulcular depth. Long-term studies[59-61] have shown that although osseous resection surgery results in attachment loss and gingival recession, it is the most effective therapy for decreasing pocket depth, which can subsequently be maintained by the patient.

Technique

Before **reflection** of the flaps, the osseous topography of the lesion is assessed. After the area to be treated has been anesthetized, a periodontal probe is inserted into the pocket and forced through the epithelial attachment and connective tissue to the osseous crest. Multiple probings are made, and the surface morphology is observed. This "sounding" of the bone provides a reasonable representation of the width and depth of the lesion and is helpful in designing the incision.

Inverse bevel incisions are made on the buccal and lingual or palatal surfaces, and full-thickness mucoperiosteal flaps are reflected to expose the osseous tissue. After the flaps are thinned and the lesions are thoroughly degranulated, the roots of the teeth are planed vigorously. Osseous resection is

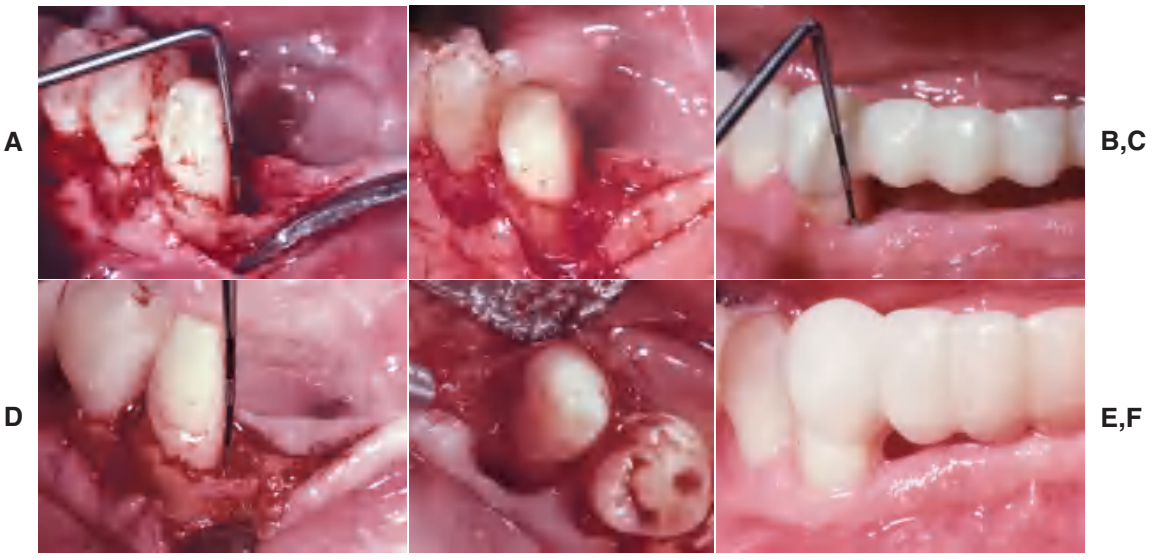


Fig. 5-18
Bone induction. **A,** Degranulation of a mesial defect on the mandibular right canine. This is a three-walled defect, with approximately 9 mm of intrabony lysis. **B,** The defect has been filled (slightly overfilled) with autogenous iliac crest marrow coagulum. **C,** Four months after surgery, the sulcular depth is approximately 3 mm. **D,** Osseous fill at reentry 1 year after surgery. Note the rim of bone at the margin of a previously existing defect (*arrow*). **E,** One year after surgery, there is a near-total fill of the defect. The rim of bone demarcates the margin of the previous intrabony lesion. **F,** Result of osseous grafting at the mesial of the canine 15 months after surgery. The gingival health and contours are excellent. Note the acrylic resin provisional restoration in place before the final restoration.



Fig. 5-19
Osseous resection. **A,** Osseous ledge and a crater defect. **B,** Osseous recontouring. **C,** Final restoration 3 months after apical positioning of the flap.

then accomplished by the combination of rotary instrumentation with carbide and/or diamond burs, chisels, and bone files. When osteoplasty of the interproximal sluiceways, furcation areas, and buccal and lingual bone is completed, the flaps are positioned at the crest of the bone in an apical position on the tooth. Surgical dressings are applied, and in 7 to 10 days, the patient is seen again for suture removal and dressing removal or change.

Postsurgical healing

After surgery, the healing of the periodontium must be considered before any restorative procedures are performed. Initial connective tissue and epithelial healing is complete at 4 to 6 weeks. Final tissue maturation and sulcus reformation, however, may not be complete until 6 months to 1 year after surgery.

If the margins of the restorations are to be placed intrasulcularly (subgingivally) or at the gingival crest, or if gingival displacement procedures are to be used in making the impression, waiting as long as possible after surgery before attempting these procedures is recommended. If the restorative margins are to be placed at a suprasulcular (supragingival) position (which may not necessitate the use of a gingival displacement cord), these restorations may be started when the gingiva exhibits initial reepithelialization and a return to clinical health (approximately 4 to 6 weeks).

Treatment of furcation involvement

Diagnosis and treatment of furcation involvement of multiroot teeth is one of the more difficult problems encountered in the periodontal-restorative dentistry continuum. Familiarity with the furcation's anatomic and morphologic variations is essential for formulating a treatment plan and prognosis for multiroot teeth.

Classification of involvements

Furcation involvements can be classified as Class (or Grade) I, II, III, and IV. Because these classifications are arbitrary, however, the reader should refer to periodontal textbooks and other readings[5-7,62] for further detail and clarification.

The normal position of the osseous crest (Fig. 5-20) is approximately 1.5 mm apical to the cementoenamel junction (CEJ) in a young, healthy adult. Vertical loss of periodontal support that is less than 3 mm apical to the CEJ is considered Class I involvement (Fig. 5-21*A*). There is no gross or radiographic evidence of bone loss. Clinically, the furca can be probed up to 1 mm horizontally. Vertical loss greater than 3 mm but without involvement of the total horizontal width of the furcation is considered Class II involvement (Fig. 5-21*B*). A portion of the bone and periodontium remains intact, but osseous loss is evident on radiographs. The furca is penetrable more than 1 mm horizontally but does not extend through and through.

A horizontal through-and-through lesion that is occluded by gingiva but allows passage of an instrument from the buccal, lingual, or palatal surface is defined as a Class III involvement (Fig. 5-21*C*). The degree of osseous loss is grossly evident on radiographs. A horizontal through-and-through lesion that is not occluded by gingiva is defined as a Class IV involvement (Fig. 5-21*D*).

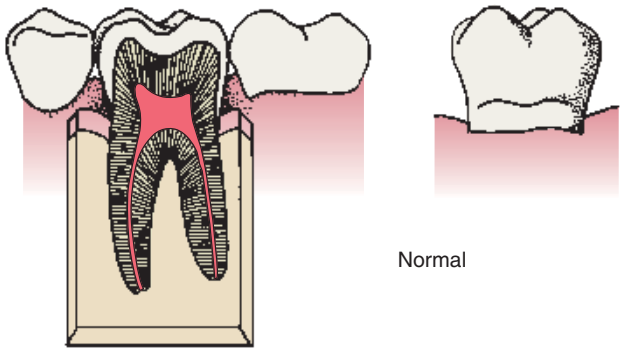


Fig. 5-20
Normal relationship of the cementoenamel junction and the osseous crest. *(From Baima RF: Considerations for furcation treatment. I. Diagnosis and treatment planning. J Prosthet Dent 56:138, 1986.)*

Review of root anatomy

The discussion of root anatomy is logically divided into subjects of maxillary and mandibular teeth.

Most maxillary molars have three roots—mesiobuccal, distobuccal, and palatal—although there may be variations, such as fused roots or fewer roots, particularly with second and third molars. The mesiobuccal root of most maxillary molars, especially the first molar, is usually biconcave and curves to the distal. The distobuccal root also is biconcave and somewhat less curved. The palatal root is wide buccolingually and mesiodistally, and it diverges palatally from the crown of the tooth. This configuration is unique to human dentition and may pose special problems in preparing, restoring, and designing restorations. The distobuccal and palatal roots tend to be in the same plane distally, and the distal furcation is more apical on the tooth than the is mesial furcation. In spite of this anatomy, the distal furca is more often involved in periodontal lesions than the mesial furca. From the apical perspective, a groove tends to unite the buccal and mesiopalatal openings of the trifurcation and can be probed when there is furcal involvement.

Most mandibular molars have two roots—mesial and distal—although, as with maxillary molars, there may be variations. The mesial root is flattened buccolingually, with concave surfaces on each proximal side. It curves distally, especially in first molars. The distal root is wider buccolingually than the mesial root and is concave on its mesial side. Its apex is often curved distally with a flat or convex distal aspect. Both root surfaces of mandibular molars facing the furca are concave, which results in an osseous chamber that is wider mesiodistally than either the buccal or the lingual furcation opening. The roof of the furcation is difficult to maintain because of mesiodistal **bifurcation** ridges.

Of importance is that maxillary and mandibular second and third molars often have more apically placed furcas than do first molars and often exhibit fused roots with little or no furcation.[63-65]

Maxillary premolars, particularly first premolars, and (at times) mandibular premolars also have furcations. However, because they are rarely amenable to treatment by odontoplasty-osteoplasty or root amputation procedures,[5] they are not discussed here. Students should refer to oral anatomy and morphology textbooks[66,67] for further clarification and study of molar root anatomy.

Odontoplasty-osteoplasty

Lesser degrees of furcation involvement can often be controlled by root planing and scaling, adequate oral hygiene, and/or gingivectomy-

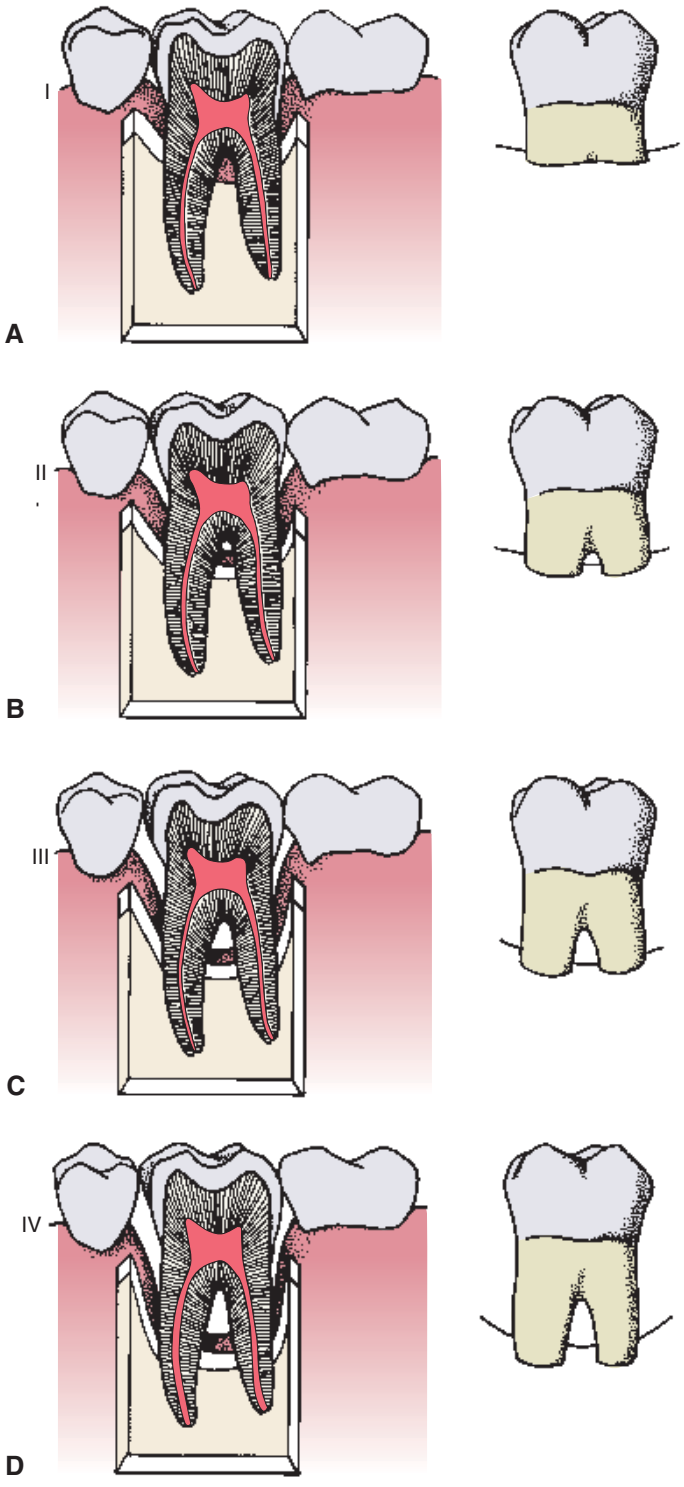


Fig. 5-21

Furcation involvements. A, Class I. B, Class II. C, Class III. D, Class IV. *(From Baima RF: Considerations for furcation treatment. I. Diagnosis and treatment planning. J Prosthet Dent 56:138, 1986.)*

gingivoplasty. However, when the involvement is more extensive, recontouring of the tooth or bone may be necessary.

Class I and incipient Class II lesions (Fig. 5-22) can be treated by reflecting the soft tissue in the furcation area and recontouring both the tooth structure and the supporting bone to improve access for cleaning.[4,68] Pocket elimination in this manner provides the best results and the fairest prognosis. A minimal amount of tooth structure and bone is lost, and the patient can easily maintain it.

Class II and Class III involvements can be treated by a procedure known as *tunneling*.[6,7] The osseous structure is completely removed in the furcation, which converts the lesion to a through-and-through defect. Teeth suitable for tunneling must have long, divergent roots, which will facilitate penetration by an oral hygiene aid (e.g., a proximal brush or a pipe cleaner). Patient selection is particularly important, because oral hygiene and patient motivation are crucial. Failure to maintain the furcation in a relatively plaque-free state may lead to caries, which are often impossible to correct. The common location of accessory canals in the roof of the furca can also be a problem. Because of irreversible pulp damage, endodontic treatment may be needed at a later date.[63,64,68-70]

Root amputation

In many patients, Class II and Class III furcation lesions are most effectively treated by root amputation (Fig. 5-23), which eliminates the furcation completely. The indications are as follows[5,7,68,71-73]:

1. Severe vertical bone loss involving one root of a mandibular molar or one or two roots of a maxillary molar.
2. Furcation involvement that is not treatable by odontoplasty-osteoplasty.
3. Vertical or horizontal fractures of roots or teeth as a result of trauma or endodontic procedures.
4. Unfavorable root proximity that precludes treatment by conservative measures.
5. Severe caries.
6. Internal or external resorption.
7. Inability to treat one root canal successfully.
8. Severe dehiscence and sensitivity of a root that precludes grafting procedures.
9. Failure of an abutment in a long-span splint or fixed dental prosthesis.
10. Strategic removal of a root to improve the prognosis of an adjacent tooth.

Certain roots are not suitable for amputation. Individual considerations include the extent of furcation involvement, the anatomy and topography of the supporting bone, the anatomy of the root canal,

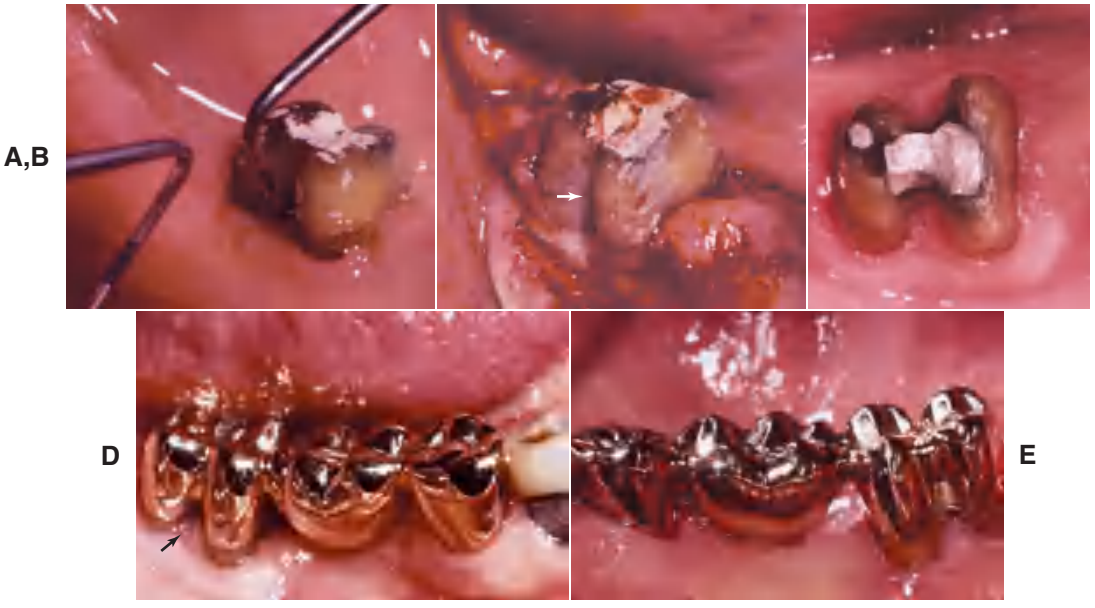


Fig. 5-22

Treatment of a Class II furcation lesion. **A,** The periodontal probe discloses approximately 3 mm of horizontal involvement. **B,** The lesion is reduced to Class I by odontoplasty-osteoplasty. Note the contours of the tooth at the coronal portion of the buccal furcation (*arrow*). **C,** Preparations for a fixed dental prosthesis to be placed in the right mandibular quadrant. Note the figure-8 shape of the molar preparation. **D,** Final restoration of the molar. There is excellent gingival health in the furcation area (*arrow*). **E,** Restoration of the quadrant. Note the slight contact of pontic on ridge and the open embrasures for access by oral hygiene instruments. *(Courtesy of Dr. H. J. Gulbransen.)*

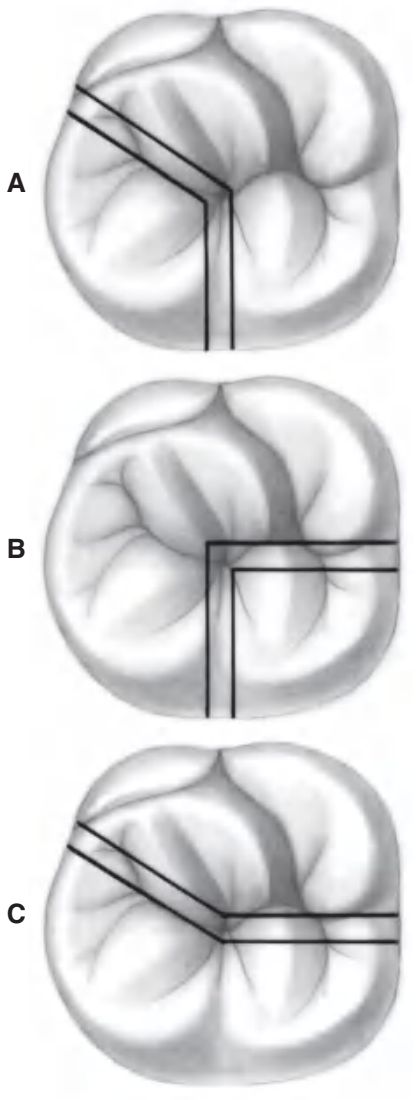


Fig. 5-23
Types of root amputation. **A,** Mesiobuccal. **B,** Distobuccal. **C,** Palatal or mesiobuccal and distobuccal.

and the periapical health of the tooth. The major contraindications to root resection are teeth exhibiting any of the following[5,69,73]:

1. Closely approximated or fused roots.
2. Significantly decreased general osseous support or an increased crown/root ratio.
3. Remaining structure that does not provide adequate resistance against the forces of mastication.
4. Excessive loss of supporting root structure.
5. Inability to be treated endodontically.
6. Remaining structure that cannot be restored.

Before the gingiva is reflected, the furca is probed with a curved furcation instrument so that the precise location of the bur cut can be determined (Fig. 5-24*A*). The cut is then made over the center of the furca but slightly toward the root to be removed. This will protect the residual root and/or tooth body. Whenever possible, the cut should be made before the flap is reflected so that the field is cleaner when the osseous tissue is exposed. When the cut is made into the root to be removed, the operator is able to inspect the residual root and remaining furcation area. A lip is often created in the furcation area, however (Fig. 5-24*B*), and after the root to be extracted has been delivered, the furcation lip is removed, and the tooth is finally contoured and finished. Removing the lip from the root of the furca is crucial to the treatment's success. If this is not done, the osseous tissue will not be recontoured properly (Figs. 5-24*C* and *D*), plaque control will be impaired, and, in effect, the furca will still be present.[4,73,74]

There are few surgical problems with root resection. The ones most frequently encountered are fracture of the root[75] and loss of a root tip in the maxillary sinus.[76,77] Osseous anatomic features such as a flat mandibular shelf and a flat palatal area can make access to the surgical site difficult and may complicate flap placement. Root proximity may complicate flap placement. Root proximity can pose a problem for separation and removal of the sectioned fragment from the surgical site. Mucogingival anatomy must be considered, because any flap procedure is contraindicated if there is a lack of keratinized attached gingiva.

Hemisection[4,71-74]

Hemisection means cutting a tooth in half. In the case of mandibular molars, hemisection is followed by removal and subsequent restoration of one root or restoration of each half of the tooth. The latter procedure is sometimes called *premolarization* or *bicuspidization.*[74]

The technical procedures of hemisection and root amputation are similar (Fig. 5-25). If one hemisected root is to be extracted, osteoplasty-osteoectomy and removal of the furcation lip are performed as previously described (Fig. 5-26). If the roots are to be maintained and restored separately, the furcation lips must be removed from each root. The individual roots may then be separated orthodontically, if necessary, to gain new interseptal osseous area.[68,78]

Provisionalization

Provisional stabilization is indicated in many cases of root resection to allow proper healing of the surgical site before definitive restorations are placed and to stabilize the remaining tooth structure against masticatory forces[63,79] (Fig. 5-27).

Normally, an acrylic resin provisional restoration (Fig. 5-27*A*) is provided (as described in Chapter

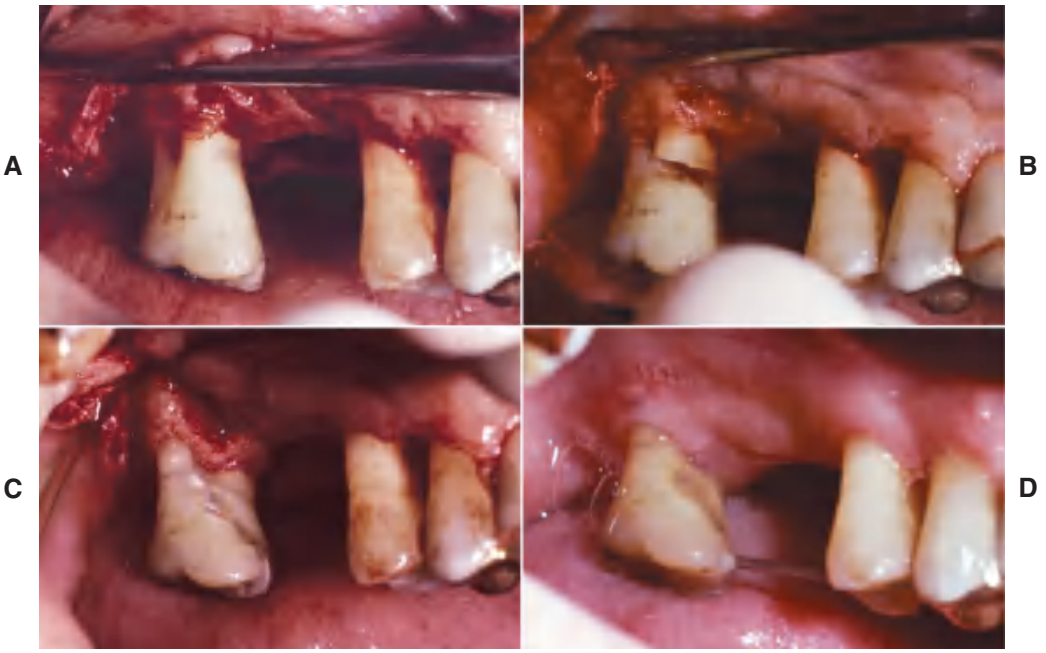


Fig. 5-24
Mesiobuccal root amputation. **A,** A full-thickness flap has been reflected to reveal Class I buccal furcation involvement and a Class II lesion in the mesiopalatal furca. **B,** The mesiobuccal root is sectioned at approximately 45 degrees to the tooth trunk. The section has been made into the root that is to be removed, and the result is a lip at the buccal furca. **C,** Final osseous contours after removal of the mesiobuccal root and osteoplasty-ostectomy. The furcation lip has also been removed. **D,** Mesiobuccal root amputation, 2 months after surgery. The remaining tooth structure is stabilized with a wire-and-acrylic resin provisional splint.



Fig. 5-25
Initial bur cut for hemisection and removal of the mesial root of a mandibular right first molar. The cut was made before reflection of the flap.

15), although on occasion an existing restoration can be successfully modified as a provisional (see Fig. 5-27*D*). Acid-etch retained composite resin or amalgam with orthodontic wire (see Fig. 5-27*B* and *C*) can also be used on an interim basis to maintain space and stabilize remaining tooth structure.

Restoration

Teeth with a resected root or roots may be restored in a variety of ways.[60,69,76-78] They may be involved in a treatment plan as single units, as fixed or removable dental prosthesis abutments, or as vertical stops for an overdenture.

The most common types of restorations for teeth with resected roots involve the following:

1. The remaining root restored as an individual tooth (Fig. 5-28).
2. The tooth used as an abutment for a fixed or partial removable dental prosthesis[80,82] (Fig. 5-29).
3. Premolarization: individual roots of a molar restored with premolar morphology[72] (Fig. 5-30).
4. Minimum treatment: amalgam placed in the root or roots and the occlusion adjusted.[83]

Evaluation of Surgical Therapy

The prognosis for a tooth whose root or roots have been resected and/or amputated depends on many factors. The manner in which the tooth is to be used in the restorative plan—as an abutment for a partial dental prosthesis or as a single crown—has a bearing on prognosis.[7,71] The amount of residual osseous structure to support the remaining tooth also influences the outlook. Most important, however, are the motivation and oral hygiene of the patient. Long-term studies accounting for all of these factors have yielded results ranging from 4% to 38% loss of residual roots with up to 53 years of postsurgical service.[68,84,85] With careful diagnosis, treatment



Fig. 5-26

A, Removal of the mesial root of a mandibular right first molar and final osseous contouring. **B,** Hemisection and removal of the mesial root, 2 months after surgery. The remaining tooth structure has been stabilized with a wire-and-acrylic resin provisional restoration.



Fig. 5-27

Provisional restorations. **A,** Acrylic resin with an overcontoured area corresponding to the mesial root of the mandibular right second molar. Ideal contouring of such a provisional would remove excess resin where the root had been amputated (*arrow*). **B,** Wire-and-acrylic resin splint stabilizing the mandibular right quadrant. **C,** Wire-and-amalgam splint. **D,** Existing restoration lined with acrylic resin (*arrow*). This can serve adequately as a provisional restoration. (***A,*** *Courtesy of Dr. S. B. Ross;* ***C,*** *courtesy of Dr. K. G. Palcanis;* ***D,*** *courtesy of Dr. H. J. Gulbransen.)*

planning, and good surgical technique, the tooth with resected roots may have a favorable prognosis. Plaque control is critical. For this reason, the patient makes the final determination about whether the tooth will ultimately be lost or remain as a healthy functioning unit in the dentition.

Guided Tissue Regeneration (Hard and Soft Tissue Procedures)

It has long been a goal of periodontal therapists to replace lost connective tissue attachment and bone. As previously described, many materials have been used in the quest for reattachment to diseased root surfaces. In the recent past, regaining lost attachment with cells from the host has been successful. Through the use of physical barriers that prevent cells from the gingival connective tissue and apically migrating oral epithelium from contacting the root surface, space is created over the root surface, which allows selective repopulation of this space by cells from the residual PDL. These cells become the regenerated PDL.[86,87]

Several types of barriers, both resorbable and nonresorbable,[88-92] as well as native periosteum,[93] have been used to regenerate the periodontium

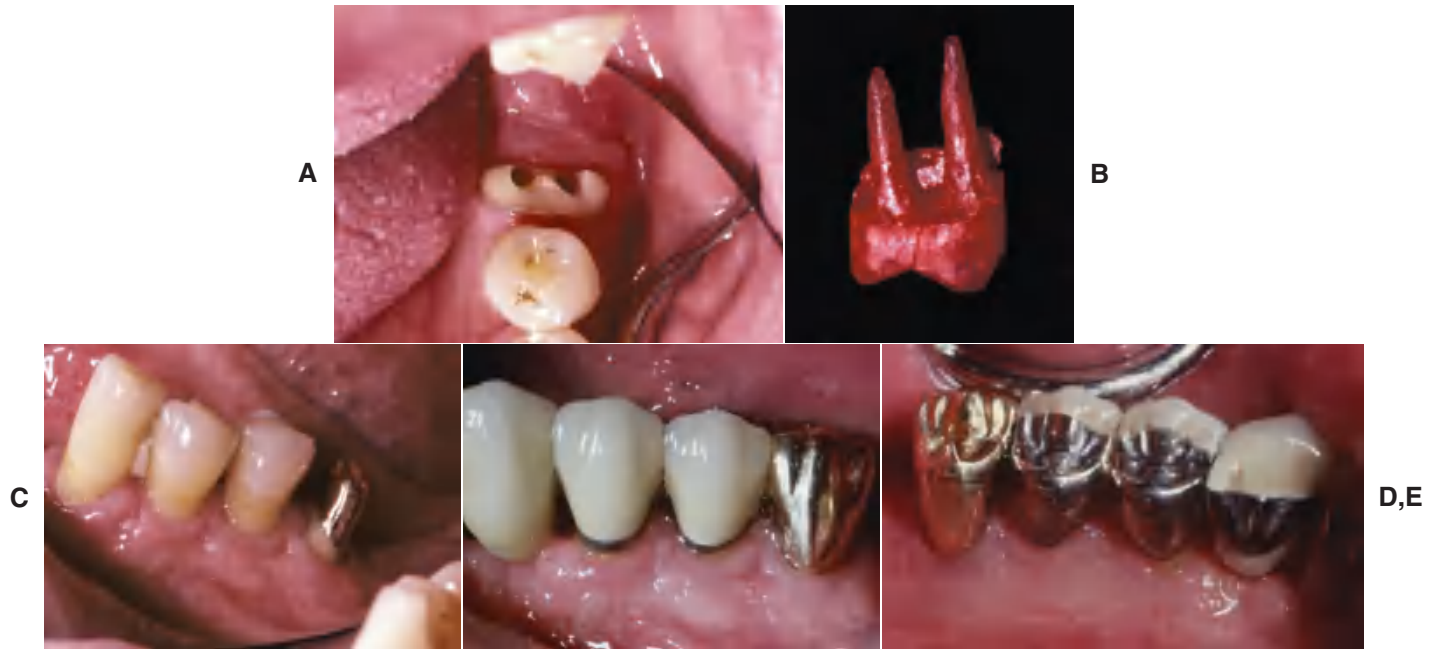


Fig. 5-28
Mesial root of a mandibular left first molar prepared for a single crown restoration. **A,** Canals have been made parallel for a dowel and core. **B,** Casting with parallel dowels. **C,** Dowel and core restoration have been cemented, and the root has been prepared for a single crown. **D** and **E,** Single nonsplinted restoration of the mesial root of a mandibular left first molar.



Fig. 5-29
Distal root of a mandibular right first molar prepared for a dowel and core restoration. **A,** The root will be used as an abutment for a fixed dental prosthesis. **B** and **C,** Dowel and core restoration of the root. **D,** Final restoration, with the root used as the distal abutment for a fixed dental prosthesis. Note the excellent gingival health and contours. **E,** Final restoration of the mandibular right quadrant, lingual view. The point contact of the totally convex pontic and the wide embrasure spaces allow optimum oral hygiene and excellent gingival health.



Fig. 5-30

Premolarization. Mesial and distal roots of a mandibular right first molar after hemisection. **A,** A wire-and-acrylic resin interim prosthesis is in place. **B,** The mesial and distal roots have been prepared for a dowel and core. Each will be restored as an individual premolar. Note that the distal root has been moved (orthodontically) 4 mm distally before the restoration was fabricated, to provide room in the newly created interproximal area for the dowel and core and crown restorations. **C,** The dowel and cores in place. Note the space between the roots created by the orthodontic movement. **D,** Dies with die relief placed and mounted on a suitable articulator for fabrication of the final restoration. **E** and **F,** Final result. The open interproximal areas and flat emergence profiles from the gingival area allow optimum oral hygiene and assist in the preservation of gingival health.

about root surfaces,[94] in furcations,[95-98] and with dental implants.[99-101] The most significant evidence has been attained by the use of a nonresorbable, polytetrafluoroethylene (PTFE) barrier (Gore-Tex Periodontal Material). Although long-term follow-up results are not conclusive, coronal movement of the connective tissue attachment has been impressive in many clinical and laboratory investigations. Although guided tissue regeneration is a technique-sensitive mode of therapy and has yet to be viewed as widely successful, it may prove to be the most promising approach to regeneration.

Technique

After diagnosis of the lesion and any initial therapy deemed appropriate, full-thickness flaps are reflected in an attempt to maintain the maximum amount of tissue for coverage of the barrier (Figs. 5-31 and 5-32). The lesion is completely débrided of granulation tissue, and the roots are planed thoroughly.

The barrier is placed at the CEJ and secured with sutures placed in a suspensory (sling)-type manner, maintaining a position covering the entire root surface. The full-thickness flap is mobilized to cover the entire surface of the barrier in both an apicocoronal and a mesiodistal direction. Antibiotic coverage and an antibacterial mouth rinse may be prescribed for the postoperative interval. Weekly monitoring for possible infection is recommended.

After a healing period of 4 to 6 weeks, a full-thickness flap is again reflected and is teased away from the external portion of the barrier. The barrier is then carefully removed to reveal a glossy and very vascular surface of new connective tissue. After the internal surface of the flap is stripped of epithelium by either sharp or rotary excision, the flap is placed to cover the entire surface of the new connective tissue. A periodontal dressing and systemic antibiotics or antibacterial mouth rinse may be used at the operator's discretion.

Clinical trials in humans[102-104] have favorably demonstrated the use of calcium sulfate (plaster of Paris) as a resorbable barrier. In addition to a significantly reduced cost in comparison with a PTFE barrier, the main advantage of this type of barrier is that the desired guided tissue regeneration may be accomplished without the need for a second surgical procedure. The techniques of flap reflection, degranulation of the defect or defects, and wound closure are similar to those used in other barriers

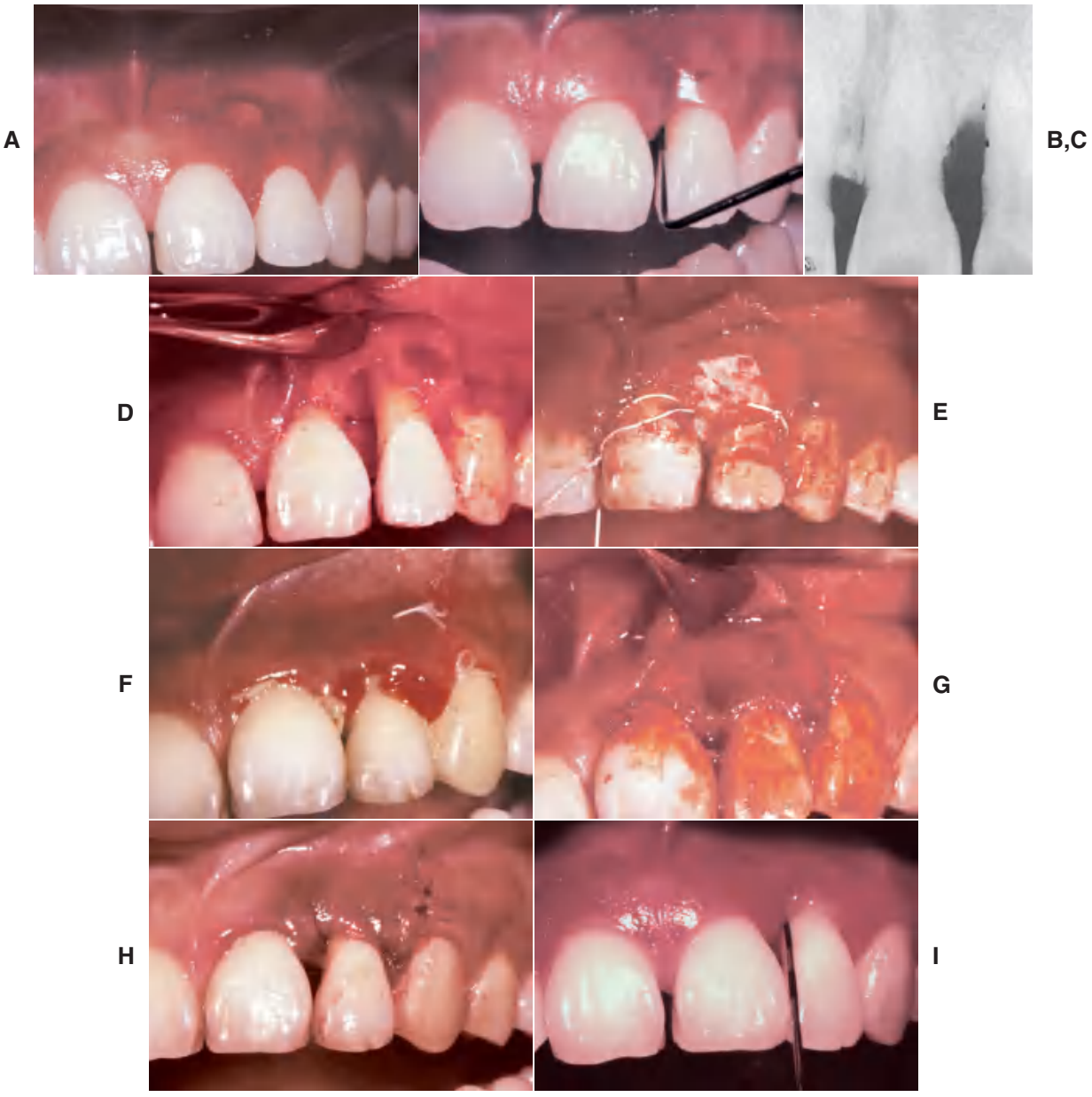


Fig. 5-31
Guided tissue regeneration about an anterior tooth. **A,** Abscess at the mesial of the left lateral incisor. **B,** After initial débridement and 3 days of antibiotic therapy. Probing depth is 8 mm. **C,** Radiograph taken at the time of barrier placement. **D,** The mesial surface after degranulation. Note the degree of bone loss. **E,** The polytetrafluoroethylene (PTFE) barrier placed at the cementoenamel junction (CEJ) completely covers the defect. **F,** Healing at 5 weeks. Note the new connective tissue coronal to the barrier and the CEJ. **G,** When the barrier is removed, the new connective tissue can be seen at the mesial and buccal surfaces. **H,** Healing 10 days after barrier removal. **I,** Healing at 9 months. Note the minimal sulcular depth with excellent tissue health. There is slight recession of the CEJ.

(Fig. 5-33), with primary wound closure over the barrier being the main objective of surgery.

Restoration

After the completion of guided tissue regeneration procedures, a period of healing that depends on the restorative needs of the patient is necessary. As a general guideline, 6 to 8 weeks should be allowed before displacement cord is used in the sulcus; this allows tissue maturation. The subsequent restorative procedures are accomplished as described earlier.

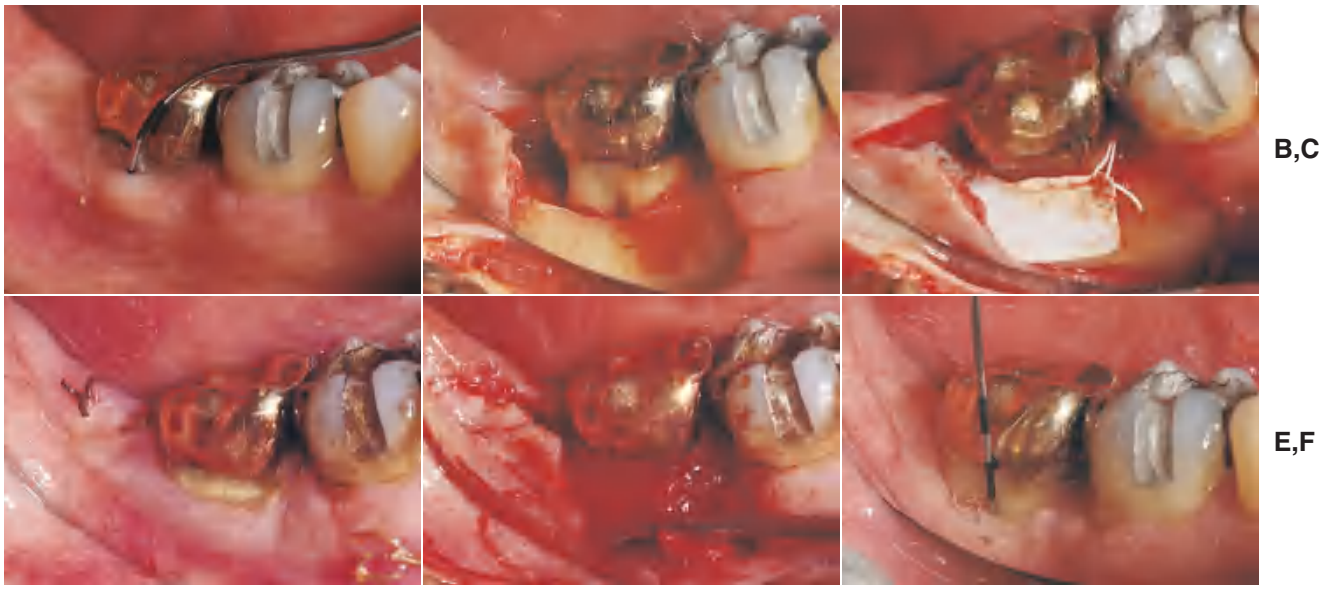


Fig. 5-32
Guided tissue regeneration in a furcation defect. **A,** Buccal aspect of a mandibular second molar showing the defect. A curved furcation probe reveals 6 mm of vertical bone loss and 3 mm of horizontal loss. **B,** With reflection of the flap, the Class II defect can be seen. **C,** Polytetrafluoroethylene (PTFE) barrier in place at the CEJ. **D,** Healing at 6 weeks. Note the recession of the flap at the coronal surface of the barrier. **E,** After barrier removal. Note the new connective tissue apical to the margin of the gold crown. **F,** Healing at 10 weeks. Despite minimum pocket depth, some loss of connective tissue is apparent.

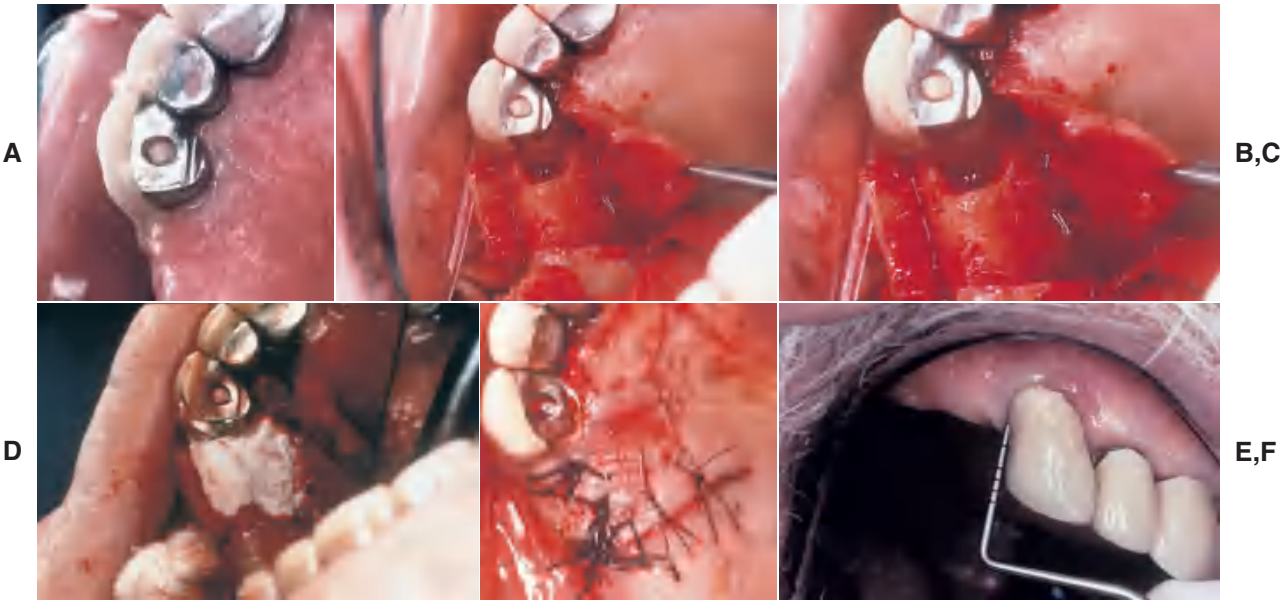


Fig. 5-33
Guided tissue regeneration with a resorbable calcium sulfate barrier. **A,** Preoperative view of the maxillary right canine to be restored with a new crown. **B,** Flaps reflected and granulomatous tissue removed from the defect at the distal surface. The three-walled intrabony defect prepared for barrier placement. **C,** Defect is filled with dense calcium sulfate graft. **D,** Calcium sulfate slurry placed to act as a barrier and facilitate guided tissue regeneration. **E,** Flap sutured to place. **F,** Minimal probing depths before final restoration. Favorable tissue contours after the elimination of the intrabony defect. *(Courtesy of Dr. V. Ng.)*

Maintenance

Continued reexamination and evaluation of periodontal status is an extension of active periodontal therapy performed at selective intervals to assist the periodontal patient in maintaining oral health. Of particular importance is the identification of areas where oral hygiene measures are partially effective or ineffective. The patient and the dentist must work together to preserve the health of the soft and hard tissues and prevent further periodontal breakdown or the recurrence of active disease. In this manner, recurrence and progression of disease and incidence of tooth loss may be minimized, and treatment of any recurrent disease may be offered in a timely manner.[105]

There is no standard maintenance schedule for patients requiring periodontal therapy. Some should be recalled only at 5- to 6-month intervals; others should be seen by the dentist (or periodontist) *and* the hygienist every 2 or 3 months. The maintenance regimen varies greatly among individuals, requires close coordination between the patient and the involved professionals, and should be tailored to the needs of each patient.[106]

Prognosis

The progress, course, and outcome of gingival and periodontal disease are crucially dependent on the patient. *Without the ability and desire of the patient to maintain his or her teeth and periodontium, any treatment will ultimately fail.* Determining a prognosis for the teeth and periodontium debilitated from moderate disease is therefore quite difficult. Unfortunately, failure is often the best teacher for patients.

There are many factors involved when the dentist attempts to arrive at a prognosis for a tooth or an arch. With optimal intentions and the best technique, a favorable result can be expected (even in the absence of good host resistance). Without them, treatment is doomed to ultimate failure. The age of the patient may help in predicting the success or failure of the treatment. In general, the prognosis is better for an older patient with a given amount of lost bone or tissue attachment than for a younger one. Many older individuals are more resistant to disease, and the disease has less effect. The amount of residual alveolar bone, the number of remaining teeth and their overall condition, any tooth mobility, and the patient's general occlusion and systemic integrity all can influence the outcome of therapy. There is substantial evidence to suggest that smoking has a debilitating effect on the periodontium.[107-109] Therapy for cessation of smoking may be incorporated into the comprehensive treatment plan for the patient in order to enhance the long-term prognosis of the dentition.

Also important to the long-term stability and function of the dentition are the condition of the arches to be restored and the ability of the restorative dentist to execute complex treatment plans without iatrogenically disturbing the gingiva and periodontium. This is a delicate undertaking and adversely affects a periodontally unstable arch if not skillfully performed.

SUMMARY

The periodontium is the most important anatomic structure of the oral cavity in fixed prosthodontics. Its main component, the PDL, anchors the teeth in the alveolar processes and provides attachment, nutrition, tissue synthesis and resorption, and mechanoreception. The practitioner embarking on a restorative program must therefore first make an accurate periodontal diagnosis and then institute effective treatment of any periodontal disease—whose main etiologic factor is neglected accumulations of plaque. Allowing the proper time for healing after periodontal surgery is also very important. The healing time required depends on the design of the restoration and is crucial to the correct placement of restorations near the free gingival margin.

STUDY QUESTIONS

1. Discuss the different types of fibers that make up the PDL.
2. Describe and discuss the processes and sequence in the development of an advanced lesion of gingivitis-periodontitis. What specifically occurs at the cellular level?
3. What are the classifications for furcation involvement?
4. List at least eight indications for root amputation. Describe the contraindications for root resection.
5. List soft tissue surgical procedures that are aimed primarily at reducing probing depths.
6. What is the typical sequence for periodontal therapy?

GLOSSARY*

al·ve·o·lar \ăl-vē′a-ler\ *adj* (1799): that part of the jaws where the teeth arise

alveolar bone \ăl-vē′a-ler bōn\: the bony portion of the mandible or maxillae in which the roots of the teeth are held by fibers of the periodontal ligament—called also *dental alveolus*

alveolar mucosa \ăl-vē′a-ler myōō-kō′sa\: the fixed mucosal covering of the alveolar process, loosely attached to the bone

attached gingival \a-tăchd′ jĭn′ja-va, jĭn′jī-\: the portion of the gingiva that is firm, dense, stippled, and tightly bound to the underlying periosteum, bone, and tooth

attachment apparatus \a-tăch′ment ăp′a-rā′tus, -răt′us\: in periodontics, a general term used to designate the cementum, periodontal ligament and alveolar bone

bi·fur·ca·tion \bī′fur-kā′shu\ *n* (1615): **1:** division into two branches 2: the site where a single structure divides into two parts, as in two roots of a tooth

biologic width \bī′a-lŏj′ĭ-kal\ (1998): the combined width of connective tissue and junctional epithelial attachment formed adjacent to a tooth and superior to the crestal bone
Gargiulo, AW et al J Periodontology 1961; 32:261-267
Cohen, DW. Lecture at Walter Reed Army Medical Center, June 3, 1962

buccal vestibule \bŭk′al vĕs′ti-byōōl\: the portion of the oral cavity that is bounded on one side by the teeth, gingiva, and alveolar ridge (in the edentulous mouth, the residual ridge) and on the lateral side by the cheek posterior to the buccal frenula

calcium sulfate \kăl′sē-um sŭl′fāt′\: a product obtained by calcination of gypsum under steam pressure. The *alpha* form is composed of regularly shaped grains, with low porosity, and requiring little water for a satisfactory mix. Forms include *alpha, alpha-modified* and *beta.*

cemento-enamel junction \sĕ′mĕn-tō ĭ-năm′al jŭngk′shun\: that area where the enamel and cementum meet at the cervical region of a tooth

ce·men·tum \sĭ-mĕn′tum\ *n* (1842): the thin calcified tissue of ectomesenchymal origin that covers the root of a tooth

connective tissue \ka-nĕk′tĭv tĭsh′ōō\: a tissue of mesodermal origin rich in interlacing processes that supports or binds together other tissues

crevicular epithelium \krĕ′vĭ-kyōō′lar ĕp′a-thē′lē-um\: the non-keratinized epithelium of the gingival crevice

crown-root ratio \kroun-rōōt rā′shō, rā′shē-ō′\: the physical relationship between the portion of the tooth within alveolar bone compared with the portion not within the alveolar bone, as determined by radiograph

de·bride·ment \dā′brēd-mäN′, dĭ-brēd′ment\ *n* (ca. 1842): the removal of inflamed, devitalized, contaminated tissue or foreign material from or adjacent to a lesion

donor site \dō′ner sīt\: an area of the body from which a graft is taken

eccentric \ĭk-sĕn′trĭk\ *adj* (14c): **1:** not having the same center **2:** deviating from a circular path **3:** located elsewhere than at the geometric center **4:** any position of the mandible other than that which is its normal position

etiologic factors \ē′tē-ō-lŏj′ĭk făk′tors\: the elements or influences that can be assigned as the cause or reason for a disease or lesion—see LOCAL E.F., SYSTEMIC E.F.

free gingival \frē jĭn′ja-va\: **1:** the part of the gingiva that surrounds the tooth and is not directly attached to the tooth surface

free gingival margin \frē jĭn′ja-val mär′jĭn\: the unattached gingiva surrounding the teeth in a collar-like fashion and demarcated from the attached gingiva by a shallow linear depression, termed the *free gingival groove*

frem·i·tus \frĕm′ĭ-tus\ *n* (1879): a vibration perceptible on palpation; in dentistry, a vibration palpable when the teeth come into contact

frenectomy: surgical excision of a frenum

fur·ca·tion \fûr′kā′shun\ *n*: the anatomic region of a multirooted tooth where the roots diverge

gin·gi·va \jĭn′ja-va, jĭn-jī-\ *n, pl* **-vae** \-vē′\: the fibrous investing tissue, covered by epithelium, which immediately surrounds a tooth and is contiguous with its periodontal membrane and with the mucosal tissues of the mouth—see ATTACHED G., FREE G., MARGINAL G.

gingival crevice \jĭn′ja-val krĕv′ĭs\: a shallow fissure between the marginal gingiva and the enamel or cementum. It is bounded by the tooth surface on one side, the crevicular epithelium on the other, and the coronal end of the junctional epithelium at its most apical point—called also *gingival sulcus*

guided tissue regeneration \gī′dĭd tĭsh′ōō rĭ-jĕn′a-rā′shun\: any procedure that attempts to regenerate lost periodontal structures or alveolar process through differential tissue responses. Barrier techniques, using synthetic materials that may or may not resorb, to exclude epithelial ingrowth *(periodontal regeneration)* or connective tissue ingrowth *(alveolar process regeneration)* that is believed to interfere with regeneration

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hemi·sec·tion \hĕm′ĭ-sĕk′shun\ *n*: the surgical separation of a multirooted tooth, especially a mandibular molar, through the furcation in such a way that a root and the associated portion of the crown may be removed

interdental papilla \ĭn′ter-dĕn′tl pa-pĭl′a\: a projection of the gingiva filling the space between the proximal surfaces of two adjacent teeth

junctional epithelium \jŭngk′shun-al ĕp′a-thē′lē-um\: a single or multi-layer of non-keratinizing cells adhering to the tooth surface at the base of the gingival crevice—called also *epithelial attachment*

ker·a·tin·i·za·tion \kĕr′a-tĭn-ĭ-zā-shun\ *n*: the process of maturation of keratinocytes. The formation of a protein layer (keratin) on the surface of some epithelia

keratinized gingival \kĕr′a-tī-nīzd jĭn′ja-va\: the oral surface of the gingiva extending from the mucogingival junction to the gingival margin. In gingival health, the coronal portion of the sulcular epithelium may also be keratinized. The pattern of keratinization may be *ortho-* or *para-*

lengthening of the clinical crown \lĕngk′tha-nĭng ŭv tha klĭn′ĭ-kal kroun\: a surgical procedure designed to increase the extent of supragingival tooth structure for restorative or esthetic purposes by apically positioning the gingival margin, removing supporting bone, or both

marginal gingiva \mär′ja-nal jĭn′ja-va\: the most coronal portion of the gingiva; often used to refer to the free gingiva that forms the wall of the gingival crevice in health

mo·bile \mō′bal, -bēl, -bīl\ *adj* (15c): capable of moving or being moved; movable

mucogingival junction \myōō′kō-jĭn′ja-val, jĭn′jī-\: the junction of gingiva and alveolar mucosa

mu·co·peri·os·te·um \myōō′kō-pĕr′ē-ŏs′tē-am\ *n*: a term synonymous with a full-thickness flap implying the inclusion of both mucosa and periosteum during flap elevation

mu·co·sa \myōō-kō′sa\ *n* (1880): a mucous membrane comprised of epithelium, basement membrane, and lamina propria—see ALVEOLAR M., ORAL M.

o·don·to·plasty \ō-dŏn′ta-plăs-tē\: the reshaping of a portion of a tooth

oral mucosa \ôr′al, ōr′- myōō-kō′sa\: the lining of the oral cavity

per·i·o·don·tal \pĕr′ē-ō-dŏn′tl\ *adj*: pertaining to or occurring around a tooth

primary occlusal trauma \prī′mĕr′ē a-klōō′al trou′ma\: the effects induced by abnormal or excessive occlusal forces acting on teeth with normal periodontal support

quadrant \kwŏd′rant\ *n* (15c): **1:** any of the four quarters into which something is divided by two real or imaginary lines that intersect each other at right angles **2:** in dentistry, one of the four sections of the dental arches, divided at the midline—see also SEXTANT, OCTANT

re·at·tach·ment \rē-a-tăch′mant\ *n*: in periodontics, the reunion of epithelial and connective tissues with root surfaces and bone such as occurs after incision or injury

re·flec·tion \rĭ-flĕk′shun\ (14c) *n*: **1:** the elevation and folding back of all or part of the mucosa to expose underlying structures **2:** the return of light or sound waves from a surface

repositioning splint \rē-pa-zĭsh′a-nĭng splĭnt\ *n*: an intraoral maxillofacial prosthesis constructed to temporarily or permanently alter the relative position of the mandible to the maxillae

secondary occlusal trauma \sĕk′an-dĕr-ē a-klōō′zal\: the effects induced by occlusal force (normal or abnormal) acting on teeth with decreased periodontal support

split-thickness graft \splĭt-thĭk′nĭs grăft\: a transplant of skin or mucous membrane consisting of epithelium and a portion of the dermis

stip·ple \stĭp′al\ *vt* **stip·pled** \stĭ′puld\ **stip·pling** \stĭp′lĭng\ (1760): **1:** to engrave by means of dots or/and flicks **2:** to make small short touches that together produce an even or softly graded shadow **3:** to speckle or fleck—**stip·pler** \stĭp′lar\ *n*

REFERENCES

1. Bhaskar SN: Orban's Oral Histology and Embryology, 11th ed. St. Louis, Mosby, 1991.
2. Bowers GM: A study of the width of the attached gingiva. J Periodontol 34:210, 1963.
3. Ainamo J, Loe H: Anatomic characteristics of gingiva: a clinical and microscopic study of the free and attached gingiva. J Periodontol 37:5, 1966.
4. Newman MG, Takei H, Carranza FA Jr: Clinical Periodontology, 9th ed. Philadelphia, WB Saunders, 2000.
5. Lindhe J: Textbook of Clinical Periodontology. Copenhagen, Munksgaard, 1989.
6. Schluger S, et al: Periodontal Disease: Basic Phenomena, Clinical Management, and Occlusal and Restorative Interrelationships, 2nd ed. Philadelphia, Lea & Febiger, 1990.
7. American Academy of Periodontology: The pathogenesis of periodontal diseases. J Periodontol 70:457, 1999.
8. Shafer WG, et al: A Textbook of Oral Pathology, 4th ed. Philadelphia, WB Saunders, 1983.

9. Thomas NG: Elastic fibers in periodontal membrane and pulp. J Dent Res 7:325, 1965.
10. Fullmer HM: A critique of normal connective tissues of the periodontium and some alterations with periodontal disease. J Dent Res 41(suppl 1):223, 1962.
11. Schroeder HE, Listgarten MA: Fine structure of the developing epithelial attachment of human teeth. Monogr Dev Biol 2:1, 1971.
12. Orban B, Kohler J: The physiologic gingival sulcus. Z Stomatol 22:353, 1924.
13. National Institute for Dental Research: Oral Health of United States Adults: The National Survey of Oral Health in U.S. Employed Adults and Seniors: 1985-1986 (NIH Publication No. 87-2868). Bethesda, Md, U.S. Department of Health and Human Services, Public Health Services, 1987.
14. Schwartz RS, Massler M: Tooth accumulated materials: a review and classification. J Periodontol 40:407, 1969.
15. Mandel ID: Dental plaque: nature, formation, and effects. J Periodontol 37:357, 1966.
16. Loe HE, et al: Experimental gingivitis in man. J Periodontol 36:177, 1965.
17. Newman HN: Calcium, matrix polymers, and plaque formation. J Periodontol 53:101, 1982.
18. Ritz HL: Microbial population shifts in developing human dental plaque. Arch Oral Biol 12:1561, 1967.
19. Slots J, et al: Microbiota of gingivitis in man. Scand J Dent Res 86:174, 1978.
20. Allen D, Kerr D: Tissue response in the guinea pig to sterile and non-sterile calculus. J Periodontol 36:121, 1965.
21. Wolff L, et al: Bacteria as risk markers for periodontitis. J Periodontol 65:498, 1994.
22. Page RC, Schroeder HE: Pathogenesis of inflammatory periodontal disease: a summary of current work. Lab Invest 34:235, 1976.
23. American Academy of Periodontology: Parameter on comprehensive periodontal examination. J Periodontol 71:847, 2000.
24. American Academy of Periodontology: Diagnosis of periodontal diseases. J Periodontol 74:1237, 2003.
25. Armitage GC: Clinical evaluation of periodontal diseases. Periodontol 2000 7:39, 1996.
26. Lang NP, et al: Monitoring disease supportive periodontal treatment by bleeding on probing. Periodontol 2000 12:44, 1996.
27. Greenstein G: Contemporary interpretation of probing depth assessments: diagnostic and therapeutic indications. J Periodontol 68:1194, 1997.
28. Turesky S, et al: Histologic and histochemical observations regarding early calculus formation in children and adults. J Periodontol 32:7, 1961.
29. Fine DH, Baumhammers A: Effect of water pressure irrigation on stainable material on the teeth. J Periodontol 41:468, 1970.
30. Bass CC: The optimum characteristics of tooth brushes for personal oral hygiene. Dent Items Interest 70:696, 1948.
31. Bass CC: The necessary personal oral hygiene for prevention of caries and periodontoclasia. J Louisiana Med Soc 101:52, 1948.
32. O'Leary TJ, et al: The Incidence of Recession in Young Males: Relationship to Gingival and Plaque Scores (Publication No. SAM-TR-67-97:1). U.S. Air Force School of Aerospace Medicine, July 1967.
33. Gjermo P, Flotra L: The plaque removing effect of dental floss and toothpicks: a group comparison study. J Periodont Res 4:170, 1969.
34. Graves R, et al: Comparative effectiveness of flossing and brushing in reducing interproximal bleeding. J Periodontol 60:243, 1989.
35. Arnim SS: The use of disclosing agents for measuring tooth cleanliness. J Periodontol 34:277, 1963.
36. Hujoel PP, et al: Non-surgical periodontal therapy and tooth loss. A cohort study. J Periodontol 71:736, 2000.
37. Westfelt E, et al: The effect of supragingival plaque control on the progression of advanced periodontal disease. J Clin Periodontol 25:536, 1998.
38. Black GV: A Work on Special Dental Pathology Devoted to the Diseases and Treatment of the Investing Tissues of the Teeth and Dental Pulp. Chicago, Medico-Dental Publishing, 1915.
39. Black AD: Treatment of chronic suppurative pericementitis. Natl Dent Assoc J 7:134, 1920.
40. Benjamin EM: The quantitative comparison of subgingival curettage and gingivectomy in the treatment of periodontitis simplex. J Periodontol 27:144, 1956.
41. Hassell TM: Epilepsy and the oral manifestations of phenytoin therapy. Monogr Oral Sci 9:1, 1981.
42. Ramfjord SP, Nissle RR: The modified Widman flap. J Periodontol 45:601, 1974.
43. Prichard J: Gingivoplasty, gingivectomy, and osseous surgery. J Periodontol 32:275, 1961.
44. Levin MP, et al: Healing of periodontal defects with ceramic implants. J Clin Periodontol 1:197, 1974.
45. Klingsberg J: Periodontal scleral grafts and combined grafts of sclera and bone: two year appraisal. J Periodontol 45:262, 1974.

46. Boyne PJ, Cooksey DE: Use of cartilage and bone implants in the restoration of edentulous ridges. J Am Dent Assoc 71:1426, 1965.
47. Forsberg H: Transplantation of os purum and bone chips in the surgical treatment of periodontal disease. Acta Odontol Scand 13:235, 1956.
48. Schaffer EM: Cementum and dentine implants in a dog and a rhesus monkey. J Periodontol 28:125, 1957.
49. Robinson RE: The osseous coagulum for bone induction technique: a review. J Calif Dent Assoc 46:18, 1970.
50. Mellonig JT, et al: Clinical evaluation of freeze-dried bone allografts in periodontal osseous defects. J Periodontol 47:125, 1976.
51. Dragoo MK, Sullivan HC: A clinical and histological evaluation of autogenous iliac bone grafts in humans. I. Wound healing 2 to 8 months. J Periodontol 44:599, 1973.
52. Schallhorn RG: Present status of osseous grafting procedures. J Periodontol 48:570, 1977.
53. Kenney EB, et al: Bone formation within porous hydroxylapatite implants in human periodontal defects. J Periodontol 57:76, 1986.
54. Stahl SS, Froum S: Histological evaluation of human intraosseous healing responses to the placement of tricalcium phosphate ceramic implants. J Periodontol 57:211, 1986.
55. Schepers EJG, Ducheyne P: The application of bioactive glass particle of narrow size range as a filler material for bone lesions. Bioceramics 6:401, 1993.
56. Ong MMA, et al: Evaluation of a bioactive glass alloplast in treating periodontal intrabony defects. J Periodontol 69:1346, 1998.
57. Haase HR, Bartold PM: Enamel matrix derivative induces matrix synthesis by cultured human periodontal fibroblast cells. J Periodontol 72:28, 2001.
58. Yukna RA, Mellonig JT: Histologic evaluation of periodontal healing in humans following regenerative therapy with enamel matrix derivative. A 10-case series. J Periodontol 71:752, 2000.
59. Olsen C, et al: A longitudinal study comparing apically positioned flaps, with and without osseous surgery. Int J Periodontics Restorative Dent 5:11, 1985.
60. Becker W, et al: A longitudinal study comparing scaling, osseous surgery and modified Widman procedures: results after one year. J Periodontol 59:351, 1988.
61. Kaldahl WB, et al: Evaluation of four modalities of periodontal therapy. Mean probing depth, probing attachment level and recession changes. J Periodontol 59:783, 1988.
62. Baima RF: Considerations for furcation treatment. I. Diagnosis and treatment planning. J Prosthet Dent 56:138, 1986.
63. Abrams L, Trachtenberg DI: Hemisection—technique and restoration. Dent Clin North Am 18:415, 1974.
64. Highfield JE: Periodontal treatment of multirooted teeth. Aust Dent J 23:91, 1978.
65. Gher ME, Vernino AR: Root anatomy: a local factor in inflammatory periodontal disease. Int J Periodontics Restorative Dent 1(5):52, 1981.
66. Cohen S, Hargreaves KM: Pathways of the Pulp, 9th ed. St. Louis, Mosby, 2006.
67. Ash MM, Nelson SJ: Wheeler's Dental Anatomy, Physiology, and Occlusion, 8th ed. Philadelphia, WB Saunders, 2003.
68. Hamp SE, et al: Periodontal treatment of multirooted teeth. Results after 5 years. J Clin Periodontol 2:126, 1975.
69. Ross IF, Thompson RH: A long-term study of root retention in the treatment of maxillary molars with furcation involvement. J Periodontol 49:238, 1978.
70. Hellden LB, et al: The prognosis of tunnel preparations in treatment of class III furcations. A follow-up study. J Periodontol 60:182, 1989.
71. Amen CR: Hemisection and root amputations. Periodontics 4:197, 1966.
72. Newell DH, et al: Fixed prosthodontics with periodontally compromised dentitions. In Malone WF, Koth DL, eds: Tylman's Theory and Practice of Fixed Prosthodontics, 8th ed. Tokyo, Ishiyaku-EuroAmerica, 1989.
73. Baima RF: Considerations for furcation treatment. II. Periodontal therapy. J Prosthet Dent 57:400, 1987.
74. Bergenholtz A: Radiectomy of multirooted teeth. J Am Dent Assoc 85:870, 1972.
75. Haskell EW, Stanley HR: A review of vital root resection. Int J Periodontics Restorative Dent 2(6):28, 1982.
76. Lee FMS: The displaced root in the maxillary sinus. Oral Surg 29:491, 1970.
77. Waldrep AC Jr: Management of fractured root fragments. Dent Clin North Am 17:549, 1973.
78. Langer B, et al: An evaluation of root resections. A ten-year study. J Periodontol 52:719, 1981.
79. Basaraba N: Root amputation and tooth hemisection. Dent Clin North Am 13:121, 1969.
80. Polson AM: Periodontal considerations for functional utilization of a retained root after furcation management. J Clin Periodontol 4:223, 1977.

81. Baima RF: Considerations for furcation treatment. III. Restorative therapy. J Prosthet Dent 58:145, 1987.
82. Caplan CM: Fixed bridge placement following endodontic therapy and root hemisection. Dent Surv 54(6):28, 1978.
83. Haskell EW, Stanley HR: Resection of two vital roots. J Endodont 1:36, 1975.
84. Carnevale G, et al: Management of furcation involvement. Periodontol 2000 9:69, 1995.
85. Carnevale G, et al: Long-term effects of root-resective therapy in furcation-involved molars: a 10-year longitudinal study. J Clin Periodontol 25:209, 1998.
86. Melcher AH: On the repair potential of periodontal tissues. J Periodont Res 47:256, 1976.
87. Aukhil I, et al: Periodontal wound healing in the absence of periodontal ligament cells. J Periodontol 58:71, 1987.
88. Nyman S, et al: The regenerative potential of the periodontal ligament. An experimental study in the monkey. J Clin Periodontol 9:257, 1982.
89. Magnusson I, et al: New attachment formation following controlled tissue regeneration using biodegradable membranes. J Periodontol 59:1, 1988.
90. Pitaru S, et al: Collagen membranes prevent the apical migration of epithelium during periodontal wound healing. J Periodont Res 22:331, 1988.
91. Cortellini P, et al: Guided tissue regeneration with different materials. Int J Periodontics Restorative Dent 10:136, 1990.
92. Eickholz P, et al: Guided tissue regeneration with bioabsorbable barriers. II. Long-term results in infrabony defects. J Periodontol 75:957, 2004.
93. Kwan SK, et al: The use of autogenous periosteal grafts as barriers for the treatment of intrabony defects in humans. J Periodont 69:1203, 1998.
94. Tonetti MS, et al: Generalizability of the added benefits of guided tissue regeneration in the treatment of deep intrabony defects. Evaluation in a multi-center randomized controlled clinical trial. J Periodontol 69:1183, 1998.
95. Pontoriero R, et al: Guided tissue regeneration in the treatment of furcation defects in man. J Clin Periodontol 14:618, 1987.
96. Caffesse RG, et al: Class II furcations treated by guided tissue regeneration in humans: case reports. J Periodontol 61:510, 1990.
97. Vernino AR, et al: Use of biodegradable polylactic acid barrier materials in the treatment of grade II periodontal furcation defects in humans—Part I: a multicenter investigative clinical study. Int J Periodontics Restorative Dent 18:572, 1998.
98. De Leonardis D, et al: Clinical evaluation of the treatment of class II furcation involvements with bioabsorbable barriers alone or associated with demineralized freeze-dried bone allografts. J Periodontol 70:8, 1999.
99. Becker W, et al: Bone formation at dehisced dental implant sites treated with implant augmentation material: a pilot study in dogs. Int J Periodontics Restorative Dent 10:92, 1990.
100. Dahlin C, et al: Membrane-induced bone augmentation at titanium implants. A report on ten fixtures followed from 1 to 3 years after loading. Int J Periodontics Restorative Dent 11:273, 1991.
101. Becker W, Becker BE: Guided tissue regeneration for implants placed into extraction sockets and for implant dehiscences: surgical techniques and case reports. Int J Periodontics Restorative Dent 10:376, 1990.
102. Sottosanti J: Calcium sulfate: a biodegradable and biocompatible barrier for guided tissue regeneration. Compend Contin Educ Dent 13:226, 1992.
103. Payne JM, et al: Migration of human gingival fibroblasts over guided tissue regeneration barrier materials. J Periodontol 67:236, 1996.
104. Kim C-K, et al: Periodontal repair with intrabony defects treated with a calcium sulfate implant and calcium sulfate barrier. J Periodontol 69:1317, 1998.
105. American Academy of Periodontology: Parameter on periodontal maintenance. J Periodontol 71: 849, 2000.
106. American Academy of Periodontology: Periodontal maintenance. J Periodontol 74:1395, 2003.
107. Bergstrom J, et al: A 10-year prospective study of tobacco smoking and periodontal health. J Periodontol 71:1338, 2000.
108. Calsina G, et al: Effects of smoking on periodontal tissues. J Clin Periodontol 29:771, 2002.
109. Baljoon M, et al: The association of smoking with vertical periodontal bone loss. J Periodontol 75:844, 2004.

6

MOUTH PREPARATION



KEY TERMS

definitive periodontal treatment
foundation restorations
minor tooth movement
occlusal adjustment
treatment sequence

As the scope of fixed prosthodontics has expanded, it has become increasingly clear that failures are often attributable to inadequate mouth preparation. In this case, mouth preparation refers to the dental procedures that need to be accomplished before fixed prosthodontics can be properly undertaken. Rarely are crowns or fixed dental prostheses provided without initial therapy of a multidisciplinary and often extensive nature, because the etiologic factors that lead to the need for fixed prosthodontics also promote other pathologic conditions (caries and periodontal disease are the most common). These must be corrected as an early phase of treatment. Fixed prosthodontics is successful only if restorations are placed on well-restored teeth in a healthy environment, a fact that can become obscured in the misguided attempt to try to help a patient by accelerating treatment; unfortunately, such action often leads to unforgivable failure.

This chapter reviews the ways in which treatment by the different dental disciplines relates to fixed prosthodontics. Detailed descriptions of the particular procedures are obviously beyond the scope of this text.

Comprehensive treatment planning ensures that mouth preparation is undertaken in a logical and efficient sequence aimed at bringing the teeth and their supporting structures to optimum health. Equally important is the need to educate and motivate the patient to maintain long-term dental health through meticulous oral hygiene practices. As a general plan, the following sequence of treatment procedures in advance of fixed prosthodontics should be adhered to:

1. Relief of symptoms (chief complaint).
2. Removal of etiologic factors (e.g., excavation of caries, removal of deposits).
3. Repair of damage.
4. Maintenance of dental health.

The following list describes a typical sequence in the treatment of a patient with extensive dental disease, including missing teeth, retained roots, caries, and defective restorations:

Preliminary assessment (Fig. 6-1*A*)
Emergency treatment of presenting symptoms (Fig. 6-1*B*)
Oral surgery (Fig. 6-1*C*)
Caries control and replacement of existing restorations (Fig. 6-1*D*)
Endodontic treatment (Fig. 6-1*E*)
Definitive periodontal treatment, possibly in conjunction with preliminary occlusal therapy (Fig. 6-1*F*)

Orthodontic treatment
Definitive occlusal treatment
Fixed prosthodontics (Fig. 6-1*G* and *H*)
Removable prosthodontics (Fig. 6-1*I*)
Follow-up care

However, the sequence of preparatory treatment should be flexible. Two or more of these phases are often performed concurrently. Carious lesions or defective restorations often prevent proper oral hygiene measures, and their elimination or correction must be a part of preparatory treatment. If caries control results in a pulpal exposure or exacerbates an existing chronic pulpitis, endodontic treatment may be needed earlier than anticipated. When the

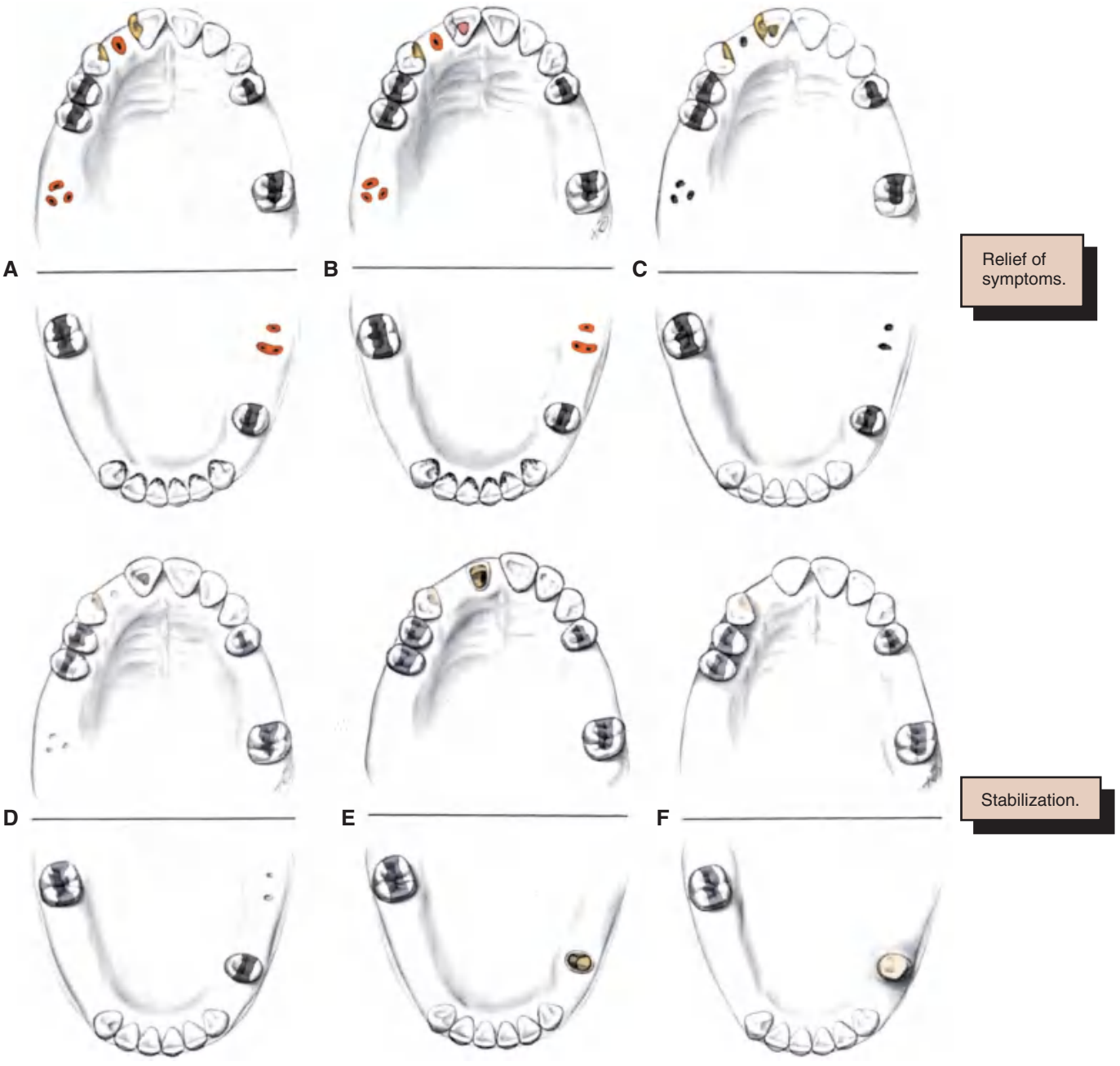


Fig. 6-1
Sequence of treatment. **A,** The patient has pain that seems to originate from the maxillary right central incisor. In addition, several teeth are missing, and retained roots, caries, calculus, and defective restorations are present. **B,** Relief of the acute problem by endodontic treatment of the incisor. **C,** Removal of deposits and unrestorable teeth. **D,** Caries are controlled, and defective restorations are replaced. The progress of ongoing disease has been halted. **E,** Endodontic treatment is undertaken, and post and cores and an interim restoration are placed. **F,** Definitive periodontal treatment is performed.

Continued



Fig. 6-1, cont'd

G, Teeth are prepared for the final restoration. **H,** The fixed restorations are completed. **I,** Active phase of the treatment has been accomplished. Note that predictable management of complex prosthodontics involving fixed and removable dental prostheses can be facilitated by adopting the technique described on p. 102.

primary symptoms have been eliminated, the occlusal needs of the patient are carefully evaluated through clinical examination and the study of articulated diagnostic casts. Extensive treatment of both arches simultaneously may be beyond the scope of the nonspecialist, and the use of cross-mounted diagnostically mounted casts should be considered (see p. 102). This enables treatment of each arch to be accomplished predictably and independently. Only when preparatory occlusal treatment is completed will the patient be ready for definitive restorative care.

ORAL SURGERY

Soft Tissue Procedures

Any soft tissue abnormalities that may necessitate surgical intervention should be recognized during the initial or radiographic examination. If necessary, the patient can be referred to an oral surgeon for further consultation and/or treatment. Diagnosis of pathologic conditions can be difficult, and the general practitioner should make the appropriate referral to a specialist when there is doubt.

Elective soft tissue surgery may include alteration of muscle attachments, removal of a wedge of soft tissue distal to the molars, increase of the vestibular depth, or modification of edentulous ridges to accommodate fixed or removable partial prostheses (Fig. 6-2).

Hard Tissue Procedures

Simple tooth removal is the most common surgical procedure involving hard tissue. It should be performed as early during treatment as possible for maximum healing time and osseous recontouring.

Tuberosity reduction (Fig. 6-3) is also common, especially when there is inadequate space to accommodate a prosthesis. Although maxillary or mandibular tori (Fig. 6-4) seldom interfere with the fabrication of a fixed partial dental prosthesis, their excision may make it easier to design a removable partial dental prosthesis and occasionally improves access for oral hygiene measures.

Impacted or unerupted supernumerary teeth should be removed if damage to adjacent structures can be avoided.

Orthognathic Surgery

Candidates for orthognathic surgery require careful restorative evaluation and attention before treatment. Otherwise, an expected improvement in

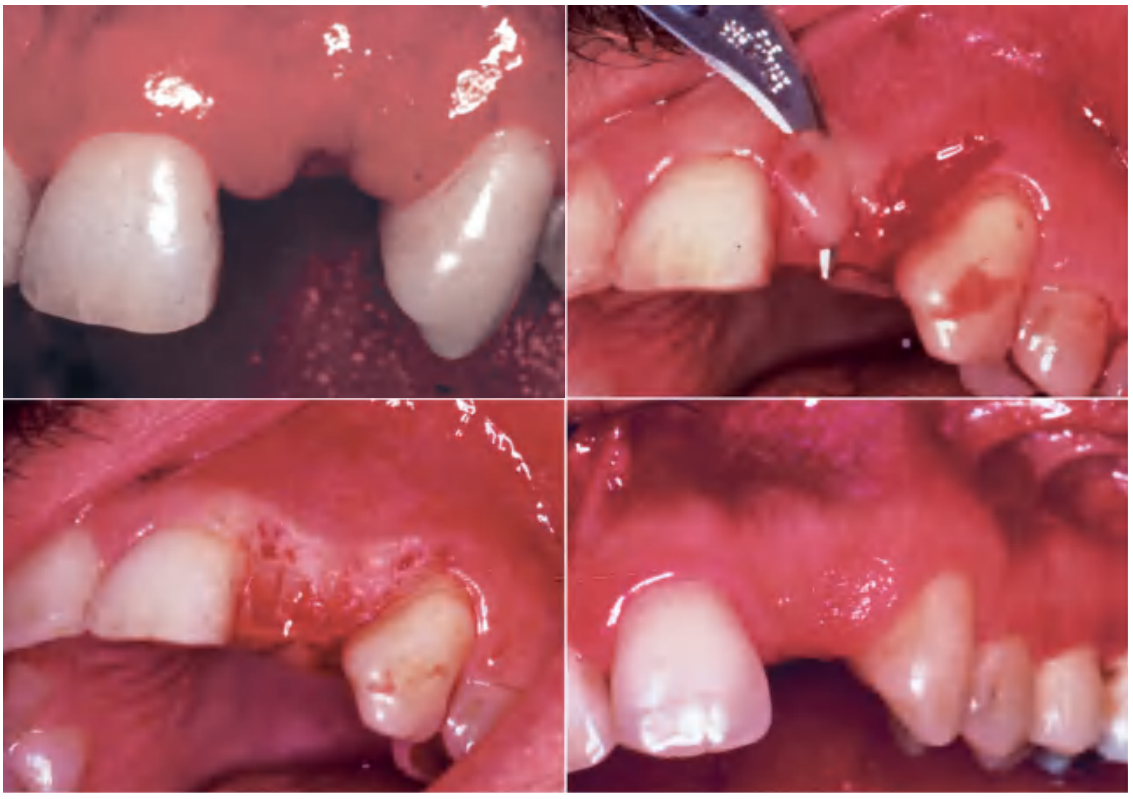


Fig. 6-2
A to **D**, Soft tissue surgery to correct an unfavorable edentulous ridge before fixed dental prosthesis fabrication.



Fig. 6-3
Tuberosity reduction was indicated for this patient to accommodate a mandibular removable dental prosthesis. *(Courtesy of Dr. J. Bergamini.)*



Fig. 6-4
A, Mandibular torus necessitating surgical reduction before the fabrication of a partial removable dental prosthesis. **B**, Buccal torus that was interfering with oral hygiene.

the facial skeleton may be accompanied by unexpected occlusal dysfunction. After surgery, the connection between plaque control, caries prevention, and periodontal health should be stressed to the patient.

Implant-Supported Fixed Prostheses

Successful implant dentistry requires meticulous selection of the patient and skillful execution of the chosen technique. A team approach to treatment is strongly recommended with close cooperation between the specialties (see Chapter 13).

CARIES AND EXISTING RESTORATIONS

Crowns and fixed dental prostheses are definitive restorations. They are time-consuming and expensive treatment options and should not be recommended unless an extended lifetime of the restoration is anticipated. Many teeth that require crowns are severely damaged or have large existing restorations. Any restoration on such teeth must be carefully examined and a determination made regarding its serviceability. If doubt exists, the restoration should be replaced. Time spent replacing an existing restoration that in retrospect might have been serviceable is a modest price to pay for the assurance that the foundation will be caries free and well restored. Studies have shown that accurately detecting caries beneath a restoration without its complete removal can be very difficult.[1-3] Even on caries-free teeth, an existing restoration may not be a suitable foundation. Preparation design is different for a foundation than for a conventional restoration, particularly with regard to the placement of retention. In general, when a crown is needed, the dentist should plan to replace any existing restorations. Although most teeth in need of restoration require **foundation restorations,** small defects resulting from less extensive lesions can often be incorporated in the design of a cast restoration or can be blocked out with cement (Fig. 6-5). The latter is recommended on axial walls where an undercut would otherwise result. If a small defect is present on the occlusal surface, however, it may be better to incorporate it into the final restoration than to block it out. The difficulty, of course, is anticipating this during the preparatory phase of treatment. Assessment is more difficult when an existing crown or fixed dental prosthesis is being replaced. In that case, the extent of damage can be seen only after the defective restoration has been removed.



Fig. 6-5
Small defects (*arrow*) that would create undercuts are best blocked out intraorally with cement or resin.

FOUNDATION RESTORATIONS

A foundation restoration, or core, is used to build a damaged tooth to ideal anatomic form before it is prepared for a crown. With extensive treatment plans, the foundation may have to serve for an extended time. It should provide the patient with adequate function and should be contoured and finished to facilitate oral hygiene. Subsequent tooth preparation is greatly simplified if the tooth is built up to ideal contour. Then it can be prepared essentially as if it were intact. Guide grooves can be used to facilitate accurate occlusal and axial reduction (see Chapter 8), and the preparation design will be consistent from tooth to tooth. The skills learned preparing preclinical mannequins with "ideal" teeth can be readily transferred to clinical practice.

Selection Criteria

Selection of the foundation material depends on the extent of tooth destruction, the overall treatment plan, and the operator's preference (Fig. 6-6). The effect of subsequent tooth preparation for the cast restoration on the retention and resistance of the foundation should be considered. Retention features such as grooves or pinholes should be placed sufficiently pulpally to allow adequate room for the definitive restoration. Adhesive retention may be helpful in preventing loss of the foundation during tooth preparation.

Dental amalgam

Despite its limitations, amalgam is still the material of choice for most foundation restorations on posterior teeth. It has good resistance to microleakage and is therefore recommended when the crown preparation will not extend more than 1 mm beyond the foundation-tooth junction.[4] It can be shaped to ideal restoration form and serves well as an interim

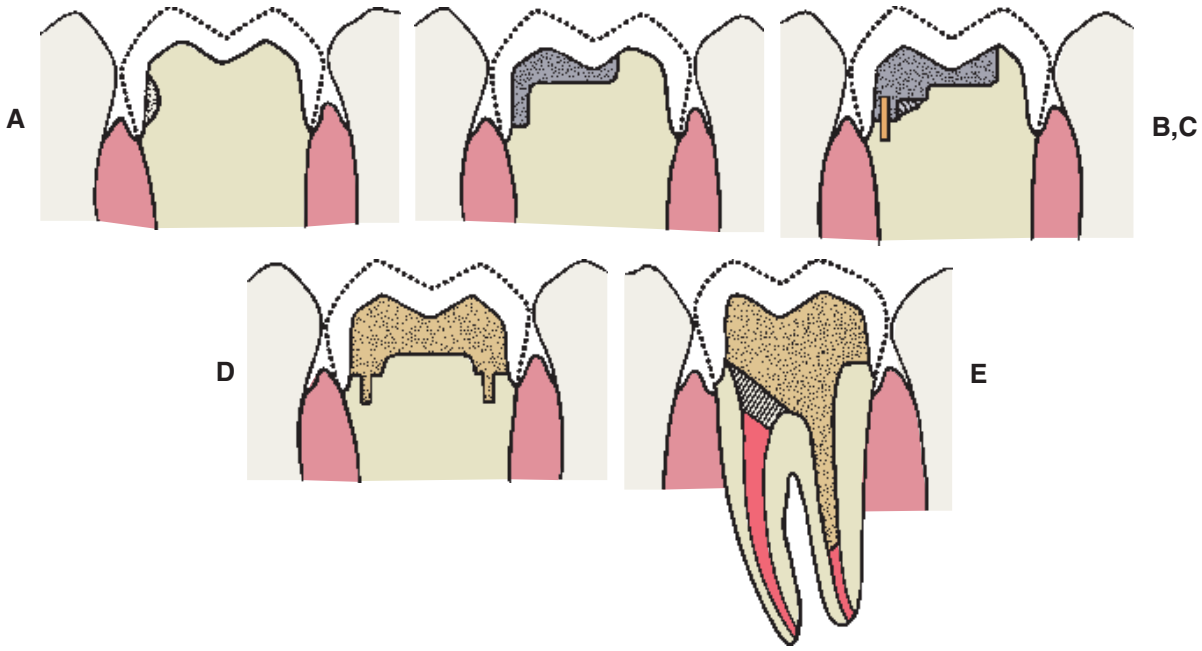


Fig. 6-6
The placement of a foundation restoration depends on the extent of damage to the tooth and should always be designed with the definitive restoration in mind. **A,** Cement. This is suitable when damage is minimal. **B,** Amalgam. **C,** Pin-retained amalgam. **D,** Cast gold. **E,** Post and core. *(See Chapter 12.)*

restoration. It has better strength than the glass ionomers, and retention can be provided by undercuts, pins, or slots. Adhesive bonding systems such as those based on 4-methacryloxyethyl trimellitate anhydride (4-META) are also available[5-8] and may reduce leakage of the restoration.[9,10] Additional retention may be provided with the use of polymeric beads supplied with the Amalgambond system.[11] Amalgam requires an absolutely rigid matrix for proper condensation; otherwise the foundation will break. Matrix placement can be demanding when a tooth with little remaining coronal tissue is restored. This is discussed in the step-by-step procedure on p. 140. Amalgam has a longer setting time than do the other foundation materials. This normally delays crown preparation until a subsequent patient visit. When this presents a problem, a rapid-setting, high-copper, spherical alloy should be chosen. These can be prepared for a crown about 30 minutes after placement. Spherical amalgams are advantageous for foundation restorations because they have greater early strength than do admixed materials, which makes fracture soon after placement less of a possibility.[12]

Resin-modified glass ionomer cement

This is a suitable choice for a small lesion. The material sets rapidly, enabling crown preparation to be performed with limited delay. When placed correctly, it exhibits adhesion to dentin, although conventional undercut retention is needed to supplement this. It is important to select a material that has adequate radiopacity. A formulation that is more radiolucent than dentin should not be used as a core, because its radiographic appearance may suggest recurrent caries.[13] The presence of fluoride in resin modified glass ionomers may help prevent recurrent caries. The chief disadvantage of glass ionomers is their comparatively low strength, which may make the material inferior to amalgam or composite resin for the longer term restoration of extensive lesions.[14,15]

Composite resin

Composite resin exhibits many of the advantages of glass ionomers. It does not require condensation and sets rapidly. Formulations are available that release fluoride, which may provide an anticariogenic benefit.[16] Bonding is achieved with a dentinal bonding agent or by etching a glass ionomer liner. Neither method develops the bond strengths needed to withstand high masticatory forces, and conventional undercut retention is also needed. There are concerns about continued polymerization of the resin and its high thermal expansion coefficient, which may lead to microleakage of the crown.[17] Also of concern is the moisture sorption properties of composite resin that causes delayed expansion and

may lead to axial binding of crowns made on composite resin cores.[18,19] Delayed expansion is not a problem with traditional glass ionomer,[20] but it is a problem with the resin-modified glass ionomers and the compomer materials.[19] Conventional tooth-colored composite resin is not recommended as a foundation material, because it is difficult to discern the composite-tooth junction. Special colored core materials should be used.

Pin-retained cast metal core

A cast metal core should be considered for an extensively damaged tooth. The cemented foundation is retained by tapered pins. The preparation requires careful location and placement of the pinholes but otherwise is straightforward. The foundation is fabricated in the laboratory as an indirect procedure. This increases the complexity and expense of treatment but facilitates obtaining good preparation form.

Advantages and disadvantages of the available materials are summarized in Table 6-1.

Step-by-Step Procedures

Amalgam core

1. Isolate the tooth. Rubber dam isolation is strongly recommended for moisture control, infection control, and optimum visibility. Placement follows techniques developed for conventional amalgam restorations, although with extensively damaged teeth, placing the dam can be a problem. Sometimes cotton roll isolation must suffice.
2. Design the tooth preparation with the intended cast restoration in mind. Be sure that the cast restoration does not eliminate retention of the foundation. The preparation differs somewhat from a conventional amalgam restoration. The ensuing discussion highlights these differences.[21]
3. Limit the extent of the outline form. In contrast to conventional amalgam preparations, which are extended to include unsupported enamel and the deep occlusal fissures, a less extensive outline is recommended for foundation restorations, because the fissures and contacts are removed during crown preparation. Although minimizing foundation outline can help conserve supporting tooth structure, the foundation should be adequate for the detection of any carious lesions (Fig. 6-7*A*).
4. Retain unsupported enamel if convenient. For a conventional amalgam tooth preparation, unsupported enamel must always be removed; otherwise, the enamel may fracture during function and leave a deficient margin. However, for a foundation restoration, the unsupported enamel may be preserved most effectively if it is substantial enough to withstand condensation forces and if the enamel-dentin junction is caries free. Preserving unsupported enamel may facilitate matrix placement and improve amalgam condensation (see Fig. 6-7*B*).

Table 6-1 FOUNDATION RESTORATION MATERIALS

	Advantages	Disadvantages	Recommended use	Precautions
Amalgam	Good strength Intermediate restoration	Preparation delay Condensation Corrosion No bonding*	Most foundations	Well-supported matrix
Glass ionomer	Rapid setting Adhesion Fluoride	Low strength Moisture sensitive†	Smaller lesions	Moisture control
Composite resin	Rapid setting Ease of use Bonding	Thermal expansion Setting contraction Delayed expansion	Smaller lesions Anterior teeth	Moisture control
Cast gold	Highest strength Indirect procedure	Two-visit procedure Interim restoration needed	Extensive lesions	Alignment of pinholes

*Bonding can be achieved with 4-methacryloxyethyl trimellitate anhydride (4-META) products.
†Resin-modified formulations are less sensitive.

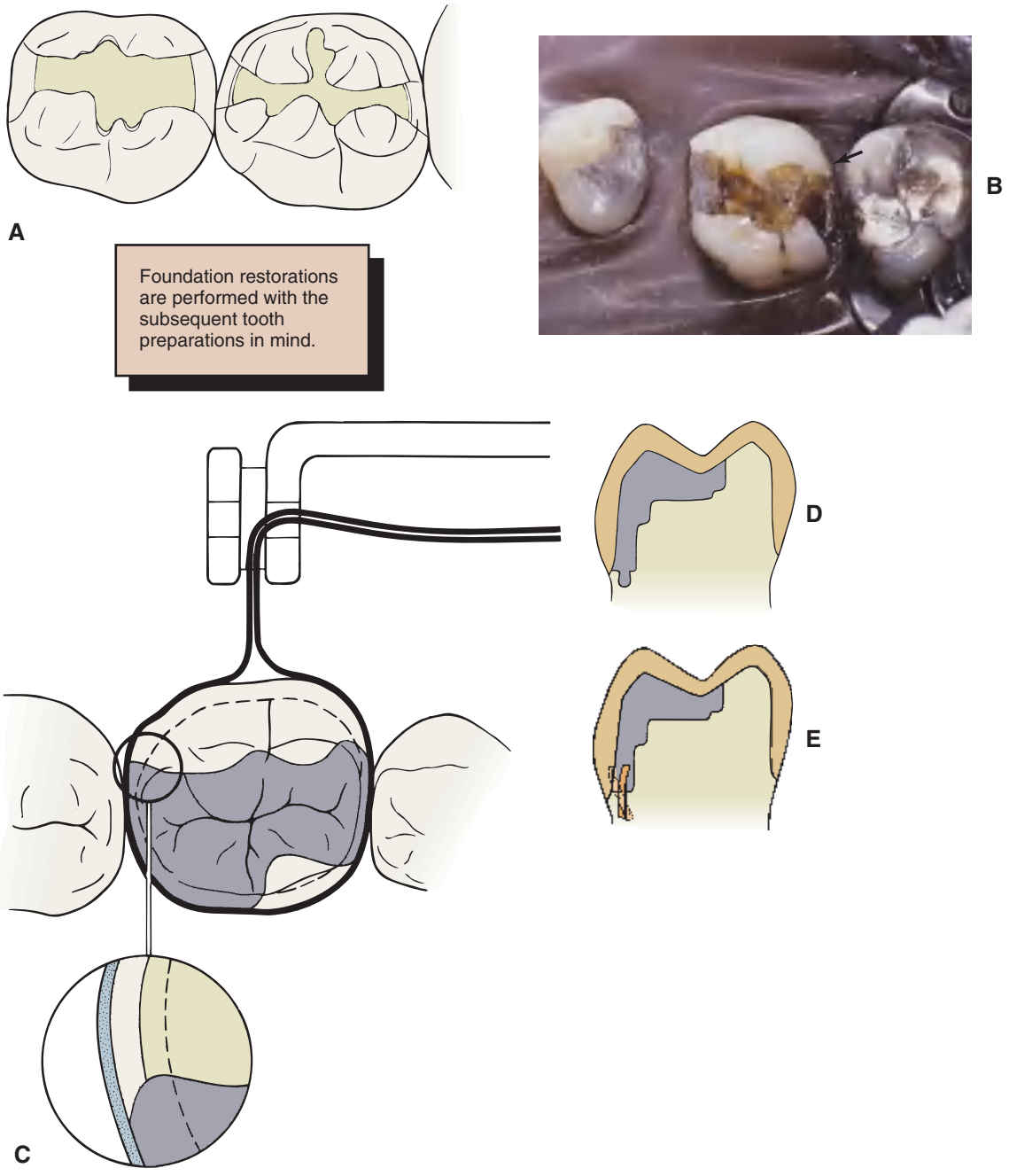


Fig. 6-7

The principles of preparation design for an amalgam foundation restoration differ slightly from those for a conventional extensive amalgam restoration. **A,** The outline form of a foundation need not include fissures or proximal or occlusal contacts, provided complete caries removal can be accomplished. **B,** Unsupported enamel (*arrow*) can sometimes be left when a foundation restoration is prepared. It may facilitate matrix placement and is removed when the crown is prepared. **C,** Acute cavosurface margins are acceptable for a foundation restoration but not for a definitive amalgam. **D,** Resistance form is improved by preparing the tooth in a series of steps perpendicular to the direction of occlusal force. **E,** When pin retention is used, pinholes should be drilled slightly pulpally and at an angle to the root surface (*solid line*), in comparison with the way they are placed for a conventional extensive amalgam restoration (*dashed line*). This ensures that retention for the foundation remains after crown preparation.

5. Finish the cavosurface margins. For conventional amalgam restorations, cavosurface margins of 90 degrees are needed to minimize the potential for fracturing the enamel and amalgam during function. However, for foundation restorations, the amalgam-tooth interface will not be subjected to high stresses (they are protected by the crown), and marginal fracture is not likely to be a problem. Therefore, a 46- to 136-degree margin is acceptable. Furthermore, such a margin conserves useful tooth substance and improves condensation (Fig. 6-7*C*).
6. Remove any carious dentin carefully and thoroughly with a hand excavator or large round bur in a low-speed handpiece. Discolored but hard dentin can be left on the pulpal wall, but caries-affected areas at the enamel-dentin junction should be removed completely. If a pulp exposure occurs during the preparation, whether carious or mechanical, endodontics or tooth removal is necessary. A direct pulp cap is not a good choice for a tooth requiring a fixed dental prosthesis; however, if endodontics is elected and the pulp cannot be extirpated immediately, a suitable sedative dressing should be placed.
7. Create optimum resistance form. Good resistance to masticatory forces is as crucial for a foundation as for a conventional restoration. Whenever possible, the tooth preparation should be perpendicular to the occlusal forces. If a sloping axial wall exists, it should be modified into a series of steps to enhance resistance form (Fig. 6-7*D*).
8. Be sure that the foundation restoration has adequate retention (augmented if necessary by pins, slots, or wells). Proper placement of retention features is essential to the preparation of a successful foundation. The features must be incorporated into the design so they are not eliminated during preparation of the crown (Fig. 6-7*D* and *E*).

This can be a particular problem with the extensive reduction necessary for a metal-ceramic restoration. Pin placement is dictated by root furcations and the size of the pulp chamber. In general, pins should be placed further pulpally than when conventional extensive pin amalgams are being provided; to prevent pulp perforation, they should be positioned at a slight angle to the long axis of the tooth. If a pin is slightly exposed during crown preparation, this may not be a problem—in contrast to the conventional pin-amalgam restoration. With a foundation restoration, the pin-amalgam interface receives little stress during function.

Retention can also be provided by slots or wells. These create less residual stress in the dentin and thus reduces the risk of pulp exposure or damage.[22-26] They should be placed pulpally to the intended crown margin, at a depth of about 1 mm, with a small carbide bur. Careful condensation of amalgam into the slots ensures good restoration retention.

Bonding agents can assist amalgam retention, but adhesion is not adequate to resist occlusal loading. Retention is currently best provided by conventional means. An example of the use of bonding agents appears in Figure 6-8. If bonding agents are used, the clinician should follow the manufacturer's directions about storage and manipulation.

Bases and varnishes

A base is necessary to prevent thermal irritation if the preparation extends close to the pulp. A material with good physical properties, such as glass ionomer or zinc phosphate, should be chosen, because weaker materials are likely to fracture during amalgam condensation. Excessively thick bases should be avoided if they would leave inadequate thickness of amalgam foundation after tooth preparation. Postoperative sensitivity can be prevented with two or more coats of cavity varnish or a dentin bonding agent. The coats should be placed after any pinholes are drilled but before the pins are placed to avoid material at the pin-amalgam interface.

Calcium hydroxide liners should be reserved for use in deep cavities when a microscopic pulp exposure is suspected. They generally have low strength and do not resist condensation forces well. Macroscopic exposures should receive endodontic treatment or, if direct pulp capping is the only option, a conventional pin-amalgam should be placed as the definitive restoration, at least until the success of the pulp capping can be guaranteed.

Matrix placement

A rigid, well-contoured matrix allows the amalgam to be properly condensed and facilitates carving. However, it can present a problem when much tooth structure is missing. Conventional matrix retainers, such as the Tofflemire, are unstable if both the lingual and the buccal walls are missing. A circumferential matrix (e.g., the AutoMatrix Retainerless Matrix System*) is useful for extensive restorations. Alternatives include copper bands or orthodontic bands. These are removed by cutting with a bur after the amalgam has set. Stability of the matrix is improved by proximal wedging, by crimping to shape, and by using modeling plastic or autopolymerizing acrylic resin for external stabilization[27,28] (Fig. 6-9).

*DENTSPLY International, L. D. Caulk, Milford, Delaware.



Fig. 6-8
Adhesives such as AmalgamBond, a 4-methacryloxyethyl trimellitate anhydride (4-META) product, may be helpful in retaining amalgam foundations. **A,** Mandibular molar with extensive tooth structure loss prepared for foundation restoration. **B,** The dentin conditioner (10% citric acid, 3% ferric chloride) is applied in accordance with the manufacturer's instructions. Then it is rinsed and lightly dried. **C,** The conditioner is primed, and the operator waits for 20 seconds. If puddles remain, the operator blows to eliminate them. It is not necessary to dry the primer. **D** to **F,** The adhesive is mixed, and the powder liner is incorporated and brushed into the prepared cavity. **G,** The amalgam is condensed while the liner is still wet. **H,** The finished restoration. *(Courtesy of Parkell Products, Inc., Farmingdale, New York.)*



Fig. 6-9
Autopolymerizing resin can help stabilize the matrix for an amalgam foundation restoration.

Condensation

Condensation follows conventional practice, with particular attention paid to condensing into wells and around pins. If the foundation is prepared during the same visit, a high-copper spherical alloy is chosen. A mechanical condenser is useful for large amalgam restorations.

Contouring and finishing

Care is needed to prevent amalgam fracture during matrix removal. After allowing time for setting, the dentist trims the amalgam away from the occlusal edge of the matrix and removes the wedges and matrix retainer. At this stage, it is helpful to cut the buccal ends of the matrix band with scissors close to the tooth. Then the band can be pulled through the

proximal contacts toward the lingual aspect. Pulling the band occlusally is more likely to fracture the freshly placed amalgam.

Contouring follows conventional practice if the foundation is to serve for a significant period. Such a foundation should also be finished to facilitate plaque control. If the foundation is to be prepared shortly after placement, a more rudimentary occlusal contour is acceptable. However, the occlusal contour should be adequate to provide proper tooth stability. Moreover, all margins should be carved properly, because excess leads to plaque retention and makes crown margin placement difficult.

Glass ionomer core

1. Isolate the tooth. As with amalgam preparations, moisture control is critical with glass ionomer preparations (Fig. 6-10). The setting material is very sensitive to moisture. When it is set, it must not be allowed to dry out; otherwise, it deteriorates rapidly. The light-cured, resin-modified glass-ionomers are less sensitive to early moisture.[29]
2. Prepare the tooth for a casting; then remove any existing restorations and bases, excavate caries, and create the undercut retention. Glass ionomer is best for small foundations on teeth with at least two axial walls of sound dentin remaining. Currently available glass ionomers are not strong enough to be used for large pin-retained foundations. (Often they are chosen when the foundation and crown preparation are completed during one visit.) After tooth preparation and the creation of undercuts, glass ionomer is used to build the tooth up to ideal preparation form, if any defects are relatively small. Adhesion to dentin can be enhanced by removing some of the smear layer with a chemical agent. However, excessive removal of the smear layer is not recommended, because it could lead to pulp irritation. A 20-second application with a dentin-conditioning agent that contains 10% polyacrylic acid should be sufficient. Dry the tooth with a cotton pledget before placing the ionomer; do not use an air syringe.
3. Using a syringe, apply the glass ionomer onto the tooth, being careful not to create voids at the cement-tooth interface. Remember that with the conventional self-hardening formulations, adhesion of glass ionomer to tooth structure occurs only if the cement is placed rapidly after mixing; 10 seconds should be allowed for loading the syringe and 10 seconds for placement and manipulation. Some manufacturers provide an encapsulated delivery system that helps place the cement rapidly. A matrix is not normally needed for a small cavity, inasmuch as the core materials do not slump. After injection, the cement can be rapidly manipulated to shape. However, manipulation beyond 3 or 4 seconds disturbs the developing bond and should be avoided. It is better to overfill slightly and reprepare the tooth after it has set (less than 5 minutes for the metal-containing cements). If a resin-modified glass ionomer is used, this is light-cured according to the manufacturer's recommendations.
4. Finish the preparation as for other types of cores. Conventional glass ionomers are extremely sensitive to drying, even when they are set, a fact that should be kept in mind when the crown preparation is fabricated, the interim restoration is made, or the impression is made. Resin-modified formulations are less moisture sensitive. Vital teeth are also sensitive to desiccation, and so this consideration should not modify normal practice.



Fig. 6-10
The foundation restoration for this crown was a silver-containing glass ionomer.

Composite resin

Composite resin foundations are much stronger than glass ionomer foundations, a difference that correlates with the higher diametral tensile strength of the composite.[30] They are strong enough for larger pin-retained cores. However, the current materials have disadvantages, particularly their absorption of moisture and high thermal expansion, which has led many dentists to avoid composite resin foundations entirely.

Moisture control

Composite resins are sensitive to moisture contamination, and rubber dam isolation is strongly recommended.

Preparation

Because the material sets rapidly (about 5 minutes), composite resin is generally chosen if the dentist wishes to place the foundation and prepare the tooth during the same visit. The crown is prepared to approximate shape first, and then existing

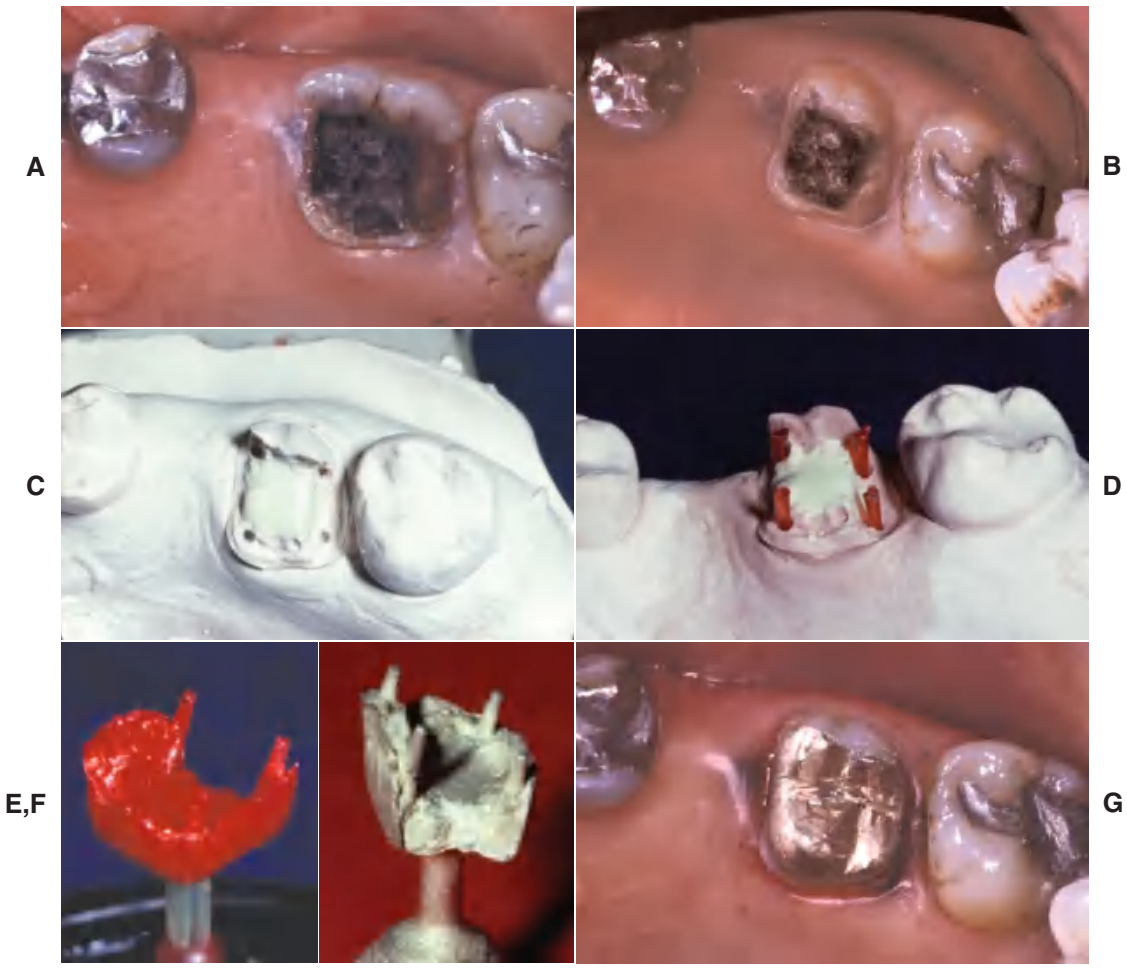


Fig. 6-11
Pin-retained cast core. **A,** Badly damaged maxillary molar. The pulp is healthy. **B,** Caries is excavated, and the tooth is prepared for a pin-retained cast core. **C, D, E,** and **F,** Four tapered pins provide retention. **G,** The completed foundation.

restorations and caries are removed. A glass ionomer is an appropriate choice of liner, with additional retention being provided by pins. For convenient access, the pinholes can be prepared and the liner placed before the pins are seated.

Placement

Both light-cured and chemically cured core composite materials are available. Light-cured composite materials have the convenience of extended working time, but there is concern about the adequacy of polymerization, especially around the pins.[31] The autopolymerizing materials need to be mixed and placed quickly, preferably with the aid of a composite syringe (C-R® syringes).* A Mylar matrix is used to confine them and provide good adaptation.

*Centrix, Inc., Shelton, Connecticut.

Finishing

Composite resin core materials are easily prepared with conventional tooth preparation diamonds.

Pin-retained cast core (Fig. 6-11)

As with glass ionomer and composite resin cores, cast cores are used to build a tooth to ideal preparation form without the need for matrix placement or condensation. However, they require the additional steps of an indirect procedure.

1. Prepare the tooth to approximate shape for a crown, removing any existing restorations and caries. Remove or block out all undercuts, and evacuate any weakly supported dentin.
2. Make pinholes, using the small-diameter twist drill that comes with self-threading pins. The locations for these pins are similar to those for self-threading pins, but all restorations with cast pins must have a common path of placement.

Prepare a flat area around each pin location with a large tapered carbide, and make the starting point for the pinhole with a small round bur. Pilot holes 2 mm deep are made for each pin, with the small-diameter twist drill carefully oriented in the planned path of placement. Use of a mouth mirror to observe the angulation of the drills helps ensure correct alignment. Plastic patterns are available for both tapered and parallel-sided cast pins. We prefer the tapered pins because they allow some leeway in paralleling the holes, and their tapered shape provides strength where needed. However, the parallel design is more retentive. The plastic patterns are manufactured to match specific bur sizes, which are used to enlarge the pilot holes. To avoid overheating, always use low rotational speeds when drilling pinholes. Finally, a small countersink is created where the pinhole meets the gingival floor; this facilitates forming a die that is free of defects and helps prevent pin fracture.

3. Make the impression with an elastomeric material, using a lentulo to fill the pinholes. Place a small quantity of mold-release substance (e.g., die lubricant) into each pinhole with a paper point to prevent tearing of the impression. As an alternative, use the plastic pattern for the impression.
4. Fabricate an interim restoration. This procedure is described in Chapter 15. Place loose-fitting pins in the pinholes to provide retention. If retention is not a problem, avoid introducing luting agent into the pinholes when cementing the interim restoration.
5, 6, and 7. Dies, waxing, and casting. These steps present no special problems. Plastic patterns are used to form the pins. If a tapered pin fits loosely, it can be shortened with a scalpel until it fits properly. Retention of pins in the wax pattern is accomplished by flattening the heads of the pins with a heated instrument. The foundation should be waxed as exactly as possible to final preparation form, with particular attention paid to the occlusal reduction. If it is properly performed, a cast core should require minimum finishing in the mouth. If necessary, the die can be sectioned, trimmed, and mounted to facilitate this. The pattern is then invested and cast with the same regimen as for inlay castings (which generally require slightly less expansion than crowns). Factors that affect casting expansion are described in Chapter 22.
8. For try-in and cementation, do all grinding or adjustment of the casting before the cementation. The newly set cement may be damaged by vibration. To be acceptable, the fit of the cast foundation should be good, with complete seating and no discernible rock. A small marginal defect can be tolerated, provided that it is not indicative of incomplete seating, because the margins will be completely covered by the definitive restoration. During cementation, fill the pinholes completely with cement; this can be done with a lentulo.

ENDODONTICS

Assessment

During the initial data collection, attention must be directed toward potential endodontic needs of the patient. The clinical examination should include vitality testing of all teeth in the dental arch. This may be done with an electric pulp tester, an "ice pencil" (conveniently made by filling an anesthetic needle cap with water and freezing), an aerosol cryogen spray, or heated gutta-percha. Tenderness to percussion should also be noted. Any abnormal sensitivity, soft tissue swellings, fistulous tracts, or discolored teeth should prompt suspicion of pulpal involvement.

Patients who have definite symptoms seldom present problems in diagnosis, because pain is generally their chief complaint. When there is doubt concerning pulpal health, however, patients should be examined radiographically during the mouth preparation phase, and the films should be carefully inspected for signs of periapical disease (a radiolucency or widening of the periodontal ligament space). When there is doubt regarding the endodontic prognosis of a tooth, radiographic findings (Fig. 6-12) should always be evaluated in reference to the results of percussion and vitality tests.

Treatment

As a general rule, conventional (or orthograde) rather than surgical (or retrograde) endodontics should be performed if possible—not only because additional trauma results from the surgical approach but also because apicoectomy adversely affects the crown/root ratio and thus the support of the planned prosthesis. If an existing post prevents access to a recurrent periapical lesion, the post can usually be removed. (A Masserann kit has shown some success with this; see Chapter 12.) When a post and core restoration is needed in an endodontically treated tooth, 3 to 5 mm of apical seal should be retained (see Chapter 12).

Performing elective endodontics may be desirable in the following situations: when there are problems in obtaining a compatible line of draw between

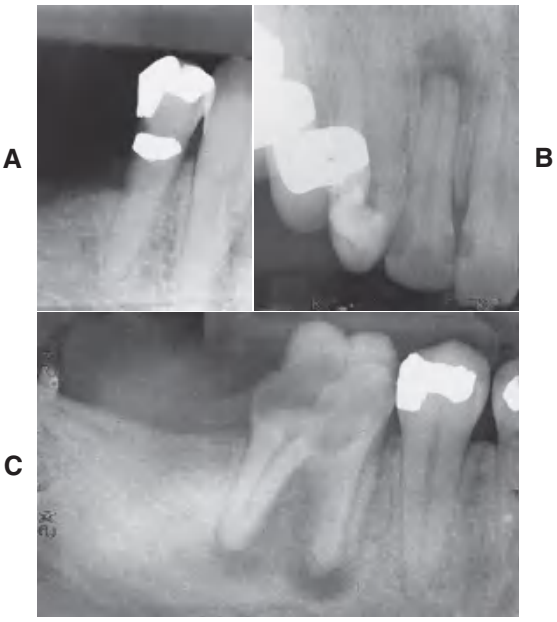


Fig. 6-12
Commonly seen periapical lesions. A, Widened periodontal ligament space. B and C, Large radiolucencies (established granulomas or cysts). *(Courtesy of Dr. G. Taylor.)*

multiple abutments, when it is impossible to gain adequate retention in a badly worn or damaged tooth, and when the endodontic prognosis of an abutment tooth is compromised and additional preparation is likely to further jeopardize its longevity.

DEFINITIVE PERIODONTAL TREATMENT

Robert F. Baima

Unless a patient's existing periodontal disease has been properly diagnosed and treated, fixed prosthodontics is doomed to failure. The treatment modalities presented in Chapter 5 form the basis for an effective approach to chronic periodontal disease. In addition, certain specific periodontal procedures may be indicated to improve the prognosis of a restoration. They are presented in the ensuing text.

Mucosal Reparative Therapy

The width of the band of attached keratinized gingiva may be increased by surgical grafting as part of mouth preparation before restorative treatment. Although the amount of gingiva necessary for long-term periodontal health is open to debate and definite conclusions are difficult to draw, comprehensive evaluation of the amount of attached keratinized tissue is always advised.[32,33] It is recommended[34,35] that a tooth to be treated with a restoration extending into the gingival sulcus have approximately 5 mm of keratinized gingiva, at least 3 mm of which is attached gingiva. Where less keratinized gingiva is present, or in areas of localized gingival recession, a grafting or other gingival augmentation procedure should be considered.

Free Autogenous Gingival Graft

A free (detached) autogenous gingival graft (Fig. 6-13) is used to increase the width of attached gingiva in areas where it is deemed inadequate. The donor site most commonly used is the hard palate, although any area of keratinized tissues, such as an edentulous ridge or the retromolar pad, may be suitable.

The recipient bed site is prepared by making a horizontal split-thickness incision just coronal to the mucogingival junction. As the incision passes apical to the junction, it may become either split thickness or full thickness.[36,37] The recipient bed is trimmed of tissue tags and thinned. (A template of tinfoil may be used as a guide for the correct size and shape of the graft.) The graft is then carefully removed from the donor site, and any fat or glandular tissue is excised, so that a maximum thickness of 1 mm is left. Sterile saline is used to keep the graft moist until it is placed on the recipient bed for a check of size and shape, and it is then further shaped if necessary. When the proper dimensions have been attained, the graft is sutured into place. Finally, the graft site and the donor site may be covered with a surgical dressing. Complete healing requires approximately 6 weeks,[38,39] at which time the donor site and the grafted site should appear normal.

Laterally Positioned Pedicle Graft

The laterally positioned pedicle graft[40,41] (Fig. 6-14) is used for an area of recession or lack of attached gingiva on a single tooth when there are adequate amounts of keratinized gingiva in adjacent teeth or edentulous spaces. Although several studies have proposed techniques in which free (detached) autogenous gingival grafts are used for root coverage,[42-44] the pedicle graft can be a more predictable treatment because of maintenance of the blood supply to the pedicle.

The recipient site is prepared by excising 1 to 3 mm of split-thickness marginal gingiva bordering the recession area. At the donor site, oblique vertical incisions are placed in the mucosa as far apically as possible to ensure adequate blood supply for the graft. The apical area of the donor tissue is made



Fig. 6-13
Free autogenous gingival graft. **A,** Planned abutment tooth lacking adequate keratinized gingiva. **B,** The recipient site is prepared. **C,** The graft is sutured to place. Some apical adjustment is needed around the premolar before application of the surgical dressing. **D,** The healed graft. (Compare the width of attached keratinized gingiva here with that in part A.) The defective restoration can be treated at this stage.

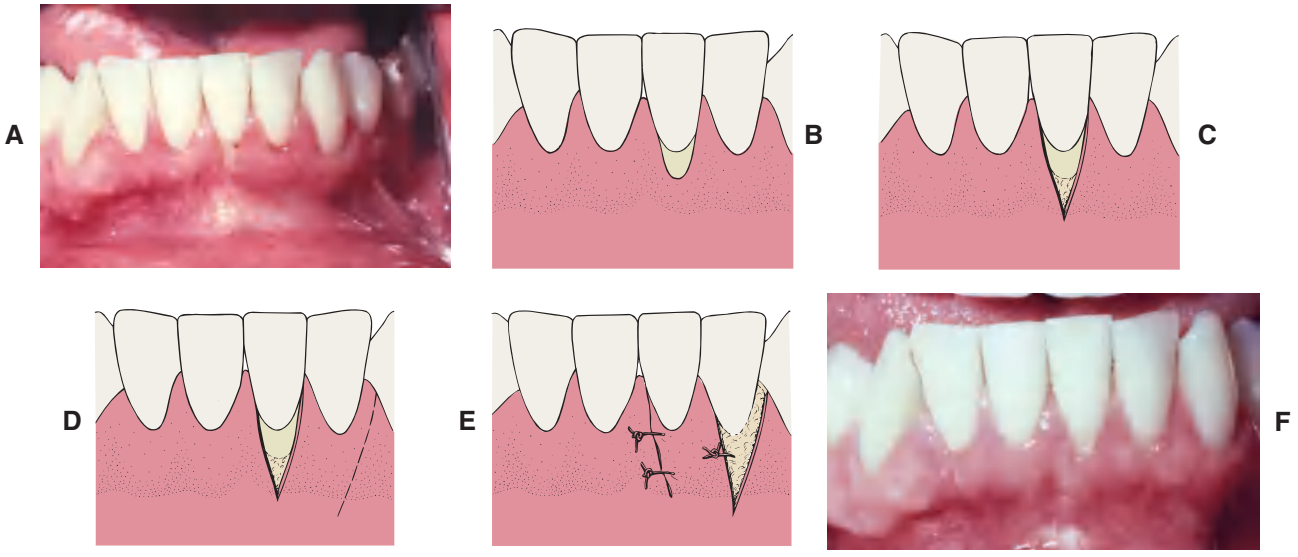


Fig. 6-14
Laterally positioned pedicle graft. **A** and **B** show localized recession around the left mandibular central incisor. The lateral incisor has an adequate band (width) of keratinized tissue, so it is suitable as a donor site. **C,** Bed preparation of the recipient site. An incision is made obliquely toward the site. **D,** Releasing incision at the distal of the donor site. The graft is rotated into position over the recipient site. **E,** Flap sutured in position. A free autogenous gingival graft may be used to cover the donor site. **F,** The healed graft. There is almost always some loss of attachment at the donor site (average, 1 mm).

wider than the coronal area. The flap is mobilized and placed on the recipient site and sutured into place. A free gingival graft may be needed to cover the donor site. A surgical dressing is placed over the site.

There are certain limitations of laterally positioned pedicle grafts:

1. Some recession always occurs at the donor site (an average of about 1 mm) when the free margin of the gingiva is involved.[45]

2. Severe recession is possible if the donor site uncovers any bony fenestration or dehiscence. However, because the graft retains its vascularity, it may be used to cover areas of recession rather than just to increase the band of attached keratinized gingiva. Success in covering areas of previously denuded root surface may be limited, depending on the amount and morphology of the recession,[46,47] and the attachment between graft and root is often epithelial rather than connective tissue.

Coronally Positioned Pedicle Graft

A coronally positioned (advanced) pedicle graft[48,49] (Fig. 6-15) is used when a single tooth exhibits gingival recession and sensitivity. If the width of the attached keratinized gingiva is inadequate, a free autogenous gingival graft may be placed to increase it before the coronal positioning.

Although there are various techniques,[50,51] divergent vertical incisions are most commonly placed as far apically as possible into the mucosa. As a result, the apical portion of the flap is broader than the coronal portion, and this ensures that the flap will have an adequate blood supply. The root surface is planed to a glasslike finish, and the graft is sutured in a coronal position to obtain maximum root coverage. Investigators have used an alternative guided tissue regeneration technique to promote reattachment before suturing the graft,[52,53] and clinical trials have shown significant root coverage with the use of enamel matrix derivative application prior before coronal positioning of the pedicle.[54,55] After the graft has been held in position with pressure to decrease hemorrhage and to obtain proper placement, it is covered with a surgical dressing.

Subepithelial Connective Tissue Graft

Connective tissue that does not carry epithelium has also been used for gingival grafting purposes. This technique involves the use of subepithelial



Fig. 6-15
Coronally positioned pedicle graft. **A,** The position of the free gingival margin after autogenous graft placement. There is approximately 4 mm of recession. **B,** Incisions for the pedicle. Divergence of the incisions ensures an adequate blood supply because the base of the flap is broad. **C,** The pedicle is coronally positioned and sutured snugly in place at the cementoenamel junction with horizontal and suspension sutures. **D,** The healed graft. *(Courtesy of Dr. S. B. Ross.)*

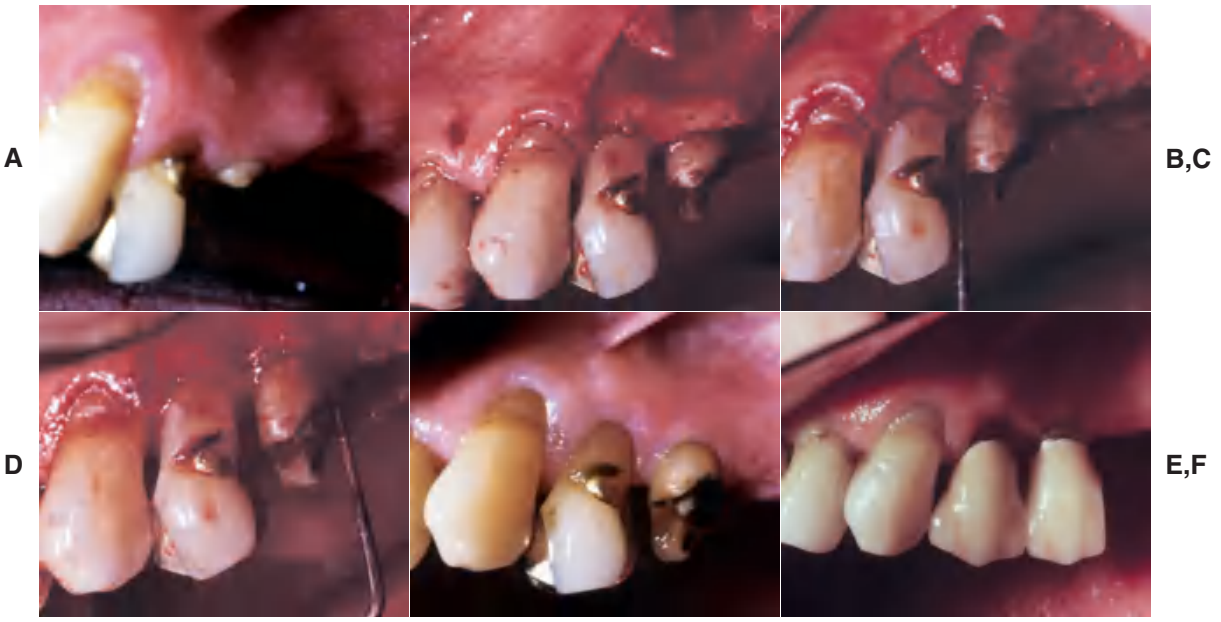


Fig. 6-16
Surgical crown lengthening. **A,** Fractured and carious second premolar. **B,** Reflection of a flap and removal of granulation tissue. **C,** Bone removed on the mesial aspect to increase the distance to the fracture site to 3.5 mm. **D,** Distally the bone is removed so that there will be 3.5 mm from the caries to the alveolar crest. **E,** Healing after the surgical crown lengthening. **F,** Final crown restoration after cementation, before restoration of the sextant with a removable dental prosthesis.

connective tissue harvested from the palate in a split-thickness manner, which allows the wound to be closed after removal of the graft. This approach minimizes patient discomfort at the donor site.

The graft is placed at the recipient site between a minimally reflected split-thickness flap and the periosteum, covering the root. This "sandwich" placement of the connective tissue supplies the graft with blood from two different sources.[43,56] Enamel matrix derivatives have been shown to enhance root coverage with connective tissue grafts,[57] and a "tunnel" placement may also be used as an alternative technique,[58] with up to 100% coverage of root recession reported. The use of connective tissue grafts for root coverage has shown long-term stability with minimal recurrent recession,[59] even when roots were previously compromised by caries.[60]

Crown-Lengthening Procedures

Surgical crown lengthening or extension (Fig. 6-16) may be indicated to improve the appearance of an anterior tooth or when the clinical crown is too short to provide adequate retention without the restoration's impinging on the normal soft tissue attachment[61] or biologic width.* This attachment averages approximately 2 mm in width, and any restoration that impinges on it may cause bone loss because of the effort of the host to maintain the 2 mm distance. If impingement occurs in an interproximal area, it can lead to problems with plaque control and possible osseous resorption.[62-64] Therefore, from the standpoint of prognosis, the biologic width should never be compromised.

In some patients, an apparently unsalvageable tooth with extensive subgingival caries, a subgingival fracture, or root perforation resulting from endodontics can be successfully restored after crown lengthening. Crown lengthening increases the crown/root ratio, however, and a pretreatment decision must be made about whether the tooth should be removed or restored.

Crown lengthening may be accomplished either surgically or with combined orthodontic-periodontic[65-69] techniques, depending on the patient and the dental situation.

Surgical crown lengthening

It is sometimes possible to achieve an effective increase in crown length by gingivectomy or removal of gingiva by electrosurgery alone (see Fig. 6-16), although osseous recontouring is most often needed to prevent encroachment of the prosthesis on the biologic width. For these procedures, a full-thickness mucoperiosteal flap is reflected, and the osseous resection creates 3.5 to 4.0 mm of space between the gingival crest and the margin of the existing restoration or carious lesion.[61,70] In these

*The term *biologic width* refers to the combined connective tissue-epithelial attachment from the crest of the alveolar bone to the base of the gingival sulcus.[34]

instances, however, the following factors should be considered:

1. *Esthetics.* When surgical crown lengthening (Fig. 6-17) is indicated, it may be difficult to achieve a harmonious transition from the tissue around the lengthened tooth to that around adjacent teeth. Alternatives include orthodontic extrusion or removal and replacement with a prosthesis. If surgery is undertaken, most of the osseous reduction should be on the lingual or palatal side, where there is usually no esthetic problem, with blending on the labial or buccal side only as necessary.
2. *Root length within bone.* If there is limited osseous support, it may be better to remove the tooth and replace it with a prosthesis than to have the patient undergo surgery on a tooth with a doubtful prognosis.
3. *Effect on adjacent teeth.* Often a fracture or defect is of such depth that it cannot be eliminated without severely endangering the adjacent teeth. In these instances, removal or orthodontic extrusion may be preferable.
4. *Root furcation exposure in a posterior tooth.* If this situation cannot be remedied by osteoplasty and/or odontoplasty, the tooth may require removal.
5. *Mobility.* Postsurgical mobility of a tooth with small or conical roots is a valid concern. If such a tooth cannot support itself or cannot be supported by the adjacent teeth, then removal may be necessary.
6. *Extent of the defect.* The severity and complications of any fracture, root caries, or cervical wear must be carefully evaluated during the treatment planning phase.
7. *Root perforation.* This is uncommon, but if it occurs during endodontic therapy, its location determines whether to remove, orthodontically extrude, or lengthen the tooth surgically.[71]
8. *Thickness of the soft tissue.* In some instances, thick gingival tissue may effect a regrowth of tissue in a coronal direction. An increased removal of osseous support may be needed at the time of crown lengthening surgery to negate this potential problem.[72]

Restoration of a tooth that has undergone crown lengthening is commonly undergone in 4 to 6 weeks after the surgical procedure. A clinicale study[73] has demonstrated that the biologic width and the position of the free margin of the gingivae exhibited no change at 3 to 6 months after surgery. Therefore, it may be advisable to provisionally restore that tooth in question, either before or immediately after surgical crown lengthening, and subsequently fabricate the final restoration after 3 months.

Although surgical crown lengthening may not be a panacea for fractured, perforated, or badly decayed teeth, it can help solve difficult and/or complex restorative problems when used with proper clinical judgment.

Maintenance and Reconstruction of the Interdental Papilla

The presence or absence of the interproximal papilla, especially in the maxillary anterior area, is a concern to the restorative dentist, the periodontist, and the patient. Multiple techniques have been used, with and without the use of guided tissue or bone regeneration, to maintain and reconstruct the



Fig. 6-17
Esthetic problems can occur after surgical crown lengthening of an anterior tooth. **A,** Lateral incisor is lengthened to include a mesial periodontal defect. **B,** Esthetics would have been better if the distal aspect had been included and the gingival contour gradually sloped.

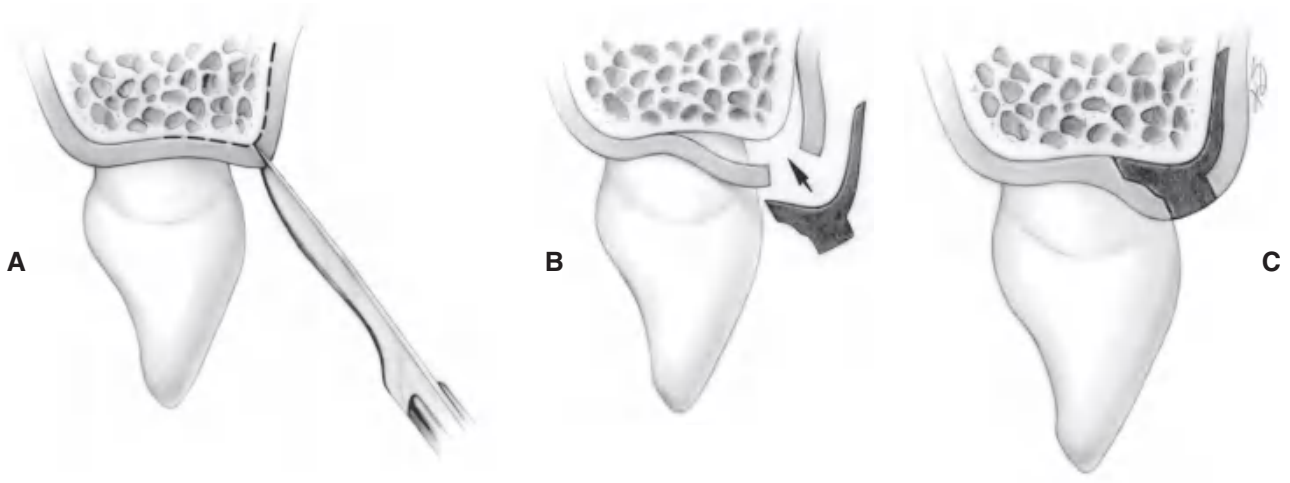


Fig. 6-18

Technique for surgical reproduction of the interdental papilla. A, Intrasulcular incision and buccal incision placed in the interdental papilla, leaving the existing papilla attached to the palatal flap. B, Split-thickness flap is elevated buccally and palatally. Connective tissue graft is prepared for placement under the buccal and palatal flaps. C, Buccal and palatal flaps are sutured after connective tissue from the retromolar area is placed under the flap. *(From Azzi R, et al: Surgical reconstruction of the interdental papilla. Int J Periodontics Restorative Dent 18:467, 1998.)*

interdental papilla (Figs. 6-18 to 6-20).[74-80] The results of these procedures have not been predictable or reproducible. The reconstruction or preservation of the papilla is dependent on multiple factors such as the amount of attachment lost in the area, the blood supply available for the newly created papilla,[75] and the distance from the contact area to the crest of the interproximal bone.[79] The majority of the techniques used for restoration or reconstruction of the interdental papilla are surgical in nature and therefore involve coordination and cotherapy with surgical or periodontal colleagues. Consultation with the appropriate surgeon before planning of the final restoration of the area is crucial.

Orthodontic-Periodontic Extrusion

Orthodontic extrusion[65,66,81] (Fig. 6-21) may be considered whenever a fracture or carious lesion extends apical to the free margin of the gingiva. However, it is especially important when esthetics is a prime concern. The margin of the fracture or lesion is moved away from the alveolar crest orthodontically (with brackets, wires, and/or elastic bands), and the gingiva often requires surgical repositioning when orthodontic therapy is completed.

• • •

ORTHODONTIC TREATMENT

Minor orthodontic tooth movement[82-85] can significantly enhance the prognosis of subsequent restorative treatment. Uprighting malpositioned abutment teeth can improve axial alignment, create more favorable pontic spaces, and improve embrasure form in the fixed prosthesis. It can also direct occlusal forces along the long axes of the teeth and often leads to a substantial conservation of tooth structure (see Fig. 7-12*B* and *C*).

Assessment

The clinical examination should focus on tooth malpositioning both buccolingually and mesiodistally. Abnormal tooth relationships such as anterior or posterior reverse articulation should alert the dentist to the possible need for orthodontic treatment. In particular, attempts to correct abnormal tooth relationships with fixed prosthodontics alone are rarely successful; orthodontic preparation is normally preferred.

The need for orthodontic treatment is determined through a careful analysis of articulated diagnostic casts, whose usefulness can be enhanced with a dental surveyor (Fig. 6-22). One helpful procedure[86] is to section a duplicate cast (Fig. 6-23) and reassemble it according to the proposed orthodontic modifications. This facilitates assessing the validity of any **minor tooth movement** (e.g., closing diastemas, uprighting molars, aligning tilted teeth) and is especially valuable when explaining the treatment proposal to the patient. Diagnostic preparations and waxing procedures made on these altered casts often clearly illustrate the benefits of minor tooth movement. Many dentists are now using computer imaging technology to optimize esthetic treat-

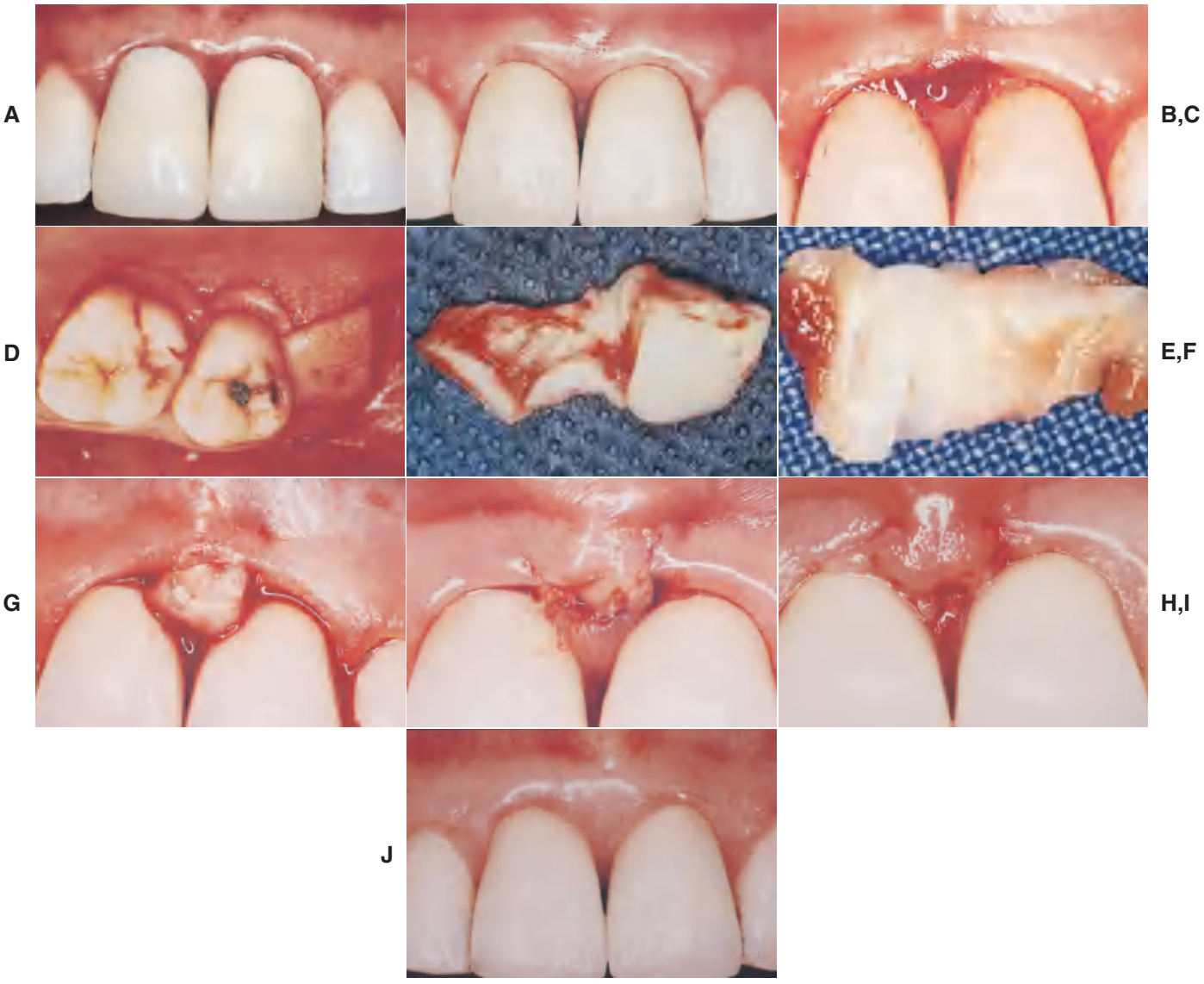


Fig. 6-19

Reconstruction of the interdental papilla. A, Poorly contoured and bulky crowns on maxillary central incisors with loss of interdental papilla. B, Replaced crowns 1 year after cementation with improved tissue contours. However, interdental papilla remains in an apical position. C, Papillary incisions. D, Incisions to harvest retromolar connective tissue combined with incisions to the thin palatal flap. E, Connective tissue harvested in bulk. F, Connective tissue graft trimmed for placement into the papillary area. G, Connective tissue graft placed under buccal and palatal flaps in the interdental area. H, Flaps are sutured over connective tissue graft. I, Three-day postoperative view of papillary graft. J, Final tissue contours around replacement crowns. *(From Azzi R, et al: Surgical reconstruction of the interdental papilla. Int J Periodontics Restorative Dent 18:467, 1998.)*

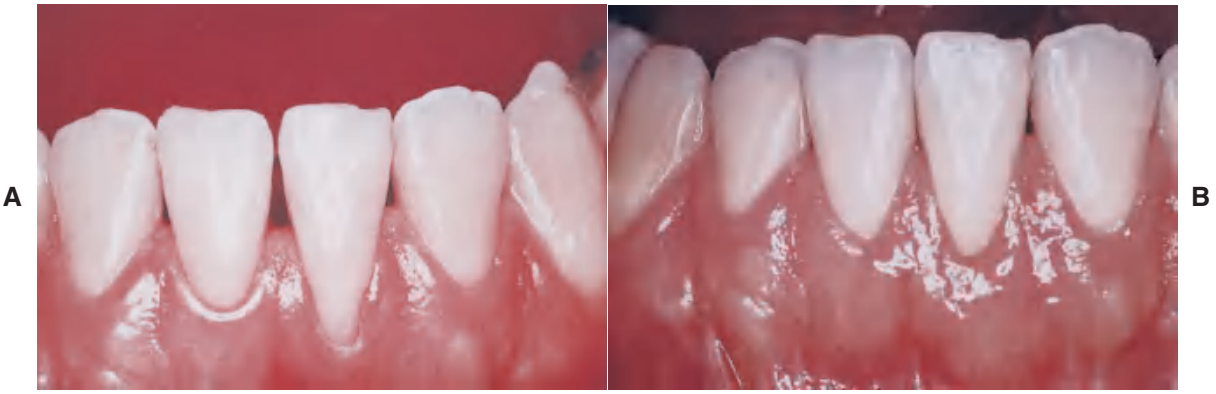


Fig. 6-20

Reconstruction of the interdental papilla. A, Preoperative view of papillary deficiency in the interproximal area of teeth #24 and #25. B, Results of papillary graft and final tissue contour. *(From Azzi R, et al: Surgical reconstruction of the interdental papilla. Int J Periodontics Restorative Dent 18:467, 1998.)*



Fig. 6-21
Orthodontic extrusion before restoring a badly damaged tooth. **A,** This maxillary first premolar has been perforated mesially (*arrow*). A surgical crown lengthening was contraindicated because of the level of the perforation apical to the osseous crest. **B,** A flap was reflected to débride the perforation and associated lesion. **C,** Orthodontic brackets cemented with rebounding wire initially. When the wire is placed in the premolar bracket, it imparts an occlusally directed force. (The occlusion must be relieved periodically as the tooth moves.) **D,** Completion of the extrusion. **E,** Osseous recontouring at this stage ensures a harmonious bony and gingival contour. **F** and **G,** Coronal tooth structure restored with a metal-ceramic crown. *(Courtesy of Dr. S. B. Ross.)*



Fig. 6-22
A and **B,** Use of diagnostic preparations and a dental surveyor in assessing the need for orthodontic treatment before fixed prosthodontics.

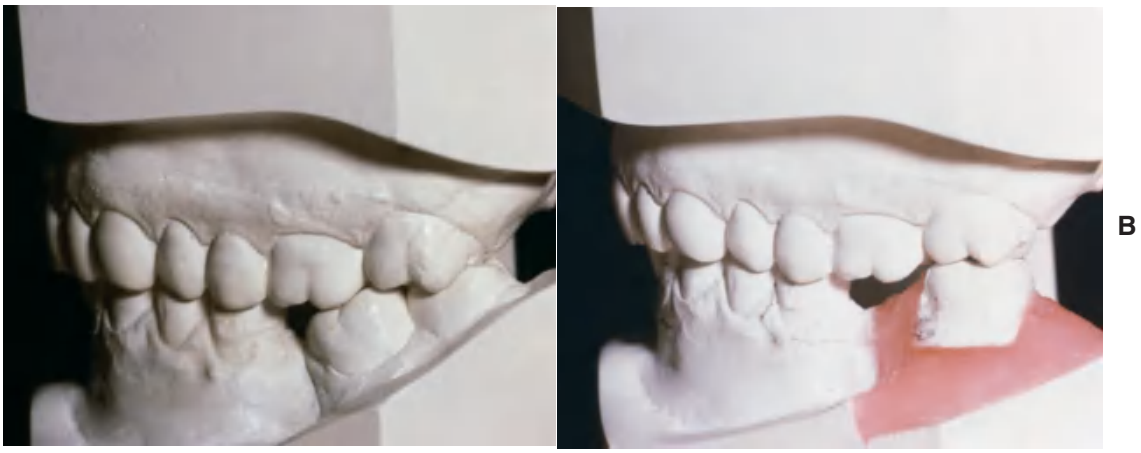


Fig. 6-23
A and B, Diagnostic cast sectioning for determination of desired orthodontic tooth movement. *(Courtesy of Dr. P. Ngan.)*

ment planning and improve patient communication[87-90] (Fig. 6-24).

Treatment

In general practice, it is often possible to perform minor tooth movement before fixed prosthodontic treatment without referral to an orthodontist. However, a specialist should be consulted if treatment is more complex than the straightforward tipping, uprighting, or extruding of an abutment tooth.

For tipping or extruding a single anterior tooth, acid-etch brackets can be used with a multistrand elastic wire ligated in place to attain the desired position. When any anterior tooth is moved, however, the amount of labial bone should be carefully evaluated and found to be adequate. Orthodontic treatment should also be considered when restorations are being used to correct a diastema. Often esthetics can be dramatically improved by distributing the space of a midline diastema around all the anterior teeth (Fig. 6-25*A* to *C*). A diagnostic waxing procedure will help determine the optimum tooth position. Uprighting a mesially tilted molar can be accomplished with a coil spring (see Fig. 6-25*D* to *G*), but the tooth should first be adjusted out of occlusion. A neglected crown preparation can be salvaged with a simple orthodontic appliance (Fig. 6-26). All orthodontic movement requires adequate anchorage so that inadvertent movement of other teeth is avoided.



Fig. 6-24
Computer imaging technology can assist in treatment planning and communicating to the patient the esthetic changes that are envisioned. The equipment consists of a video camera, a monitor, and a computer. The software allows the video image to be manipulated to ascertain the posttreatment appearance. *(Courtesy of Dentrix Dental Systems, Inc. © 2005. All rights reserved.)*

DEFINITIVE OCCLUSAL TREATMENT

Mouth preparation often involves reorganization of the patient's occlusion, typically to make maximum intercuspation coincident with centric relation and remove eccentric interferences (see Chapter 4). This



Fig. 6-25
Orthodontic tooth movement as an adjunct to fixed prosthodontics. **A** to **C,** Minor tooth movement before correction of a diastema. **D** to **G,** A mesially tilted molar uprighted with a coil spring before the provision of a fixed dental prosthesis. (***D*** *to* ***G,*** *Courtesy of Dr. P. Ngan.)*



Fig. 6-26
A, The maxillary premolar (*arrow*) was prepared for a metal-ceramic crown but was inadequately provisionalized. Unfortunately, the patient failed to return when the interim restoration became dislodged. The tooth had moved distally and was in contact with the first molar, making crown placement impossible. **B,** A removable appliance was used to reposition the tooth before impression making. *(Courtesy of Dr. P. Ngan.)*

may be done therapeutically, principally to relieve symptoms of occlusal dysfunction, or as a prerequisite to extensive restorative treatment. The coincidence of centric relation and maximum intercuspation greatly facilitates accurately transferring the patient's casts to an articulator. **Occlusal adjustment** as a therapeutic modality is fraught with controversy. The current balance of research places a low priority on the influence of occlusion in disorders of the temporomandibular joints and associated musculature.[91] Also, there is clinical evidence contraindicating occlusal adjustment.[92-94] However, these disorders should be diagnosed and alleviated before definitive fixed prosthodontics is undertaken. This can generally be achieved by noninvasive, reversible means.[95] The role of occlusal forces in the progress of periodontal disease is also controversial. The balance of current research indicates that

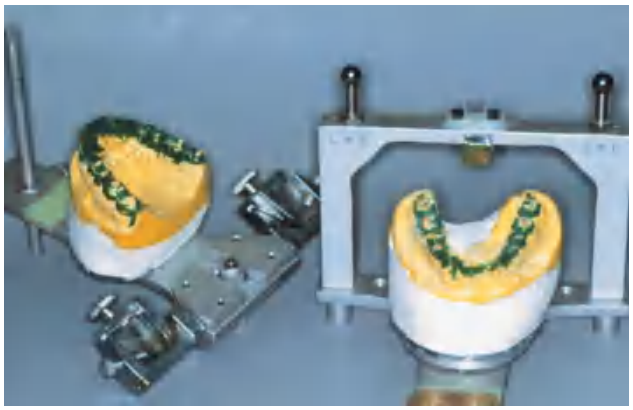


Fig. 6-27
Diagnostic occlusal adjustment on articulated casts.

occlusal forces do not initiate periodontitis but may modify attachment loss caused by plaque-induced inflammatory periodontal disease.[96]

When selective reshaping of the natural dentition is being considered, it is important to remember that this is a purely subtractive procedure (tissue is removed), and it is limited by the thickness of the enamel. Obviously, before any irreversible changes are made in the dentition, a careful diagnosis must establish whether restorations are needed.

Diagnostic Adjustment

Two sets of articulated diagnostic casts (Fig. 6-27) are required for diagnostic occlusal adjustment. One set serves as a reference; the other is used to evaluate how much tooth structure has been removed and how much more must be removed to meet the objectives of the procedure. This reveals the efficacy of the treatment plan before anything is done clinically.

The occlusal surfaces of each cast are painted with poster paint (which does not soak into the stone) to demonstrate the extent of any planned corrective reshaping. The pin setting on the articulator is recorded before adjustment so that the operator can judge the amount of enamel that must be removed. Each step of the adjustment is recorded sequentially on a reshaping list. When completed, the procedure is reviewed carefully. Areas where enamel is likely to be penetrated are identified so that the patient can be advised of the likely need for additional restorations on these teeth.

The primary objectives of selective occlusal reshaping are as follows:

- To redistribute forces parallel to the long axes of the teeth by eliminating contacts on inclined planes and creating cusp-fossa occlusion.
- To eliminate deflective occlusal contacts: centric relation coincides with the maximum intercuspation.
- To improve worn occlusal anatomy, enhance cuspal shape, narrow occlusal tables, and reemphasize proper developmental and supplemental grooves in otherwise flat surfaces.
- To correct marginal ridge discrepancies and extrusions so that oral hygiene will be easier.
- To correct tooth malalignment through selective reshaping.

It is not always possible to achieve each of these goals. If a choice must be made, corrective therapy should not be at the expense of functional surfaces and should not destroy any functional contact.

Clinical Occlusal Adjustment

Patient selection

Careful analysis of the diagnostic occlusal adjustment is necessary to determine whether the patient is a good candidate for such irreversible subtractive treatment. Precise reduction and close attention to the sequence are essential. A written record of each reduction is also recommended. If too much is ground off a tooth, it cannot be put back on. The following should be considered as contraindications to definitive occlusal adjustment:

1. A bruxer whose habit cannot be controlled.
2. A diagnostic correction that indicates that too much tooth structure will be removed.
3. A complex spatial relationship (e.g., an Angle Class II and a skeletal Class III).
4. Maxillary lingual cusps contacting mandibular buccal cusps.
5. An open anterior occlusal relationship.
6. Excessive wear.
7. Before orthodontic or orthognathic treatment.
8. Before physical or occlusal appliance therapy.
9. A patient with temporomandibular joint pain.
10. A patient whose jaw movements cannot be manipulated easily.

Occlusal adjustment needs to be undertaken in a logical sequence to avoid repetition and improve the efficacy of treatment. Although different sequences have been proposed, we find the one described next to be successful.

Elimination of centric relation interferences

As the mandible rotates around the terminal hinge axis, each mandibular tooth follows its own arc of closure. If the intercuspal and centric relation positions do not coincide, premature contacts are unavoidable.

Step-by-step procedure

1. Manipulate the mandible and mark the teeth so that both the initial contact in centric relation and the extent and direction of jaw movement to intercuspation are seen. This movement, or slide, can be in either an anterior or a lateral direction.
2. Find any interferences that cause the condylar processes to be displaced anteriorly (protrusive interferences). These are usually between the mesial inclines of maxillary teeth and the distal inclines of mandibular teeth (Fig. 6-28).
3. Continue the adjustment until all teeth contact evenly (except possibly the incisors). If excursive movements are guided adequately by the canines, it may be better to stop when bilateral canine-to-canine contact has been reestablished.
4. When dealing with a laterally displacing prematurity, adjust the buccally facing inclines of the maxillary and the lingually facing inclines of the mandibular teeth. The premature contact is usually on either the laterotrusive or the mediotrusive side of the mandible (lateral slide or medial slide).
5. When dealing with a lateral slide, adjust the buccal inclines of the maxillary lingual cusps and the lingual inclines of the mandibular buccal cusps until there is contact on the cusp tips (Fig. 6-29).
6. When dealing with a medial slide, adjust the buccal inclines of the mandibular buccal cusps or the lingual inclines of the maxillary lingual cusps until there is contact on the cusp tips. At this time, any further adjustments can be made through widening of the opposing central grooves by reduction of the internal inclines of the maxillary buccal and mandibular lingual cusps (Fig. 6-30).

Evaluation

The foregoing rules for occlusal adjustment should be followed as closely as possible while the normal anatomic form of the tooth is maintained. When the discrepancy between centric relation and maximum intercuspation has been corrected, there is uniform contact between all posterior teeth. This can be verified with thin Mylar shim stock held in forceps (Fig. 6-31).

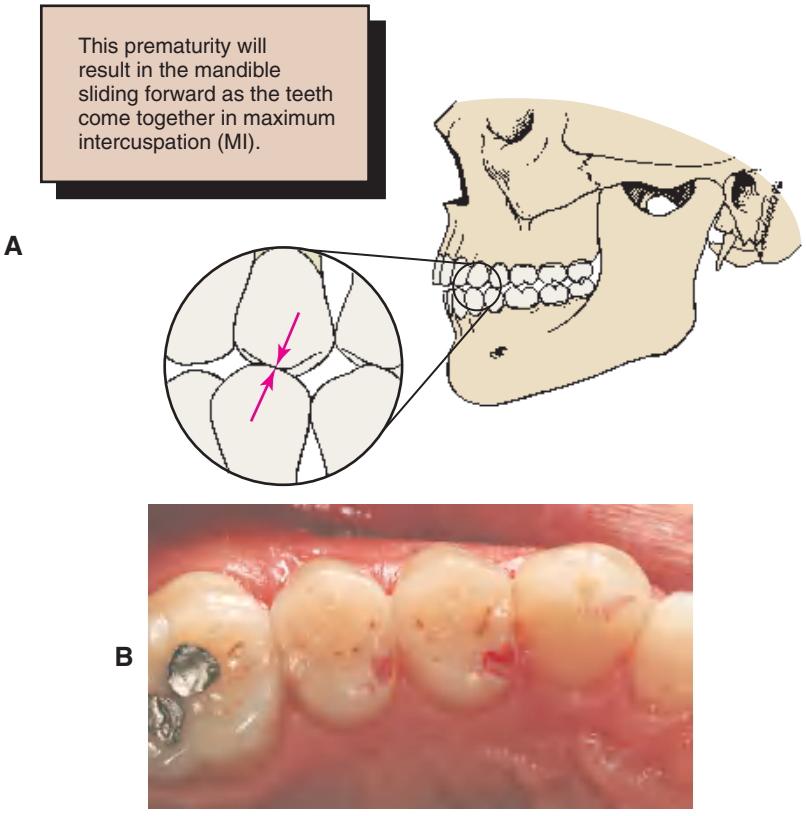


Fig. 6-28
A and **B,** Interferences that deflect the mandible anteriorly (protrusive interferences) are found between the mesial inclines of maxillary teeth and the distal inclines of mandibular teeth.

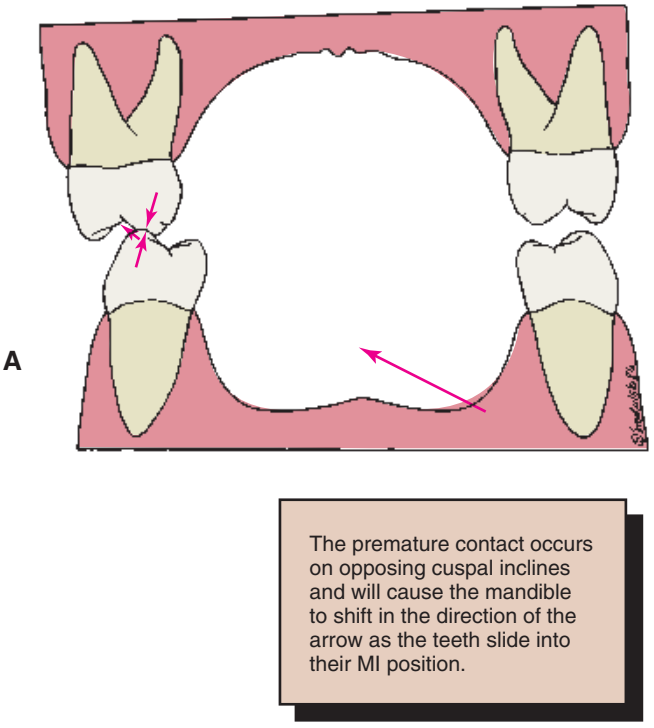




Fig. 6-29
Laterally displacing contact between the buccal incline of a maxillary lingual cusp and the lingual incline of a mandibular buccal cusp. MI, maximum intercuspation.

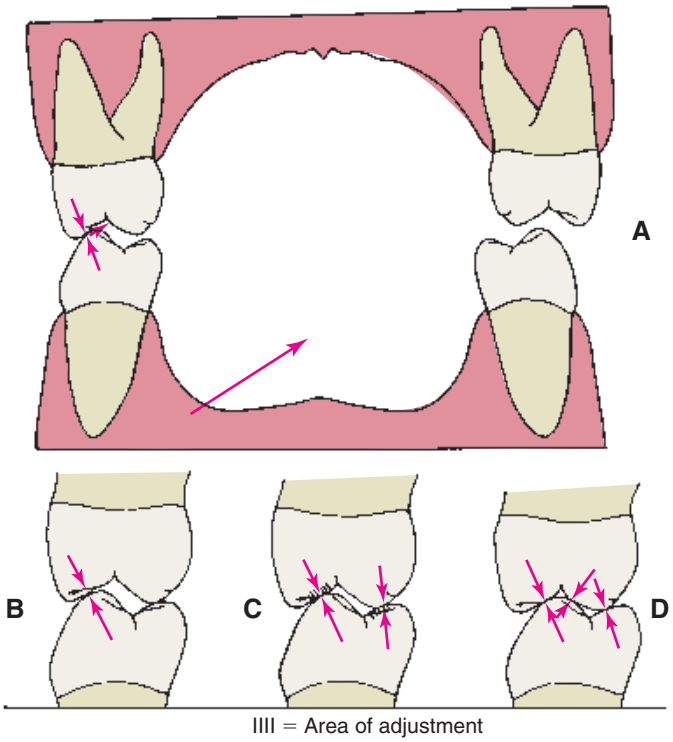


Fig. 6-30
Correcting a medial slide by selective grinding. **A,** The contacting inclines are adjusted until the cusp tips are in contact (**B**). The opposing central grooves are then widened (**C** and **D**).

Elimination of lateral and protrusive interferences

The second phase of occlusal adjustment concentrates on laterotrusive, mediotrusive, and protrusive interferences. The dentist uses red and blue marking ribbons to distinguish between centric and eccentric contacts.

The goals of this second phase of adjustment are to eliminate contact between all posterior teeth during protrusive movements and to eliminate any interferences on the nonworking (mediotrusive) side as well as on the working (laterotrusive) side. In certain patients, group function of the working side contacts should be considered rather than the more ideal mutually protected occlusion (e.g., when there is mobility or poor bone support of the canines). In other patients, group function may be retained because of wear or malpositioning of the canines.

During this phase of adjustment, it is essential that no centric contacts be removed. In general, lateral and protrusive interferences are eliminated by creating a groove that permits escape of the functional cusp during eccentric movement (Fig. 6-32).

SUMMARY

A logical **treatment sequence** should be planned before any fixed prosthodontic intervention begins. Such planning is normally multidisciplinary: It incorporates oral surgery; operative dentistry; and endodontic, periodontic, orthodontic, and/or occlusal therapies. Mouth preparation is particularly important for fixed prosthodontics, which, like all dental disciplines, is facilitated and enhanced by meticulous preparatory treatment.



Fig. 6-31
Verifying occlusal contacts with thin Mylar shim stock.

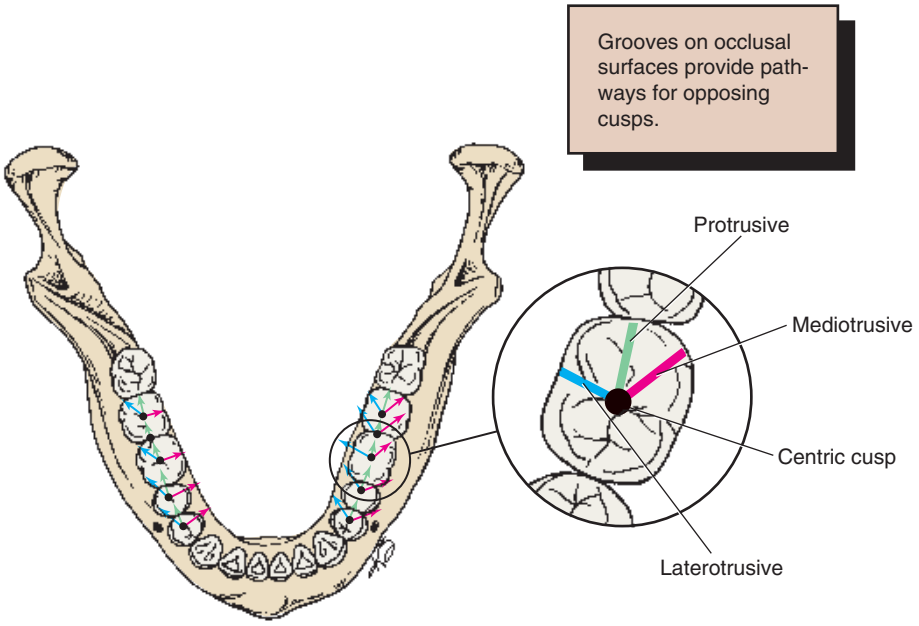


Fig. 6-32
Detection of eccentric interferences is facilitated by understanding where they normally occur. The *arrows* represent the paths of opposing functional cusps during each excursion (mediotrusive, protrusive, and laterotrusive). Look, for example, to find a mediotrusive interference distobuccal to a centric contact. In the maxillary arch, the pattern is reversed.

STUDY QUESTIONS

1. Discuss in detail the recommended sequence of preparatory treatment procedures before initiation of definitive fixed prosthodontic treatment.
2. Discuss the advantages, disadvantages, indications, and any applicable precautions for the various foundation restoration materials.
3. How does the tooth preparation for an extensive amalgam foundation restoration differ from a conventional extensive amalgam restoration? Why?
4. Discuss three types of periodontal grafting procedures, their indications, and their limitations.
5. What are the indications for minor tooth movement before fixed prosthodontic treatment is initiated?
6. What are the indications and contraindications for comprehensive occlusal reshaping? If it is indicated, what is the recommended procedure and sequence of events?

GLOSSARY*

acquired eccentric relation \a-kwīrd′ ĭk-sĕn′trĭk rĭ-lā′shun\: any eccentric relationship position of the mandible relative to the maxilla, whether conditioned or learned by habit, which will bring the teeth into contact

ad·just·ment \a-jŭst′mant\ *n* (1644) **1:** the act or process of modifying physical parts **2:** in dentistry, a modification made on a dental prosthesis or natural tooth to enhance fit, function, or acceptance by the patient—see OCCLUSAL A.

articulating paper \är-tĭk′ya-lāt′ing pā′per\: ink-coated paper strips used to locate and mark occlusal contacts

balancing interference \băl′ans ĭng ĭn′ter-fear′ans\: undesirable contact(s) of opposing occlusal surfaces on the nonworking side

[1]base \bās\ *vt* (1587): the act of placing a lining material under a dental restoration

[2]base \bās\ *n* (14c): any substance placed under a restoration that blocks out undercuts in the preparation, acts as a thermal or chemical barrier to the pulp, and/or controls the thickness of the overlying restoration—called also *base material*—*usage*: adjectives such as insulating b., therapeutic b. may also be used

BULL: *acronym* for *Buccal* of the *Upper*, *Lingual* of the *Lower* (cusps); applies to Clyde H. Schuyler's rules for occlusal adjustment of a normally related dentition in which those cusps contacting in maximum intercuspation (mandibular buccal and maxillary lingual) are favored by adjustment of those cusps that are not in occlusal contact in maximum intercuspation (maxillary buccal and mandibular lingual)—called also the BULL RULE

calcium hydroxide \kăl′sē-um hī-drŏk′sīd\: an odorless white powder that is very slightly soluble in water and insoluble in alcohol. Aqueous and non-aqueous suspensions of calcium hydroxide are often employed as cavity liners to protect the pulp from the irritant action of restorative materials; also used in pulp capping, pulpotomy and apexification procedures

copper band \kŏp′er bănd\: a copper cylinder employed as a matrix for making an impression

[1]creep \krēp\ *vi* **crept** \krĕpt\; **creep·ing** \krēp′ĭng\ (12c): to slip or gradually shift position; to change shape permanently due to prolonged stress or exposure to high temperature

[2]creep \krēp\ *n* (1818): the slow change in dimensions of an object due to prolonged exposure to high temperature or stress

de·bride·ment \dā′brēd-mäN′, dĭ-brēd′ment\ *n* (ca. 1842): the removal of inflamed, devitalized, contaminated tissue or foreign material from or adjacent to a lesion

defective occlusal contact \dĭ-fĕk′tĭv a-klōō′sal kŏn′tăkt′\ *obs*: contact that is capable of guiding the mandible from its original path of action into a different path of motion or capable of disturbing the relation between a denture base and its supporting tissues (GPT-1)

deflective occlusal contact \dĭ-flĕk′tĭv a-klōō′sal kŏn′tăkt\: a contact that displaces a tooth, diverts the mandible from its intended movement, or displaces a removable denture from its basal seat—*usage:* see OCCLUSAL DISHARMONY, OCCLUSAL PREMATURITY

direct pulp capping \dĭ-rĕkt, dī- pŭlp kăp′ing\: application of a material to exposed vital pulp to protect it and promote healing

equil·i·brate \ĭ-kwĭl′a-brāt\ *v* **-brat·ed** \-brā′tĭd\; **-brat·ing** \-brā′tĭng\ *vt*; (1635): to bring or to place in equilibrium

equil·i·bra·tion \ĭ-kwĭl′a-brā′shun\ *n* (1635): **1:** the act or acts of placing a body in a state of equilibrium **2:** the state or condition of being in equilibrium—*usage:* see MANDIBULAR E., OCCLUSAL E.

ex·po·sure \ĭk-spō′zher\ *n* (1606): **1:** the act of laying open, as a surgical or dental exposure **2:** in radiology, a measure of the roentgen rays or gamma radiation at a certain place based on its ability to cause ionization. The unit of exposure is the roentgen, called also exposure dose—see ROENTGEN RAY

ex·tru·sion \ĭk-strōō′zhun\ *n* (1540): the movement of teeth beyond the natural occlusal plane that may be accompanied by a similar movement of their supporting tissues

foundation restoration \foun-dā′shun rĕs′ta-rā′shun\: the core buildup portion of a natural tooth restoration

graft \graft\ *n* (14c): a tissue or material used to repair a defect or deficiency—see ALLOGRAFT, ALLOPLASTIC G., AUTOGENOUS G., AUTOGRAFT, FULL THICKNESS G., HETEROGRAFT, HOMOGRAFT, ISOGRAFT, SPLIT-THICKNESS G., XENOGENIC G.

indirect pulp capping \ĭn′dĭ-rĕkt′, -dī- pŭlp kăp′ĭng\: a procedure that seeks to stimulate formation of reparative dentin by placing a material over sound or carious dentin

in·ter·fer·ence \ĭn′ter-fĭr′ans\ *n* (1783): in dentistry, any tooth contacts that interfere with or hinder harmonious mandibular movement

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intermediate abutment \ĭn′ter-mē′dē-ĭt a-bŭt′ment\: a natural tooth located between terminal abutments that serve to support a fixed or removable dental prosthesis

mandibular repositioning \măn-dĭb′ya-lar rē′pa-zĭsh′a-nĭng\: guidance of the mandible to cause closure in a predetermined, altered position

ma·trix \mā′trĭks\ *n, pl* **ma·tri·ces** \mā′trĭ-sēz′\ (15c): **1:** a mold or impression in which something is formed **2:** the portion of an attachment system that receives the patrix

maximal intercuspal position \măk′sa-mal ĭn′ter-kŭs′pal′ pa-zĭsh′an\: the complete intercuspation of the opposing teeth independent of condylar position, sometimes referred to as the best fit of the teeth regardless of the condylar position—called also *maximal intercuspation*—*comp* CENTRIC OCCLUSION

mouth guard \mouth gard\: a removable dental prosthesis made of resilient material which is useful in reducing mouth injuries and protecting the teeth and surrounding structures from injury

myogenous pain \mī′a-jēn′ŭs\: deep somatic musculoskeletal pain originating in skeletal muscles, fascial sheaths, or tendons

occlusal adjustment \a-klōō′zal, -sal a-jŭst′mant\ **1:** any change in the occlusion intended to alter the occluding relation **2:** any alteration of the occluding surfaces of the teeth or restorations—see also OCCLUSAL RESHAPING

occlusal vertical dimension \a-klōō′zal, -sal vûr′tĭ-kal dĭ-mĕn′shun\: the distance measured between two points when the occluding members are in contact

orthognathic surgery: surgical repositioning of all or parts of the maxillae or mandible

pier abutment: see INTERMEDIATE ABUTMENT

[1]plas·tic \plăs′tĭk\ *adj* (1632): **1:** capable of being shaped or formed **2:** pertaining to the alteration or reformation of living tissues

[2]plas·tic \plăs′tĭk\ *n* (ca. 1909): any of numerous organic synthetic or processed materials that generally are thermoplastic or thermosetting polymers, usually of high molecular weight. They can be cast, extruded, molded, drawn, or laminated into films, filaments, and objects

preprosthetic surgery \prē-prŏs-thĕt′ĭk sûr′ja-rē\: surgical procedures designed to facilitate fabrication of a prosthesis or to improve the prognosis of prosthodontic care

protrusive deflection \prō-trōō′sĭv dĭ-flĕk′shun\: a continuing eccentric displacement of the midline incisal path on protrusion, symptomatic of a restriction of movement

pulp \pŭlp\ *n*: the richly vascularized connective tissue of mesodermal origin with much innervation contained in the central cavity of the tooth

pulp capping \pŭlp kăp′ĭng\: application of a material to protect the pulp from external influences and promote healing, done either directly or indirectly

res·to·ra·tion \rĕs′ta-rā′shun\ *n* (1660): a broad term applied to any material or prosthesis that restores or replaces lost tooth structure, teeth, or oral tissues

self-threading pin \sĕlf-thrĕd′ĭng pĭn\: a pin screwed into a hole prepared in dentin to enhance retention

sock·et \sŏk′ĭt\ (15c): any opening or hollow that forms a holder for something, e.g., a tooth

[1]splint \splĭnt\ *n* (14c): **1:** a rigid or flexible device that maintains in position a displaced or movable part; also used to keep in place and protect an injured part **2:** a rigid or flexible material used to protect, immobilize, or restrict motion in a part—see ANDERSON S., CAP S., ESSIG S., FUNCTIONAL OCCLUSAL S., GUNNING'S S., INTERDENTAL S., KINGSLEY S., LABIAL S., LINGUAL S., PROVISIONAL S., RESIN-BONDED S., SOFT S., SURGICAL S., WIRE S.

TMD: *acronym* for *TemporoMandibular Disorders*—see TEMPOROMANDIBULAR DISORDERS

tor·us \tôr′us\ *n, pl* **tori** (1563): **1:** a smooth rounded anatomical protuberance **2.** in dentistry, prominence (s) sometimes seen on the lingual surface of the mandible and the midline of the hard palate

trau·ma \trou′ma, trô′-\ *n, pl* **trau·ma·ta** \trou′ma-ta\ or **trau·mas** \trou′mas\ **trau·mat·ic** \trou′măt-ĭk\ *adj*—**trau·mat·i·cal·ly** \trou′măt-ĭ-kă-lc\ *adv* (1693): an injury or wound, whether physical or psychic

REFERENCES

1. Horowitz AM: A report on the NIH Consensus Development Conference on Diagnosis and Management of Dental Caries Throughout Life. J Dent Res 83(Spec No C):C15, 2004.
2. Kidd EM: Caries diagnosis within restored teeth. Oper Dent 14:149, 1989.
3. Nair MK, et al: The effects of restorative material and location on the detection of simulated recurrent caries. A comparison of dental film, direct digital radiography and tuned aperture computed tomography. Dentomaxillofac Radiol 27:80, 1998.
4. Tjan AHL, Chiu J: Microleakage of core materials for complete cast gold crowns. J Prosthet Dent 61:659, 1989.
5. Fischer GM, et al: Amalgam retention using pins, boxes, and Amalgambond. Am J Dent 6:173, 1993.

6. Ramos JC, Perdigao J: Bond strengths and SEM morphology of dentin-amalgam adhesives. Am J Dent 10:152, 1997.
7. Diefenderfer KE, Reinhardt JW: Shear bond strengths of 10 adhesive resin/amalgam combinations. Oper Dent 22:50, 1997.
8. Olmez A, et al: Clinical evaluation and marginal leakage of Amalgambond Plus: three-year results. Quintessence Int 28:651, 1997.
9. Tarim B, et al: Marginal integrity of bonded amalgam restorations. Am J Dent 9:72, 1996.
10. Korale ME, Meiers JC: Microleakage of dentin bonding systems used with spherical and admixed amalgams. Am J Dent 9:249, 1996.
11. Ratananakin T, et al: Effect of condensation techniques on amalgam bond strengths to dentin. Oper Dent 21:191, 1996.
12. Schulte GA, et al: Early fracture resistance of amalgapin-retained complex amalgam restorations. Oper Dent 23:108, 1998.
13. Prevost AP, et al: Radiopacity of glass ionomer dental materials. Oral Surg 70:231, 1990.
14. Plasmans PJ, et al: A preliminary study on a resin-modified glass-ionomer cement for transitional restorations and subsequent core buildups. Int J Prosthodont 13: 373, 2000.
15. Wilson NH, et al: A short-term clinical evaluation of a tricure glass-ionomer system as a transitional restoration and core buildup material. Quintessence Int 30:405, 1999.
16. Cohen BI, et al: A five year study. Fluoride release of four reinforced composite resins. Oral Health 88:81, 1998.
17. Hormati AA, Denehy GE: Microleakage of pin-retained amalgam and composite resin bases. J Prosthet Dent 44:526, 1980.
18. Oliva RA, Lowe JA: Dimensional stability of composite used as a core material. J Prosthet Dent 56:554, 1986.
19. Martin N, Jedynakiewicz N: Measurement of water sorption in dental composites. Biomaterials 19:77, 1998.
20. Cooley RL, et al: Dimensional stability of glass ionomer used as a core material. J Prosthet Dent 64:651, 1990.
21. Lambert RL, Goldfogel MH: Pin amalgam restoration and pin amalgam foundation. J Prosthet Dent 54:10, 1985.
22. Outhwaite WC, et al: Pin vs. slot retention in extensive amalgam restorations. J Prosthet Dent 41:396, 1979.
23. Shavell HM: The amalgapin technique for complex amalgam restorations. J Calif Dent Assoc 8:48, 1980.
24. Bailey JH: Retention design for amalgam restorations: pins versus slots. J Prosthet Dent 65:71, 1991.
25. Irvin AW, et al: Photoelastic analysis of stress induced from insertion of self-threading retentive pins. J Prosthet Dent 53:311, 1985.
26. Felton DA, et al: Pulpal response to threaded pin and retentive slot techniques: a pilot investigation. J Prosthet Dent 66:597, 1991.
27. Bonilla ED, et al: A customized acrylic resin shell for fabricating an amalgam core on the coronally debilitated, endodontically treated posterior tooth. Quintessence Int 26:317, 1995.
28. Livaditis GJ: Crown foundations with a custom matrix, composites, and reverse carving. J Prosthet Dent 77:540, 1997.
29. Nicholson JW, Croll TP: Glass-ionomer cements in restorative dentistry. Quintessence Int 28:705, 1997.
30. Kerby RE, Knobloch L: Strength characteristics of conventional and silver-reinforced glass-ionomer cements. Oper Dent 17:170, 1992.
31. Butchart DGM, Lloyd CH: The retention of self-threading pins embedded in visible light-cured composites. J Dent 15:253, 1987.
32. American Academy of Periodontology: Guidelines for periodontal therapy. J Periodontol 69:405, 1998.
33. American Academy of Periodontology: Parameter on mucogingival conditions. J Periodontol 71:861, 2000.
34. Maynard JG, Wilson RDK: Physiologic dimensions of the periodontium significant to the restorative dentist. J Periodontol 50:170, 1979.
35. Wilson RDK, Maynard JG: Intracrevicular restorative dentistry. Int J Periodontics Restorative Dent 1:34, 1981.
36. Sullivan HC, Atkins JH: Free autogenous gingival grafts. I. Principles of successful grafting. Periodontics 6:121, 1968.
37. Dordick B, et al: Clinical evaluation of free autogenous gingival grafts placed on alveolar bone. Part I. Clinical predictability. J Periodontol 47:559, 1976.
38. Oliver RC, et al: Microscopic evaluation of the healing and revascularization of free gingival grafts. J Periodontal Res 3:84, 1968.
39. Staffileno H Jr, Levy S: Histological and clinical study of mucosal (gingival) transplants in dogs. J Periodontol 40:311, 1969.
40. Grupe HE, Warren RF: Repair of gingival defects by a sliding flap operation. J Periodontol 29:92, 1956.
41. Bjorn H: Coverage of denuded root surfaces with a lateral sliding flap: use of free gingival grafts. Odontol Rev 22:37, 1971.
42. Holbrook T, Ochsenbien C: Complete coverage of the denuded root surface with a one-stage gingival graft. Int J Periodontics Restorative Dent 3:9, 1983.

43. Miller PD Jr: Root coverage using the free soft tissue autograft following citric acid application. III. A successful and predictable procedure in areas of deep wide recession. Int J Periodontics Restorative Dent 5:15, 1985.
44. Raetzke PB: Covering localized areas of root exposure employing the "envelope" technique. J Periodontol 56:397, 1985.
45. Caffesse RG, Guinard EA: Treatment of localized gingival recessions. IV. Results after three years. J Periodontol 51:167, 1980.
46. Sullivan HC, Atkins JH: Free autogenous gingival grafts. III. Utilization of grafts in the treatment of gingival recession. Periodontics 6:152, 1968.
47. Miller PD Jr: A classification of marginal tissue recession. Int J Periodontics Restorative Dent 5:9, 1985.
48. Bernimoulin JP, et al: Coronally repositioned periodontal flap. Clinical evaluation after one year. J Clin Periodontol 2:1, 1975.
49. Maynard JG: Coronal positioning of a previously placed autogenous gingival graft. J Periodontol 48:151, 1977.
50. Tarnow DP: Semilunar coronally repositioned flap. J Clin Periodontol 13:182, 1986.
51. Allen EP, Miller PD Jr: Coronal positioning of existing gingiva: short-term results in the treatment of shallow marginal tissue recession. J Periodontol 60:316, 1989.
52. Pini Prato GP, et al: Guided tissue regeneration versus mucogingival surgery in the treatment of human buccal recessions. A 4-year follow-up study. J Periodontol 67:1216, 1996.
53. Matarasso MD, et al: Guided tissue regeneration versus coronally repositioned flap in the treatment of recession with double papillae. Int J Periodontics Restorative Dent 18:445, 1998.
54. Berlucci I, et al: Enamel matrix proteins (Emdogain) in combination with coronally advanced flap or subepithelial connective tissue graft in the treatment of shallow gingival recession. Int J Periodontics Restorative Dent 22:583, 2002.
55. Cueva MA, et al: A comparative study of coronally advanced flaps with and without the addition of enamel matrix derivative in the treatment on marginal tissue recession. J Periodontol 75:949, 2004.
56. Langer B, Langer L: Subepithelial connective tissue graft technique for root coverage. J Periodontol 56:715, 1985.
57. McGuire MK, Nunn M: Evaluation of human recession defects treated with coronally advanced flaps and either enamel matrix derivative or connective tissue. Part 1. Comparison of clinical parameters. J Periodontol 74:1110, 2003.
58. Zabalegui I, et al : Treatment of multiple gingival recessions with the tunnel subepithelial connective tissue graft: a clinical report. Int J Periodontics Restorative Dent 19:199, 1999.
59. Harris RJ: Root coverage with connective tissue grafts: an evaluation of short- and long-term results. J Periodontol 73:1054, 2002.
60. Goldstein M, et al: Coverage of previously carious roots is as predictable a procedure as coverage of intact roots. J Periodontol 73:1419, 2002.
61. Davarpanah M, et al: Restorative and periodontal considerations of short clinical crowns. Int J Periodontics Restorative Dent 18:5, 1998.
62. Palomo F, Kopczyk RA: Rationale and methods for crown lengthening. J Am Dent Assoc 96:257, 1978.
63. Ochsenbien C, Ross SE: A reevaluation of osseous surgery. Dent Clin North Am 13:87, 1969.
64. Maynard JG: Personal communication, 1993.
65. Ross SB, et al: Orthodontic extrusion: a multidisciplinary treatment approach. J Am Dent Assoc 102:189, 1981.
66. Brown IS: The effect of orthodontic therapy on certain types of periodontal defects: clinical findings. J Periodontol 44:742, 1973.
67. Ingber JS: Forced eruption. I. A method of treating isolated one and two wall infrabony osseous defects: rationale and case report. J Periodontol 45:199, 1974.
68. Delivanis P, et al: Endodontic-orthodontic management of fractured anterior teeth. J Am Dent Assoc 97:483, 1978.
69. Potashnik SR, Rosenberg ES: Forced eruption: principles in periodontics and restorative dentistry. J Prosthet Dent 48:141, 1982.
70. Baima RF: Extension of clinical crown length. J Prosthet Dent 55:547, 1986.
71. Rosenberg ES, et al: Tooth lengthening procedures. Compend Contin Educ Dent 1:161, 1980.
72. Pontoriero R, Carnevale G: Surgical crown lengthening: A 12-month clinical wound healing study. J Periodontol 72:841, 2001.
73. Lanning SK, et al: Surgical crown lengthening: evaluation of the biological width. J Periodontol 74:468, 2003.
74. Evian C, et al: Retained interdental procedure for maintaining anterior esthetics. Comp Contin Educ Dent 6:5, 1985.
75. Han TJ, Takei HH: Progress in gingival papilla reconstruction. Periodontol 2000 11:65, 1996.
76. Cortellini P, et al: The modified papilla preservation technique with bioresorbable barrier membranes in the treatment of intrabony defects. Case reports. Int J Periodontics Restorative Dent 16:547, 1996.

77. Beagle JR: Surgical reconstruction of the interdental papilla: case report. Int J Periodontics Restorative Dent 12:145, 1992.
78. Azzi R, et al: Surgical reconstruction of the interdental papilla. Int J Periodontics Restorative Dent 18:467, 1998.
79. Tarnow DP, et al: The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal papilla. J Periodontol 63:995, 1992.
80. Pini Prato GP, et al: Interdental papilla management: A review and classification of the therapeutic approaches. Int J Periodontics Restorative Dent 24:246, 2004.
81. Johnson GK, Sivers JE: Forced eruption in crown-lengthening procedures. J Prosthet Dent 56:424, 1986.
82. Tuncay OC: Orthodontic tooth movement as an adjunct to prosthetic therapy. J Prosthet Dent 46:41, 1981.
83. Miller TE: Orthodontic therapy for the restorative patient. I. The biomechanic aspects. J Prosthet Dent 61:268, 1989.
84. Celenza F, Mantzikos TG: Periodontal and restorative considerations of molar uprighting. Compendium 17:294, 1996.
85. Shaughnessy TG: Implementing adjunctive orthodontic treatment. J Am Dent Assoc 126:679, 1995.
86. Proffit WR: Contemporary Orthodontics, 2nd ed. St. Louis, Mosby, 1993.
87. Ackerman JL, Proffit WR: Communication in orthodontic treatment planning: bioethical and informed consent issues. Angle Orthod 65:253, 1995.
88. Grubb JE, et al: Clinical and scientific applications/advances in video imaging. Angle Orthod 66:407, 1996.
89. Levine JB: Esthetic diagnosis. Curr Opin Cosmet Dent 9, 1995.
90. Goldstein RE, Miller MC: The role of high technology in maintaining esthetic restorations. J Esthet Dent 8:39, 1996.
91. Clark GT, et al: The validity and utility of disease detection methods and of occlusal therapy for temporomandibular disorders. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 83:101, 1997.
92. Kirveskari P: The role of occlusal adjustment in the management of temporomandibular disorders. Oral Surg 83:87, 1997.
93. Kirveskari P, et al: Occlusal adjustment and the incidence of demand for temporomandibular disorder treatment. J Prosthet Dent 79:433, 1998.
94. Kerstein RB, et al: A comparison of ICAGD (immediate complete anterior guidance development) to mock ICAGD for symptom reductions in chronic myofascial pain dysfunction patients. Cranio 15:21, 1997.
95. McNeill C: Craniomandibular disorders: guidelines for evaluation, diagnosis, and management. In American Academy of Craniomandibular Disorders: Oral and Facial Pain, Chicago, Quintessence Publishing, 1990.
96. Gher ME: Changing concepts. The effects of occlusion on periodontitis. Dent Clin North Am 42:285, 1998.

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7

PRINCIPLES OF TOOTH PREPARATION



KEY TERMS

causes of injury
clearance
conservation of tooth structure
diagnostic tooth preparations
margin designs
margin placement
path of placement
resistance
retention
supragingival
taper
undercut

Teeth do not possess the regenerative ability found in most other tissues. Therefore, once enamel or dentin is lost as a result of caries, trauma, or wear, restorative materials must be used to reestablish form and function. Teeth require preparation to receive restorations, and these preparations must be based on fundamental principles from which basic criteria can be developed to help predict the success of prosthodontic treatment. Careful attention to every detail is imperative during tooth preparation. A good preparation ensures that subsequent techniques (e.g., interim fabrication, impression making, pouring of dies and casts, waxing) can be accomplished.

The principles of tooth preparation may be divided into three broad categories:

1. Biologic considerations, which affect the health of the oral tissues.
2. Mechanical considerations, which affect the integrity and durability of the restoration.
3. Esthetic considerations, which affect the appearance of the patient.

Successful tooth preparation and subsequent restoration depend on simultaneous consideration of all these factors. Improvement in one area often adversely affects another area, and striving for perfection in one may lead to failure in another. For example, in the fabrication of a metal-ceramic crown (see Chapter 24), sufficient thickness of porcelain is necessary for a lifelike appearance. However, if too much tooth structure is removed to accommodate a greater thickness of porcelain for esthetic reasons, the pulpal tissue may be traumatized (biologic consideration) and the tooth unduly weakened (mechanical consideration). In-depth knowledge and an understanding of the various criteria are prerequisite to the development of satisfactory tooth preparation skills. Predictable accomplishment of optimum tooth preparation (Fig. 7-1) often includes finding the best combination of compromises among the applicable biologic, mechanical, and esthetic considerations.

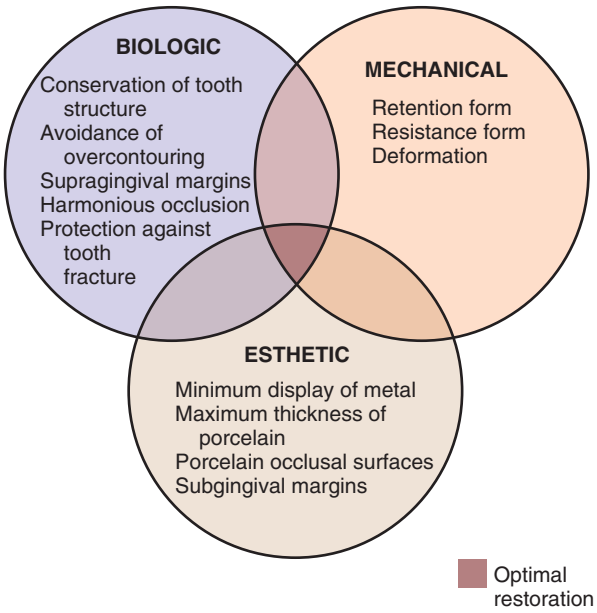


Fig. 7-1
The optimum restoration should satisfy biologic, mechanical, and esthetic requirements.

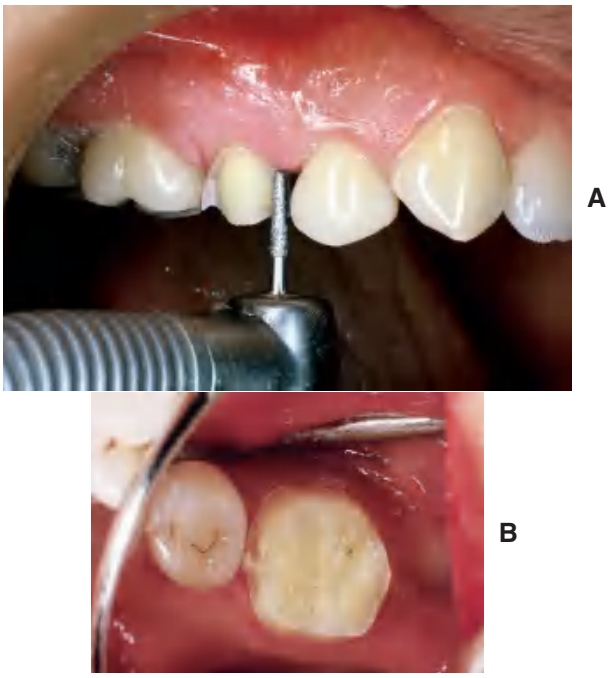


Fig. 7-2
Damage to adjacent teeth is prevented by positioning the diamond so a thin lip of enamel is retained between the bur and the adjacent tooth. **A,** Note that the orientation of the diamond parallels the long axis of this premolar. **B**, Proximal reduction almost complete. Note that enamel was maintained mesial to the path of the diamond as the reduction progressed.

BIOLOGIC CONSIDERATIONS

Surgical procedures involving living tissues must be carefully executed to avoid unnecessary damage. The adjacent teeth, soft tissues, and the pulp of the tooth being prepared are easily damaged in tooth preparation. If poor preparation leads to inadequate marginal fit or deficient crown contour, plaque control around fixed restorations becomes more difficult. This impedes the long-term maintenance of dental health.

Prevention of Damage during Tooth Preparation

Adjacent teeth

Iatrogenic damage to an adjacent tooth is a common error in dentistry. Even if a damaged proximal contact area is carefully reshaped and polished, it is more susceptible to dental caries than was the original undamaged tooth surface. This is presumably because the original surface enamel contains higher fluoride concentrations and the interrupted layer is more prone to plaque retention.[1] The technique of tooth preparation must avoid and prevent damage to the adjacent tooth surfaces.

A metal matrix band around the adjacent tooth for protection may be helpful; however, the thin band can nonetheless be perforated and the underlying enamel damaged. The preferred method is to use the proximal enamel of the tooth that is being prepared for protection of the adjacent structures. Teeth are 1.5 to 2 mm wider at the contact area than at the cementoenamel junction. Therefore, a thin, tapered diamond can be passed through the interproximal contact area (Fig. 7-2) to leave a slight lip or fin of enamel without resulting in excessive tooth reduction or necessitating undesirable angulation of the rotary instrument. The latter situation, tipping the diamond unnecessarily away from the adjacent proximal surface, is a common clinical error.

Soft tissues

Damage to the soft tissues of the tongue and cheeks can be prevented by careful retraction with an aspirator tip, mouth mirror (Fig. 7-3), or flanged saliva ejector. Great care is needed to protect the tongue when the lingual surfaces of mandibular molars are being prepared.

Pulp

Great care also is needed to prevent pulpal injuries during fixed prosthodontic procedures, especially complete crown preparation. Pulpal degeneration that occurs many years after tooth preparation has been documented.[2] Extreme temperatures, chemi-



Fig. 7-3
Soft tissue protection. A mouth mirror is used to retract the tongue during preparation.

cal irritation, or microorganisms can cause an irreversible pulpitis,[3] particularly when they occur on freshly sectioned dentinal tubules. Prevention of pulpal damage necessitates selection of techniques and materials that reduce the risk of damage while tooth structure is prepared.[4]

Tooth preparations must account for the structure of the dental pulp chamber. Pulp size, which can be evaluated on a radiograph, decreases with age. Up to about age 50, it decreases more so occlusocervically than faciolingually. Average pulp dimensions have been related to coronal contour[5] and are presented in Table 7-1 and Figure 7-4.

Causes of injury

Temperature

Considerable heat is generated by friction between a rotary instrument and the surface being prepared (Fig. 7-5). Excessive pressure, higher rotational speeds, and the type, shape, and condition of the cutting instrument (Fig. 7-6) may all increase generated heat.[6] With a high-speed handpiece, a feather-light touch allows efficient removal of tooth material with minimal heat generation. Nevertheless, even with the lightest touch, the tooth overheats unless a water spray is used. This must be accurately directed at the area of contact between tooth and bur. The spray also removes debris—which is important because clogging reduces cutting efficiency (Fig. 7-7)—and prevents desiccation of the dentin (a cause of severe pulpal irritation).[2,7] Debris accumulation has been shown to vary with rotary instrument shape. Shoulder- and chamfer-shaped diamonds may accumulate less debris. Debris is not readily removed after 5 minutes of ultrasonic cleaning.[8]

If the spray prevents adequate visibility, as may be the case when a lingual margin is being finished, a slow-speed handpiece or hand instrumentation should be used. Relying on air cooling with a high-

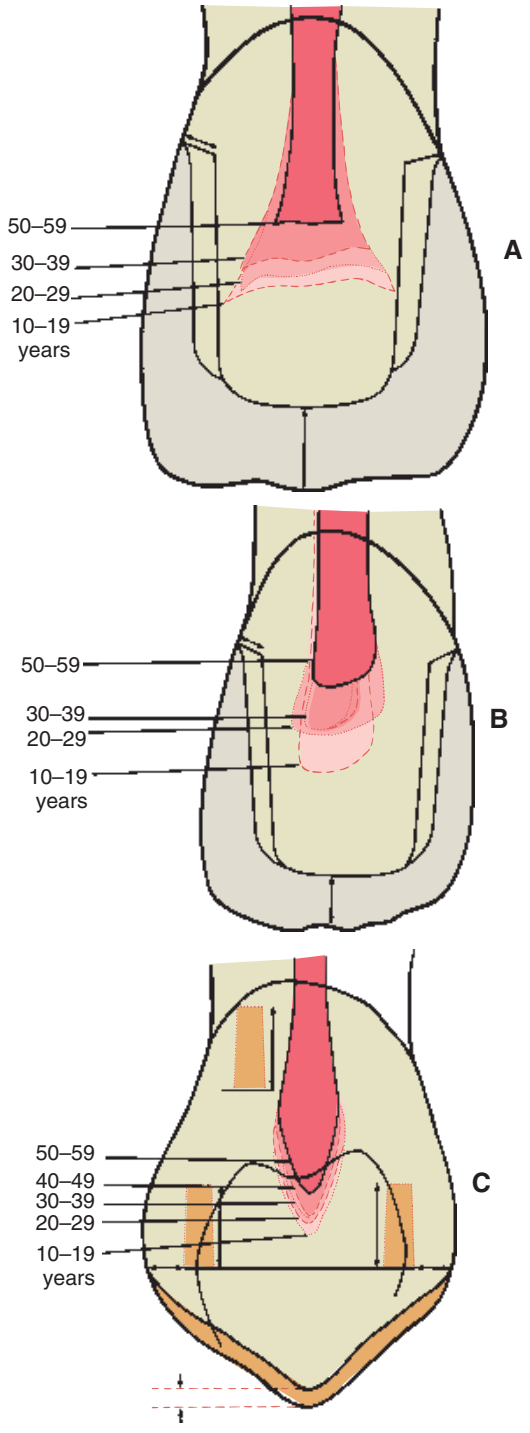


Fig. 7-4
Relationship between tooth preparation and pulp chamber size. The *dotted lines* represent pulp chamber structure at various ages. **A,** Maxillary central incisor with a metal-ceramic crown preparation. **B,** Maxillary lateral incisor with a metal-ceramic crown preparation. **C,** Maxillary canine with a pinledge preparation. *(From Ohashi Y: Research related to anterior abutment teeth of fixed partial denture. Shikagakuho 68:726, 1968.)*

Table **7-1** **DIMENSIONS OF PULP AND THE CORONAL CONTOUR**

Age range (years)	Coronal length (mm)	Incisal to MPH (mm)	Incisal to DPH (mm)	Mesial surface to MPH (mm)	Distal surface to DPH (mm)	Labial surface to MPH (mm)	Labial surface to DPH (mm)	Palatal surface to MPH (mm)	Palatal surface to DPH (mm)
MAXILLARY CENTRAL INCISOR									
10-19	12.1	4.7	4.8	1.7	2.1	1.8	1.8	1.4	1.3
20-29	11.5	4.8	5.1	2.2	2.3	1.9	1.9	1.4	1.2
30-39	11.2	5.3	5.5	2.1	2.5	2.3	2.4	2.1	2.0
40-49	10.8	6.3	6.2	2.5	2.9	2.0	2.1	2.0	1.8
50-59	12.3	6.3	6.2	2.6	2.6	2.8	2.3	2.2	2.1
Mean ± SD	11.58 ± 0.34	5.5 ± 0.25	5.6 ± 0.28	2.2 ± 0.16	2.5 ± 0.14	2.2 ± 0.12	2.1 ± 0.12	1.8 ± 0.16	1.7 ± 0.19
Range	9.70-14.00	4.0-6.2	4.0-6.2	1.2-3.3	1.4-3.5	1.5-2.9	1.5-2.9	1.0-2.9	1.1-2.9
MAXILLARY LATERAL INCISOR									
10-19	10.1	3.9	4.3	2.4	2.6	2.0	2.1	1.3	1.3
20-29	10.2	4.8	5.2	2.5	3.2	2.4	2.4	1.9	1.9
30-39	10.0	4.8	–	2.4	3.2	2.1	2.3	2.0	1.7
40-49	9.0	4.8	5.2	1.9	2.2	2.1	2.1	1.7	1.5
50-59	9.7	6.0	–	2.2	2.3	2.3	2.3	2.6	2.5
Mean ± SD	8.84 ± 0.23	4.9 ± 0.40	4.9 ± 0.32	2.3 ± 0.20	2.7 ± 0.19	2.2 ± 0.04	2.2 ± 0.15	1.9 ± 0.11	1.8 ± 0.17
Range	7.90-11.91	3.6-6.2	3.6-6.4	1.2-3.2	1.8-3.6	1.7-2.7	1.8-2.7	1.2-3.2	1.1-2.9

Age range (years)	Coronal length (mm)	Incisal to PH (mm)	Mesial surface to PH (mm)	Distal surface to PH (mm)	Labial surface to PH (mm)	Palatal surface to PH (mm)
MAXILLARY CANINE						
10-19	10.7	4.4	3.4	4.0	2.7	2.3
20-29	10.6	4.6	3.3	3.7	3.1	2.6
30-39	10.5	4.8	3.0	4.0	2.9	2.5
40-49	9.5	4.8	3.0	3.6	2.8	2.8
50-59	9.5	5.4	2.8	3.4	2.9	3.0
Mean ± SD	10.23 ± 0.26	4.8 ± 0.20	3.1 ± 0.13	3.7 ± 0.12	2.9 ± 0.11	2.6 ± 0.15
Range	8.29-12.70	3.8-7.2	2.3-3.6	2.9-4.8	2.5-3.5	1.9-3.7

From Ohashi Y: Research related to anterior abutment teeth of fixed partial denture. Shikagakuho 68:726, 1968.
DPH, distal pulp horn; MPH, mesial pulp horn; PH, pulp horn.

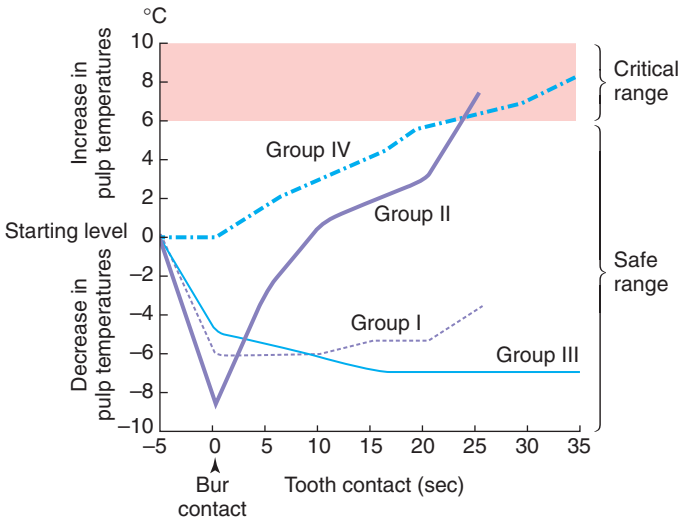


Fig. 7-5
Pulpal temperature rise during tooth preparation. Group I, air turbine, water cooled. Group II, air turbine, dry. Group III, low speed, water cooled. Group IV, low speed, dry. *(From Zach L, Cohen G: Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol 19:515, 1965.)*

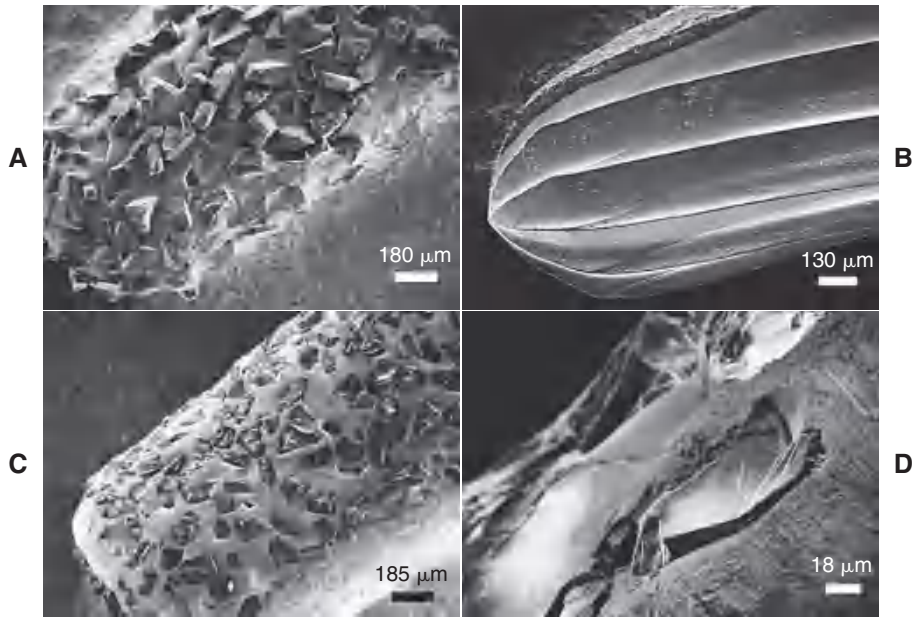


Fig. 7-6
Scanning electron micrographs of a rotary instrument. A, Unused diamond. B, Unused carbide. C, Worn diamond. D, Diamond particles have fractured at the level of the binder. *(Courtesy of Dr. J. L. Sandrik.)*

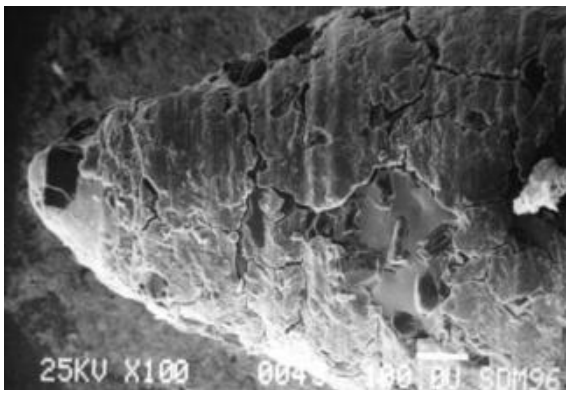


Fig. 7-7
Clogging on the tapered tip of a cylindrical diamond after one molar tooth preparation reduces cutting efficiency.

speed handpiece is hazardous, because it can easily overheat a tooth and damage the pulp.[9]

Particular care is needed for preparing grooves or pinholes, because coolant cannot reach the cutting edge of the bur. To prevent heat buildup, these retention features should be prepared at low rotational speed.

Chemical action

The chemical action of certain dental materials (bases, restorative resins, solvents, and luting agents) can cause pulpal damage,[10] particularly when they are applied to freshly cut dentin. Cavity varnish or dentin bonding agents form an effective barrier in most instances, but their effect on the retention of a cemented restoration is controversial.[11-13]

Chemical agents are sometimes used for cleaning and degreasing tooth preparations. However, they have been shown[14] to be pulpal irritants. Thus, their use is generally contraindicated, particularly because they do not improve the retention of cemented restorations.[15]

Bacterial action

Pulpal damage under restorations has been attributed[16,17] to bacteria that either were left behind or gained access to the dentin because of microleakage. However, many dental materials, including zinc phosphate cement, have an antibacterial effect.[18] Because vital dentin seems to resist infection,[19] the routine use of antimicrobial agents may not be advantageous. Many dentists now use an antimicrobial agent, such as chlorhexidine gluconate disinfecting solution (Consepsis*), after tooth preparation and before cementation, although the benefit has not been documented in clinical trials.[20]

Of importance is that all carious dentin should be removed before placement of a restoration that will serve as a foundation for a fixed prosthesis. An indirect pulp cap is not recommended on teeth that will subsequently receive cast restorations, because its later failure is likely to jeopardize extensive prosthodontic treatment.

Conservation of Tooth Structure

One of the basic tenets of restorative dentistry is to conserve as much tooth structure as possible while preparation design remains consistent with the mechanical and esthetic principles of tooth preparation. Tissue preservation reduces the harmful pulpal effects of the various procedures and materials used. The thickness of remaining dentin has been shown[21] to be inversely proportional to the pulpal response, and tooth preparations extending in close proximity to the pulp should be avoided. Dowden[22] argued that any damage to the odontoblastic processes would adversely affect the cell nucleus at the dentin-pulp interface, no matter how far from the nucleus it occurred. For this reason, in the assessment of likely adverse pulpal response, the amount of removed dentin is important; particular care must be exercised when vital teeth are prepared for complete-coverage restorations (Fig. 7-8).

Tooth structure is conserved through adherence to the following guidelines:

1. Use of partial-coverage rather than complete-coverage restorations (Fig. 7-9).
2. Preparation of teeth with the minimum practical convergence angle (**taper**) between axial walls (Fig. 7-10).
3. Preparation of the occlusal surface so that reduction follows the anatomic planes to give uniform thickness in the restoration (Fig. 7-11).
4. Preparation of the axial surfaces so that a maximal thickness of residual tooth structure surrounding pulpal tissues is retained; if necessary, teeth should be orthodontically repositioned (Fig. 7-12) which permits teeth to be prepared with

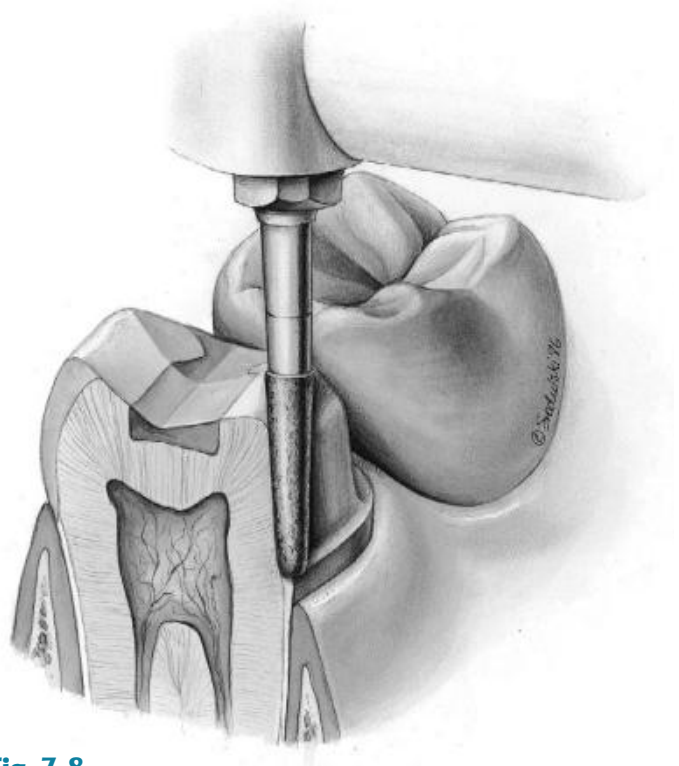


Fig. 7-8
A considerable amount of care is needed when a tooth is prepared for a complete crown, because of the extensive nature of the reduction, with many dentinal tubules sectioned. Each tubule communicates directly with the dental pulp.

*Ultradent Products, Inc., South Jordan, Utah.

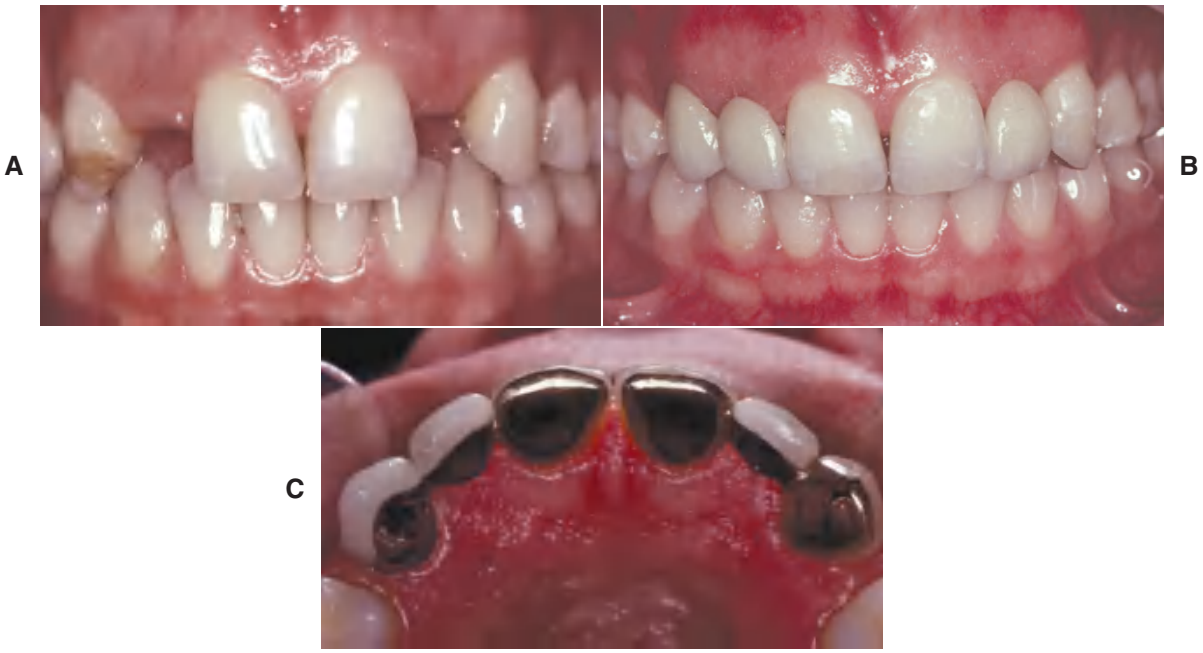


Fig. 7-9
Conservation of tooth structure by using partial-coverage restorations. In this case, they are used as fixed dental prosthetic abutments to replace congenitally missing lateral incisors.

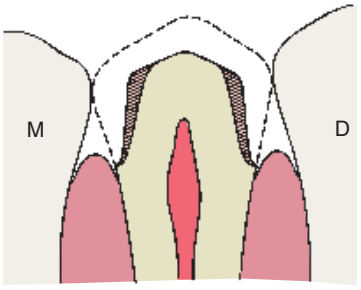


Fig. 7-10
Excessive taper results in considerable loss of tooth structure (*shaded area*).

less axial convergence than necessary when tooth alignment is less than optimal to accommodate fixed dental prosthetic retainer preparations.

5. Selection of a margin geometry that is conservative and yet compatible with the other principles of tooth preparation (Fig. 7-13).
6. Avoidance of unnecessary apical extension of the preparation (Fig. 7-14).

Considerations Affecting Future Dental Health

Improper preparation of a tooth may have an adverse effect on long-term dental health. For example, insufficient axial reduction inevitably results in overcontoured restorations that hamper plaque control. This may cause periodontal disease[23]

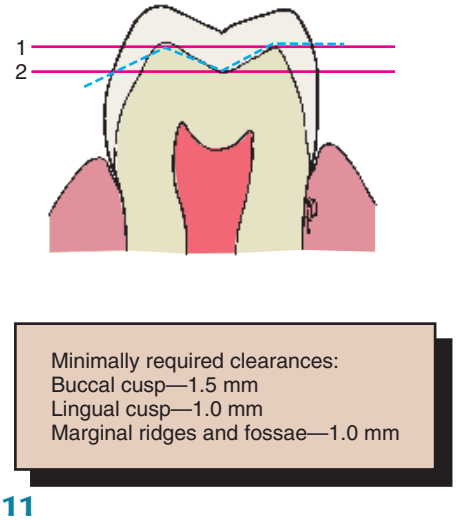


Fig. 7-11
An anatomically prepared occlusal surface results in adequate clearance without excessive tooth reduction. A flat occlusal preparation will result in either insufficient clearance (*1*) or an excessive amount of reduction (*2*).

or dental caries. Alternatively, inadequate occlusal reduction may result in poor form and subsequent occlusal dysfunction. Poor choice of margin location, such as in the area of occlusal contact, may cause chipping of enamel or cusp fracture.

Axial reduction

Gingival inflammation is commonly associated with crowns and fixed dental prosthetic abutments that

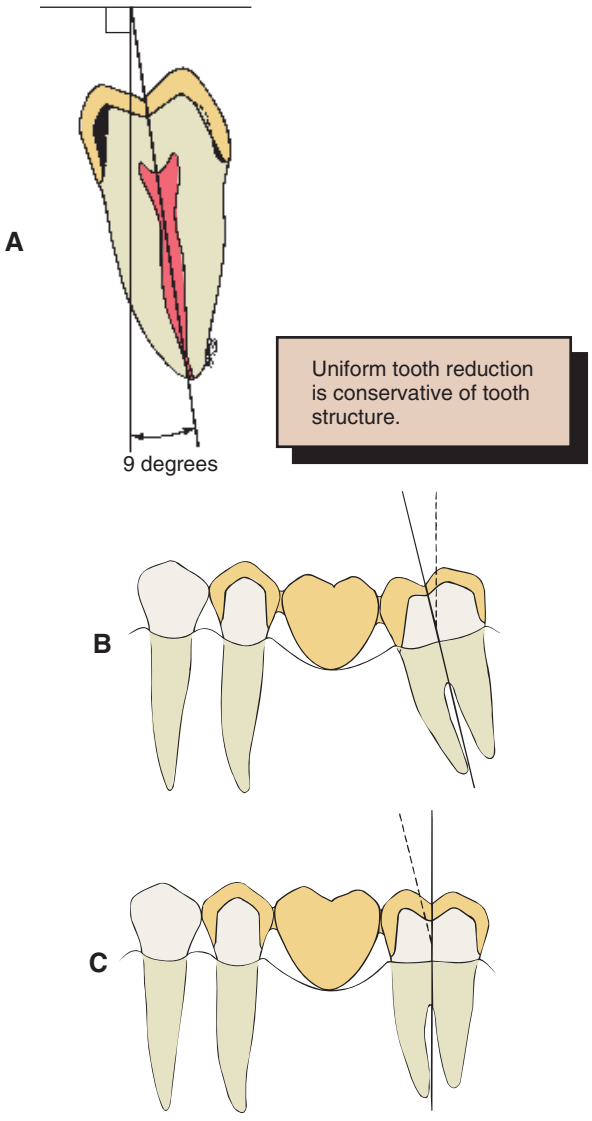


Fig. 7-12
To conserve tooth structure, the preparation of axial walls should be as uniform as possible. **A**, The path of placement should coincide with the long axis of the tooth, which for a mandibular molar is typically inclined 9 to 14 degrees lingually. Preparing such a tooth with a path of placement that is perpendicular to the occlusal plane of the mandibular arch is a commonly observed clinical error that results in additional unnecessary removal of tooth structure (*shaded area*). Malaligned teeth, such as a mesially tipped molar (**B**), necessitate additional removal of tissue on the mesial aspect of the molar abutment to achieve compatible paths of placement for a planned fixed dental prosthesis. **C**, If the molar abutment is orthodontically uprighted before tooth preparation, a more conservative crown preparation can be achieved.

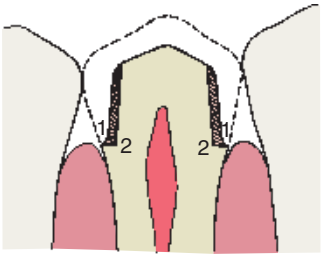


Fig. 7-13
A shoulder margin (*2*) is indicated when esthetic restorations are planned to achieve sufficient material thickness to achieve a lifelike appearance, but it is much less conservative than a chamfer (*1*).

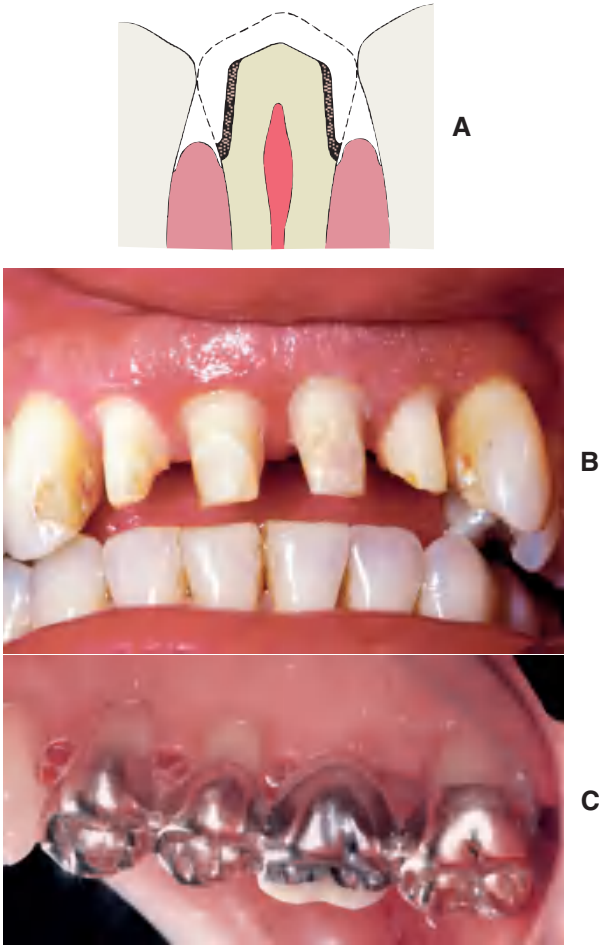


Fig. 7-14
A, Apical extension of the preparation can necessitate additional tooth reduction because coronal diameter becomes smaller. **B**, Preparations for periodontally involved teeth may necessitate considerable reduction if the margins are to be placed subgingivally for esthetic reasons. **C**, Supragingival margins are preferred where applicable.

have excessive axial contours, probably because it is more difficult for the patient to maintain plaque control around the gingival margin[24] (Fig. 7-15). A tooth preparation must provide sufficient space for the development of good axial contours. This enables the junction between the restoration and the tooth to be smooth and free of any ledges or abrupt changes in direction.

Under most circumstances, a crown should duplicate the contours and profile of the original tooth (unless the restoration is needed to correct a malformed or malpositioned tooth). If an error is made, a slightly undercontoured flat restoration is better because it is easier to keep free of plaque; however, increasing proximal contour on anterior crowns to maintain the interproximal papilla[25] (see Chapter 5) may be beneficial. Sufficient tooth structure must be removed to allow the development of correctly formed axial contours (Fig. 7-16), particularly in the interproximal and furcation areas of posterior teeth, where periodontal disease often progresses with serious consequences.

Margin placement

Whenever possible, the margin of the preparation should be **supragingival.** Subgingival margins of cemented restorations have been identified[26-31] as a major etiologic factor in periodontal disease, particularly where they encroach on the epithelial attachment (see Chapter 5). Supragingival margins are easier to prepare accurately without trauma to the soft tissues. They can usually also be situated on hard enamel, whereas subgingival margins are often on dentin or cementum.

Other advantages of supragingival margins include the following:

1. They can be easily finished without associated soft-tissue trauma.
2. They are more easily kept plaque free.
3. Impressions are more easily made, with less potential for soft tissue damage.
4. Restorations can be easily evaluated at the time of placement or at recall appointments.

A subgingival margin (Fig. 7-17), however, is justified if any of the following pertain:

1. Dental caries, cervical erosion, or restorations extend subgingivally, and a crown-lengthening procedure (see Chapter 6) is not indicated.
2. The proximal contact area extends to the gingival crest.
3. Additional ***retention*** and/or ***resistance*** is needed (see "Mechanical Considerations" section, p. 226).



Fig. 7-15

A, Unhealthy gingival tissue resulting from overcontoured restorations. **B**, The tooth preparations are underreduced; **C**, Once the restorations are recontoured, gingival health returns.

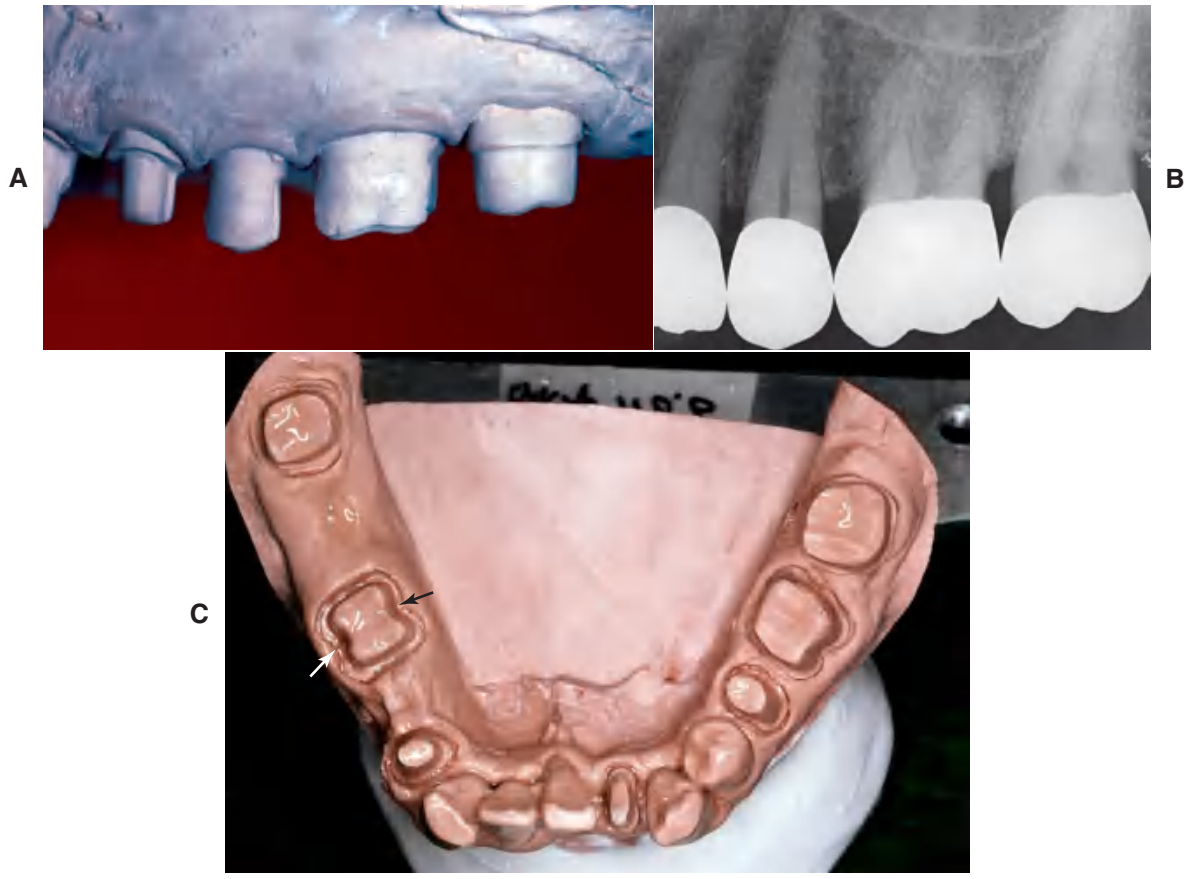


Fig. 7-16

A and **B,** Tooth preparations with adequate axial reduction allow the development of properly contoured embrasures. Tissue is conserved through the use of partial coverage and supragingival margins where possible. **C,** Preparing furcation areas adequately is important *(arrows)*; otherwise, the restoration is excessively contoured, making plaque control difficult.



Fig. 7-17

Examples of when subgingival margins are indicated. **A,** To include an existing restoration. **B,** To extend apical to the proximal contact (adequate proximal clearance). **C** and **D,** To hide the metal collar of metal-ceramic crowns.

4. The margin of a metal-ceramic crown is to be hidden behind the labiogingival crest.
5. Root sensitivity cannot be controlled by more conservative procedures, such as the application of dentin bonding agents.
6. Modification of the axial contour is indicated, such as to provide an **undercut** to provide retention for the clasp of a partial removable dental prosthesis (see Chapter 21).

Margin adaptation

The junction between a cemented restoration and the tooth is always a potential site for recurrent caries because of dissolution of the luting agent and inherent roughness. The more accurately the restoration is adapted to the tooth, the lesser is the chance of recurrent caries or periodontal disease.[32] Although a precise calculation for acceptable margin adaptation is not available, a skilled technician can routinely make castings that fit to within 10 μm[33] and a porcelain margin that fits to within 50 μm,[34] provided the tooth is properly prepared. A well-designed preparation has a smooth and even margin. Rough, irregular, or "stepped" junctions greatly increase overall margin length and substantially reduce the adaptation accuracy of the restoration (Fig. 7-18). The clinical significance of preparing smooth margins cannot be overemphasized. Time spent obtaining a smooth margin makes the subsequent steps of tissue displacement, impression making, die formation, waxing, and finishing much easier and ultimately results in a longer-lasting restoration.

Margin geometry

The cross-sectional configuration of the margin has been the subject of much analysis and debate.[35-42] Different shapes have been described and advocated.[43,44] For evaluation, the following guidelines for margin design should be considered:

1. Ease of preparation without overextension or unsupported enamel.
2. Ease of identification in the impression and on the die.
3. A distinct boundary to which the wax pattern can be finished.
4. Sufficient bulk of material (to enable the wax pattern to be handled without distortion and to give the restoration strength and, when porcelain is used, esthetics).
5. Conservation of tooth structure (if the other criteria are met).

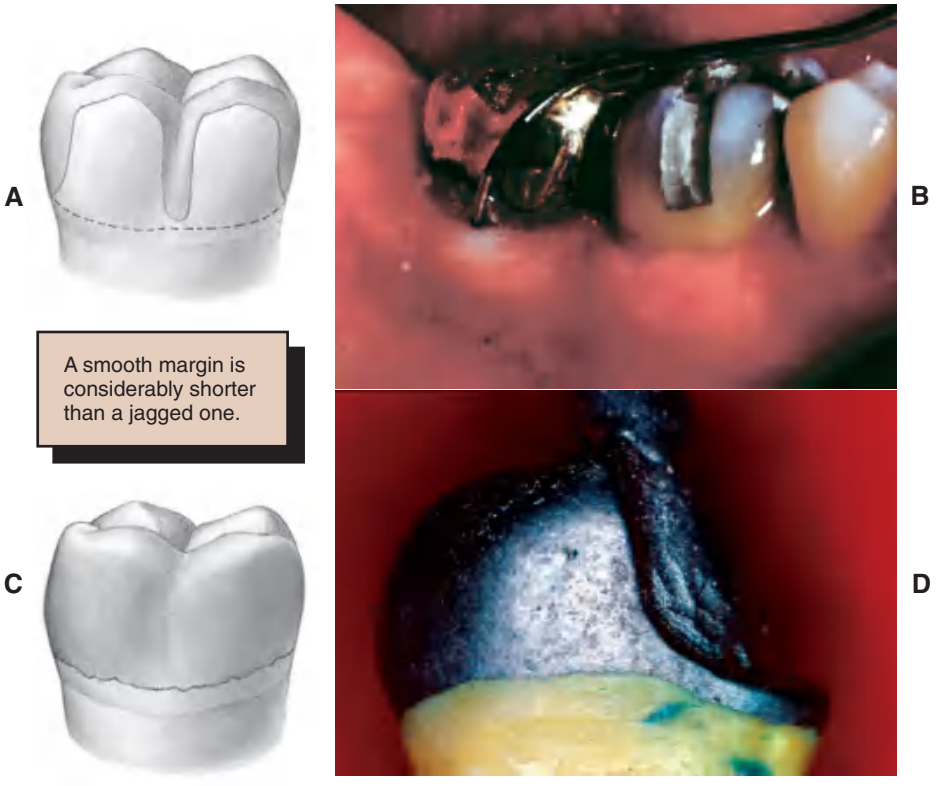


Fig. 7-18
A and **B,** Poor preparation design, leading to increased margin length. **C,** A rough, irregular margin makes the fabrication of an accurately fitted restoration almost impossible. **D,** An accurately fitting margin is possible only if it is prepared smoothly.

Proposed **margin designs** are presented in Table 7-2.

Although they are conservative of tooth structure, feather edge or shoulderless crown preparations (Fig. 7-19*A*) should be avoided because they do not provide adequate bulk at the margins. Overcontoured restorations often result from feather edge margins because the technician can handle the wax pattern without distortion only by increasing its bulk beyond the original contours. A variation of the feather edge, the chisel edge margin (Fig. 7-19*B*), is formed when there is a larger angle between the axial surfaces and the unprepared tooth structure. Unfortunately, this margin is frequently associated with preparations with excessive angles of convergence (taper) and preparations in which the orientation of the axial reduction is not correctly aligned with the long axis of the tooth.

Under most circumstances, feather edges and chisel edges are unacceptable. Historically, their main advantage was that they facilitated impression making with rigid modeling compound in copper bands (a technique rarely used today). They were useful for that purpose, because there was no ledge on which a band could catch. A chamfer margin (Fig. 7-19*C*) is particularly suitable for cast metal crowns and the metal-only portion of metal-ceramic crowns (Fig. 7-20). It is distinct and easily identified, and it provides room for adequate bulk of material and development of anatomically correct axial contours. Chamfers can be placed expediently and with precision, although care is needed to avoid leaving a ledge of unsupported enamel.

Probably the most suitable instrument for making a chamfer margin is the tapered diamond with a rounded tip; the resulting margin is the exact image of the instrument (Fig. 7-21). Marginal accuracy depends on having a high-quality diamond and a true-running handpiece. The gingival margin is prepared with the diamond held precisely in the intended **path of placement** of the restoration (Fig. 7-22).

Tilting it away from the tooth will create an undercut, whereas angling it toward the tooth will lead to overreduction and loss of retention. The chamfer should never be prepared wider than half the tip of the diamond; otherwise, an unsupported lip of enamel may result (Fig. 7-23). Some authorities have recommended the use of a diamond with a noncutting guide tip to aid accurate chamfer placement.[45] However, such guides have been shown to damage tooth structure beyond the intended preparation margin.[46]

Under some circumstances a beveled margin (see Fig. 7-19*D*) is more suitable for cast restorations, particularly if a ledge or shoulder already exists, possi-

Table 7-2 ADVANTAGES AND DISADVANTAGES OF DIFFERENT MARGIN DESIGNS

Margin design	Advantages	Disadvantages	Indications
Feather edge	Conservative of tooth structure	Does not provide sufficient bulk	Not recommended
Chisel edge	Conservative of tooth structure	Location of margin difficult to control	Occasionally on tilted teeth
Bevel	Removes unsupported enamel, allows finishing of metal	Extends preparation into sulcus if used on apical margin	Facial margin of maxillary partial-coverage restorations and inlay/onlay margins
Chamfer	Distinct margin, adequate bulk, easier to control	Care needed to avoid unsupported lip of enamel	Cast metal restorations, lingual margin of metal-ceramic crowns
Shoulder	Bulk of restorative material	Less conservative of tooth structure	Facial margin of metal-ceramic crowns, complete ceramic crowns
Sloped shoulder	Bulk of material, advantages of bevel	Less conservative of tooth structure	Facial margins of metal-ceramic crowns
Shoulder with bevel	Bulk of material, advantages of bevel	Less conservative, extends preparation apically	Facial margin of posterior metal-ceramic crowns with supragingival margins

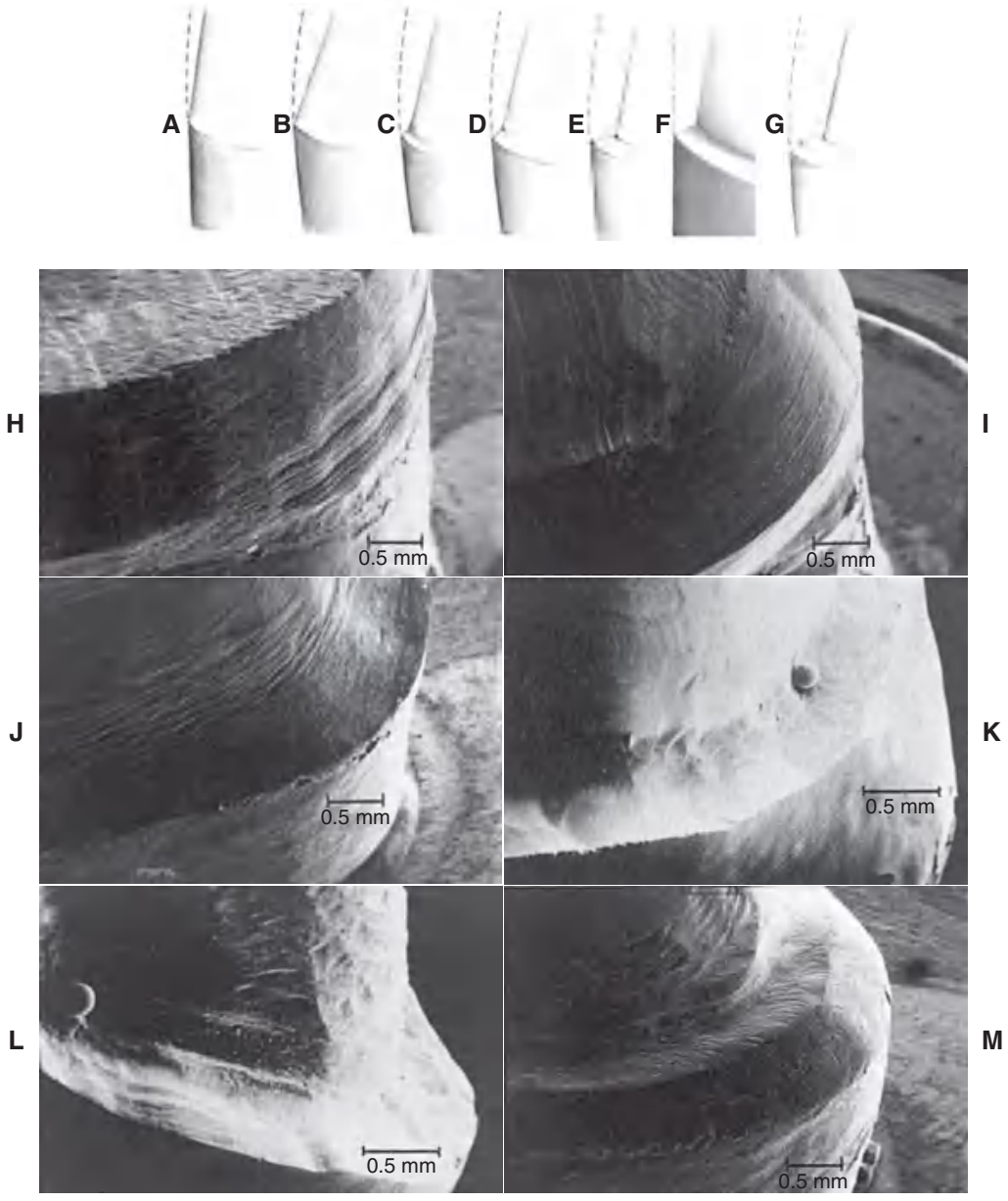


Fig. 7-19

Margin designs. A, Feather edge. **B,** Chisel. **C,** Chamfer. **D,** Bevel. **E,** Shoulder. **F,** Sloped shoulder. **G,** Beveled shoulder. **H** to **M,** Scanning electron micrographs. **H,** Feather-chisel edge. **I,** Bevel. **J,** Chamfer. **K,** Shoulder. **L,** Sloped shoulder. **M,** Beveled shoulder. *(Courtesy of Dr. H. Lin.)*



Fig. 7-20

Chamfer margins are recommended for cast metal crowns (A) and the lingual margin of a metal-ceramic crown (B).

bly as a result of dental caries, cervical erosion, or a previous restoration. The objective in beveling is threefold: (1) to allow the cast metal margin to be bent or burnished against the prepared tooth structure; (2) to minimize the marginal discrepancy[35] caused by a complete crown that fails to seat completely (however, Pascoe[40] showed that when an oversized crown is considered, the discrepancy is increased rather than decreased [Fig. 7-24]); and (3) to protect the unprepared tooth structure from chipping (e.g., by removing unsupported enamel). NOTE: when access for burnishing is limited, there is little advantage in beveling. This applies particularly to a gingival margin, where beveling would lead to subgingival extension of the preparation or placement of the margin on dentin rather than on enamel. Facial margins of maxillary partial-coverage restorations should be beveled to eliminate all unsupported enamel, to protect the remaining tooth structure from fracture, and to allow for burnishing of the casting.

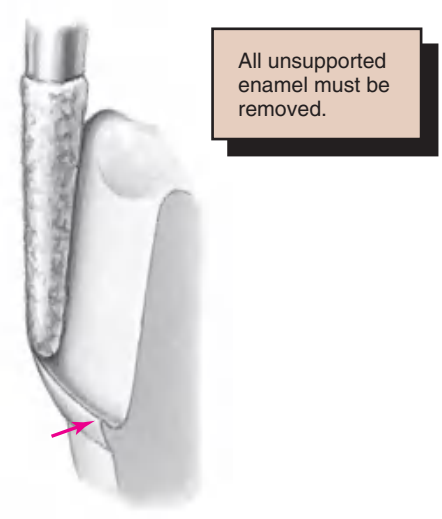


Fig. 7-21
A chamfer margin is formed as the negative image of a round-ended tapered diamond.

Because a shoulder margin (Fig. 7-19*E*) allows room for porcelain, it is recommended for the facial part of metal-ceramic crowns, especially when the porcelain margin technique is used. It should form a 90-degree angle with the unprepared tooth surface. An acute angle is likely to chip (Fig. 7-25*A*). In practice, dentists tend to underprepare the facial shoulder,[47] which leads to restorations with inferior esthetics or poor axial contour.

Some authorities[48] have recommended a heavy chamfer rather than a shoulder margin, and some find a chamfer easier to prepare with precision. Earlier workers[38,39] found less distortion of the metal framework during porcelain application with a shoulder margin, although with modern alloys, these results could not be replicated.[49-52]

A 120-degree sloped shoulder margin (Fig. 7-19*F*) is sometimes used as an alternative to the 90-degree shoulder for the facial margin of metal-ceramic crowns. The sloped shoulder reduces the possibility of leaving unsupported enamel but leaves sufficient bulk to allow thinning of the metal framework to a knife-edge for acceptable esthetics.

A beveled shoulder margin (Fig. 7-19*G*) is recommended by some authorities for the facial surface of a metal-ceramic restoration in which a metal collar

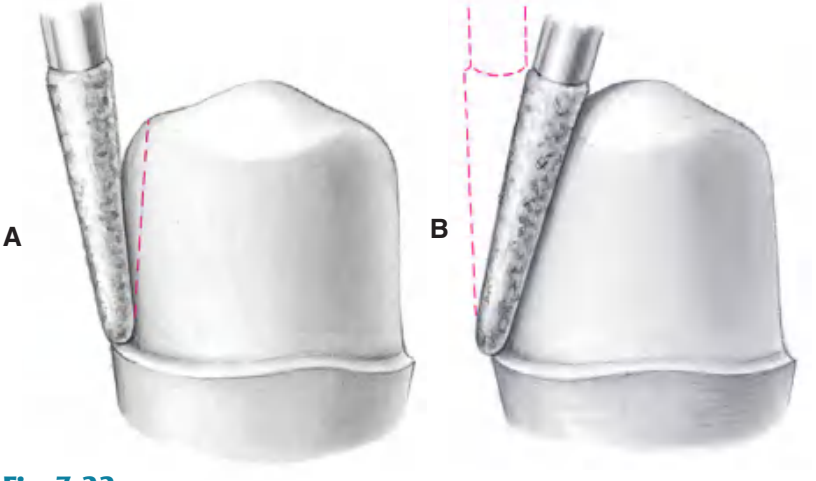


Fig. 7-22
Precise control of the orientation of the diamond is very important. **A,** Tilting away from the tooth creates an undercut: Opposing axial preparation walls diverge in an occlusal direction. **B,** Tilting toward the tooth results in an excessive convergence angle of the preparation.



Fig. 7-23
A chamfer should not be wider than half the bur used to form it. Otherwise, a lip of unsupported enamel will be left.

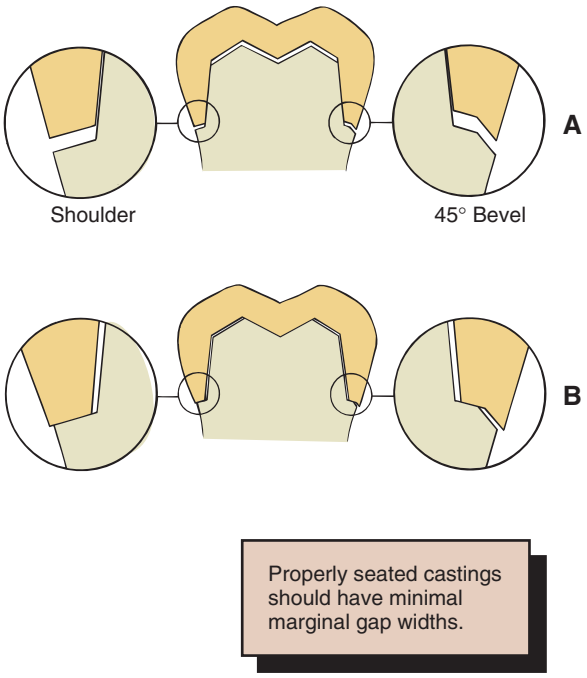


Fig. 7-24
Effect on marginal fit of beveling the gingival margin. **A,** If the internal cross-section of a crown is the same as or less than that of the prepared tooth, a 45-degree bevel decreases the marginal discrepancy by 70%. **B,** If the internal diameter is slightly larger than the prepared tooth, beveling increases the marginal discrepancy. In practice, crowns are made slightly larger than the prepared tooth to allow for the luting agent.

(as opposed to a porcelain labial margin) is used. The beveling removes unsupported enamel and may allow some finishing of the metal. However, a shoulder or sloped shoulder is preferred for biologic and esthetic reasons. This allows improved esthetics because the metal margin can be thinned to a knife edge and hidden in the sulcus without the need for positioning the margin closer to the epithelial attachment (Fig. 7-25*B*). Table 7-3 illustrates chamfer and shoulder preparations obtained with selected instruments.

A comprehensive 2001 literature review of current scientific knowledge on complete coverage tooth preparations suggests that margin design selection should be based on the type of crown, applicable esthetic requirements, ease of formation, and operator experience. Research has not validated the expectation of enhanced fit being associated with selection of certain types of finish line geometry.[53]

Occlusal considerations

A satisfactory tooth preparation allows sufficient space for developing a functional occlusal scheme in the finished restoration. Sometimes the patient's occlusion is disrupted by supraerupted or tilted teeth (Fig. 7-26). When these teeth are prepared for restoration, the eventual occlusal plane must be carefully analyzed and the teeth reduced accordingly. Considerable reduction is often needed to compensate for the supraeruption of abutment teeth. In turn, this may shorten tooth preparation axial wall height, with associated mechanical consequences such as reduced retention and resistance (see p. 226).

Sometimes even endodontic treatment is necessary to make enough room. However, under these circumstances, compromising the principle of conservation of tooth structure is preferable to the potential harm from a traumatic occlusal scheme. Careful judgment is obviously needed. **Diagnostic tooth preparations** and waxing procedures are essential to help determine the exact amount of reduction necessary to develop an optimum occlusion.

Preventing tooth fracture

No tooth is unbreakable. If teeth are smashed together (as in an automobile accident, sport injury, or biting unexpectedly on a hard object), a cusp may break. Cuspal fracture also can occur from parafunctional habits such as bruxism.

The likelihood that a restored tooth will fracture can be lessened if the tooth preparation is designed to minimize potentially destructive stresses (Fig. 7-27). For example, an intracoronal cast restoration (inlay) has a greater potential for fracture because when occlusal forces are applied to the restoration,

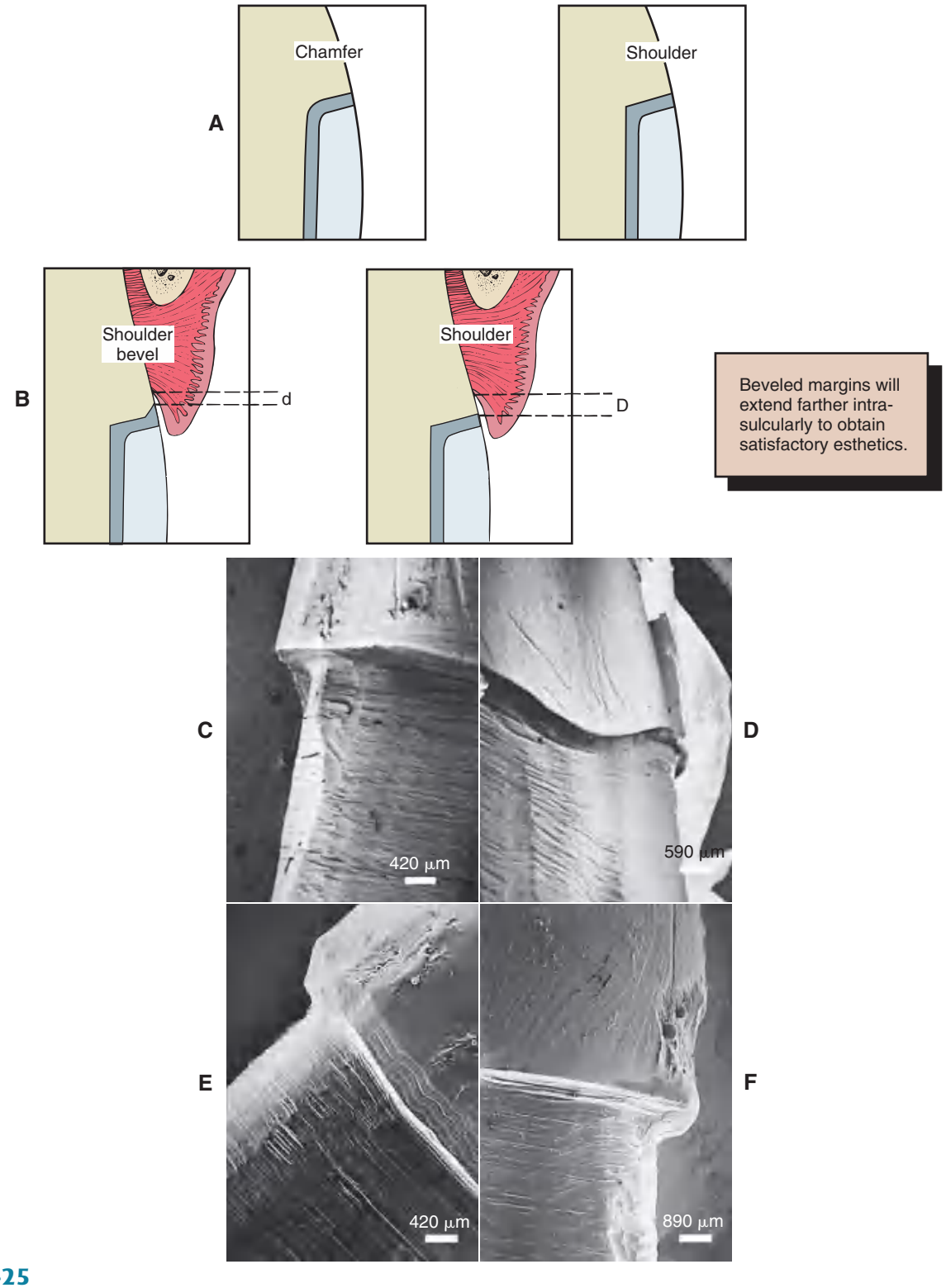


Fig. 7-25

A, A shoulder provides more bulk of metal than a heavy chamfer, which may facilitate the laboratory steps. **B,** A disadvantage of the shoulder bevel is that its margin must be placed deeper in the gingival sulcus so that the wider band of metal will be hidden (compare *d* with *D*). **C,** Scanning electron micrograph of a shoulder margin prepared with a high-speed diamond. **D,** This margin has been refined with a sharp chisel. **E,** This has been beveled with a tungsten carbide bur. **F,** This bevel was placed with a sharp hand instrument. *(Microscopy by Dr. J. Sandrik; teeth prepared by Dr. G. Byrne.)*

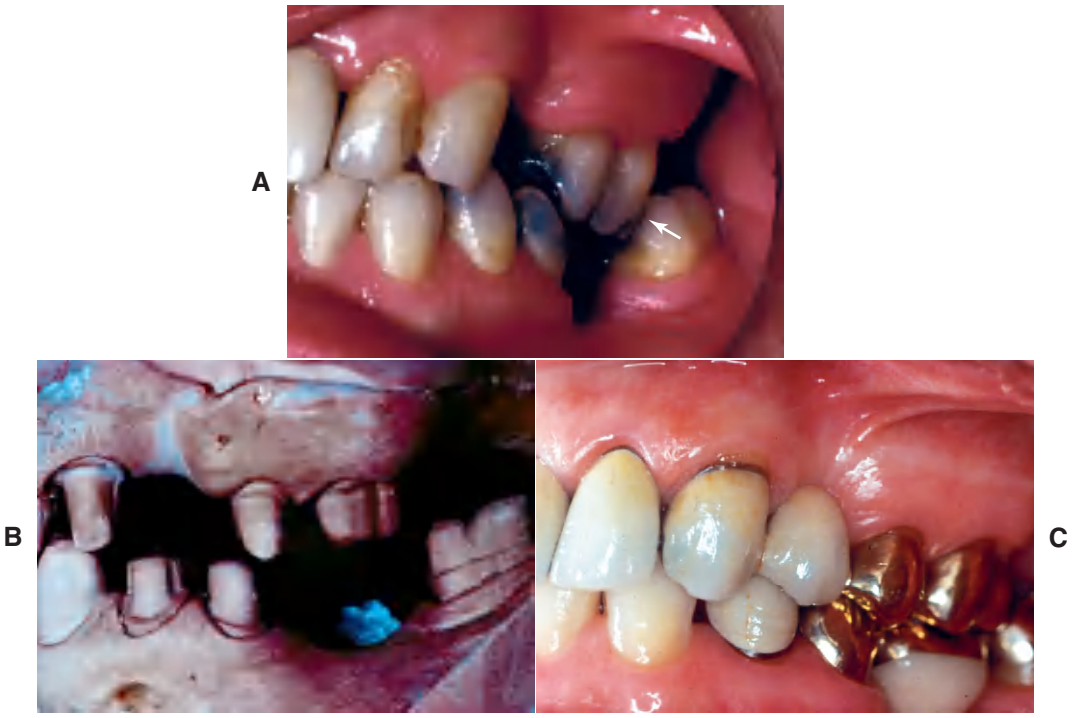


Fig. 7-26

A, Nonreplacement of missing teeth has led to supraocclusion and a protrusive interference (*arrow*). **B,** Teeth reduced with the help of trial tooth preparations and diagnostic waxing. **C,** Restorations with anterior guidance.

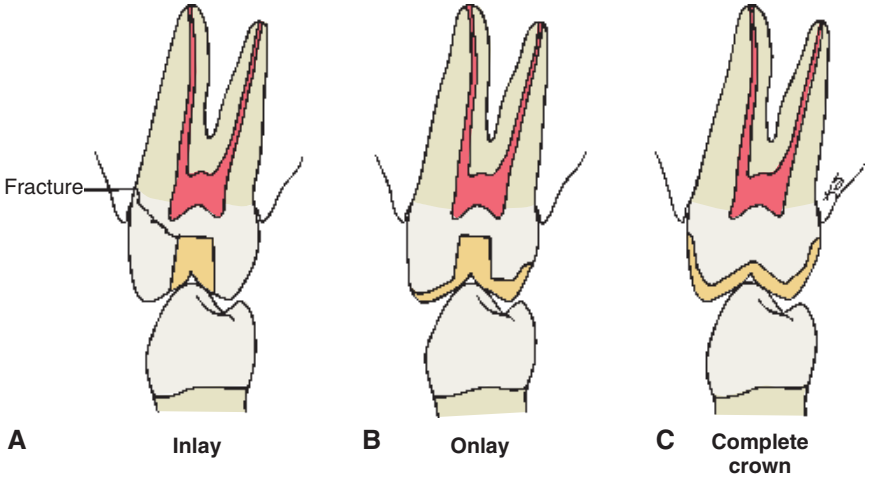


Fig. 7-27

A, An intracoronal cast restoration (inlay) can act as a wedge during cementation or function. If the cusps are weakened, fracture will occur. **B,** A cuspal-coverage onlay provides better protection but often lacks retention. **C,** A complete crown provides the best protection against fracture. It also has the best retention, but it can be associated with periodontal disease and poor esthetics. *(Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment, London, Kluwer Publishing, 1983.)*

it tends to wedge opposing walls of the tooth apart. This wedging must be resisted by the remaining tooth structure; if the remaining tooth structure is thin (as with a wide preparation isthmus), the tooth may fracture during function. Providing a cuspal coverage restoration (onlay) rather than an inlay lessens the chance of such fracture.[54] However, although not as conservative of tooth structure, a complete crown is often a better solution, because it offers the greatest protection against tooth fracture, tending to "hold" the cusps of the tooth together.

MECHANICAL CONSIDERATIONS

The design of tooth preparations for fixed prosthodontics must adhere to certain mechanical principles; otherwise, the restoration may become dislodged or may distort or fracture during service. These principles have evolved from theoretical and clinical observations and are supported by experimental studies.

Mechanical considerations can be divided into three categories:

1. Providing retention form.
2. Providing resistance form.
3. Preventing deformation of the restoration.

Retention Form

Certain forces (e.g., when the jaws are moved apart after biting on very sticky food) act on a cemented restoration in the same direction as the path of placement. The quality of a preparation that prevents the restoration from becoming dislodged by such forces parallel to the path of placement is known as *retention.* Only dental caries and porcelain failure outrank lack of retention as a cause of failure of crowns and fixed dental prostheses.[55,56]

The following factors must be considered when the dentist decides whether retention is adequate for a given fixed restoration:

1. Magnitude of the dislodging forces.
2. Geometry of the tooth preparation.
3. Roughness of the fitting surface of the restoration.
4. Materials being cemented.
5. Film thickness of the luting agent.

Magnitude of the dislodging forces

Forces that tend to remove a cemented restoration along its path of placement are small in comparison with those that tend to seat or tilt it. A fixed dental prosthesis or splint can be subjected to such forces by pulling with floss under the connectors; however, the greatest removal forces generally arise when exceptionally sticky food (e.g., caramel) is eaten. The magnitude of the dislodging forces exerted by the elevator muscles depends on the stickiness of the food and the surface area and surface texture of the restoration.

Geometry of the tooth preparation

Most fixed dental prostheses depend on the geometric form of the preparation rather than on adhesion for retention because most of the traditional cements (e.g., zinc phosphate) are nonadhesive (i.e., they act by increasing the frictional resistance between tooth and restoration). The grains of cement prevent two surfaces from sliding, although they do not prevent one surface from being lifted from another. This is analogous to the effect of particles of sand or dust within machinery. They do not have a specific adhesion to metal, but they increase the friction between sliding metal parts. If sand or dust gets into an old-fashioned mechanical camera or watch, the increase in friction can effectively jam the mechanism.

Cement is effective only if the restoration has a single path of placement (i.e., the tooth is shaped to restrain the free movement of the restoration). The relationship between a nut and a bolt is an example of restrained movement (Fig. 7-28). The nut is not free to move in any direction but can move only along the precisely determined helical path of the threads on the bolt.

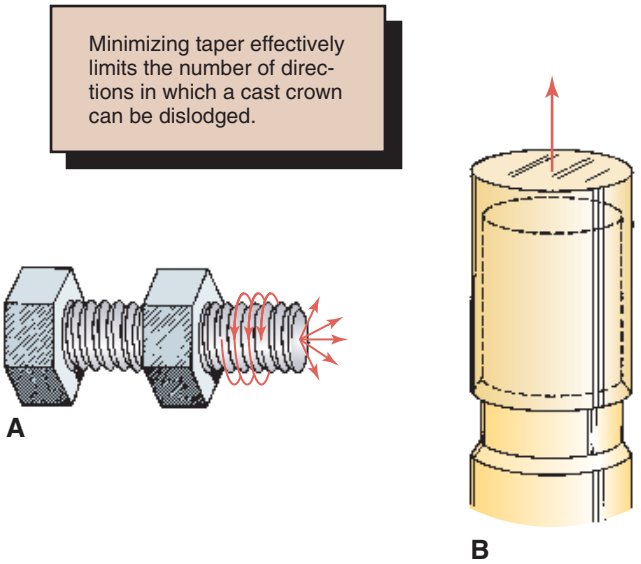


Fig. 7-28
A, The relationship of a nut and a bolt is an example of restrained movement; the nut must move along a precisely defined helical path (*arrows*). **B,** For effective retention, a tooth preparation must constrain the movement of a restoration. For this to occur, it must be cylindrical. (See Fig. 7-29.)

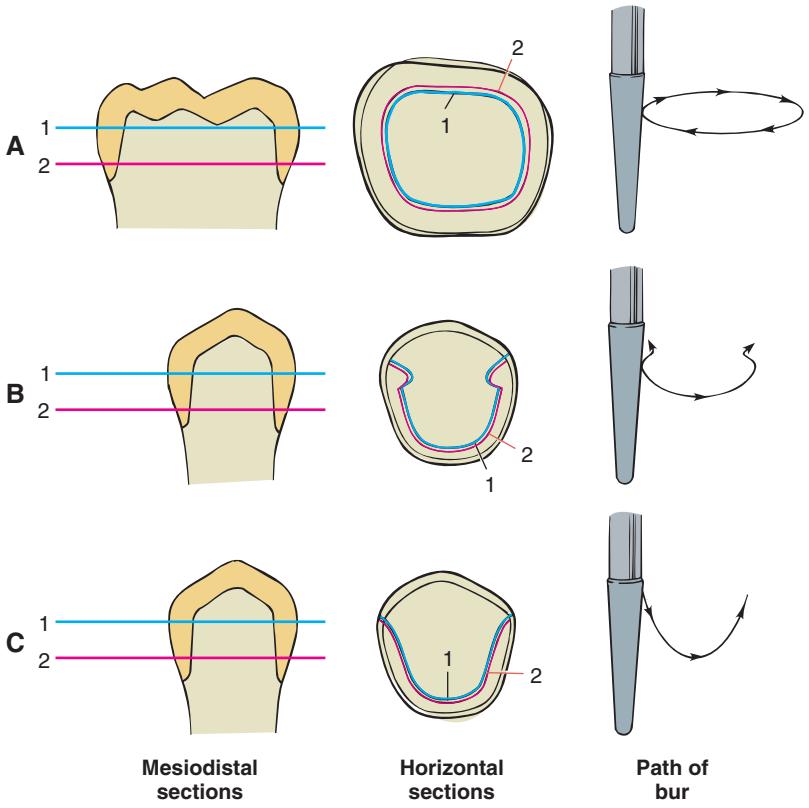


Fig. 7-29

A preparation is cylindrical if the two horizontal cross-sections of the prepared axial tooth surface (*1* and *2*) are coincident. A, This complete crown is cylindrical and therefore retentive. B, A partial crown is retentive if its sections are coincident and perpendicular movement is prevented by grooves. C, This preparation is cylindrical (*1* and *2* coincide) but not retentive, because it can move perpendicularly to the axis of the cylinder. *(Redrawn from Rosenstiel E: The retention of inlays and crowns as a function of geometrical form. Br Dent J 103:388, 1957.)*

The relationship between two bodies, one (in this case a tooth preparation) restraining movement of the other (a cemented restoration), has been studied mathematically and is known in analytical mechanics as a *closed lower pair of kinematic elements.*[57] In fixed prosthodontics, a *sliding pair* is the only pair that has relevance. It is formed by two cylindrical* surfaces constrained to slide along one another. The elements are constrained if the curve that defines the cylinder is closed or shaped to prevent movement at right angles to the axis of the cylinder (Fig. 7-29).

A tooth preparation is cylindrical if the axial surfaces are prepared by a cylindrical bur held at a constant angle. The gingival margin of the preparation becomes the fixed curve of the mathematical definition, and the occlusoaxial line angle of the tooth preparation should be a replica of the gingival margin geometry. The curve of a complete crown preparation is closed, whereas the grooves of a partial crown preparation prevent movement at right angles to the long axis of the cylinder. However, if one wall of the complete crown preparation is overtapered, it is no longer cylindrical, and the cemented restoration is not constrained by the preparation because the restoration then has multiple paths of withdrawal. Under these circumstances, the cement particles tend to lift away from rather than slide along the preparation, and the only retention is a result of the cement's limited adhesion (Fig. 7-30).

Taper

Taper is defined as the convergence of two opposing external walls of a tooth preparation as viewed in a given plane. The extension of those planes form an angle described as the *angle of convergence.* Theoretically, maximum retention is obtained if a tooth preparation has parallel walls. However, it is neither desirable nor practical to prepare a tooth this way with current techniques and instrumentation,

**Cylinder* is defined in its mathematical sense as the solid generated by a straight line parallel to another straight line and moving so that its ends describe a fixed curve.

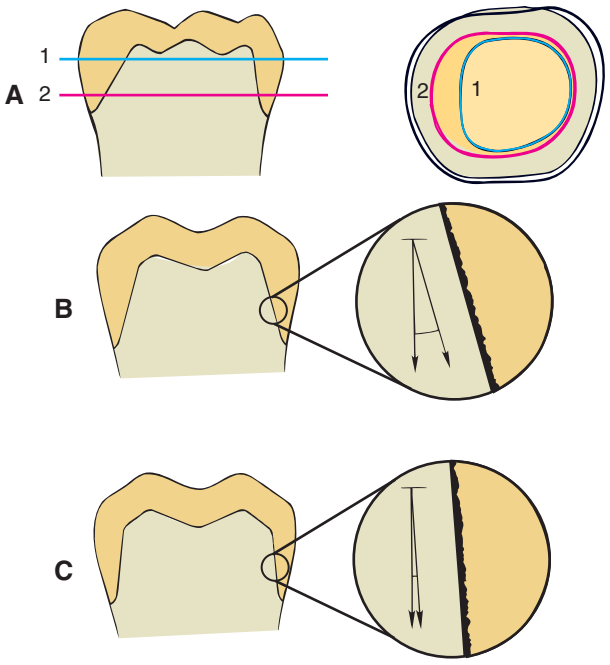


Fig. 7-30

A, Cross sections *1* and *2* do not coincide, and the preparation thus has little retention. **B,** Under these circumstances, very little friction develops between the cement and the axial walls, and the cement is subjected to tensile stress. **C,** A retentive near-parallel preparation with frictional resistance. The cement is placed under shear stress. (***A,*** *Redrawn from Rosenstiel E: The retention of inlays and crowns as a function of geometrical form. Br Dent J 103:388, 1957.)*

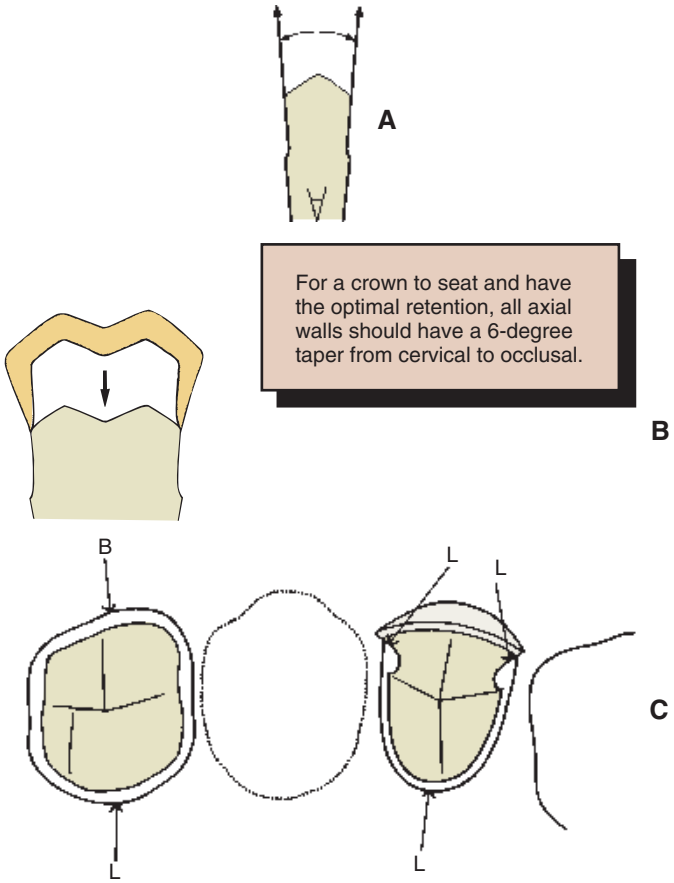


Fig. 7-31

A, An undercut is formed if opposing walls diverge. **B,** A tooth prepared with an undercut does not permit the crown to seat, inasmuch as it cannot pass over the divergent walls. **C,** Undercuts are possible in other locations when fixed dental prostheses or restorations with preparation features such as grooves or boxes are prepared. Here one buccally facing wall (*B*) can be undercut relative to (four) lingual facing walls (*L*).

because slight undercuts that prevent the restoration from seating are then created.

An undercut on a complete crown preparation is defined as any irregularity in the wall of a prepared tooth that prevents the withdrawal or seating of a wax pattern or casting. Such is the case when divergence is inadvertently created between opposing axial walls, or wall segments, in a cervical-occlusal direction (Fig. 7-31*A*). In other words, if the cervical diameter of a tooth preparation at the margin is narrower than at the occlusoaxial junction (reverse taper), it is impossible to seat a complete cast crown of similar geometry (see Fig. 7-31*B*). Undercuts can be present whenever two axial walls face in opposite directions (see Fig. 7-31*C*). Thus, the mesial wall of a complete cast crown preparation can be undercut in relation to the distal wall; in addition, the buccal wall can be undercut in relation to the lingual wall, and the mesiobuccal wall can be undercut in relation to the distolingual wall; in a partial veneer preparation, in accordance with the same principle, the lingual wall of a proximal groove can be undercut in relation to the lingual wall of the preparation, but the buccal wall of the same groove cannot be undercut in relation to the lingual preparation wall; either of these walls may restrict the number of directions in which a casting can be placed on the preparation in relation to the other, however.

A slight convergence, or taper, is clinically desirable in complete crown preparations. As long as this taper is small, the movement of the cemented restoration will be effectively restrained by the preparation and will have what is known as a *limited path of placement.* As taper increases, however, so does the free movement of the restoration, and consequently, retention will be reduced.

The relationship between the degree of axial wall taper and the magnitude of retention was first

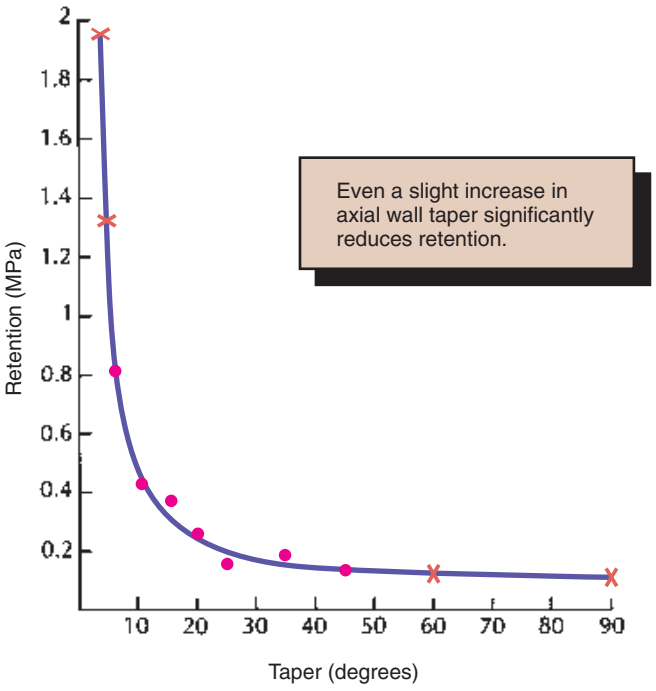


Fig. 7-32
Relationship between retention and convergence angle. •, Experimental values; x, calculated values outside the experimental range. *(Redrawn from Jørgensen KD: The relationship between retention and convergence angle in cemented veneer crowns. Acta Odontol Scand 13:35, 1955.)*

demonstrated experimentally by Jørgensen[58] in 1955. He cemented brass caps on Galalith cones of different tapers and measured retention with a tensile-testing machine. The relationship was found to be hyperbolic, with retention rapidly becoming less as taper increased (Fig. 7-32), although the relationship was no longer hyperbolic when the internal surfaces of the caps were roughened. The retention of a cap with 10 degrees of taper* was approximately half that of a cap with 5 degrees. Similar results have been reported by other workers.[59-61]

Selection of the appropriate degree of taper for tooth preparation involves compromise. Too small a taper may lead to unwanted undercuts; too large leads to a lack of retention. The recommended convergence between opposing walls is 6 degrees, which has been shown to optimize retention for zinc phosphate cement.[62] Being able to recognize this angle is important (Fig. 7-33). It is necessary to be able to rapidly quantify the approximate angle of

*In this discussion, as is generally the case in the dental literature, *taper* and *convergence* are used interchangeably and refer to the angle between diametrically opposed axial walls.



Fig. 7-33
The recommended convergence angle is 6 degrees. This is a very slight taper. (The angle between the hands of a clock showing 12:01 is 5½ degrees.)

convergence between preparation walls. It is not necessary to deliberately tilt a rotary cutting instrument to create a taper, because this invariably leads to overpreparation. Rather, teeth are readily prepared with a rotary instrument of the desired taper held at a constant angulation. The rotary instrument is moved through a cylindrical path as the tooth is prepared, and the taper of the instrument should produce the desired axial wall taper on the completed preparation. In practice, many dentists experience difficulty consistently avoiding excessively tapered preparations, particularly when preparing posterior teeth with limited access.[63-65]

Clinicians have a tendency to overtaper preparations in a buccolingual direction more so than mesiodistally, and abutments for fixed dental prostheses tend to be prepared with greater taper than do single crown preparations.[66]

Some authorities recommend the routine use of grooves to reduce the incidence of restoration displacement. It is unclear, however, whether accurate groove alignment is achieved more easily than axial wall convergence. Skillfully prepared axial walls at a minimal convergence are very conservative of tooth structure.

Surface area

If the restoration has a limited path of placement, its retention depends on the length of this path or, more precisely, on the surface area that is in sliding contact. Therefore, crowns with tall axial walls are more retentive than those with short axial walls,[67] and molar crowns are more retentive than premolar crowns of similar taper, because of the greater diameter of the molar. Surfaces on which the crown is essentially being pulled away from rather than sliding along the tooth, such as the

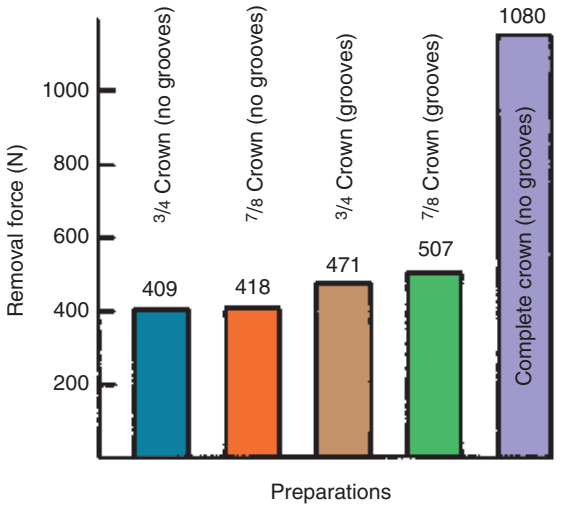


Fig. 7-34

Retention of different preparation designs. *(From Potts RG, et al: Retention and resistance of preparations for cast restorations. J Prosthet Dent 43:303, 1980.)*

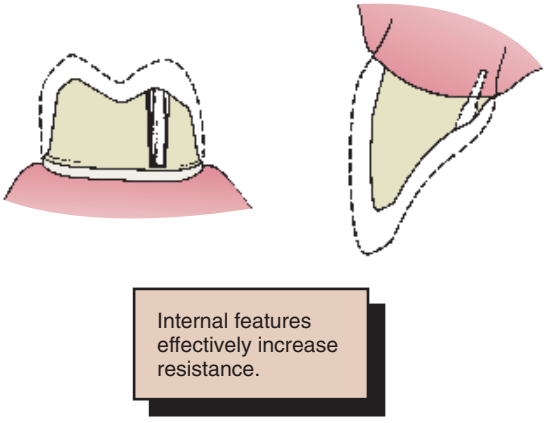


Fig. 7-35

Retention form of an excessively tapered preparation can be increased by adding grooves or pinholes, because these limit the paths of withdrawal.

occlusal surface, do not add significantly to total retention.

Stress concentration

When a retentive failure occurs, cement often adheres to both the tooth preparation and the fitting surface of the restoration. In these cases, cohesive failure occurs through the cement layer because the strength of the cement is less than the induced stresses. A computerized analysis of these stresses[68,69] reveals that they are not uniform throughout the cement but are concentrated around the junction of the axial and occlusal surfaces. Sharp occlusoaxial line angles should be rounded to minimize these stresses, which can precipitate retentive failure.[68,69] Changes in preparation geometry may thus indirectly increase the retention of the restoration.

Type of preparation

Different types of preparation have different retentive values that correspond fairly closely to the total surface area of the axial walls with restricted taper, as long as other factors (e.g., preparation height) are kept constant. Thus, the retention of a complete crown is more than double that of partial-coverage restorations[70] (Fig. 7-34).

Adding grooves or boxes (Fig. 7-35) to a preparation with a limited path of placement does not markedly affect its retention, because the surface area is not increased significantly. However, where the addition of a groove limits the paths of placement, retention is increased.[71,72]

Roughness of the surfaces being cemented

When the internal surface of a restoration is very smooth, retentive failure occurs not through the cement but at the cement-restoration interface. Under these circumstances, retention is increased if the restoration is roughened or grooved.[73-75] The casting is most effectively prepared by air-abrading the fitting surface with 50 µm of alumina. This should be done carefully to avoid abrading the polished surfaces or margins. Airborne particle abrasion has been shown[76] to increase in vitro retention by 64%. Similarly, acid-etching of the fitting surface of restorations can improve retention with certain luting agents.

Failure rarely occurs at the cement-tooth interface. Therefore, deliberately roughening the tooth preparation hardly influences retention and is not recommended, because roughness adds to the difficulty of subsequent technical steps in crown fabrication such as impression making and waxing (see Chapters 14 and 18).

Materials being cemented

Retention is affected by both the type of casting alloy and any core or buildup material that is present on the axial walls of the crown preparation. The clinical significance of laboratory testing results have yet to be confirmed by longer term clinical studies, but it appears that the more reactive the alloy is, the more adhesion there is with selected luting agents. Therefore, base metal alloys are better retained than are less reactive metals with high gold content.[77] The effect of adhesion to different core materials also has been tested, with conflicting

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Table 7-3 MARGINS PRODUCED BY VARIOUS TYPES OF BURS

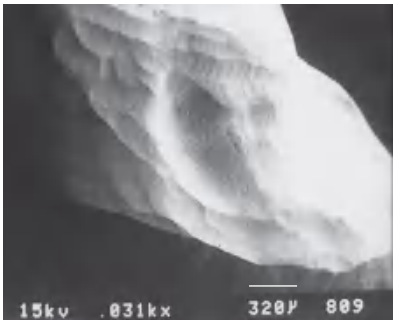
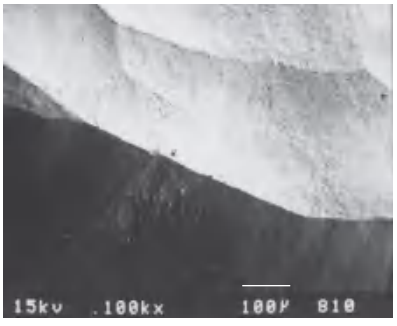
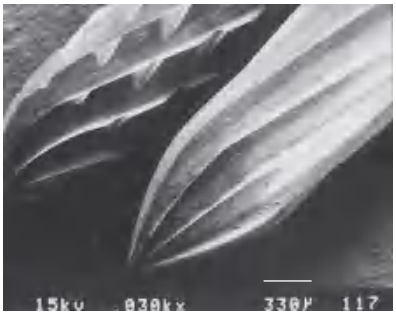
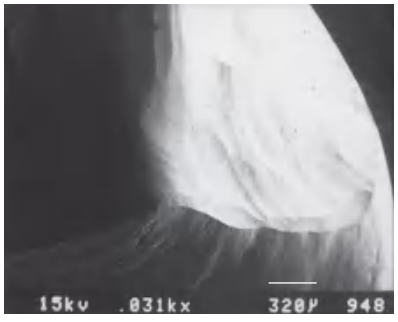
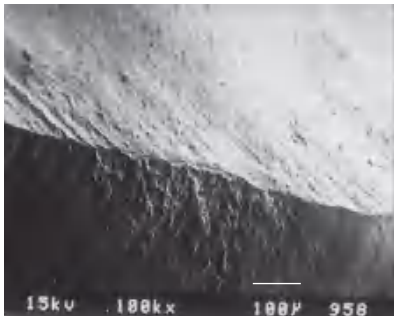
Bur appearance	Low magnification of the prepared margin	High magnification of the prepared margin
CHAMFERS		
Chamfer carbide (high speed)			
Chamfer carbide (high speed) Finishing carbide (high speed)			
Chamfer carbide (high speed) Finishing carbide (low speed)			

Table **7-3—cont'd**

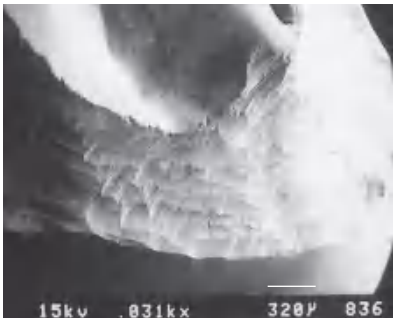
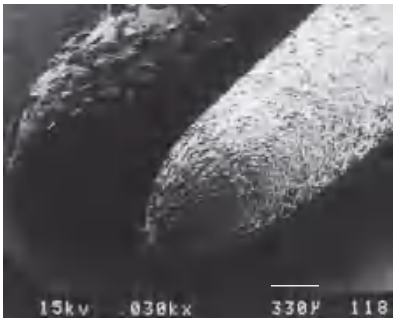
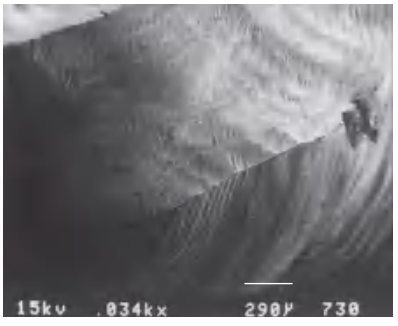
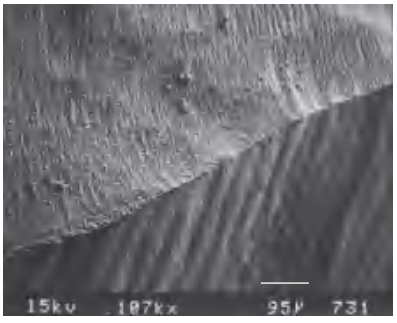
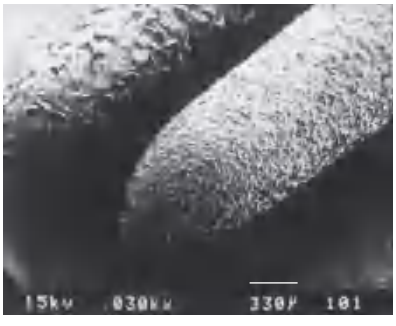
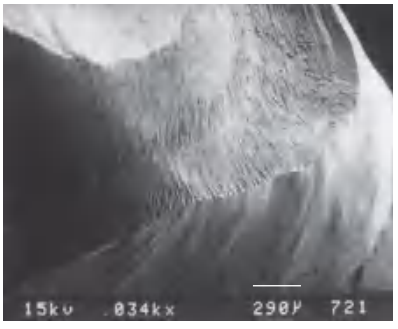
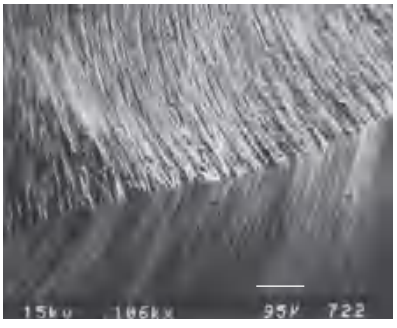
Bur appearance	Low magnification of the prepared margin	High magnification of the prepared margin
CHAMFERS, cont'd		
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Chamfer diamond coarse (high speed) Fine diamond (high speed)			
Chamfer diamond coarse (high speed) Chamfer diamond fine (low speed)			

Table **7-3—cont'd**

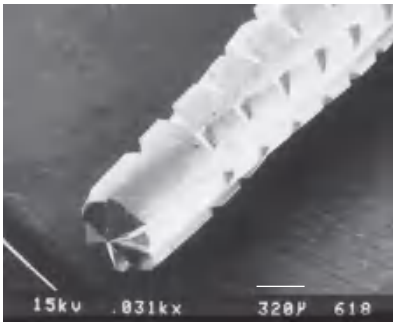
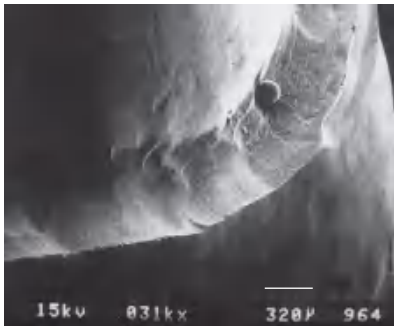
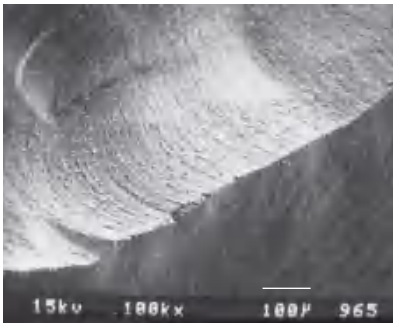
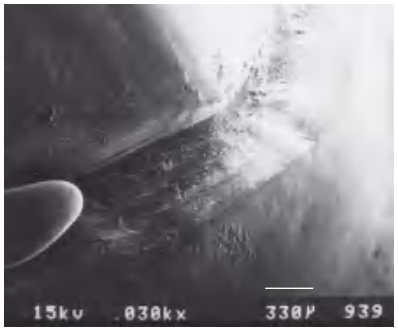
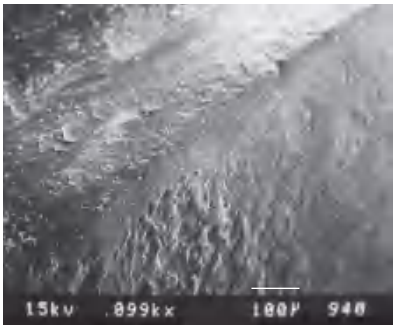
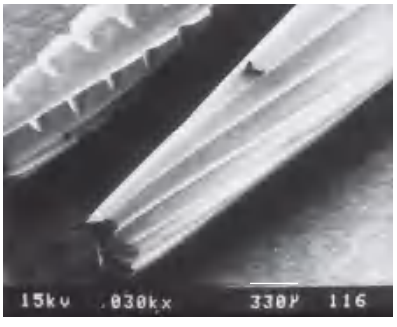
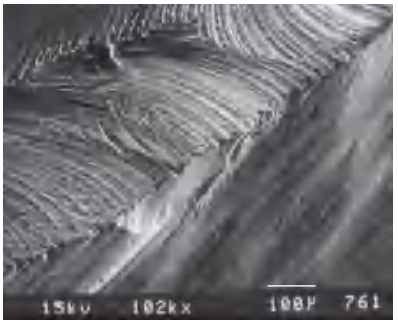
Bur appearance	Low magnification of the prepared margin	High magnification of the prepared margin
SHOULDERS		
Cross-cut fissure (high speed)			
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Cross-cut fissure carbide (high speed) Finishing carbide (high speed)			

Table **7-3—cont'd**

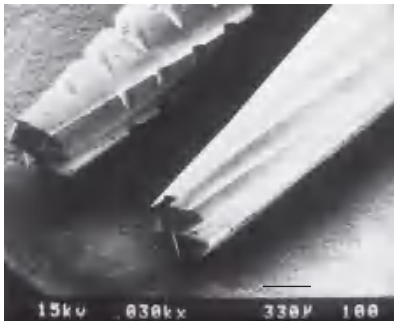
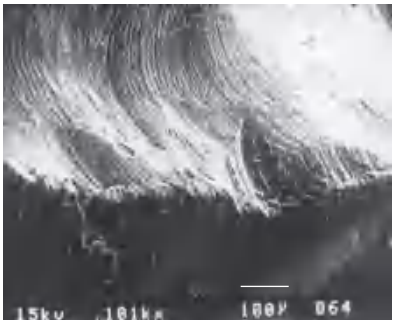
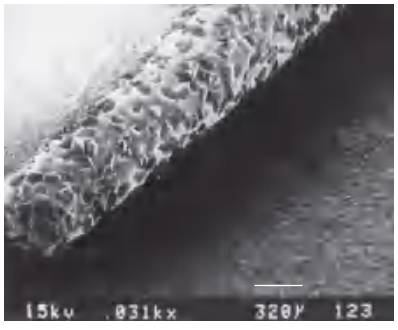
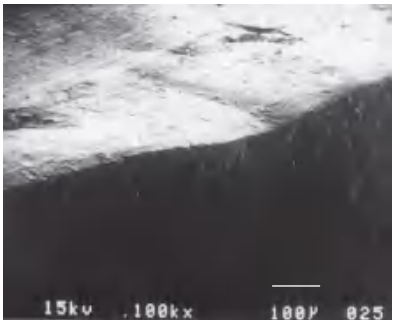
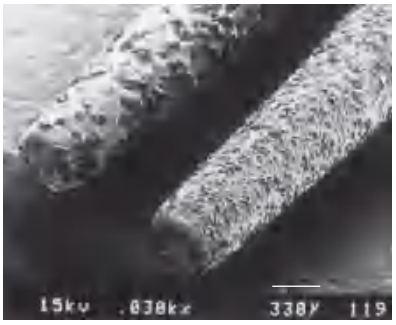
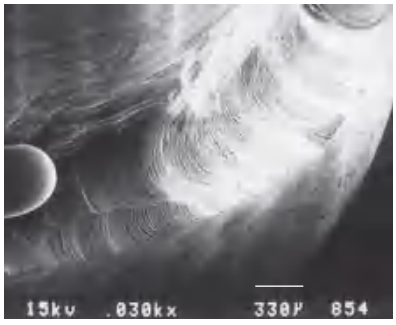
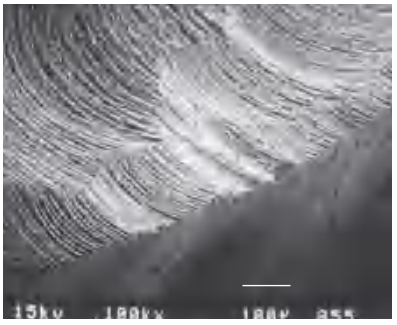
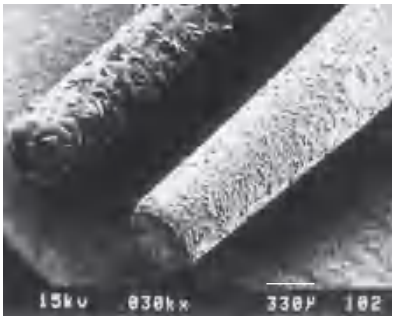
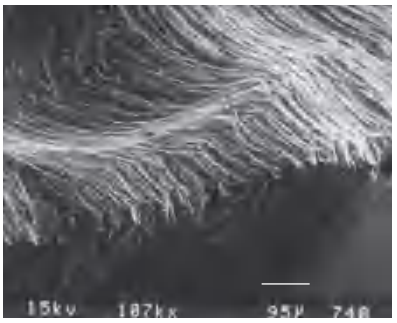
Bur appearance	Low magnification of the prepared margin	High magnification of the prepared margin
SHOULDERS, cont'd		
Cross-cut fissure carbide (high speed) Finishing carbide (low speed)			
Flat-end coarse diamond (high speed)			
Flat-end coarse diamond (high speed) and hoe			

Table **7-3—cont'd**

Bur appearance	Low magnification of the prepared margin	High magnification of the prepared margin
SHOULDERS, cont'd		
Flat-end coarse diamond (high speed) Fine grit diamond (high speed)			
Flat-end coarse diamond (high speed) Fine grit diamond (low speed)			

Courtesy of Dr. H. Lin.

results. In one laboratory study,[78] researchers examining adhesion between cements and core materials found that the cement adhered better to amalgam than to composite resin or cast gold. However, when crowns were tested for retention, higher values were found with the composite resin than with amalgam cores.[79] The differences may have resulted from dimensional changes of the core materials, although the clinical implications of this finding are not clear.

Type of luting agent

The type of luting agent chosen affects the retention of a cemented restoration.[80-82] However, the decision regarding which agent to use is also based on other factors. In general, the data suggest that adhesive resin cements are the most retentive[83,84] (Fig. 7-36), although long-term clinical evidence about the durability of the bond is not available. Of concern is that long-term in vitro studies have shown deterioration of the resin-dentin bond associated with permeability of the hybrid layer to small ions or molecules, so-called nanoleakage.[85,86]

Film thickness of the luting agent

There is conflicting evidence[87-90] about the effect of increased thickness of the cement film on retention of a restoration. This may be important if a slightly oversized casting is made (as when the die-spacer technique is used; see Chapter 18).

The factors that influence the retention of a cemented restoration are summarized in Table 7-4.

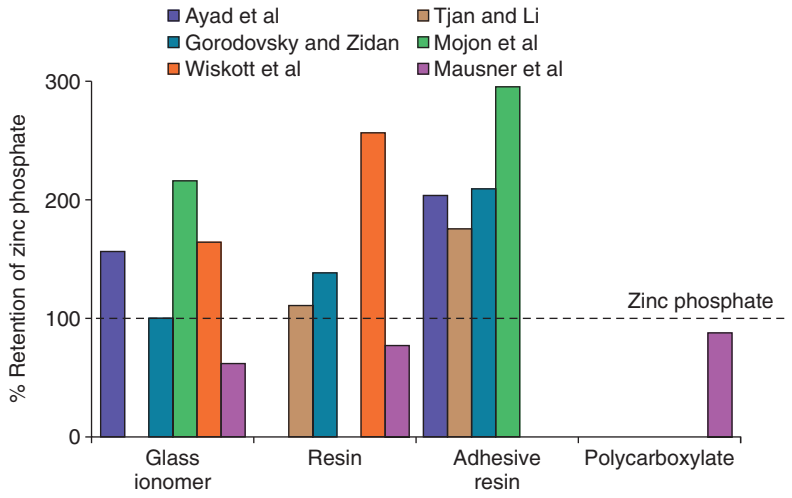


Fig. 7-36

Crown retention studies. Effect of luting agent. Six in vitro studies evaluated the effect of luting agent on crown retention.[†] The data were normalized as a percentage of the retention value with zinc phosphate cement. Adhesive resins had consistently greater retention than zinc phosphate. Conventional resins and glass ionomers yielded less consistent results. *(From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)*

Resistance Form

Certain features must be present in the preparation to prevent dislodgment of a cemented restoration. Mastication and parafunctional activity may subject a prosthesis to substantial horizontal or oblique forces. These forces are normally much greater than the ones overcome by retention, especially if the restoration is loaded during eccentric contact between posterior teeth. Lateral forces tend to displace the restoration by causing rotation around the gingival margin. Rotation is prevented by any areas of the tooth preparation that are placed in compression, called *resistance areas* (Fig. 7-37). Multiple resistance areas cumulatively make up the resistance form of a tooth preparation, which is defined as the features of a tooth preparation that enhance the stability of a restoration and resist dislodgment along an axis other than the path of placement.

Adequate resistance depends on the following:

1. Magnitude and direction of the dislodging forces.
2. Geometry of the tooth preparation.
3. Physical properties of the luting agent.

Magnitude and direction of the dislodging forces

Some patients can develop enormous biting forces. Gibbs and colleagues[91] discovered one individual (Fig. 7-38) who had a biting force of 4340 N (443 kg).* Although this is considered extraordinary,

When quantifying resistance, ask yourself the following question: How much tooth structure needs to break, or how much does the crown have to deform in order to dislodge this restoration?

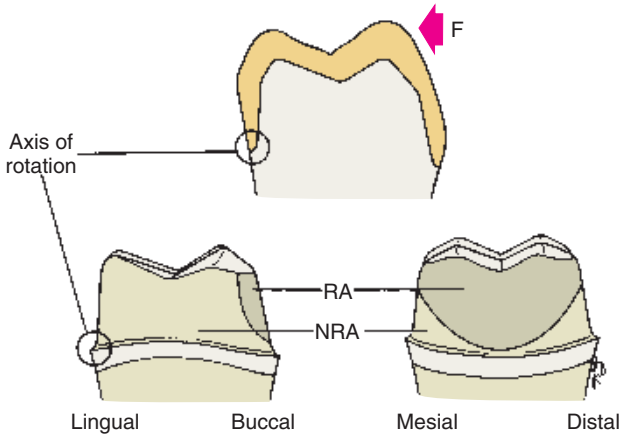


Fig. 7-37

The resistance area (*RA*) of a complete crown is placed under compression when a lateral force (*F*) is applied. *NRA*, Nonresisting area. *(Redrawn from Hegdahl T, Silness J: Preparation areas resisting displacement of artificial crowns. J Oral Rehabil 4:201, 1977.)*

*This compares with the world record super heavyweight (over 105 kg) snatch of 213 kg.

[†]References 13, 82, 84, 92, 111, 112

Table **7-4** **FACTORS INFLUENCING THE RETENTION OF A CEMENTED RESTORATION**

	Greater Retention → **Lesser Retention**
Taper	Parallel → 6 degrees → Excessive
Surface area	Large → Small
Type of preparation	Molar complete crown → Premolar complete crown → Partial crown → Intracoronal restoration
Surface texture	Rough → Smooth
Film thickness	Effect uncertain
Luting agent	Adhesive resin → Glass ionomer → Polycarboxylate / Zinc phosphate → Zinc oxide-eugenol



Fig. 7-38

Mr. H. sitting beside 443 kg of gymnasium weights to illustrate the magnitude of his biting strength. *(Reproduced from Gibbs CH, et al: Limits of human bite strength. J Prosthet Dent 56:226, 1986.)*

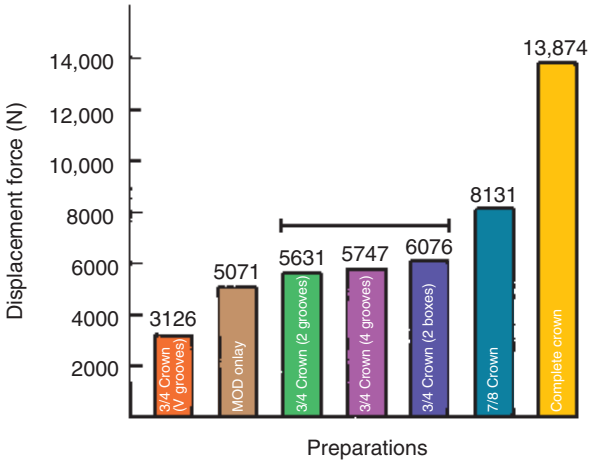


Fig. 7-39

Resistance of different preparation designs. The line connects preparations with statistically similar displacement forces ($p > 0.05$). MOD, mesio-occlusal-distal. *(Modified from Kishimoto M, et al: Influence of preparation features on retention and resistance. Part II: three-quarter crowns. J Prosthet Dent 49:188, 1983.)*

restorations should nevertheless be designed to withstand forces approaching such magnitude. In one laboratory study,[68] a complete crown cemented on a nickel-chromium test die was found to be capable of withstanding more than 13,500 N (1400 kg)—a far greater force than would occur in the mouth—before becoming displaced (Fig. 7-39).

In a normal occlusion, biting force is distributed over all the teeth; most of it is axially directed. If a fixed prosthesis is carefully made with a properly designed occlusion, the load should be well distributed and favorably directed (see Chapter 4). However, if a patient has a biting habit such as pipe smoking or bruxing, it may be difficult to prevent fairly large oblique forces from being applied to a restoration. Consequently, the completed tooth preparation and restoration must be able to withstand considerable oblique forces as well as the normal axial ones, and it has been argued that from a clinical durability perspective, adequate resistance form may be more crucial than overall preparation retentiveness.[92,93]

Geometry of the tooth preparation

As with retention, preparation geometry plays a key role in attaining desirable resistance form. The tooth preparation must be shaped so that particular areas of the axial wall prevent rotation of the crown. A good way to determine whether tooth preparation geometry provides adequate resistance form is to answer the question: "How much tooth structure needs to break off in order for this crown to be displaced by tipping off the tooth?"

Resistance is a function of the relationship between axial wall taper, preparation diameter, and preparation height. It decreases as taper or diameter increases, or preparation height is reduced.[94]

The relationship between preparation height, or diameter, and resistance to displacement is approximately linear.[95]

Preparation taper of 5 to 22 degrees has been suggested as being within a clinically acceptable range.[96,97] However, at the higher end of this range, the tipping resistance of both cemented and uncemented cast restorations is inadequate but increases significantly as taper is reduced.[96,98]

Short tooth preparations with large diameters were found to have very little resistance form. In general, molar teeth require more parallel preparation than do premolar or anterior teeth to achieve adequate resistance form.[99] A 3-mm preparation height provides adequate resistance if taper is restricted to 10 degrees or less,[98] but additional height is necessary as tooth diameter increases. Thus, on molar crown preparations in which many more preparations are observed that lack resistance,[100] minimal preparation wall height should ideally be in the range of 3.5 to 4 mm.

Hegdahl and Silness[100] analyzed how the areas that provide resistance form change as modifications are made in the geometry of the tooth preparation. They demonstrated that increasing preparation taper and rounding of axial angles tend to reduce resistance, pyramidal preparations thus having greater resistance than conical ones. Proximal grooves or boxes placed in healthy tooth structure

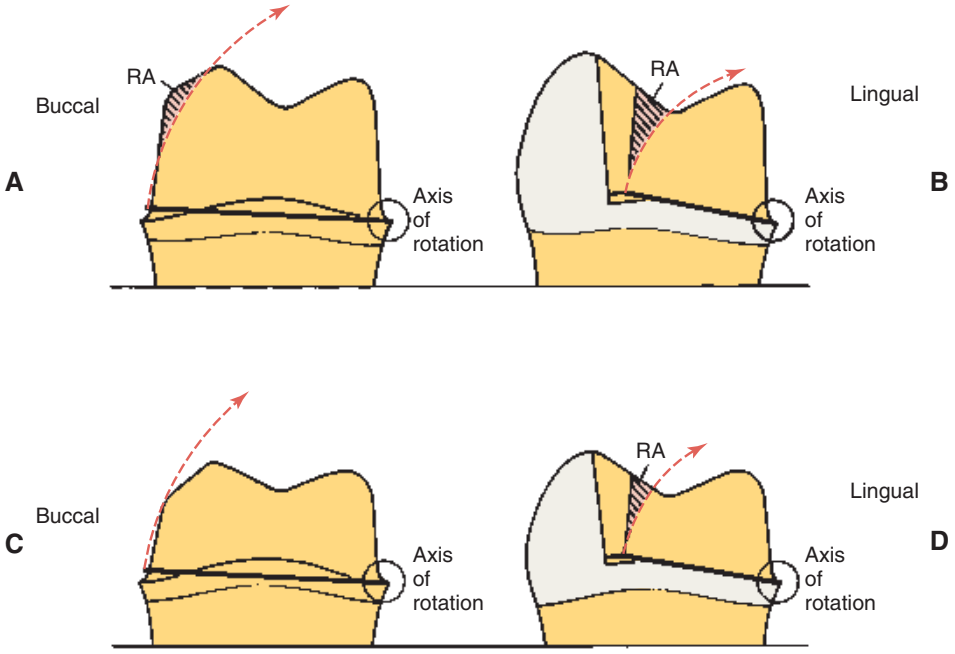


Fig. 7-40

Resistance form of partial and complete crowns. **A,** The buccoaxial wall (*RA*) of a complete crown should provide good resistance to rotation around a lingual axis. **B,** In a partial crown, resistance must be furnished by mesial and distal grooves. **C,** In a short or excessively tapered complete crown, resistance form is minimal because most of the buccal wall is missing. A mesiodistal groove should be placed to increase resistance form. **D,** Poor resistance form is less a problem in a short partial crown, if the grooves have sufficient definition. However, lack of retention form may indicate the need for complete coverage.

are particularly effective in enhancing the resistance form of crown preparations because these interfere with rotational movement (tipping) of the crown and in so doing subject additional areas of the luting agent to compression. Thus, the resistance form of an excessively tapered preparation can be improved by adding such grooves or boxes. As an alternative, pinholes can be prepared to achieve the same effect.

Preparation modifications may not be used as often[99] as clinical failure data suggest they should be.[93]

A partial-coverage restoration may have less resistance (Fig. 7-40) than a complete crown because it has no buccal resistance areas. Here, resistance is provided by boxes or grooves (Fig. 7-41) and is greatest if the groove and/or box walls are perpendicular to the direction of the applied force. Thus, U-shaped grooves or flared boxes provide more resistance than V-shaped ones.[70] Similarly, in order to more effectively enhance resistance, grooves that are placed in excessively inclined preparation walls should be prepared to greater depth in their cervical aspect than occlusally. Taper restriction in the cervical aspect of an excessively tapered crown preparation has been shown to be more effective than grooves that are prepared flush with excessively inclined preparation walls.[101]

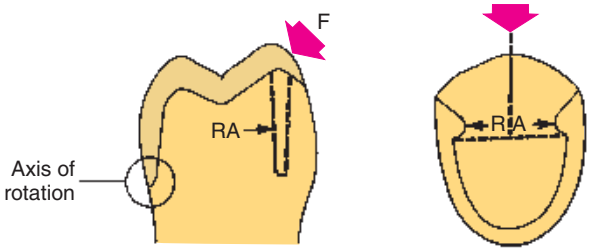


Fig. 7-41

A, The grooves of a partial crown should provide the maximum resistance to rotation around an axis situated at the linguogingival margin. **B,** The lingual walls of the groove—the resistance areas (*RA*)—should be prepared perpendicular to the direction of force (*F*).

Physical properties of the luting agent

Resistance to deformation is affected by physical properties of the luting agent, such as compressive strength and modulus of elasticity. To satisfy American Dental Association/American National Standards Institute specification no. 96 (Interna-

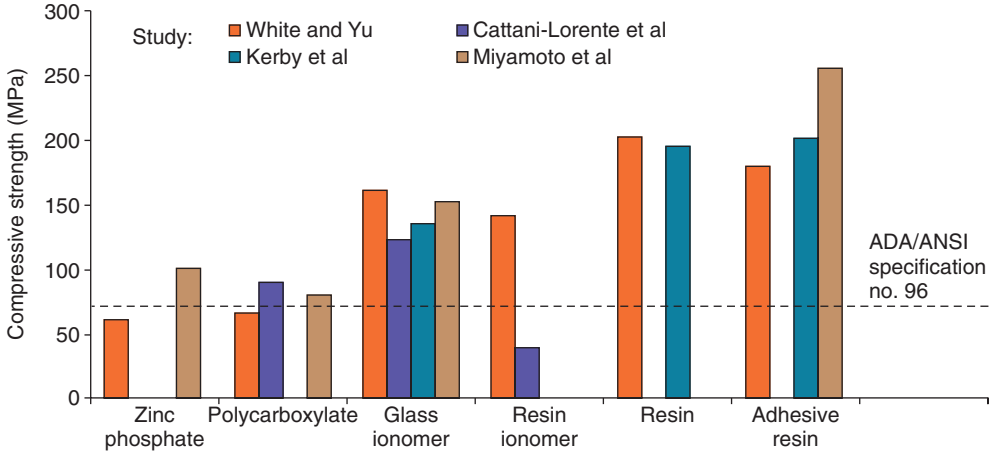


Fig. 7-42

Compressive strength of luting agents. Higher-strength values were reported in these studies[113-116] with the resin cements and glass ionomers than with zinc phosphate or polycarboxylate. Resin-modified glass ionomer exhibited greater variation than other cements. ADA, American Dental Association; ANSI, American National Standards Institute. *(From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)*

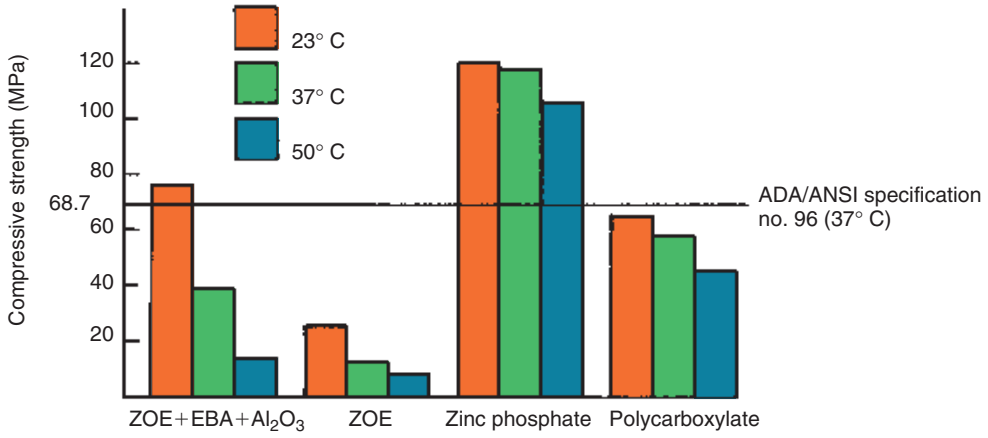


Fig. 7-43

Compressive strength of luting agents at different temperatures. ADA, American Dental Association; EBA, ethoxybenzoic acid; ZOE, zinc oxide-eugenol. *(Redrawn from Mesu FP: J Prosthet Dent 49:59, 1983.)*

tional Standards Organization specification no. 9917), the compressive strength of zinc phosphate cement must exceed 70 MPa* at 24 hours (Fig. 7-42). Glass ionomer cements and most resins have higher compressive strength, whereas polycarboxylates have similar values to those of zinc phosphate.[102]

Increasing temperature has a dramatic effect on the compressive strength of luting agents, particularly weakening reinforced zinc oxide-eugenol cement (Fig. 7-43). An increase from room temperature (23° C) to body temperature (37° C) halves the compressive strength of reinforced zinc oxide-eugenol cements, and a rise in temperature to 50° C (equivalent to hot food) reduces the compressive strength by over 80%.[103] Equivalent testing of more modern cements has not been reported.

Zinc phosphate cements have a higher modulus of elasticity than do polycarboxylate cements, which exhibit relatively large plastic deformation.[104] This may account for the observation that the retentive ability of polycarboxylate cement is more dependent on the taper of the preparation than is the retention with zinc phosphate cement.[105]

*One megapascal (MPa) equals 1 million newtons per square meter or about 145 pounds per square inch (psi).

The factors that affect the resistance to displacement of a cemented restoration are summarized in Table 7-5.

Preventing Deformation

A restoration must have sufficient strength to prevent permanent deformation during function (Fig. 7-44); otherwise, it will fail (typically at the restoration-cement, or the metal-porcelain, interface). This may be a result of inappropriate alloy selection, inadequate tooth preparation, or poor metal-ceramic framework design (see Chapter 19).

Alloy selection

Although type I and type II gold alloys (see Chapter 22) are satisfactory for intracoronal cast restorations, they are too soft for crowns and fixed dental prostheses, for which type III or type IV gold alloys (or an appropriate low-gold alternative) are chosen. These are harder, and their strength and hardness can be further increased by heat treatment.

Metal-ceramic alloys with high noble metal content have a hardness equivalent to that of type IV gold alloys, whereas nickel-chromium alloys are considerably harder. These may be indicated when large forces are anticipated, such as with a long-span fixed dental prosthesis, although their use presents certain problems (see Chapter 19).



Fig. 7-44
Ceramic failure resulting from deformation of the metal substructure.

Adequate tooth reduction

Even the stronger alloys need sufficient bulk, however, if they are to withstand occlusal forces (see Figs. 8-4 and 9-1*B*).

Largely according to empirical data, there should be a minimum alloy thickness of about 1.5 mm over functional cusps (buccal in the mandible, lingual in the maxilla). The less stressed nonfunctional cusps can be protected with less metal (1 mm is adequate in most circumstances) for a strong and long-lasting restoration. Occlusal reduction should be as uniform as possible, following the cuspal planes of the teeth; this ensures that sufficient occlusal **clearanc**e is combined with preservation of as much tooth structure as possible. In addition, an anatomically prepared occlusal surface (Fig. 7-45) gives rigidity to the crown because of the "corrugated effect"[106] of the planes.

When teeth are malaligned or overerupted, the occlusal surface needs to be prepared with the thickness requirements of the eventual restoration in mind. For example, a supraerupted tooth may need considerably more than 1.5 mm of reduction to establish adequate clearance in order to reestablish optimal occlusal form and the appropriate plane while ensuring adequate restoration thickness (Fig. 7-46). Diagnostic tooth preparation and waxing are helpful in determining the correct tooth reduction.

Margin design

Distortion of the restoration margin is prevented by designing the preparation outline form so that occlusal contact is avoided in this area. Keeping preparation margins approximately 1 to 1.5 mm away from occlusal contact areas satisfies this requirement. Also, tooth reduction should provide sufficient room for bulk of metal at the margin to prevent distortion. For example, as discussed previously, one disadvantage of the feather edge preparation is that the resulting thin layer of gold is not as strong as the comparatively thicker restoration of a

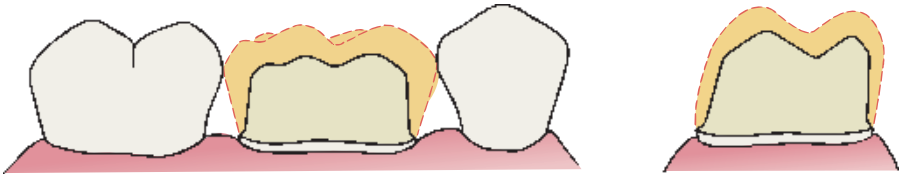


Fig. 7-45
Anatomic occlusal reduction is conservative of tooth structure and gives rigidity to the restoration.

Table 7-5 **FACTORS INFLUENCING THE RESISTANCE OF CEMENTED RESTORATIONS**

	Higher Resistance → **Lower Resistance**				
Dislodging forces	Habits	→ Eccentric interferences	→ Anterior guidance		
Taper	Minimum	→ 6 degrees	→ Excessive		
Diameter	Small (premolar)	→ Large (molar)			
Height	Long	→ Average	→ Short		
Type of preparation	Complete coverage	→ Partial coverage	→ Onlay		
Luting agent	Adhesive resin	→ Glass ionomer	→ Zinc phosphate	→ Polycarboxylate	→ Zinc oxide-eugenol

chamfer preparation. When teeth have been prepared with increased taper, however, it is advisable to reduce margin width in order to maintain adequate dentin thickness between the axial preparation wall and the pulpal tissues.[107]

The grooves and ledges incorporated in a partial-coverage preparation provide essential strengthening for the casting; in particular, anterior pinledge retainers benefit from the resulting beamlike reinforcement that results (Fig. 7-47).

ESTHETIC CONSIDERATIONS

The restorative dentist should develop skill in determining the esthetic expectations of the patient. Most patients prefer their dental restorations to look as natural as possible. However, esthetic considerations should not be pursued at the expense of the prognosis of the patient's long-term oral health or function.

At the initial examination, a full assessment is made of the appearance of each patient, noting which areas of which teeth show during speech, smiling, and laughing. The patient's esthetic expectations must be discussed and related to oral hygiene needs and the potential for development of future disease. The final decision regarding an appropriate restoration can then be made with the full cooperation and informed consent of the patient.

Esthetic restorations include partial veneer crowns, which maintain an intact labial or buccal surface in original tooth structure; metal-ceramic restorations, which consist of a metal cast substructure that in visible areas has an esthetic porcelain veneer; and all-ceramic restorations.



Fig. 7-46
This molar relationship is a result of extreme occlusal wear. When designing a tooth preparation, consideration of the eventual occlusal plane is essential. This is done with the aid of a diagnostic tooth preparation and waxing procedures.

All-Ceramic Restorations

Some of the most pleasing esthetic restorations are all-ceramic crowns, inlays, onlays, and veneers (see Chapter 25). They can mimic original tooth color better than the other restorative options. Although at somewhat greater risk of brittle fracture, the newest materials have improved physical properties and can be strengthened through the use of resin-bonded luting agents.

Not all ceramic crown preparations are conservative of tooth structure, as a wide 90-degree heavy chamfer margin must be prepared around the entire



Fig. 7-47
Grooves and ledges provide added rigidity to pinledge restorations (**A** to **C**). This partial veneer crown preparation benefits from added material thickness in the central groove area and in the location of the mesial and distal proximal grooves (**D**).

tooth to ensure increased material thickness and material strength. For the same reason, additional reduction on the lingual surface is needed for these restorations. A minimal material thickness of approximately 1 to 1.2 mm is necessary to ensure optimal esthetics. This limits the use of these restorations on faciolingually thin teeth and on teeth with large pulps, as in young individuals.

Metal-Ceramic Restorations

A compromised appearance of some metal-ceramic restorations (see Chapters 19 and 24) is often caused by insufficient porcelain thickness. On the other hand, adequate porcelain thickness is sometimes obtained at the expense of proper axial contour (such overcontoured restorations almost invariably lead to periodontal disease). In addition, the labial margin of a metal-ceramic crown is not always accurately placed. To correct all these deficiencies, certain principles are recommended during tooth preparation that ensure sufficient room for porcelain and accurate placement of the margins. Otherwise, good appearance would be achievable only at the expense of periodontal health.

Facial tooth reduction

If there is to be sufficient bulk of porcelain for appearance and metal for strength, adequate reduction of the facial surface is essential. The exact amount of reduction depends to some extent on the physical properties of the alloy used for the substructure, as well as on the manufacturer and the shade of the porcelain. A good color match for some restorations in older individuals typically requires a slightly greater porcelain thickness than is needed in younger patients. A minimum reduction of 1.5 mm typically is required for optimal appearance. Adequate thickness of porcelain (Fig. 7-48) is needed to create a sense of color depth and translucency. Shade problems are frequently encountered in maxillary incisor crowns at the incisal and cervical thirds of the restoration, where direct light reflection from the opaque layer can make the restoration appear very noticeable. Because opaque porcelains generally have a shade different from that of body porcelains, they often need to be modified with special stains in these areas[108] (see Chapter 24).

With very thin teeth (e.g., mandibular incisors), it may be impossible to achieve adequate tooth reduction without exposing the pulp or leaving a severely weakened tooth preparation. Under these circumstances, a less-than-ideal appearance may have to be accepted.

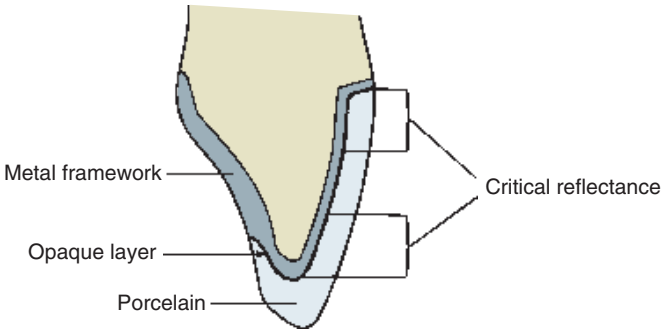


Fig. 7-48
Adequate porcelain thickness is essential for preventing direct light reflection from the highly pigmented opaque porcelain. The most critical areas are the gingival and incisal thirds; in practice, opaque modifying stains are often used in these areas.
(Redrawn from McLean JW: The Science and Art of Dental Ceramics, vol 1. Chicago, Quintessence Publishing, 1979.)

The labial surfaces of anterior teeth should be prepared for metal-ceramic restorations in two distinct planes (Fig. 7-49). If they are prepared in a single plane, insufficient reduction in either the cervical or the incisal area of the preparation results.

Incisal reduction

The incisal edge of a metal-ceramic restoration has no metal backing and can be made with a translucency similar to that of natural tooth structure. An incisal reduction of 2 mm is recommended for good esthetics. Excessive incisal reduction must be avoided because it reduces the resistance and retention form of the preparation.

Proximal reduction

The extent of proximal reduction is contingent on exact predetermination of the location of the metal-ceramic junction in the completed restoration. The proximal surfaces of anterior teeth look most natural if they are restored at the incisal edges, without metal backing. This allows some light to pass through the restoration in a manner similar to what occurs on a natural tooth (Fig. 7-50). Obviously, if the restoration is part of a fixed dental prosthesis, the need for connectors makes this impossible.

Labial margin placement

Supragingival margin placement has many biologic advantages. The restorations are easier to prepare properly and easier to keep clean. Nevertheless, subgingival margins may be indicated for esthetic reasons, particularly when the patient has a high lip line and when the use of a metal collar labial margin is contemplated.

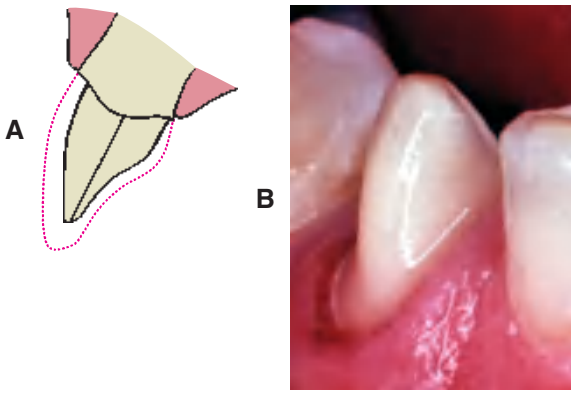


Fig. 7-49
Recommended tooth preparation for maxillary (**A**) and mandibular (**B**) metal-ceramic restoration. In each case, the facial reduction has two distinct planes.



Fig. 7-50
The proximal surfaces of these anterior metal-ceramic crowns are restored in porcelain, which allows light to be transmitted for maximum esthetics. The occluding lingual surfaces are in metal, which prevents abrasion to the opposing teeth.

The patient's smile is observed as part of the initial examination (see Chapter 1). It is important to record which teeth and which parts of each tooth are exposed. Patients with a high lip line, which exposes considerable gingival tissue, present the greatest problem if complete crowns are needed. Where the root surface is not discolored, appearance can be restored with a metal-ceramic restoration with a supragingival porcelain labial margin (see Chapter 24). If the patient has a low lip line, a metal supragingival collar may be placed because the metal is not seen during normal function. Metal margins generally have a more accurate fit than porcelain margins.

However, it cannot be assumed that the patient will be happy with a supragingival metal collar just because the metal is not visible during normal function. Some patients have reservations about exposed metal, and the advantages of such supragingival margins must be carefully explained before treatment.

Metal collars can be hidden below the gingival crest, although there is some discoloration if the gingival tissue is thin. Successful margin placement within the gingival sulcus requires care to ensure that inflammation and/or recession, with resulting metal exposure, are avoided or minimized. The periodontium must be healthy before the tooth is prepared. If periodontal surgery is needed, the sulcular space should not be eliminated completely; rather, a postsurgical depth of about 2 mm should be the objective. Sufficient time should be allowed after surgery for the periodontal tissues to stabilize. Wise[109] found that the gingival crest does not stabilize until 20 weeks after surgery (see Chapter 5).

Margins should not be placed so far apically that they encroach on the attachment; extension to within 1.5 mm of the alveolar crest leads to bone resorption.[110] The margin should follow the contour of the free gingiva, being further apical in the middle of the tooth and further incisal interproximally. A common error (Fig. 7-51) is to prepare the tooth so the margin lies almost in one plane, with exposure of the collar labially and irreversible loss of bone and papilla proximally.

Partial-Coverage Restorations

Whenever possible, accomplishment of an esthetically acceptable result without the use of complete crowns is preferred, because tooth structure is conserved and because no restorative material can approach the appearance of intact tooth enamel. Esthetic partial-coverage restorations (see Chapter 10) depend on accurate placement of the potentially visible facial and proximal margins. Understandably, many patients do not readily accept a visible display of metal. If a partial-coverage restoration is poorly prepared, the patient may demand that it be replaced by a metal-ceramic crown, and the result is unnecessary loss of tooth structure and a greater potential for tissue damage.

Proximal margin

Precise placement of the proximal margins (particularly the mesial, generally more visible, margin) is crucial for the esthetic result of a partial-coverage restoration. The rule is to place the margin just buccal to the proximal contact area, where metal is hidden by the distal line angle of the neighboring tooth and yet provides adequate access to the tooth-restoration interface for plaque control. Tooth preparation angulation is critical and should normally follow the long axes of posterior teeth and the incisal two thirds of the facial surface of anterior teeth. If a



Fig. 7-51
Poor preparation design. **A,** These badly damaged incisors were treatment planned for metal-ceramic crowns. **B** and **C,** The apical margin of the preparation does not follow the free gingival contours. **D,** The restoration displays a metal collar labially, and the deep proximal margins have led to periodontal disease.

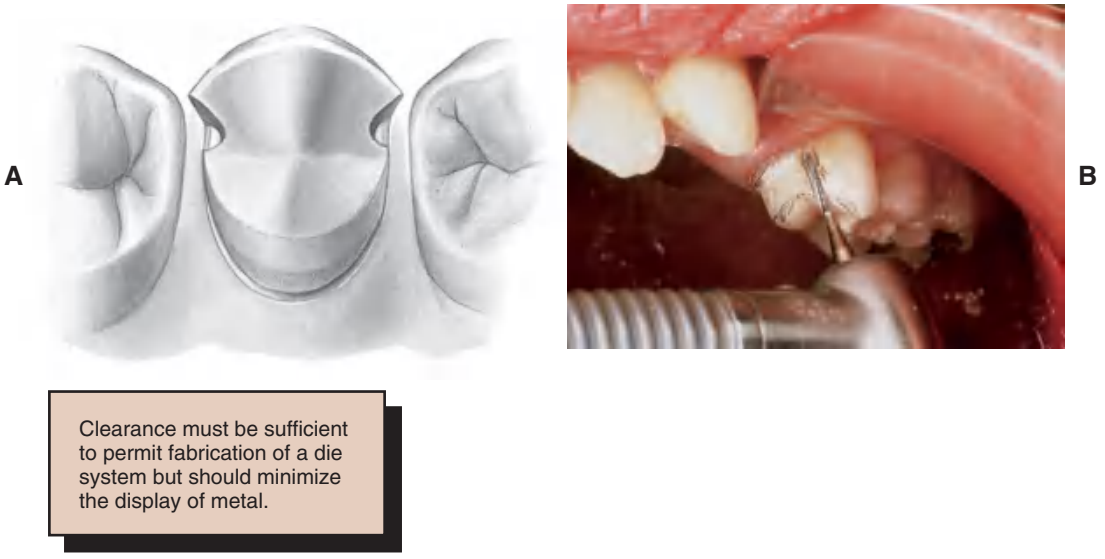


Fig. 7-52
A, Correct placement of the mesial margin of a partial-coverage restoration is essential for good esthetics. To allow proper access for finishing, the restoration must extend just beyond the contact area, but the metal must remain hidden from the casual observer. **B,** The tooth should be prepared in its long axis; otherwise, metal is displayed.

buccal or lingual tilt is given to the tooth preparation, the likelihood that metal will be visible increases significantly (Fig. 7-52).

The distal margin of posterior partial-coverage restorations is less visible than the mesial margin. In this area, it is often advantageous to extend the preparation farther beyond the contact point for easier preparation and finishing of the restoration and easier access for oral hygiene.

Facial margin

The facial margin of a maxillary partial-coverage restoration should be extended just beyond the occlusofacial line angle. A short **bevel** is needed to

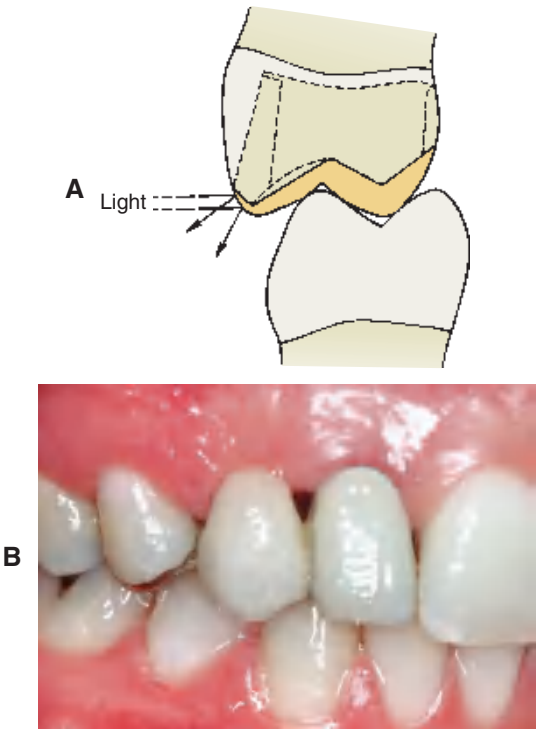


Fig. 7-53
A, The facial margin of a partial cast crown should be shaped so that light is not reflected directly to the observer. **B,** A three-unit fixed dental prosthesis. The mesial abutment is a canine, shaped to look like a lateral incisor. The distal abutment is a partial cast crown, which proved to be esthetically acceptable because the metal had been correctly contoured.

prevent enamel chipping. A chamfer can be placed where appearance is less important (e.g., on molars) because this provides greater bulk of metal for strength.

If the buccal margin of metal is correctly shaped (Fig. 7-53), it does not reflect light to an observer. As a result, the tooth appears to be merely a little shorter than normal and not as though its buccal cusp is outlined in metal. If the buccal margin is skillfully placed so as to follow the original cuspal contour, the final restoration has an acceptable appearance.

When mandibular partial cast crowns are made, metal display is unavoidable because the occlusal surface of mandibular teeth can be seen during speech. A chamfer, rather than a bevel, is recommended for the buccal margin because it provides a greater bulk of metal around the highly stressed functional cusp (Fig. 7-54). If the appearance of metal is unacceptable to the patient, a metal-ceramic restoration with porcelain coverage on the occlusal surface can be made.

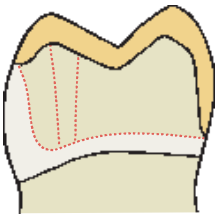


Fig. 7-54
A substantial chamfer is recommended for the functional buccal cusp of a mandibular partial cast crown. It provides greater bulk of metal in a stressed area.

Anterior partial-coverage restorations can be fabricated to show no metal (Fig. 7-55), but their preparation requires considerable care. The facial margin is extended just beyond the highest contour of the incisal edge but not quite to the incisolabial line angle. Here the metal protects the tooth from chipping but is not visible.

PLANNING AND EVALUATING TOOTH PREPARATIONS

Tooth preparation is a technically complicated and irreversible procedure. Thus, it is the practitioner's responsibility to carry it out properly, every time. Mistakes are often difficult, if not impossible, to correct.

Diagnostic Tooth Preparations

Diagnostic tooth preparations are performed on articulated casts before the actual clinical preparation. They yield information with regard to the following:

- Selecting the appropriate path of placement for a fixed dental prosthesis, particularly when the abutment teeth are tilted or have an atypical coronal contour (Fig. 7-56).
- Deciding on the amount of tooth reduction necessary to accomplish a planned change in the occlusion.
- Determining the best location for the facial and proximal margins of a partial-coverage restoration so that the metal is not visible (Fig. 7-57).

An important advantage of diagnostic tooth preparations is that the operator can practice each step of the intended restoration. Mistakes are not permanently destructive. Also, diagnostic preparations can be used in the prefabrication of interim restorations, significantly reducing appointment time duration at tooth preparation (the indirect/direct technique is described in Chapter 15).

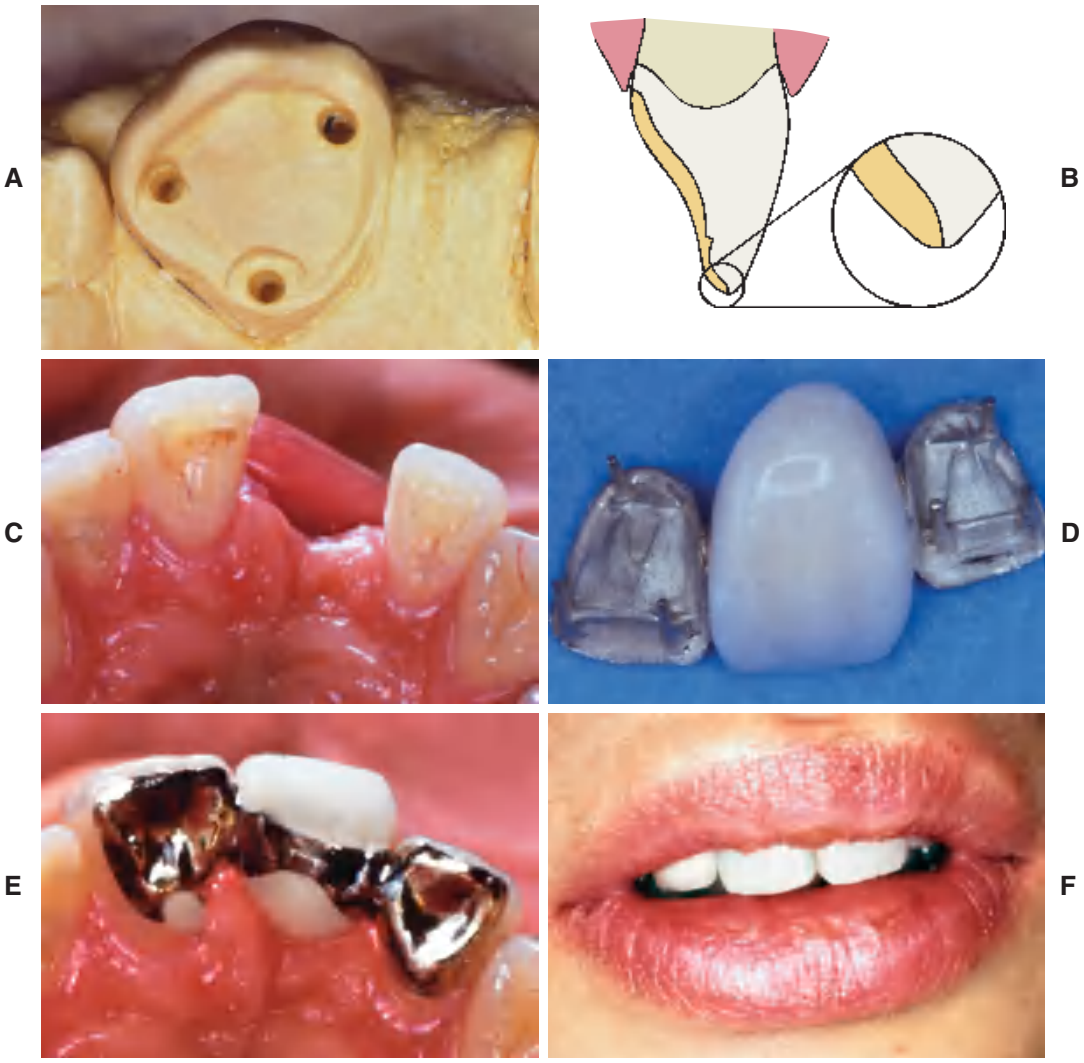


Fig. 7-55
A, Teeth can be prepared for partial-coverage restorations that do not show any metal. Success depends on very careful margin placement. **B,** The incisal edge is not completely covered. The restoration margin is located between the highest point of the incisal contour and the incisofacial angle. **C,** Intact anterior teeth on either side of an edentulous space. **D,** Three-unit fixed dental prosthesis with pinledge retainers and a metal-ceramic pontic. **E,** Occlusal view of fixed dental prosthesis. **F,** Acceptable esthetic result is obtained.

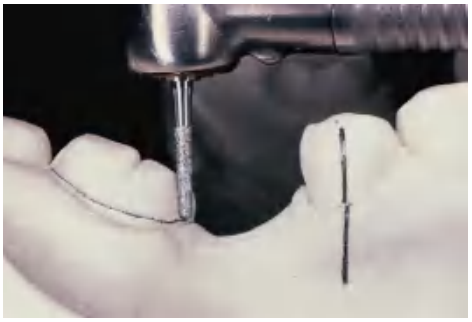


Fig. 7-56
Selecting the best path of placement for a fixed dental prosthesis with the aid of diagnostic tooth preparations.

Diagnostic waxing procedures

For all but the most straightforward prosthodontic treatment plans, a diagnostic waxing procedure (Fig. 7-58) should be performed. This is done on diagnostic tooth preparations and establishes the optimum contour and occlusion of the eventual prosthesis. The procedure is of particular benefit if the patient's occlusal scheme or anterior (incisal) guidance requires alteration.

Evaluative procedures during tooth preparation

Each step of a tooth preparation should be carefully evaluated with direct vision or indirectly with a

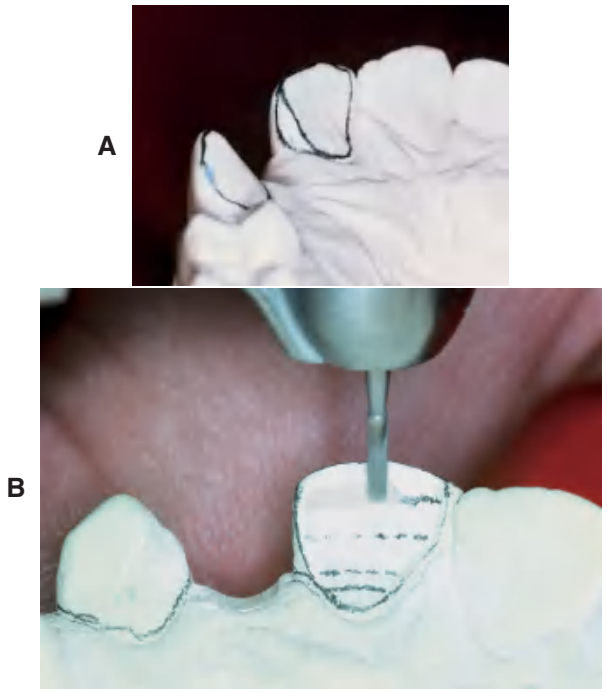


Fig. 7-57
A and **B**, Diagnostic tooth preparations are extremely helpful in determining the ideal reduction for esthetic partial-coverage restorations.

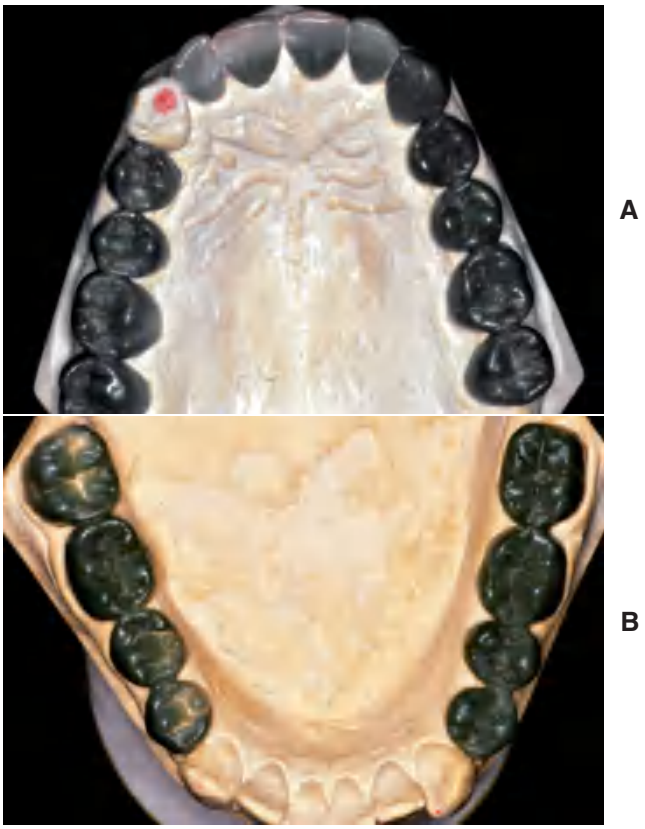


Fig. 7-58
A and **B**, Diagnostic waxing procedure. *(Courtesy of Dr. M. Padilla.)*

dental mirror. Alignment of multiple abutment teeth can be a special problem, and using the mirror helps to superimpose the image of adjacent abutment teeth. Complex preparations should be evaluated by making an alginate impression and pouring it in fast-setting stone. A dental surveyor (Fig. 7-59) can then be used to precisely measure the **axial inclinations** of the tooth preparation. The less experienced dentist may hesitate to make such an impression for fear of losing time. However, the information obtained often saves time in subsequent procedures by identifying problems that can then be addressed immediately. For tooth preparation, it is useful to learn to use the contra-angle handpiece as both a measuring and a cutting instrument. This is done by concentrating on the top surface of the turbine head, which is perpendicular to the shank of the bur. If the top surface is kept parallel to the occlusal surface of the tooth being prepared, the bur is automatically in the correct orientation (Fig. 7-60). To prevent undercuts or excessive convergence during axial reduction, the handpiece must be maintained at the same angulation. The correct taper is imparted by the diamond instrument. Keeping the turbine head at its correct angulation initially is often most effectively done by supporting it with a finger of the opposite hand.



Fig. 7-59
A dental surveyor can be used to evaluate the axial alignment of tooth preparations.

Patient and Operator Positioning

Learning the proper patient and operator positions is as beneficial as learning the proper preparation steps. Of particular importance are the advantages of obtaining a direct view of the preparation, which is always preferred to an indirect or mirror view. However, certain areas (e.g., the distal surfaces of maxillary molars) cannot be seen directly.

Inexperience, coupled with a hesitation to move the patient's head into a more favorable position, can unnecessarily complicate tooth preparation. For instance, having the patient rotate the head to the left or right side can considerably improve the visibility of molar teeth that are being prepared. In most instances, a direct view can be obtained by subtly changing the operator's or the patient's position. Having the patient open maximally does not necessarily provide the best view. If the jaw is partially open, the cheek may be retracted more easily (Fig. 7-61), and if the patient is encouraged to make a lateral excursion, the distobuccal line angle, together with the buccal third of the distal wall, may be seen directly. In practice, the mirror is essential only for visualizing a small portion of the distal surface. When a complete crown is prepared, the parts of the tooth most easily seen should be prepared first, leaving the other areas for preparation with the help of the mirror as a final stage.

Figure 7-62 shows patient and right-handed dentist positioned for tooth preparation of the less accessible maxillary posterior teeth.

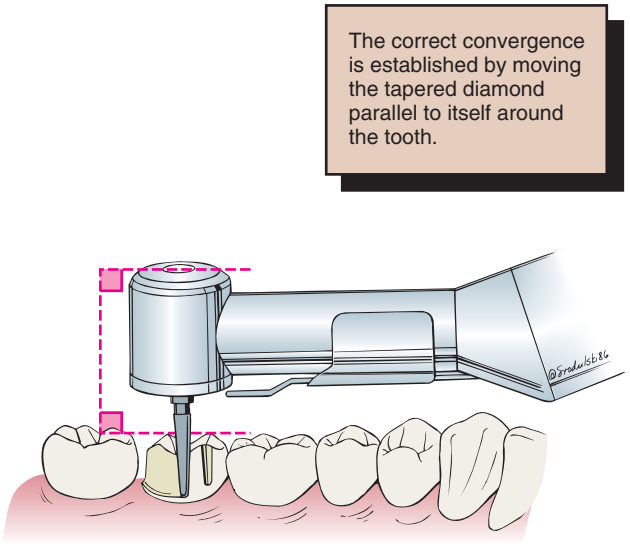


Fig. 7-60
Top surface of the handpiece held parallel to the occlusal surface. The rotary instrument is in correct axial alignment.

SUMMARY

The principles of tooth preparation can be categorized into biologic, mechanical, and esthetic considerations. Often these principles conflict, and the practitioner must decide how the restoration should be designed. One area may be given too much emphasis, and the long-term success of the procedure may be limited by a lack of consideration of other factors.

Experience helps in determining whether preparations are "complete." Each tooth preparation must be measured by clearly defined criteria, which can be used to identify and correct problems. Diagnostic tooth preparations and evaluative impressions are often very helpful. The types of preparation described in the following chapters are explained in a step-by-step format. Understanding the pertinent theories underlying each step is crucial. Successful preparation can be obtained most easily by systematically following the steps. It is crucial to refrain from "jumping ahead" before the previous step has been evaluated and, if necessary, corrected. If the clinician proceeds too rapidly, precious chair time will be lost, and the quality of the preparation will probably suffer.

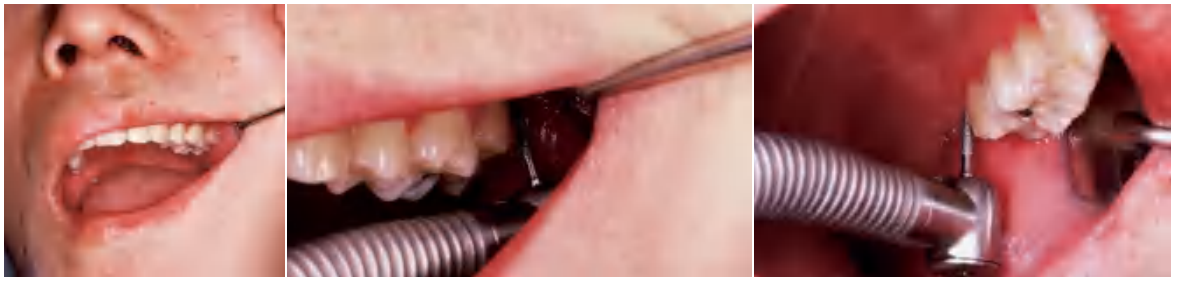


Fig. 7-61
Careful patient positioning can help obtain a direct view during tooth preparation. **A,** Often access is better if the mouth is not open maximally, because partial opening allows the cheek to be more easily retracted. **B,** Access to the buccal surface. **C,** Access to the palatal surface. A direct view is obtained by tilting the patient's head.



Fig. 7-62

A, Maxillary right posterior sextant. Buccal or buccal half of occlusal surface reduction. Operator is at the 9 to 11 o'clock position in relation to the chair. Patient turns head to left to improve direct vision. **B,** Maxillary right posterior sextant. Palatal or palatal half of occlusal surface reduction, including functional cusp bevel. Operator is at the 11 o'clock position. Patient turns head to right to improve direct vision. **C,** Maxillary left posterior sextant. Buccal or buccal half of occlusal surface reduction. Operator is at the 9 o'clock position. Patient turns head to right to improve direct vision. **D,** Maxillary left posterior sextant. Palatal or palatal half of occlusal surface reduction, including functional cusp bevel. Operator is at the 9 o'clock position. Patient turns head to left to improve direct vision. **E,** Maxillary left posterior sextant. Distal surface reduction. Operator is at the 9 o'clock position. Access is improved by having the patient tilt the head, partially close, and move the mandible in a left lateral excursion.

STUDY QUESTIONS

1. Discuss how the manipulation and condition of the armamentarium being used can contribute to injury.
2. Discuss optimal occlusocervical margin placement. What are some reasons for deviating from the ideal? Why?
3. Discuss the difference between retention and resistance. What can be done to enhance retention, and what can be done to improve the resistance form of a tooth preparation?
4. Discuss six different margin configurations. Discuss their advantages, disadvantages, indications, and contraindications as applicable.
5. What is an undercut? How is an undercut eliminated? Can a buccal and lingual wall be undercut in relation to each other? Why or why not?
6. What are the differences in retention and resistance form between a partial veneer crown preparation and complete cast crown preparation on the same tooth? How does clinical crown length and tooth size influence either? Why?
7. List six different means of conserving tooth structure during tooth preparation design, and explain why they result in the objective.
8. What is the purpose of diagnostic waxing? Give four indications for a diagnostic waxing procedure.

GLOSSARY*

adaptation \ăd′ăp-tā′shun\ *n* (1610): **1:** the act or process of adapting; the state of being adapted **2:** the act of purposefully adapting two surfaces to provide intimate contact **3:** the progressive adjustive changes in sensitivity that regularly accompany continuous sensory stimulation or lack of stimulation **4:** in dentistry, (**a**) the degree of fit between a prosthesis and supporting structures, (**b**) the degree of proximity of a restorative material to a tooth preparation, (**c**) the adjustment of orthodontic bands to teeth

axial inclination \ăk′sē-al īn′kla nā′shun\ **1:** the relationship of the long axis of a body to a designated plane **2:** in dentistry, the alignment of the long axis of a tooth to a selected plane, often the horizontal plane

axis of preparation \ăk′sĭs ŭv prĕp′a-rā′shun\: the planned line or path of placement and removal for a dental restoration

[1]bevel \bĕv′al\ *n* (1611): a slanting edge

[2]bevel \bĕv′al\ *vt*: the process of slanting the finish line and curve of a tooth preparation

bur \bûr\ *n* (14c): a steel or tungsten carbide rotary cutting instrument

bur head \bûr hĕd\ *n* (2005): the cutting portion of a dental bur

bur head length \bûr hĕd lĕngkth, lĕngth\: the axial dimension of the bur head

bur head shape \bûr hĕd shāp\ (2005): the geometrical outline form of the cutting surface edges, usually described successively by proximity from the shank to the tip end

bur shank \bûr shăngk\ *n* (2005): that component of a dental bur which fits into the hand piece; the shaft section of the dental bur that may be friction gripping or latch-type in form

butt \bŭt\ *v* (14c): to bring any two flat-ended surfaces into contact without overlapping, as in a butt joint

[1]cham·fer \chăm′fer\ *n*: **1:** a finish line design for tooth preparation in which the gingival aspect meets the external axial surface at an obtuse angle **2:** a small groove or furrow **3:** the surface found by cutting away the angle of intersection of two faces of a piece of material (i.e., stone, metal, wood): a beveled edge

[2]cham·fer \chăm′fer\ *vt* **cham·fer·ed**; **cham·fer·ing**; **cham·fers**: **1:** to cut a furrow in **2:** to make a chamfer on; to cut or reduce to a chamfer; bevel **3:** generally thought of as producing a curve from the axial wall to the cavosurface

chamfer angle \chăm′fer ăng′gel\ *n*: the angle between a chamfered surface and one of the original surfaces from which the chamfer is cut

clear·ance \klîr′ens\ *n* (1563) *obs*: a condition in which bodies may pass each other without hindrance. Also, the distance between bodies (GPT-4)

clinical crown \klĭn′ĭ-kel kroun\: the portion of a tooth that extends from the occlusal table or incisal edge to the free gingival margin

complete crown \kŏm-plēt kroun\: a restoration that covers all the coronal tooth surfaces (mesial, distal, facial, lingual, and occlusal)

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convergence angle \kon-vûr′jens ăng′gel\: **1:** the taper of a crown preparation **2:** the angle, measured in degrees, formed between opposing axial walls when a tooth or teeth are prepared for single crowns or fixed dental prostheses. *Usage-* this term is best described as the *total occlusal convergence*

[1]crown \kroun\ *n* (12c): **1:** the highest part, as the topmost part of the skull, head or tooth; the summit; that portion of a tooth occlusal to the dentinoenamel junction or an artificial substitute for this **2:** an artificial replacement that restores missing tooth structure by surrounding part or all of the remaining structure with a material such as cast metal, porcelain, or a combination of materials such as metal and porcelain

[2]crown \kroun\ *vt* (12c): to place on the head, as to place a crown on a tooth, dental implant or tooth substitute—*usage:* implies fabrication of a restoration for a tooth on a natural tooth, dental implant and/or dental implant abutment

de·for·ma·tion \dē′fôr-mā′shun, dĕf′-er-\ *n* (15c): the change of form or shape of an object

den·tin \dĕn′tĭn\ *n* (1840): a calcareous material similar to but harder and denser than bone that comprises the principle mass of the tooth—**den·tin·al** *adj;* also spelled **den·tine** \dĕn′tēn\

di·ver·gence \dĭ-vûr′jens, dī-\ *n* (1656) **1:** a drawing apart as a surface extends away from a common point **2:** the reverse taper of walls of a preparation for a restoration—di·ver·gen·cy *n*, *pl* **-cies**\-cēz\ (1709)

divergence angle \dĭ-vûr′jens ăng′gl\ (1998): the sum of the angles of taper of opposing walls of a tooth preparation that diverge away from each other

draw \drô\ *vt* (bef. 12c): the taper or convergence of walls of a preparation for a restoration; *slang*—DRAFT, DRAUGHT

ex·tra·coro·nal \ĕk′stra-kôr′a-nal, kŏr′-, ka-rō′nal\ *adj*: that which is outside or external to, the crown portion of a natural tooth; e.g., an extracoronal preparation, restoration, partial or complete crown

extracoronal retainer \ĕk′stra-kôr′a-nal, kŏr′-, ka-rō′nal rĭ-tā′ner\: that part of a fixed dental prosthesis uniting the abutment to the other elements of a prosthesis that surrounds all or part of the prepared crown

finish line \fĭn′ĭsh līn\ *n* (1899): **1:** a line of demarcation determined by two points **2:** *(obs)* the peripheral extension of a tooth preparation **3:** the planned junction of different materials **4:** *(obs)* the terminal portion of the prepared tooth

fit \fĭt\ *v*, **fit·ted** \fĭt′ĭd\, also **fit** \fĭt\; **fit·ting** \fĭt′ĭng\ *vt* (1586): **1:** to be suitable or to be in harmony with **2a:** to conform correctly to the shape or size of **2b:** to insert or adjust until correctly in place; to make or adjust to the correct size or shape, i.e., to adapt one structure to another, as the adaptation of any dental restoration to its site, in the mouth

groove \grōōv\ *n*: a long narrow channel or depression, such as the indentation between tooth cusps or the retentive features placed on tooth surfaces to augment the retentive characteristics of crown preparations

i·at·ro·gen·ic \ī-ăt′ra-jĕn′ĭk\ *adj* (1924): resulting from the activity of the clinician; applied to disorders induced in the patient by the clinician

interocclusal clearance \ĭn′ter-a-klōō′sal klîr′ans\: **1:** the arrangement in which the opposing occlusal surfaces may pass one another without any contact **2:** the amount of reduction achieved during tooth preparation to provide for an adequate thickness of restorative material

line angle \līn ang′gal\: the point of convergence of two planes in a cavity preparation

lingual inclination \lĭng′gwal ĭn-kla-nā′shun\: deviation of the coronal portion of a tooth from the vertical plane toward the tongue

lin·guo·ver·sion \lĭng′gwa-vûr′zhun, -shun\ *n*: lingual or palatal position of a tooth beyond the normal arch form

long axis \lŏng ăk′sĭs\: a theoretical line passing lengthwise through the center of a body

mar·gin \mär′jĭn\ *n* (14c): the outer edge of a crown, inlay, onlay, or other restoration. The boundary surface of a tooth preparation and/or restoration is termed the *finish line* or *finish curve*

path of placement \păth, path ŭv plās′mant\: the specific direction in which a prosthesis is placed on the abutment teeth or dental implants

point angle \point ăng′gal\: in the development of a cavity preparation, that place of convergence of three planes or surfaces—*comp* LINE ANGLE

re·ten·tion \rĭ-tĕn′shun\ *n* (15c): that quality inherent in the prosthesis acting to resist the forces of dislodgment along the path of placement—see DIRECT R., INDIRECT R.

retention arm \rĭ-tĕn′shun ärm\: an extension that is part of a removable dental prosthesis and is used to aid in the fixation of the prosthesis; a part of a clasp

retention form \rĭ-tĕn′shun form\: the feature of a tooth preparation that resists dislodgment of a crown in a vertical direction or along the path of placement

shoulder finish line \shŏl′dar fĭn′ĭsh līn\ *n*: a finish line design for tooth preparation in which the gingival floor

meets the external axial surfaces at approximately a right angle

su·pra·gin·gi·val \sōō′pra-jĭn′ja-val\ *adj*: **1:** located above the gingiva **2:** that portion of a natural or artificial tooth that is coronal to the gingival crest

ta·per: in dentistry, the convergence of two opposing external walls of a tooth preparation as viewed in a given plane. The extension of those average lines within that plane form an angle describe as the *angle of convergence*

[1]un·der·cut \ŭn′dur-kŭt\ *n* (1859) **1:** the portion of the surface of an object that is below the height of contour in relationship to the path of placement **2:** the contour of a cross-sectional portion of a residual ridge or dental arch that prevents the insertion of a dental prosthesis **3:** any irregularity in the wall of a prepared tooth that prevents the withdrawal or seating of a wax pattern or casting

[2]un·der·cut \ŭn′dur-kŭt\ *v* (ca. 1598): to create areas that provide mechanical retention for materials placement

veneer \va-nîr′\ *n* (1702)**: 1:** a thin sheet of material usually used as a finish **2:** a protective or ornamental facing **3:** a superficial or attractive display in multiple layers, frequently termed a *laminate veneer*

REFERENCES

1. Qvist V, et al: Progression of approximal caries in relation to iatrogenic preparation damage. J Dent Res 71:1370, 1992.
2. Zoellner A, et al: Histobacteriology and pulp reactions to long-term dental restorations. J Marmara Univ Dent Fac 2:483, 1996.
3. Langeland K, Langeland LK: Pulp reactions to crown preparation, impression, temporary crown fixation, and permanent cementation. J Prosthet Dent 15:129, 1965.
4. Baldissara P, et al: Clinical and histological evaluation of thermal injury thresholds in human teeth: a preliminary study. J Oral Rehabil 24:791, 1997.
5. Ohashi Y: Research related to anterior abutment teeth of fixed partial denture. Shikagakuho 68:726, 1968.
6. Morrant GA: Dental instrumentation and pulpal injury. II. Clinical considerations. J Br Endod Soc 10:55, 1977.
7. Brännsträm M: Dentinal and pulpal response. II. Application of an air stream to exposed dentine, short observation period: an experimental study. Acta Odontol Scand 18:17, 1960.
8. Land MF, et al: SEM evaluation of differently shaped diamond burs after tooth preparation. Abstract #344 (oral presentation), AADR General Session. J Dent Res 76(special issue):56, 1997.
9. Laforgia PD, et al: Temperature change in the pulp chamber during complete crown preparation. J Prosthet Dent 65:56, 1991.
10. Hume WR, Massey WL: Keeping the pulp alive: the pharmacology and toxicology of agents applied to dentine. Aust Dent J 35:32, 1990.
11. Johnson GH, et al: Crown retention with use of a 5% glutaraldehyde sealer on prepared dentin. J Prosthet Dent 79:671, 1998.
12. Felton DA, et al: Effect of cavity varnish on retention of cemented cast crowns. J Prosthet Dent 57:411, 1987.
13. Mausner IK, et al: Effect of two dentinal desensitizing agents on retention of complete cast coping using four cements. J Prosthet Dent 75:129, 1996.
14. Going RE: Status report on cement bases, cavity liners, varnishes, primers and cleansers. J Am Dent Assoc 85:654, 1972.
15. Dahl BL: Effect of cleansing procedures on the retentive ability of two luting cements to ground dentin in vitro. Acta Odontol Scand 36:137, 1978.
16. Brännström M, Nyborg H: Cavity treatment with a microbicidal fluoride solution: growth of bacteria and effect on the pulp. J Prosthet Dent 30:303, 1973.
17. Watts A: Bacterial contamination and the toxicity of silicate and zinc phosphate cements. Br Dent J 146:7, 1979.
18. Dahl BL: Antibacterial effect of two luting cements on prepared dentin in vitro and in vivo. Acta Odontol Scand 36:363, 1978.
19. Mjör IA: Bacteria in experimentally infected cavity preparations. Scand J Dent Res 85:599, 1977.
20. Quarnstrom F, et al: A randomized clinical trial of agents to reduce sensitivity after crown cementation. Gen Dent 46(1):68, 1998.
21. Seltzer S, Bender IB: The Dental Pulp: Biologic Considerations in Dental Procedures, 2nd ed, p 180. Philadelphia, JB Lippincott, 1975.
22. Dowden WE: Discussion of methods and criteria in evaluation of dentin and pulpal responses. Int Dent J 20:531, 1970.
23. Sorensen JA: A rationale for comparison of plaque-retaining properties of crown systems. J Prosthet Dent 62:264, 1989.
24. Perel ML: Axial crown contours. J Prosthet Dent 25:642, 1971.
25. Han TJ, Takei HH: Progress in gingival papilla reconstruction. Periodontology 2000 11:65, 1996.

26. Silness J: Periodontal conditions in patients treated with dental bridges. III. The relationship between the location of the crown margin and the periodontal condition. J Periodont Res 5:225, 1970.
27. Karlsen K: Gingival reactions to dental restorations. Acta Odontol Scand 28:895, 1970.
28. Newcomb GM: The relationship between the location of subgingival crown margins and gingival inflammation. J Periodontol 45:151, 1974.
29. Bader JD, et al: Effect of crown margins on periodontal conditions in regularly attending patients. J Prosthet Dent 65:75, 1991.
30. Block PL: Restorative margins and periodontal health: a new look at an old perspective. J Prosthet Dent 57:683, 1987.
31. Ackerman MB: The full coverage restoration in relation to the gingival sulcus. Compendium 18:1131, 1997.
32. Felton DA, et al: Effect of in vivo crown margin discrepancies on periodontal health. J Prosthet Dent 65:357, 1991.
33. Byrne G, et al: Casting accuracy of high-palladium alloys. J Prosthet Dent 55:297, 1986.
34. Belser UC, et al: Fit of three porcelain-fused-to-metal marginal designs in vivo: a scanning electron microscope study. J Prosthet Dent 53:24, 1985.
35. Rosner D: Function, placement, and reproduction of bevels for gold castings. J Prosthet Dent 13:1160, 1963.
36. Rosenstiel E: The marginal fit of inlays and crowns. Br Dent J 117:432, 1964.
37. Hoard RJ, Watson J: The relationship of bevels to the adaptation of intracoronal inlays. J Prosthet Dent 35:538, 1976.
38. Shillingburg HT Jr, et al: Preparation design and margin distortion in porcelain-fused-to-metal restorations. J Prosthet Dent 29:276, 1973.
39. Faucher RR, Nicholls JI: Distortion related to margin design in porcelain-fused-to-metal restorations. J Prosthet Dent 43:149, 1980.
40. Pascoe DF: Analysis of the geometry of finishing lines for full crown restorations. J Prosthet Dent 40:157, 1978.
41. Gavelis JR, et al: The effect of various finish line preparations on the marginal seal and occlusal seat of full crown preparations. J Prosthet Dent 45:138, 1981.
42. Hunter AJ, Hunter AR: Gingival crown margin configurations: a review and discussion. I. Terminology and widths. J Prosthet Dent 64:548, 1990.
43. Dykema RW, et al: Johnston's Modern Practice in Crown and Bridge Prosthodontics, 4th ed, p 27. Philadelphia, WB Saunders, 1986.
44. Shillingburg HT, et al: Fundamentals of Fixed Prosthodontics, 3rd ed, p 128. Chicago, Quintessence Publishing, 1997.
45. Dimashkieh MR: Modified rotary design instruments for controlled finish line crown preparation. J Prosthet Dent 69:120, 1993.
46. Ramp MH, et al: Tooth structure loss apical to preparations for fixed partial dentures when using self-limiting burs. J Prosthet Dent 79:491, 1998.
47. Seymour K, et al: Assessment of shoulder dimensions and angles of porcelain bonded to metal crown preparations. J Prosthet Dent 75:406, 1996.
48. Hoffman EJ: How to utilize porcelain fused to gold as a crown and bridge material. Dent Clin North Am 9:57, 1965.
49. Richter-Snapp K, et al: Change in marginal fit as related to margin design, alloy type, and porcelain proximity in porcelain-fused-to-metal restorations. J Prosthet Dent 60:435, 1988.
50. Byrne G: Influence of finish-line form on crown cementation. Int J Prosthodont 5:137, 1992.
51. Syu JZ, et al: Influence of finish-line geometry on the fit of crowns. Int J Prosthodont 6:25, 1993.
52. Hamaguchi H, et al: Marginal distortion of the porcelain- bonded-to-metal complete crown: an SEM study. J Prosthet Dent 47:146, 1982.
53. Goodacre CJ, et al: Tooth preparations for complete crowns: an art form based on scientific principles. J Prosthet Dent 85:363, 2001.
54. Farah JW, et al: Effects of design on stress distribution of intracoronal gold restorations. J Am Dent Assoc 94:1151, 1977.
55. Walton JN, et al: A survey of crown and fixed partial denture failures: length of service and reasons for replacement. J Prosthet Dent 56:416, 1986.
56. Lindquist E, Karlsson S: Success rate and failures for fixed partial dentures after 20 years of service. I. Int J Prosthodont 11:133, 1998.
57. Rosenstiel E: The retention of inlays and crowns as a function of geometrical form. Br Dent J 103:388, 1957.
58. Jørgensen KD: The relationship between retention and convergence angle in cemented veneer crowns. Acta Odontol Scand 13:35, 1955.
59. Kaufman EG, et al: Factors influencing the retention of cemented gold castings. J Prosthet Dent 11:487, 1961.
60. Dodge WW, et al: The correlation of resistance and retention to convergence angle [Abstract no. 880]. J Dent Res 62:267, 1983.

61. Hovijitra S, et al: The relationship between retention and convergence of full crowns when used as fixed partial denture retainers. J Indiana Dent Assoc 58(4):21, 1979.
62. Wilson AH, Chan DC: The relationship between preparation convergence and retention of extracoronal retainers. J Prosthodont 3:74, 1994.
63. Nordlander J, et al: The taper of clinical preparations for fixed prosthodontics. J Prosthet Dent 60:148, 1988.
64. Ohm E, Silness J: The convergence angle in teeth prepared for artificial crowns, J Oral Rehabil 5(4):371, 1978.
65. Ayad MF, et al: Assessment of convergence angles of tooth preparations for complete crowns among dental students. J Dent 33:633, 2005.
66. Mack J: A theoretical and clinical investigation into the taper achieved on crown and inlay preparations. J Oral Rehabil 7:255, 1980.
67. Reisbick MH, Shillingburg HT: Effect of preparation geometry on retention and resistance of cast gold restorations. Calif Dent Assoc J 3:51, 1975.
68. Nicholls JI: Crown retention. I. Stress analysis of symmetric restorations. J Prosthet Dent 31:179, 1974.
69. Nicholls JI: Crown retention. II. The effect of convergence angle variation on the computed stresses in the luting agent. J Prosthet Dent 31:651, 1974.
70. Potts RG, et al: Retention and resistance of preparations for cast restorations. J Prosthet Dent 43:303, 1980.
71. Kishimoto M, et al: Influence of preparation features on retention and resistance. Part II: three-quarter crowns. J Prosthet Dent 49:188, 1983.
72. Galun EA, et al: The contribution of a pinhole to the retention and resistance form of veneer crowns. J Prosthet Dent 56:292, 1986.
73. Worley JL, et al: Effects of cement on crown retention. J Prosthet Dent 48:289, 1982.
74. Smith BGN: The effect of the surface roughness of prepared dentin on the retention of castings. J Prosthet Dent 23:187, 1970.
75. Arcoria CJ, et al: Effect of undercut placement on crown retention after thermocycling. J Oral Rehabil 17:395, 1990.
76. O'Connor RP, et al: Effect of internal microblasting on retention of cemented cast crowns. J Prosthet Dent 64:557, 1990.
77. Saito C, et al: Adhesion of polycarboxylate cements to dental casting alloys. J Prosthet Dent 35:543, 1976.
78. Chan KC, et al: Bond strength of cements to crown bases. J Prosthet Dent 46:297, 1981.
79. DeWald JP, et al: Crown retention: a comparative study of core type and luting agent. Dent Mater 3:71, 1987.
80. McComb D: Retention of castings with glass ionomer cement. J Prosthet Dent 48:285, 1982.
81. Arfaei AH, Asgar K: Bond strength of three cements determined by centrifugal testing. J Prosthet Dent 40:294, 1978.
82. Tjan AHL, Li T: Seating and retention of complete crowns with a new adhesive resin cement. J Prosthet Dent 67:478, 1992.
83. el-Mowafy OM, et al: Retention of metal ceramic crowns cemented with resin cements: effects of preparation taper and height. J Prosthet Dent 76:524, 1996.
84. Ayad MF, et al: Influence of tooth surface roughness and type of cement on retention of complete cast crowns. J Prosthet Dent 77:116, 1997.
85. Prati C, et al: Permeability of marginal hybrid layers in composite restorations. Clin Oral Investig 9(1):1, 2005.
86. Chersoni S, et al: Water movement in the hybrid layer after different dentin treatments. Dent Mater 20:796, 2004.
87. Jørgensen KD, Esbensen AL: The relationship between the film thickness of zinc phosphate cement and the retention of veneer crowns. Acta Odontol Scand 26:169, 1968.
88. Hembree JH, Cooper EW: Effect of die relief on retention of cast crowns and inlays. Oper Dent 4:104, 1979.
89. Gegauff AG, Rosenstiel SF: Reassessment of die-spacer with dynamic loading during cementation. J Prosthet Dent 61:655, 1989.
90. Carter SM, Wilson PR: The effect of die-spacing on crown retention. Int J Prosthodont 9:21, 1996.
91. Gibbs CH, et al: Limits of human bite strength. J Prosthet Dent 56:226, 1986.
92. Wiskott HW, et al: The relationship between abutment taper and resistance of cemented crowns to dynamic loading. Int J Prosthodont 9:117, 1996.
93. Trier AC, et al: Evaluation of resistance form of dislodged crowns and retainers. J Prosthet Dent 80:405, 1998.
94. Weed RM, Baez RJ: A method for determining adequate resistance form of complete cast crown preparations. J Prosthet Dent 52:330, 1984.
95. Wiskott HW, et al: The effect of tooth preparation height and diameter on the resistance of complete crowns to fatigue loading. Int J Prosthodont 10:207, 1997.
96. Dodge WW: The effect of convergence angle on retention and resistance form. Quintessence Int 16:191, 1985.

97. Shillingburg HT, et al: Fundamentals of Fixed Prosthodontics, 3rd ed, p. 120 Chicago, Quintessence Publishing, 1997.
98. Woolsey GD, Matich JA: The effect of axial grooves on the resistance form of cast restorations. J Am Dent Assoc 97:978, 1978.
99. Parker MH, et al: New guidelines for preparation taper. J Prosthodont 2:61, 1993.
100. Hegdahl T, Silness J: Preparation areas resisting displacement of artificial crowns. J Oral Rehabil 4:201, 1977.
101. Proussaefs P, et al: The effectiveness of auxillary features on a tooth preparation with inadequate resistance form. J Prosthet Dent 91:33, 2004.
102. Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.
103. Mesu FP: The effect of temperature on compressive and tensile strengths of cements. J Prosthet Dent 49:59, 1983.
104. Branco R, Hegdahl T: Physical properties of some zinc phosphate and polycarboxylate cements. Acta Odontol Scand 41:349, 1983.
105. McLean JW: Polycarboxylate cements: five years' experience in general practice. Br Dent J 132:9, 1972.
106. Guyer SE: Multiple preparations for fixed prosthodontics. J Prosthet Dent 23:529, 1970.
107. Doyle MG: The effect of tooth preparation design on the breaking strength of Dicor crowns: 3. Int J Prosthodont 3:327, 1990.
108. McLean JW: The Science and Art of Dental Ceramics, vol 1, p 136. Chicago, Quintessence Publishing, 1979.
109. Wise MD: Stability of gingival crest after surgery and before anterior crown placement. J Prosthet Dent 53:20, 1985.
110. Palomo F, Kopczyk RA: Rationale and methods for crown lengthening. J Am Dent Assoc 96:257, 1978.
111. Gorodovsky S, Zidan O: Retentive strength, disintegration, and marginal quality of luting cements. J Prosthet Dent 68:269, 1992.
112. Mojon P, et al: Maximum bond strength of dental luting cement to amalgam alloy. J Dent Res 68:1545, 1989.
113. Kerby RE, et al: Some physical properties of implant abutment luting cements. Int J Prosthodont 5:321, 1992.
114. Cattani-Lorente M-A, et al: Early strength of glass ionomer cements. Dent Mater 9:57, 1993.
115. Miyamoto S, et al: Study on fatigue toughness of dental materials. I. Compressive strength on various luting cements and composite resin cores. Nippon Hotetsu Shika Gakkai Zasshi 33:966, 1989.
116. White SN, Yu Z: Compressive and diametral tensile strengths of current adhesive luting agents. J Prosthet Dent 69:568, 1993.

8

THE COMPLETE CAST CROWN PREPARATION



Although esthetic factors may limit its application, the all-metal complete cast crown should always be offered to patients requiring restoration for badly damaged posterior teeth. The complete cast crown has the best longevity of all fixed restorations. It can be used to rebuild a single tooth or as a retainer for a fixed dental prosthesis. It involves all axial walls, as well as the occlusal surface of the tooth being restored (Fig. 8-1).

Preparation for a complete cast crown requires that adequate tooth structure be removed to allow restoration of the tooth to its original contours. Tooth structure should be preserved when possible, but reduction should produce a crown of acceptable strength.

ADVANTAGES

Because all axial surfaces of the tooth are included in the preparation, the complete cast crown has greater retention than a more conservative restoration on the same tooth (e.g., a seven-eighths or three-quarter crown [see Fig. 7-34]).

Normally, a complete cast crown preparation also has greater resistance form than does a partial-coverage restoration on the same tooth. For a partial veneer crown to rotate off the tooth, only the tooth structure immediately lingual to the occlusal portion of the proximal groove or box need fail. However, if the axial walls of a complete cast crown have been prepared with the proper degree of taper or convergence, a significant amount of tooth structure must fail before the crown can be torqued off.

The strength of a complete cast crown is superior to that of other restorations. Its cylinder-like configuration encircles the tooth and is reinforced by a corrugated occlusal surface. Just as an O-shaped link in a chain resists deformation better than a C-shaped link, this restoration is less easily deformed than its counterparts, which are more conservative of tooth structure.

A complete cast crown allows the operator to modify axial tooth contour. This can be of special significance with malaligned teeth, although the extent of possible recontouring is limited by periodontal considerations. Similarly, it is possible to allow better access to furcations for improved patient oral hygiene through recontouring of buccal and lingual walls (Fig. 8-2). When special requirements exist for axial contours, such as when retainers are needed for partial removable dental prostheses, a complete crown is often the only restoration that allows the necessary modifications for the creation of properly shaped survey lines, guide planes, and occlusal rests (Fig. 8-3) (see Chapter 21).

The restoration permits easy modification of the occlusion, which is often difficult to accomplish if a more conservative restoration is made. This is



Fig. 8-1
Complete cast crowns used to restore the molar teeth. **A** and **B,** The canines and premolars, which are more visible because of their more anterior arch position, have been restored with metal-ceramic crowns.

especially important when supraerupted teeth are present or when the occlusal plane needs to be reestablished.

DISADVANTAGES

Because all coronal surfaces are involved in the preparation for a complete cast crown, removal of tooth structure is extensive and can have adverse effects on the pulp and periodontium. Because of the proximity of the margin to the gingiva, it is not uncommon to see inflammation of gingival tissues (although a properly fitting complete cast crown with good axial contour should minimize this).

After cementation, it is no longer feasible to perform electric vitality testing of an abutment tooth. The conductivity of the metal interferes with the test. This can be a disadvantage if future complications occur, although thermal tests occasionally yield the necessary information.

Patients may object to the display of metal associated with complete cast crowns, and in those with a normal smile line, the restoration may be restricted to maxillary molars and mandibular molars and premolars.

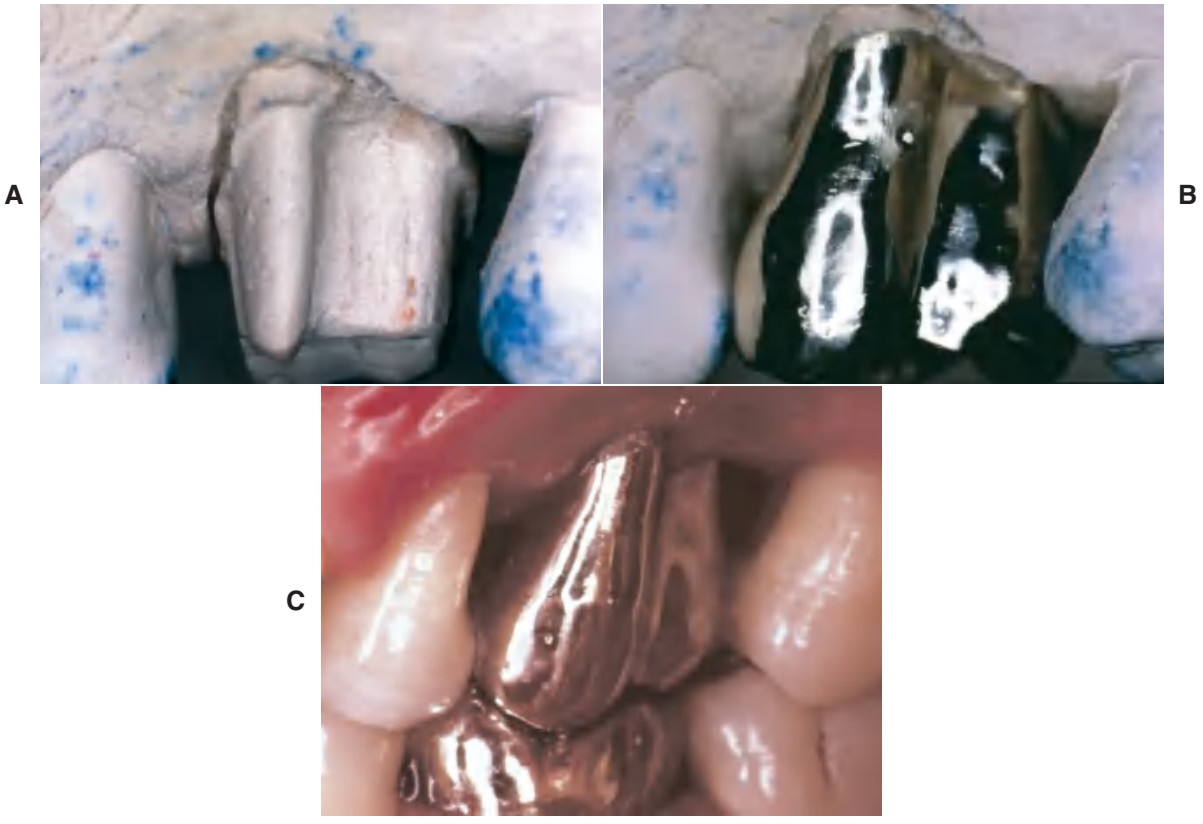


Fig. 8-2
A, B, and **C,** Fluting of the axial walls of a molar complete cast crown allows better access to the furcation area for oral hygiene and improves the long-term prognosis of the restoration.



Fig. 8-3
Complete cast crowns used as retainers to accommodate a mandibular partial removable dental prosthesis. Metal-ceramic crowns have been placed on the mandibular left canine (**A**) and the maxillary first molar (**B**). Note the occlusal rests (**A,** *arrows*) and the survey contours (**B**), which extend to form reciprocating guide planes. (See Chapter 21.)

INDICATIONS

The complete cast crown is indicated on teeth that exhibit extensive coronal destruction by caries or trauma. It is the restoration of choice whenever maximum retention and resistance are needed. On short clinical crowns or when high displacement forces are anticipated, such as for the retainer of a long-span fixed dental prosthesis, grooves should be included as additional retentive features.

This restoration is fabricated when correction of axial contours is not feasible with a more conservative technique. The restoration also may be used to support a partial removable dental prosthesis, because obtaining the necessary contours with a partial-coverage restoration is more difficult. Although proximal guide planes can sometimes be prepared through simple enamel modification, arriving at properly oriented reciprocal guide planes and survey contours is often impractical. The minimum dimensions required for occlusal rests of a partial removable dental prosthetic framework necessitate removing significant amounts of enamel and, if the dentin is exposed, restoring the tooth with a cast crown.*

*On mandibular premolars, a rest can sometimes be placed on top of the modified occlusal surface without interfering with the occlusion or articulation.

The complete cast crown is indicated on endodontically treated teeth. Its superior strength compensates for the loss of tooth structure that results from previous restorations, carious lesions, and endodontic access.

CONTRAINDICATIONS

The complete cast crown is contraindicated if treatment objectives can be met with a more conservative restoration. Wherever an intact buccal or lingual wall exists, use of a partial-coverage restoration should be considered. In particular, if less than maximum retention and resistance are needed (e.g., on a short-span fixed dental prosthesis), a preparation more conservative of tooth structure is called for. Similarly, if an adequate buccal contour exists or can be obtained through enamel modification (enameloplasty), a complete crown is not indicated. If a high esthetic need exists (e.g., for anterior teeth), a complete cast crown is also contraindicated.

CRITERIA

The occlusal reduction must allow adequate room for the restorative material from which the cast crown is to be fabricated: type III or IV gold casting alloy or their low-gold content equivalent. Minimum recommended clearance is 1 mm on nonfunctional (noncentric) cusps and 1.5 mm on functional (centric) cusps. The occlusal reduction should follow normal anatomic contours to remain as conservative of tooth structure as possible. Axial reduction should parallel the long axis of the tooth but allow for the recommended 6-degree taper or convergence, which is the angle measured between opposing axial surfaces.

The margin should have a chamfer configuration and is ideally located supragingivally. Sometimes crown lengthening is indicated to obtain a supragingival margin, rather than risk future periodontal disease (see Chapter 6). The chamfer should be smooth and distinct and allow for approximately 0.5 mm of metal thickness at the margin. Typically, it is an exact replica of half the rotary instrument that was used to prepare it. (The recommended dimensions for reduction are shown in Fig. 8-4.)

Special Considerations

Functional (centric) cusp bevel

Proper tooth preparation for a complete cast crown results in the reduction's being directly beneath the cusps of the crown (see Fig. 7-45). This is important for ensuring optimum restoration contour with maximum durability and conservation of tooth struc-

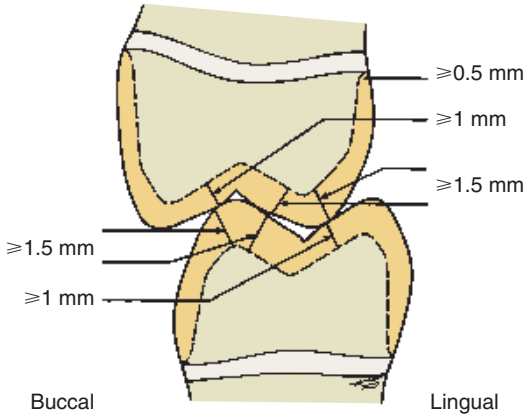


Fig. 8-4
Recommended dimensions for a complete cast crown. On functional cusps (buccal mandibular and lingual maxillary), the occlusal clearance should be equal to or greater than 1.5 mm. On nonfunctional cusps, a clearance of at least 1 mm is needed. The chamfer should allow for approximately 0.5 mm of metal thickness at the margin.



Fig. 8-5
The functional cusp bevel is prepared by slanting the bur at a flatter angle than the cuspal angulation. This ensures additional reduction for the functional cusp.

ture. Proper placement of the functional cusp bevel achieves this outcome. Because additional reduction is needed for the functional cusps (to provide 1.5 mm of occlusal clearance), the bevel must be angled flatter than the external surface (Fig. 8-5). On most teeth, the functional cusp bevel is placed at about 45 degrees to the long axis.

Nonfunctional (noncentric) cusp bevel

All complete crown preparations should be assessed for adequate reduction at the occlusoaxial line angles of the nonfunctional cusps. A minimum of 0.6 mm of clearance is needed here for adequate strength. Maxillary molars in particular often require an additional reduction bevel in this area (Fig. 8-6). Without it, an overcontoured restoration that does not follow normal configuration may result. Such additional reduction is often unnecessary for mandibular molars, however, because they are lingually inclined and their profile is relatively straight.

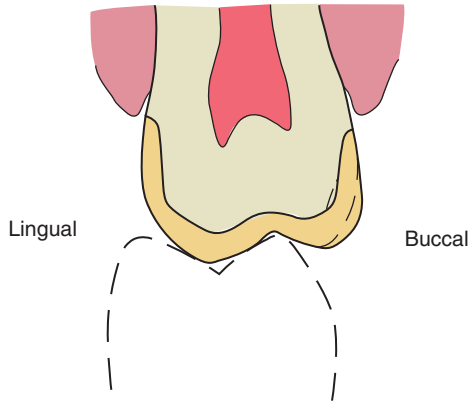


Fig. 8-6
The configuration of the facial wall of the maxillary molars may necessitate slight additional reduction in the occlusal third to prevent overcontouring of the restoration. This reduction is termed the *nonfunctional cusp bevel*.

Chamfer width

Increasing the faciolingual width of a complete crown is a common error in practice and is a leading cause of periodontal disease associated with restorations. Adequate chamfer width (minimum 0.5 mm) is important for developing optimum axial contour. On small premolars, however, it may be advantageous to prepare a slightly narrower chamfer to conserve tooth structure and retention form. This requires increasingly careful manipulation of the wax pattern during fabrication of the restoration and careful assessment to ensure that the crown is not excessively contoured.

PREPARATION

The clinical procedure to prepare a tooth for a complete cast crown consists of the following steps:

- Occlusal guiding grooves.
- Occlusal reduction.
- Axial alignment grooves.
- Axial reduction.
- Finishing and evaluation.
- Armamentarium (Fig. 8-7 and Table 8-1).

Step-by-Step Procedure

In this chapter, the tooth preparation steps have been illustrated for a mandibular second molar. Depending on the tooth to be prepared (e.g., a premolar versus a molar) the exact number of guiding grooves may vary. The recommended sequence remains identical, however.

Table **8-1** **ARMAMENTARIUM**

INSTRUMENT	USE
Tapered carbide bur or diamond	Occlusal guiding grooves Additional retentive features
Narrow, round-tipped, tapered diamond (regular grit) (0.8 mm)	Occlusal reduction Axial alignment grooves Axial reduction Chamfer preparation
Wide, round-tipped, tapered diamond (fine grit) (1.2 mm)	Finishing
Utility wax and wax caliper Occlusal reduction gauge	Verification of occlusal clearance
High- and low-speed friction grip contra-angles	



Fig. 8-7
Armamentarium for the complete cast crown preparation.



Fig. 8-8
Guiding grooves are placed on the occlusal surface. They are deeper on the functional cusp, and for the functional cusp bevel they diminish in depth from the cusp tip to the cervical margin.

Guiding grooves for occlusal reduction

A tapered carbide or a narrow, tapered diamond is recommended for placing the guiding grooves for occlusal reduction.*

1. Place depth holes approximately 1 mm deep in the central, mesial, and distal fossae, and connect them so that a channel runs the length of the central groove and extends into the mesial and distal marginal ridge.
2. Place guiding grooves in the buccal and lingual developmental grooves and in each triangular ridge extending from the cusp tip to the center of its base (Figs. 8-8 and 8-9).
3. To ensure that the centric or functional cusp will be protected by an adequate thickness of metal, place a functional cusp bevel in the area of contact with the opposing tooth. The depth of this guiding groove should be slightly less than 1.5 mm (to allow for smoothing) in the area of the centric stop, and it should gradually diminish in a cervical direction.
4. Use the guiding grooves to ensure that occlusal reduction follows anatomic configuration and thus minimizes the loss of tooth structure while ensuring adequate reduction, as dictated by the mechanical properties of the alloy from which the restoration is to be fabricated. The guiding grooves must be placed with accuracy; the practitioner should concentrate on the position, depth, and angulation of each groove. A groove should

*The use of guiding grooves for occlusal reduction is helpful only if the tooth is in good occlusal relationship before preparation. On most teeth, this can be achieved with a foundation restoration and is done as part of the mouth preparation phase of treatment. When this is not practical (e.g., in correcting occlusal discrepancies or replacing existing crowns), a matrix is made from the diagnostic waxing procedure, and this is used to assess optimal reduction (see Fig. 15-14A).

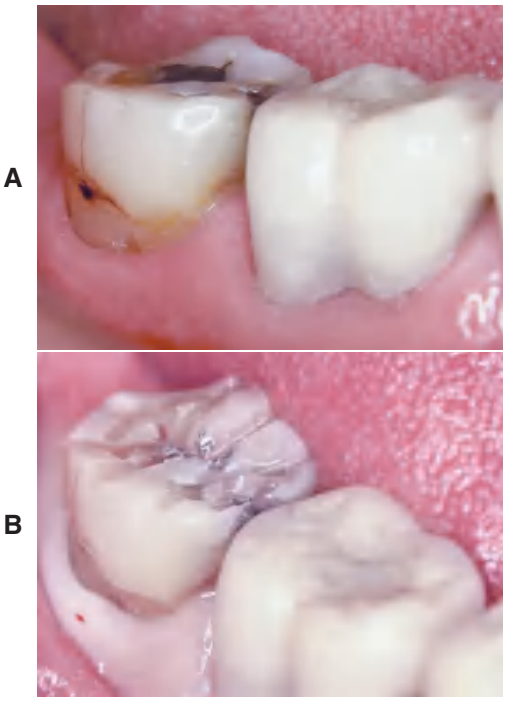


Fig. 8-9
A, A complete cast crown is indicated on this mandibular second molar with occlusal, proximal, and cervical lesions, as well as a buccal longitudinal fracture. **B,** Initial depth grooves placed for occlusal reduction. Note that they have not yet been extended onto the buccal surface, where the functional cusp bevel will be placed.

be placed in the low point and high point of each cusp. The low points are the central and developmental grooves; the high points are the cusp tips and triangular ridges. Correct depth (0.8 mm for the central groove and nonfunctional cusps, 1.3 mm for the functional cusps*) is achieved by knowledge of the instruments being used. The practitioner should memorize the diameters of the rotary instruments; this facilitates assessment of the adequacy of the reduction in progress. If necessary, a periodontal probe can be used to measure the extent of reduction. Correct angulation of the grooves is needed to ensure that the occlusal reduction is correctly situated beneath the occlusal surface of the restoration. On the nonfunctional cusp, the groove should parallel the intended cuspal inclination; on the functional cusp, it should be angled slightly flatter to ensure the additional reduction of the functional cusp.

Occlusal reduction

Once the guiding grooves have been deemed satisfactory, the tooth structure that remains between the

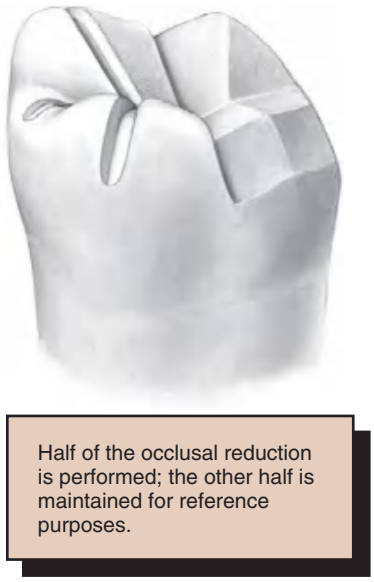


Fig. 8-10
After the guiding grooves are placed, the occlusal reduction is performed. Either the mesial or the distal half is maintained initially as a reference.

grooves is removed with the carbide or the narrow, round-end, tapered diamond. Proper placement of the grooves automatically results in adequate occlusal clearance.

5. Complete the occlusal reduction in two steps (Fig. 8-10). Half the occlusal surface is reduced first so that the other half can be maintained as a reference. When the necessary reduction of the first half has been accomplished, reduction of the remaining half can be completed (Fig. 8-11).
6. On completion, check that a minimum clearance of 1.5 mm has been established on functional cusps and at least 1.0 mm on nonfunctional cusps. This clearance must be verified in all excursive movements that the patient can make. The patient should close into several layers of dark-colored utility wax in maximum intercuspation (Fig. 8-12*A*).
7. Remove the wax from the mouth and evaluate it for thin spots, which can be measured with a wax caliper (Fig. 8-12*B*).
8. Place the wax back in the patient's mouth and have the patient move the mandible into protrusive and excursive positions. On removal, the thickness of the utility wax is again measured, this time to verify that adequate clearance exists in the dynamic range, as well as in maximum intercuspation. A convenient alternative is to use an occlusal reduction gauge† (Fig. 8-13).

*Allow 0.2 mm in both for smoothing the preparation.

†Hu-Friedy, Chicago, Illinois.

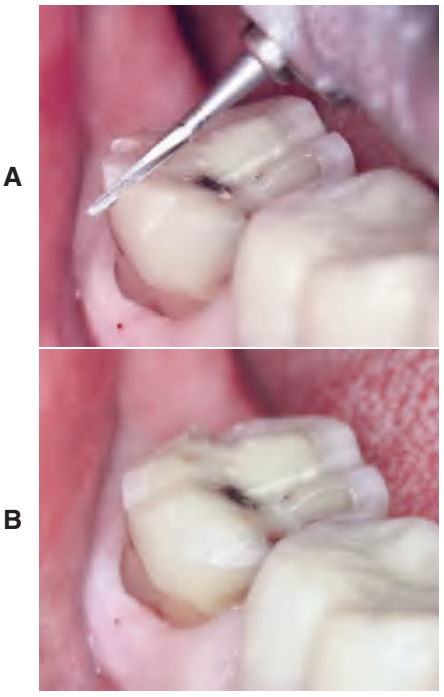


Fig. 8-11
A, Note the angulation of the bur as the functional cusp bevel is placed. **B,** Completed occlusal reduction. Note that it follows normal occlusal form. Three distinct planes can be seen buccolingually.

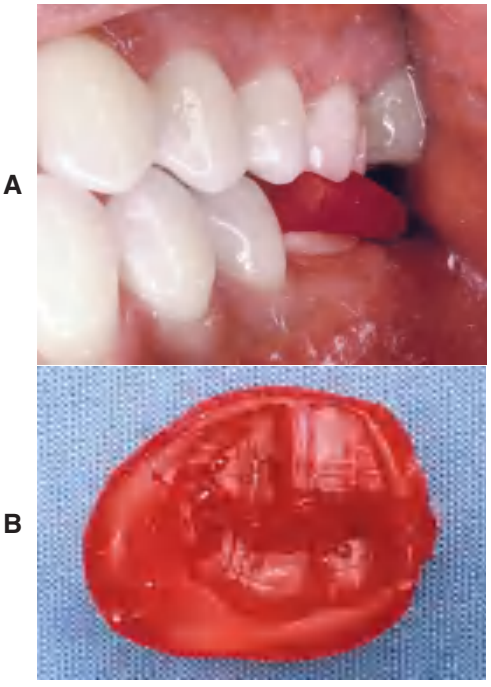


Fig. 8-12
Evaluation of the adequacy of occlusal clearance. **A,** The patient closes into softened wax. **B,** The thickness of the wax is assessed visually and measured with a wax caliper after it has been removed from the mouth.

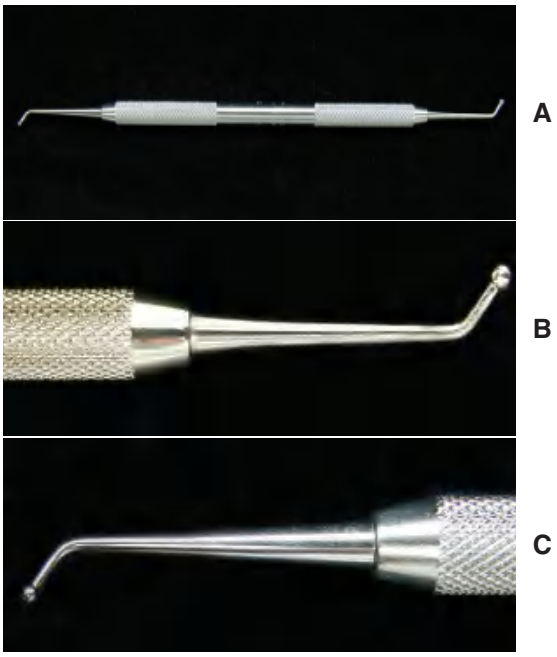


Fig. 8-13
Occlusal clearance can be judged intraorally with a reduction gauge. This instrument (**A**) has 1.5-mm-diameter (**B**) and 1-mm-diameter (**C**) spherical tips.

Alignment grooves for axial reduction

After the occlusal reduction is completed, three alignment grooves are placed in each buccal and lingual wall with a narrow, round-end, tapered diamond. One is placed in the center of the wall, and one in each mesial and distal transitional line angle (Fig. 8-14).

1. When these guiding grooves are placed, be sure that the shank of the diamond is parallel to the proposed path of placement of the restoration. This automatically produces a convergence between the axial walls of the alignment grooves that is identical to the taper of the diamond. If a diamond with a 6-degree taper is used, an identical axial convergence on the preparation wall will result.
2. Do not let the diamond cut into the tooth beyond the point where its tip is buried in tooth structure up to the midpoint; otherwise, a lip of unsupported tooth enamel will be created (see Fig. 7-21). Gingivally, the resulting depth of the alignment grooves therefore should be no more than one half the width of the tip of the diamond. Occlusocervically, the placement of the tip of the instrument determines the location of the margin (Fig. 8-15).
3. Note that the alignment grooves determine the path of placement of the restoration. They should



When placing these grooves, keep reduction to a minimum at the tip of the diamond.

Fig. 8-14
Alignment grooves for axial reduction are placed in the buccal and lingual surfaces parallel to the long axis of the tooth buccolingually and mesiodistally.



Fig. 8-15
A, The diamond is aligned parallel to the long axis of the tooth as the buccal guiding grooves for axial alignment are placed. **B,** All six grooves have been placed. Note that they are deep occlusally but shallower toward the cervical margin.



Fig. 8-16
If axial reduction is completed first on either the distal or the mesial half of the tooth, evaluation is simplified because the remaining intact tooth can serve as a reference.

be placed parallel to the proposed path of placemnt, typically the long axis of the tooth.

4. Use a periodontal probe to assess the relative parallelism of the alignment grooves with one another or with the proposed path of placement of a secondary retainer if the prepared tooth is to serve as a fixed dental prosthesis abutment. When the correct placement of alignment grooves is uncertain (as is likely on long-span fixed dental prosthetic abutments), making an impression with irreversible hydrocolloid (alginate) is especially helpful. This can be poured in rapid-setting stone, and the resulting cast can be analyzed with a dental surveyor.* At this time, corrections may still be easily made before unnecessary tooth reduction has occurred.

Axial reduction

The technique for axial reduction is similar to that for occlusal reduction. The remaining islands of tooth structure between the alignment grooves are removed while the chamfer margin is being placed, and the same narrow, round-tipped diamond is used for the procedure (Figs. 8-16 and 8-17).

5. As with the occlusal reduction, perform the axial reduction for half the tooth at a time, maintaining the other half as a reference for assessing adequacy of the preparation.
6. Pay special attention to the interproximal areas to prevent unintentional damage to the adjacent teeth. This often results if the practitioner is impatient and attempts to force the diamond into the area. Sufficient time must be allowed for the

*The same cast can be used to fabricate the interim restoration (see Chapter 15).



Fig. 8-17
A, Note the alignment of the diamond as tooth structure between the alignment grooves is removed. **B,** Axial reduction. The distobuccal axial reduction has been completed.

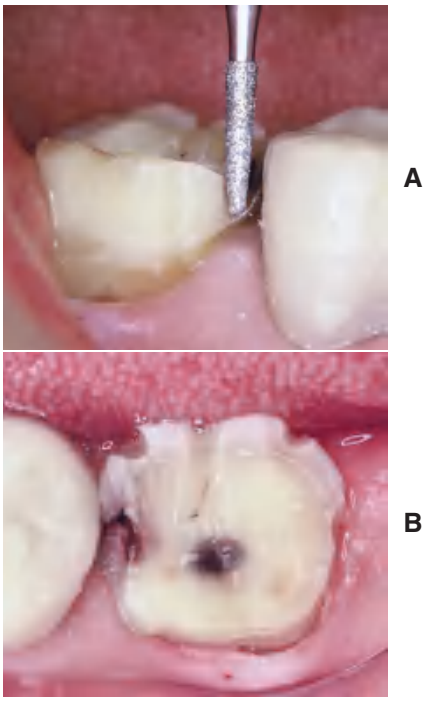


Fig. 8-18
A, As the mesiobuccal axial reduction is performed, a cervical chamfer is placed. **B,** Make the chamfer of relatively even width and maintain the somewhat angular preparation outline form to maximize resistance form.

cutting instrument to create its own space (Fig. 8-18).

Typically, if the proper cervical placement of the margin has been selected with proper axial alignment of the instrument, a lip of tooth enamel is maintained between the diamond and the adjacent tooth that protects it from any damage (Fig. 8-19).

7. If desired, protect the adjacent teeth by placing a metal matrix band. The most difficult interproximal areas to reduce are those with significant buccolingual dimension and those with root proximity. Typically, however, the critical area is only a few millimeters in length.
8. Cut into the proximal area from both sides until only a few millimeters of interproximal island remain (Fig. 8-20). This area can then be removed and contact broken by using thinner, tapered diamonds. If the adjacent proximal surface is damaged, it must be polished with white stones, silicone points, and prophylaxis paste before impression making. Ideally, a fluoride application is given for improved resistance and to prevent demineralization of the surface enamel.
9. Place the cervical chamfer concurrently with axial reduction. Its width should be approximately 0.5 mm, which allows adequate bulk of metal at the margin. This chamfer must be smooth and continuous mesiodistally, and a distinct resistance against vertical displacement should be detected when probed with the tip of an explorer (Fig. 8-21). Unsupported enamel cannot be tolerated because it is likely to fracture when the restoration is evaluated or cemented, which results in an open margin and early failure of the restoration.



Fig. 8-19
A lip of enamel (*arrow*) protects the adjacent tooth from iatrogenic damage as the axial reduction is completed.

Finishing

A smooth surface finish and continuity of all prepared surfaces aid most phases of fabrication of the restoration. Smooth transitions from occlusal to axial surfaces facilitate impression making, waxing,



As the axial reduction is performed, eventually a small island of tooth structure will remain in the interproximal area. When removing this, maintain a narrow "lip" of tooth structure between the diamond and the adjacent tooth to protect the latter from damage.

Fig. 8-20
Preparation of the proximal contact area.

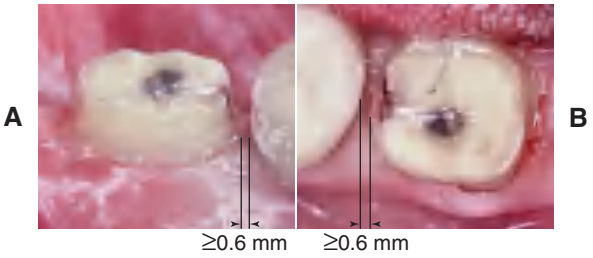


Fig. 8-21
A, Note that adequate clearance (≥0.6 mm) exists between the external surface of the proximal chamfer and the adjacent tooth. **B,** Occlusal view of the preparation.

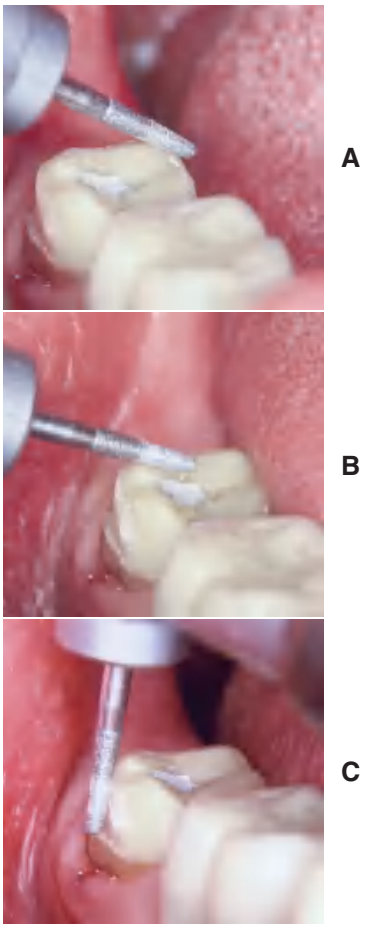


Fig. 8-22
A, The transition from lingual to occlusal surfaces is rounded with a fine-grit diamond. **B,** All sharp line angles between occlusal reduction and functional cusp bevel are similarly rounded. **C,** The margin is refined, and any minor irregularities are removed.

investing, and casting because bubble formation is reduced (Fig. 8-22).

1. Use a fine-grit diamond or carbide bur of slightly greater diameter for finishing the chamfer margin. This should be done as smoothly as possible, with the handpiece operating at reduced speed. Some practitioners favor using a low-speed contra-angle for the finishing. A properly finished margin should be glassy smooth when touched by the tine of an explorer.
2. Finish all prepared surfaces and slightly round all line angles. If necessary, place a nonfunctional cusp bevel at this time. During finishing of the chamfer, the use of air cooling alone is recommended to improve visibility. However, when only air cooling is used, a water spray should be applied from time to time to prevent the tooth from dehydrating, and the possible development of pulpal damage, as well as to wash away debris. The wider diamond is recommended because it smooths out any unwanted ripples that may have been created during axial reduction and eliminates any unsupported enamel at the margin (Fig. 8-23).
3. Place additional retentive features as needed (e.g., grooves or boxes) with the tapered carbide bur using the slow speed handpiece (Fig. 8-24).

The criteria used to determine the need for such features to enhance retention and resistance are described in Chapter 7.

Evaluation

Upon completion, the preparation is evaluated to assess whether all the criteria have been fulfilled (Fig. 8-25).



Fig. 8-23
Completed preparation. The carious lesions have been excavated and the resulting irregularities blocked out with amalgam. **A,** Buccal appearance. **B,** Occlusal appearance.

One of the more common errors in complete cast crown preparations is overtapering of the opposing axial walls. This significantly reduces the retention of the completed restoration. If a tooth preparation has been inadvertently overreduced through excessive tapering of axial walls, it should be carefully evaluated to determine how it can be corrected. If a band of several millimeters of tooth structure can be prepared circumferentially with a restricted taper of approximately 6 degrees, it is probably unnecessary to modify the preparation further to compensate for areas of excessive reduction in the occlusal third. If this is not the case, an approach slightly less conservative of tooth structure may be warranted: (1) uprighting overtapered axial walls to obtain the mechanical advantage of increased retention or (2) using grooves, boxes, or pinholes as needed.

No undercuts between any opposing axial walls can be accepted. When the diamond is placed against the axial surface of the prepared tooth, parallel to the path of placement, it should be possible to move the instrument around the tooth so that the entire height of the preparation is touching the diamond at all times. The tip of the diamond should rest on the chamfer throughout this movement, and no light should be visible between the instrument and the axial surface.

Finally, occlusal and proximal clearances are assessed. They should be adjusted if inadequate pro-

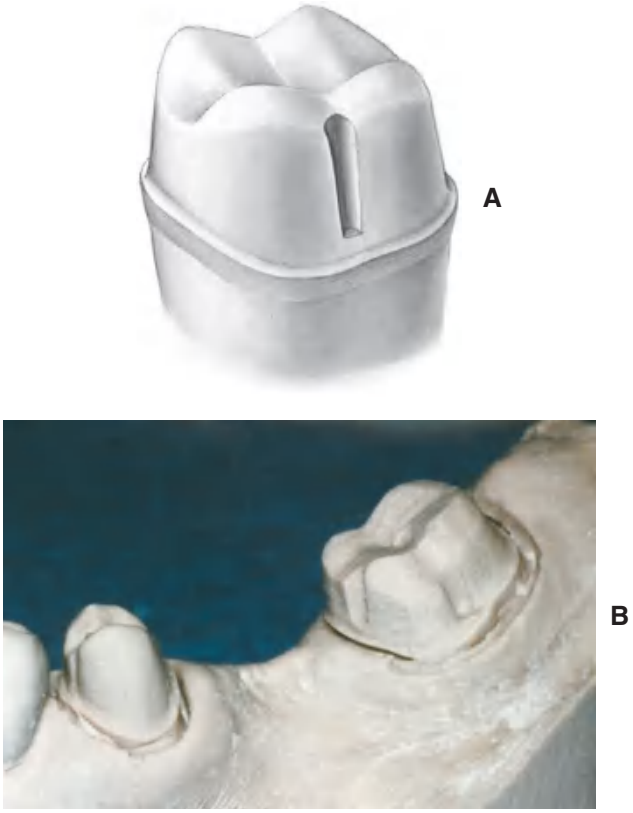


Fig. 8-24
A, When opposing axial walls are excessively tapered, internal features such as this buccal groove can be used to improve retention and resistance form. **B,** Mesially tipped molars and short premolars often benefit from grooves and/or boxes incorporated in the preparation design.



Fig. 8-25
The completed preparation is characterized by a smooth, even chamfer; a 6-degree taper; and gradual transitions between all prepared surfaces.



Fig. 8-26
A, Acrylic resin interim restoration is cemented. **B** and **C,** Complete cast crown is cemented.

vision has been made for the restorative material. Any problems must be corrected before making the interim restoration (Fig. 8-26) and the impression.

SUMMARY

The complete cast crown, an all-metal restoration often used on single posterior teeth as a retainer for a fixed dental prosthesis, provides greater retention and resistance than any other type of restoration. It is not indicated for every restorative circumstance, however. It is unnecessary if the buccal and/or lingual walls of a tooth are intact or if less than maximum retention is needed. The rather extensive removal of tooth structure required in its preparation can have adverse pulpal and periodontal effects. The high strength of the complete cast crown makes it especially suitable for restoring an endodontically treated tooth, although in patients who find visible metal a significant drawback, the metal-ceramic or a more conservative partial-coverage restoration may be preferred.

A well-organized approach to preparation for a complete cast crown should be based on the selective use of guiding grooves of predetermined depth correlated with specific properties of the restorative material. Adequate occlusal reduction is necessary, in accordance with the normal anatomic tooth contours, and the axial reduction should also conform to the normal configuration of the tooth, with minimum taper (6 degrees). Under no circumstances should undercuts remain in the proximal walls. These must be removed by additional tooth preparation or blocked out with a suitable base material. The chamfer is the margin of choice for a complete cast crown. It should be distinct and of adequate width. No unsupported enamel can be permitted. Occlusocervically, the margin should be supragingival, and it should be smooth and continuous mesiodistally. When assessing the adequacy of the chamfer, the examiner should be able to feel distinct resistance against vertical displacement by an explorer or periodontal probe.

STUDY QUESTIONS

1. What are the indications and contraindications for complete cast crowns?
2. What are the advantages and disadvantages of complete cast crowns?
3. What is the recommended armamentarium, and in what sequence should a mandibular molar be prepared, for a complete cast crown?
4. What are the minimum criteria for each step described in question 3?

SUMMARY CHART
COMPLETE CAST CROWN

Indications	Contraindications	Advantages	Disadvantages
Extensive destruction from caries or trauma	Less than maximum retention necessary	Strong	Removal of large amount of tooth structure
Endodontically treated teeth	Esthetics	High retentive qualities	Adverse effects on tissue
Existing restoration	–	Usually easy to obtain adequate resistance form	Vitality testing not readily feasible
Necessity for maximum retention and strength	–	Option to modify form and occlusion	Display of metal
To provide contours to receive a removable appliance	–	–	–
Other recontouring of axial surfaces (minor corrections of malinclinations)	–	–	–
Correction of occlusal plane	–	–	–

Preparation steps	Recommended armamentarium	Criteria
Depth grooves for occlusal reduction	Tapered carbide or diamond	Minimum clearance on noncentric cusps: 1 mm
Functional cusp bevel	Tapered carbide or diamond	Minimum clearance on centric cusps: 1.5 mm
Occlusal reduction (half at a time)	Regular-grit, round-tipped diamond	Flatter than cuspal plane, to allow additional reduction at functional cusp
Alignment grooves for axial reduction	Tapered diamond	Should follow normal anatomic configuration of occlusal surface
Axial reduction (half at a time)	Tapered diamond	Chamfer allows 0.5 mm of thickness of wax at margins
Finishing of chamfer	Tapered diamond	Reduction performed parallel to long axis
Additional retentive features if needed	Wide, round-tipped diamond or carbide	Smooth mesiodistally and buccolingually; resistance to vertical displacement by tip of explorer or periodontal probe
Finishing	Tapered carbide	Grooves, boxes, pinholes as described for partial-coverage restorations
	Fine-grit diamond or carbide	Rounding of all sharp line angles to to facilitate impression making, die pouring, waxing, and casting

9



THE METAL-CERAMIC CROWN PREPARATION

In many dental practices, the metal-ceramic crown is one of the most widely used fixed restorations. This has resulted in part from technologic improvements in the fabrication of this restoration by dental laboratories and in part from the growing amount of cosmetic demands that challenge dentists today.

The restoration consists of a complete-coverage cast metal crown (or substructure) that is veneered with a layer of fused porcelain to mimic the appearance of a natural tooth. The extent of the veneer can vary.

To be successful, a metal-ceramic crown preparation requires considerable tooth reduction wherever the metal substructure is to be veneered with dental porcelain. Only with sufficient thickness can the darker color of the metal substructure be masked and the veneer duplicate the appearance of a natural tooth. The porcelain veneer must have a certain minimum thickness for esthetics. Consequently, much tooth reduction is necessary, and the metal-ceramic preparation is one of the least conservative of tooth structures (Fig. 9-1).

Historically, attempts to veneer metal restorations with porcelain had several problems. A major challenge was the development of an alloy and a ceramic material with compatible physical properties that would provide adequate bond strength. In addition, it was initially difficult to obtain a natural appearance.

The technical aspects of the fabrication of this restoration are discussed further in Chapter 24. For now, only a brief description is provided. The metal substructure is waxed and then cast in a special metal-ceramic alloy that has a higher fusing range and a lower thermal expansion than do conventional gold alloys. After preparatory finishing procedures, this substructure, or framework, is veneered with dental porcelain. The porcelain is fused onto the framework in much the same manner as household articles are enameled. Modern dental porcelains fuse at a temperature of about 960° C (1760° F). Because conventional gold alloys would melt at this temperature, the special alloys are necessary.

INDICATIONS

The metal-ceramic crown is indicated on teeth that require complete coverage and for which significant esthetic demands are placed on the dentist (e.g., the

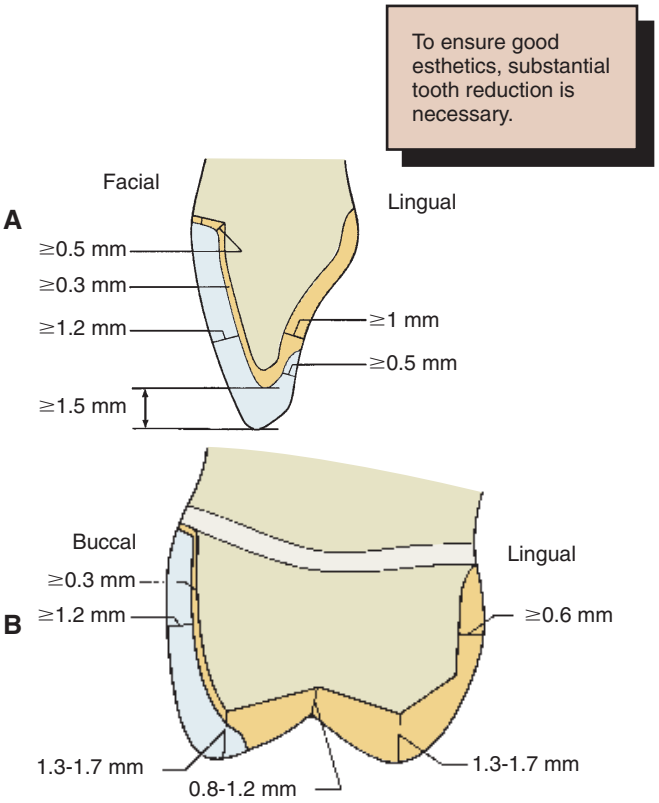


Fig. 9-1
Recommended minimum dimensions for a metal-ceramic restoration on an anterior tooth (**A**) and a posterior tooth (**B**). Note the significant reduction needed compared to that for a complete cast or partial veneer crown.

anterior teeth). It should be recognized, however, that, if esthetic considerations are paramount, an all-ceramic crown (see Chapters 11 and 25) has distinct cosmetic advantages over the metal-ceramic restoration; nevertheless, the metal-ceramic crown is more durable than the all-ceramic crown and generally has superior marginal fit. Furthermore, it can serve as a retainer for a fixed dental prosthesis because its metal substructure can accommodate cast or soldered connectors. Whereas the all-ceramic restoration cannot accommodate a rest for a removable prosthesis, the metal-ceramic crown may be successfully modified to incorporate occlusal and cingulum rests as well as milled proximal and reciprocal guide planes in its metal substructure (see Chapter 21).

Typical indications are similar to those for all-metal complete crowns: extensive tooth destruction as a result of caries, trauma, or existing previous restorations that precludes the use of a more conservative restoration; the need for superior retention and strength; an endodontically treated tooth in conjunction with a suitable supporting structure (a post and core); and the need to recontour axial surfaces or correct minor malinclinations. Within certain limits, this restoration can also be used to correct the occlusal plane.

CONTRAINDICATIONS

Contraindications for the metal-ceramic crown, as for all fixed restorations, include patients with active caries or untreated periodontal disease. In young patients with large pulp chambers, the metal-ceramic crown is also contraindicated because of the high risk of pulp exposure (see Fig. 7-4). If at all possible, a more conservative restorative option such as a composite resin or porcelain laminate veneer (see Chapter 25) or an all-ceramic crown with less reduction (see Chapter 11) is preferred.

A metal-ceramic restoration should not be considered whenever a more conservative retainer is feasible, unless maximum retention is needed, as for a long-span fixed dental prosthesis. If the facial wall is intact, the practitioner should decide whether it is truly necessary to involve all axial surfaces of the tooth in the proposed restoration. Although perhaps technically more demanding and time consuming, a more conservative solution that satisfies the patient's needs and may provide superior long-term service can usually be found.

ADVANTAGES

The metal-ceramic restoration combines, to a large degree, the strength of cast metal with the esthetics of an all-ceramic crown. The underlying principle is to reinforce a brittle, more cosmetically pleasing material through support derived from the stronger metal substructure. Natural appearance can be closely matched by good technique and, if desired, through characterization of the restoration with internally or externally applied stains. Retentive qualities are excellent because all axial walls are included in the preparation, and it is usually quite easy to ensure adequate resistance form during tooth preparation. The complete-coverage aspect of the restoration permits easy correction of axial form. In addition, the required preparation is often much less demanding than for partial-coverage retainers. In general, the degree of difficulty of a metal-ceramic preparation is comparable to that of preparing a posterior tooth for a complete cast crown.

DISADVANTAGES

The preparation for a metal-ceramic crown requires significant tooth reduction to provide sufficient space for the restorative materials. To achieve better

esthetics, the facial margin of an anterior restoration is often placed subgingivally, which increases the potential for periodontal disease. However, a supragingival margin can be used if significant cosmetic concerns do not preclude it or if the restoration incorporates a porcelain labial margin (see Chapter 24).

In comparison with an all-ceramic restoration, the metal-ceramic crown may have slightly inferior esthetics, but it can be used in higher stress situations or on teeth that would not provide adequate support for an all-ceramic restoration.

Because of the glasslike nature of the veneering material, a metal-ceramic crown is subject to brittle fracture (although such failure can usually be attributed to poor design or fabrication of the restoration). A frequent problem is the difficulty of accurate shade selection and of communicating it to the dental ceramist. This is often underestimated by the novice. Because many procedural steps are required for both metal casting and porcelain application, laboratory costs generally render the metal-ceramic restoration among the more expensive of dental procedures.

PREPARATION

The recommended sequence of preparation is illustrated for a maxillary right central incisor (Fig. 9-2); however, the same step-by-step approach can be applied to other teeth (Fig. 9-3). As with all tooth preparations, a systematic and organized approach to tooth reduction saves time.

Armamentarium

The instruments needed to prepare teeth for a metal-ceramic crown (Fig. 9-4) include:

- Round-tipped rotary diamonds (regular grit for bulk reduction, fine grit for finishing) or carbides
- Football- or wheel-shaped diamond (for lingual reduction of anterior teeth)
- Flat-ended, tapered diamond (for shoulder preparation)
- Finishing stones
- Explorer and periodontal probe
- Off-angle hatchets (see Fig. 9-4*B* to *D*)

The actual sequence of steps can be varied slightly, depending on operator preference.

Step-By-Step Procedure

The preparation is divided into five major steps: guiding grooves, incisal or occlusal reduction, labial or buccal reduction in the area to be veneered with porcelain, axial reduction of the proximal and lingual surfaces, and final finishing of all prepared surfaces.

Guiding grooves

1. Place three depth grooves (Fig. 9-5), one in the center of the facial surface and one each in the approximate locations of the mesiofacial and distofacial line angles (see Fig. 9-2*A* to *E*). These are in two planes: the cervical portion to parallel the long axis of the tooth and the incisal (occlusal) portion to follow the normal facial contour (see Fig. 9-2*D* and *E*).
2. Perform the facial reduction in the cervical and incisal planes. The cervical plane determines the path of placement of the completed restoration. The incisal or occlusal plane provides the space needed for the porcelain veneer; it should be approximately 1.3 mm deep to allow for additional reduction during finishing. The secondary facial grooves usually extend halfway down the facial surface, although (depending on the shape of the tooth) they may extend to include the incisal two thirds. Cervical grooves are generally made parallel to the long axis of the tooth. However, they can be adjusted slightly to create a more desirable path of placement; in particular, some labial inclination improves retention on a tooth with little cingulum height. On small teeth, it may be advisable to keep the cervical grooves somewhat shallower near the margin.
3. Place three depth grooves (about 1.8 mm deep) in the incisal edge of an anterior tooth. These provide the needed reduction of 2 mm and allow finishing (see Fig. 9-2*F* and *G*). Verify the depth of these grooves with a periodontal probe. On posterior teeth on which the occlusion is to be established in porcelain, 2 mm of clearance must exist. If the occlusion is to be established in metal, the same minimum clearances are needed as for a complete cast crown. Posterior occlusal reduction incorporates a functional cusp bevel on the lingual cusp, similar to that for a complete cast crown. When the diamond is initially positioned for anterior teeth, it may be helpful to observe the long axis of the opposing tooth in maximum intercuspation and to orient the instrument perpendicular to that (Fig. 9-6). The grooves must not be too deep; otherwise, an overreduced and undulating surface results.

Incisal (occlusal) reduction

The completed reduction of the incisal edge on an anterior tooth should allow 2 mm for adequate

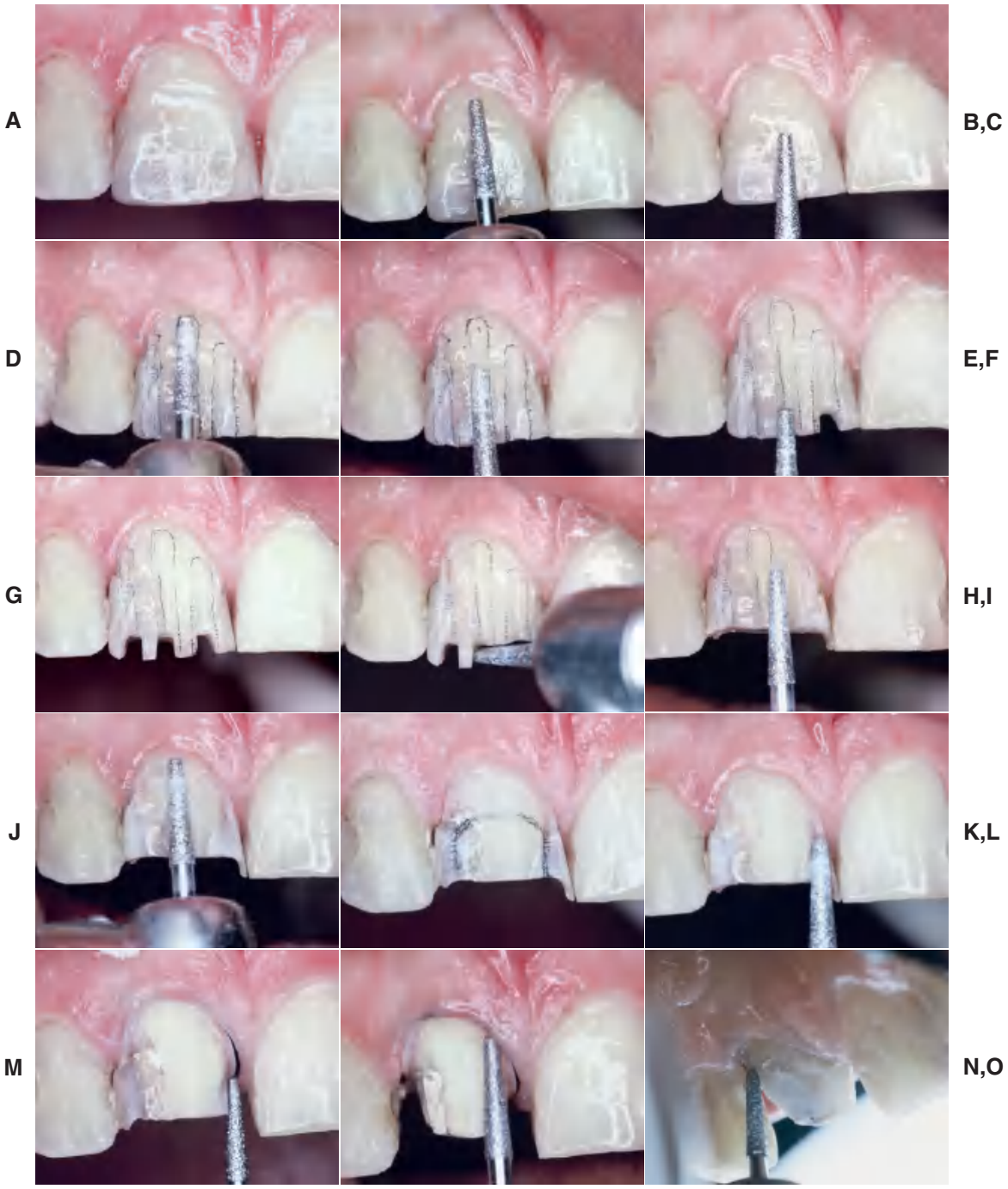


Fig. 9-2

Preparation of a maxillary incisor for a metal-ceramic crown. **A,** Heavily restored maxillary central incisor. **B** and **C,** Rotary instrument aligned with the cervical one third and incisal two thirds to gauge correct planes of reduction. **D** and **E,** Guiding grooves placed in the two planes. The cervical groove is made parallel to the path of placement, which usually coincides with the long axis of the tooth. The secondary facial depth groove is prepared parallel to the facial contour of the tooth. **F** and **G,** Incisal guiding grooves are placed. **H,** Incisal edge reduction. **I** to **K,** Facial reduction accomplished in two planes. **L,** Breaking proximal contact, maintaining a lip of enamel to protect the adjacent tooth from inadvertent damage. **M** and **N,** Proximal reduction. **O,** Placing a 0.5-mm lingual chamfer.

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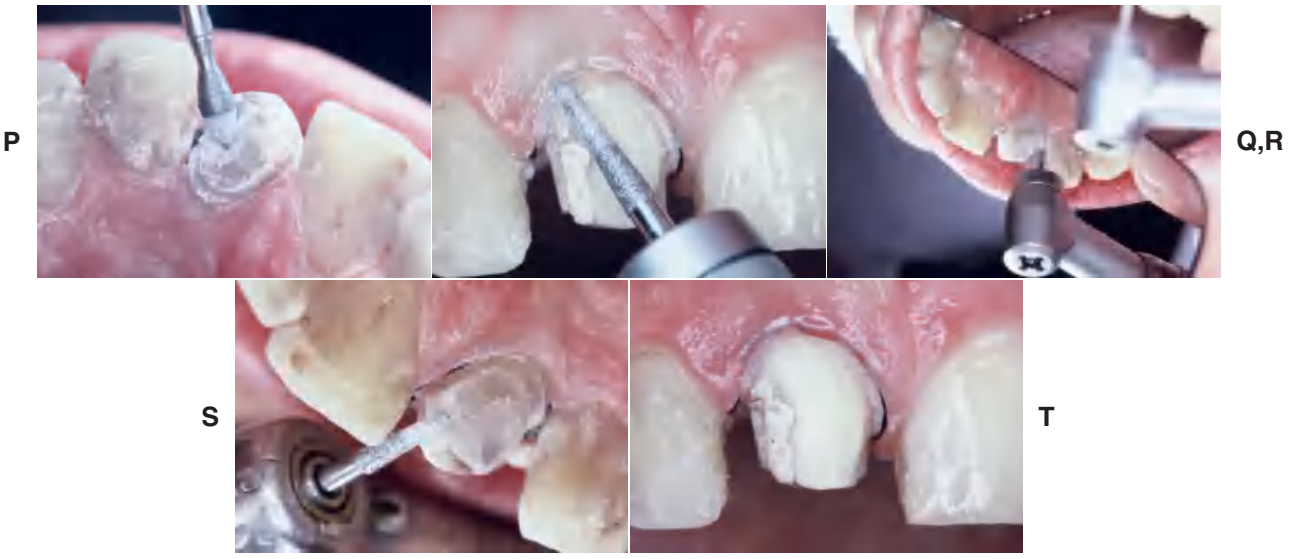


Fig. 9-2, cont'd
P, A football-shaped diamond is recommended for lingual reduction of anterior teeth. **Q** to **S,** Finishing the preparation with a fine-grit diamond. **T,** The completed preparation.

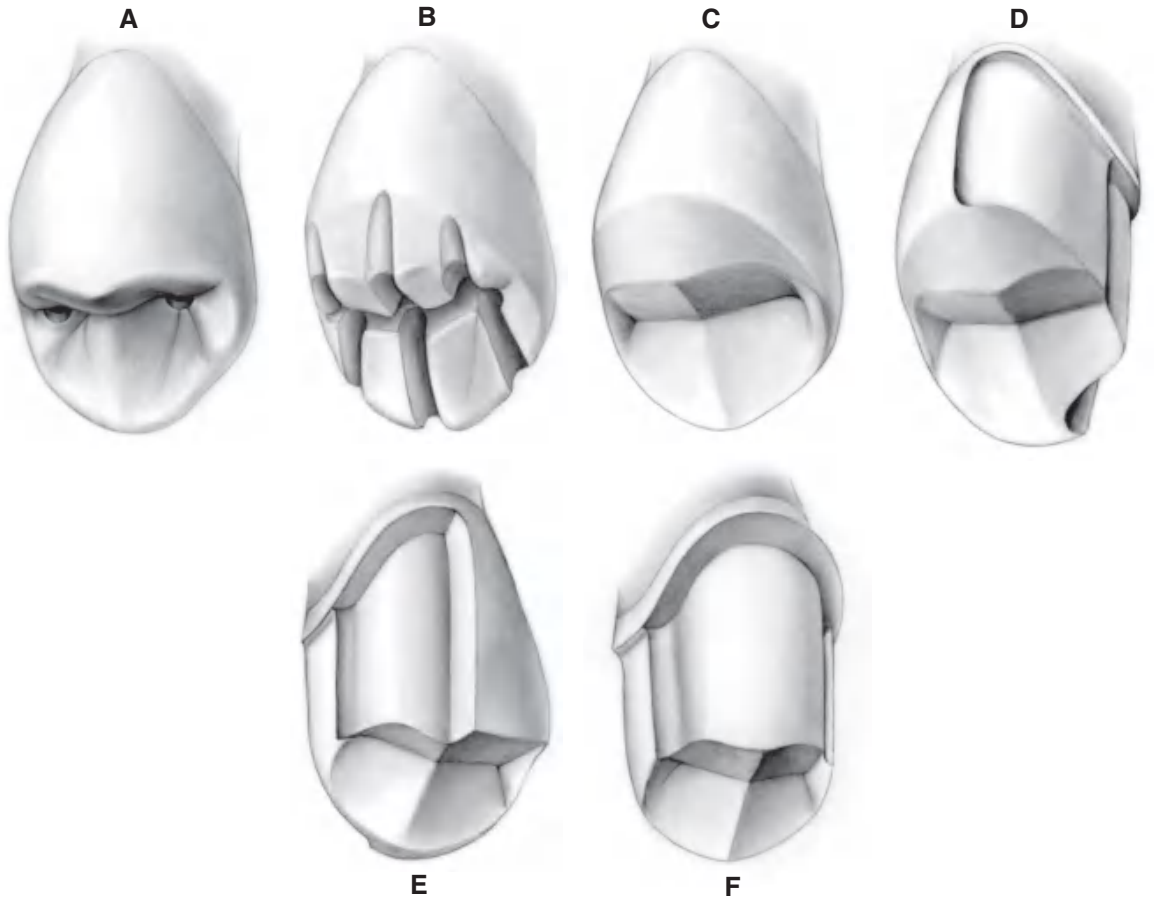


Fig. 9-3
Preparation of a maxillary premolar for a metal-ceramic crown. **A,** Depth holes. **B,** Occlusal depth cuts. **C,** Completed occlusal reduction. **D** and **E,** Lingual chamfer and facial shoulder are prepared on half the tooth (lingual view [**D**] and facial view [**E**]. **F,** Completed preparation.



Fig. 9-4
Armamentarium for the metal-ceramic crown preparation. **A,** Diamond rotary instrument. **B** to **D**, Off-angle hatchets. These are useful for smoothing the shoulder margins of metal-ceramic crown preparations.



Fig. 9-5
Depth grooves in the facial wall are placed in two directions: incisally, parallel to the tooth contour, and cervically, parallel to the path of placment. The grooves should be 1.3 mm deep.



Fig. 9-6
A, Depth grooves 1.8 mm deep placed in the incisal edges to ensure adequate and even reduction. **B,** Incisal reduction completed on the left central and lateral incisors. Note the angulation of the diamond, perpendicular to the direction of loading by the mandibular anterior teeth.

material thickness to permit translucency in the completed restoration. Posterior teeth generally require less reduction (1.5 mm) because esthetics is not as critical. Caution must be used, however, because excessive occlusal reduction shortens the axial walls and thus is a common cause of inadequate retention and resistance form in the completed preparation. This can be particularly problematic on anterior teeth (on which, as a consequence of tooth form, most of the retention is derived from the proximal walls).

4. Remove the islands of remaining tooth structure. On anterior teeth, access is usually unrestricted, and the thickest portion of the cutting instrument can be used to maximize cutting efficiency (see Fig. 9-2*H*). On posterior teeth, the same protocol is followed as in preparing depth grooves for a complete cast functional (see Chapter 8). This includes the use of a functional cusp bevel, although additional occlusal reduction is needed where the porcelain is to be applied (see Fig. 9-3*A* to *C*).

Labial (buccal) reduction

When completed, the reduction of the facial surface should have produced sufficient space to accommodate the metal substructure and porcelain veneer. A minimum of 1.2 mm is necessary for the ceramist to produce a restoration with satisfactory appearance (1.5 mm is preferable). This requires significant tooth reduction. For comparison, the cervical diameter of a maxillary central incisor averages between 6 and 7 mm.

In the cervical area of small teeth, obtaining optimal reduction is not always feasible (see Fig. 7-4.) A compromise is often made with lesser reduction in the area where the cervical shoulder margin is prepared.

5. Remove the remaining tooth structure between depth grooves (see Fig. 9-2*I* to *L*), creating a shoulder at the cervical margin (Fig. 9-7). If a restoration with a narrow subgingival metal collar is to be fabricated and sufficient sulcular depth is present, place the shoulder approximately 0.5 mm apical to the crest of the free gingiva at this time. Additional finishing then results in a margin that is 0.75 to 1 mm subgingival. Use adequate water spray during the entire phase of preparation, because a significant amount of tooth structure is being removed and copious irrigation (along with intermittent strokes) expedites the preparation process. Such a cautious approach prevents unnecessary trauma to the pulp. The resulting shoulder should be approximately 1 mm wide and should extend well into the proximal embrasures when viewed from the incisal (occlusal) side (Fig. 9-8). Where access allows, establishing this shoulder from the proximal gingival crest toward the middle of the facial wall is preferred. This minimizes placement of the initial shoulder preparation too close to the epithelial attachment. If the margin is established from facial to proximal, a tendency exists to "bury" the instrument and encroach on the epithelial attachment. Proper margin position must be maintained in relation to the crest of the free gingiva (see Fig. 7-51). The location and specific configuration of the facial margin depend on several factors: the type of metal-ceramic restoration selected, the cosmetic expectations of the patient, and operator preference.

From a periodontal point of view, a supragingival margin is always preferred. Its application is restricted, however, because patients often object to a visible metal collar or discolored root surface. Such objections are common, even when the gingival margin is not visible during normal function, as in

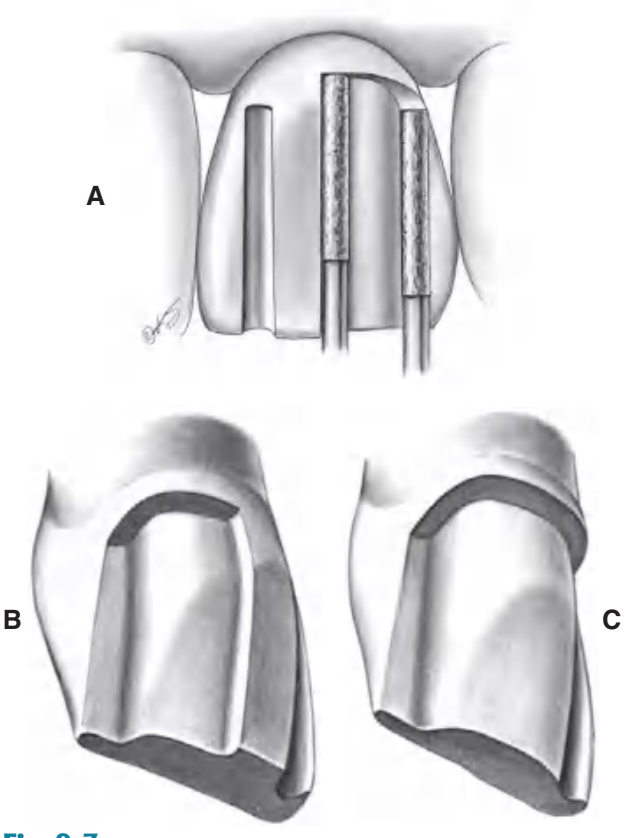


Fig. 9-7
A, The cervical shoulder is established as the tooth structure between the depth grooves is removed. The rotary instrument is moved parallel to the intended path of placement during this procedure. **B,** The facial reduction should be completed in two phases; initially, one half is maintained intact for assessment of the adequacy of reduction. Note the two distinct planes of reduction on the facial. The proximal aspect parallels the cervical reduction on the facial wall. **C,** Facial reduction completed. A 6-degree taper has been established between the proximal walls.

To ensure esthetics, the shoulder margin must extend into the interproximal area.

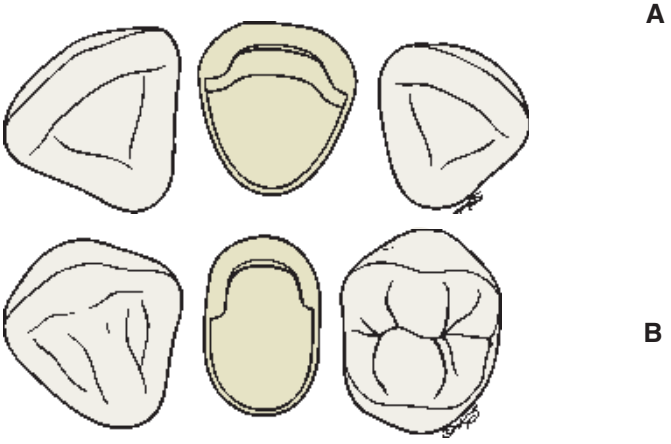


Fig. 9-8
A, The facial shoulder preparation should wrap around into the interproximal embrasure and extend at least 1 mm lingual to the proximal contact. **B,** The shoulder preparation extends adequately to the lingual side of the proximal contact. Note that on the mesial (visible) side, the preparation extends slightly farther than on the distal (cosmetically less critical) side.

patients with a low lip line, and generally limit the use of supragingival margins to posterior teeth (Fig. 9-9) and to undiscolored anterior teeth (in which case a porcelain labial margin is preferred; see Chapter 24). The optimum location of the margin should be carefully determined with the full cooperation of the patient. Where a subgingival margin is to be placed, careful tissue manipulation is essential; otherwise, there will be damage that leads to permanent gingival recession and subsequent exposure of the metal collar. This is most effectively avoided through meticulous gingival displacement with a cord before finishing (Fig. 9-10). The configuration of the margin is also finalized at this time (Fig. 9-11).

Axial reduction of the proximal and lingual surfaces

Sufficient tooth structure must be removed to provide a distinct, smooth chamfer of about 0.5 mm width (see Fig. 9-2*M* to *P*).



Fig. 9-9 Supragingival margins on the maxillary premolars. They were possible because of a favorable lip line hiding the cervical aspect of these posterior teeth. The subgingival margins on the mandibular premolars were prepared only because of previously existing restorations.

6. Reduce the proximoaxial and linguoaxial surfaces with the diamond held parallel to the intended path of placment of the restoration. These walls should converge slightly from cervical to incisal or occlusal. A taper of approximately 6 degrees, as measured as the angle between opposing axial walls, is recommended. On anterior teeth, a lingual concavity is prepared for adequate clearance for the restorative materials. Typically, 1 mm is required if the centric contacts in the completed restoration are to be located on metal. When contact is on porcelain, additional reduction is necessary. For anterior teeth, usually only one groove is placed, in the center of the lingual surface. For molars, three grooves can be placed in a manner similar to that described for the all-metal complete cast crown (see chapter 8).
7. Make a lingual alignment groove by positioning the diamond parallel to the cervical plane of the facial reduction. When the round-tipped diamond of appropriate size and shape is aligned properly, it is submerged almost halfway into the tooth structure. Verify the alignment of the groove, and carry the axial reduction from the groove along the lingual surface into the proximal; maintain the originally selected alignment of the diamond at all times.
8. As the lingual chamfer is developed, extend it buccally into the proximal to blend with the interproximal shoulder placed earlier (Fig. 9-12). Alternatively, a facial approach may be used. Although this is slightly more difficult initially, after some practice it should be easy to eliminate the lingual guiding groove and to perform the proximal and lingual axial reduction in one step; however, this requires that the diamond be held freehand parallel to the path of placement. The proximal



Fig. 9-10
A, Gingival displacement cord (under tension) is placed in the interproximal sulcus. **B,** A second instrument can be used to prevent the cord from rebounding from the sulcus after it has been packed.



Fig. 9-11
A, After tissue displacement, the facial margin is extended apically. Caution is needed, because if the diamond inadvertently grabs the cord, it may be ripped out of the sulcus and traumatize the epithelial attachment. **B,** Note the additional apical extension of the shoulder on the distal aspect. **C,** The entire facial shoulder is placed at a level that will be subgingival after the tissue rebounds. **D,** The facial margin has been prepared to the level of the previously placed cord.



Fig. 9-12
A lingual chamfer is prepared to allow adequate space for metal. A smooth transition from interproximal shoulder to chamfer is essential.

flange that resulted from the shoulder preparation can be used as a reference for judging alignment of the rotary instrument (Fig. 9-13). The interproximal margin should not be inadvertently placed too far gingivally and thereby infringe on the attachment apparatus. It must follow the soft tissue contour (see p. 190). On posterior teeth, the lingual wall reduction blends into the functional cusp bevel placed during the occlusal reduction. Anterior teeth require an additional step: After preparation of the cingulum wall, one or more depth grooves are placed in the lingual surface. These are approximately 1 mm deep.

9. Use a football-shaped diamond to reduce the lingual surface of anterior teeth (see Fig. 9-2*P*). It is helpful to stop when half this reduction has been completed, to evaluate clearance in maximum intercuspation and all excursions. The remaining intact tooth structure can serve as a reference.

Finishing

The margin must provide distinct resistance to vertical displacement of an explorer tip, and it must be smooth and continuous circumferentially. (A properly finished margin should feel like smooth glass slab.) All other line angles should be rounded, and the completed preparation should have a satin finish free from obvious diamond scratch marks. Tissue displacement is particularly helpful when subgingival margins are being finished (Fig. 9-14). Sometimes this step is postponed until just before impression making after tissue displacement.

10. Finish the margins with diamonds, hand instruments, such as the off-angle hatchets (see Fig. 9-4*B*) or carbides (see Fig. 9-2*Q* and *R*). All internal line angles should be rounded to facilitate the impression-making and die-pouring steps (see Fig. 9-2*S*). The finishing steps for the facial margin depend on the design of margin



Fig. 9-13
A, Proximal reduction of the flange with a facial approach. **B,** Once sufficient tooth structure has been removed, the cervical chamfer is prepared simultaneously with the lingual axial surface. After the distolingual preparation has been completed, the mesial chamfer is blended into a smooth transition with the shoulder.

chosen (Fig. 9-15; see also Table 7-2). A porcelain labial margin requires proper support for the porcelain. A shoulder with a 90-degree cavosurface angle is recommended. This type of shoulder can also be used for a crown with a conventional metal collar and offers the advantage of allowing the collar to be kept narrow. However, there is then the risk of leaving unsupported enamel. For this reason, the margin is often beveled or sloped to create a more obtuse cavosurface angle (Fig. 9-16). A flat-ended diamond in a low-speed handpiece creates the 90-degree shoulder. Any unsupported enamel must be removed subsequently by careful planing with a sharp chisel. Care must also be taken to orient the rotary instrument as it moves around the tooth if inadvertent undercuts are to be avoided. When a metal-collar design of ceramic restoration is planned, the need for a 90-degree shoulder is less crucial. A sloping shoulder has been advocated to ensure the elimination of unsupported enamel and to minimize marginal gap width (see Chapter 7). Such a shoulder (cavosurface angle of about 120 degrees) can be accomplished with a flat-ended diamond by changing its alignment, with particular attention to the configuration of the tooth structure cervical to the margin. Alternatively, a



Fig. 9-14
Controlled tissue displacement can be helpful when finishing the margin with a fine-grit diamond or another rotary instrument.



Fig. 9-15
A, Completed preparation. Note that the transition from incisal to axial walls is rounded, and a distinct 90-degree or slightly sloping shoulder has been established. **B,** An even chamfer width and a smooth transition between lingual and axial surfaces. The chamfer is distinct and blends smoothly into the facial shoulder.

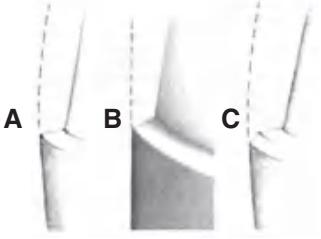


Fig. 9-16
A, 90-degree shoulder. **B,** 120-degree shoulder. **C,** Shoulder bevel.

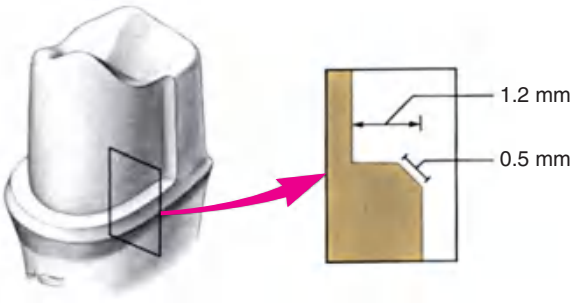


Fig. 9-17
The shoulder bevel.

hatchet can be used to plane the margin to the correct angulation. Again, be careful to avoid undercutting the axial wall of the preparation where it meets the shoulder during finishing. A shoulder-bevel margin is most effectively achieved with a flame-shaped carbide bur or hand instrument, depending on the length of bevel required (Fig. 9-17). In general, a short bevel with a cavosurface angle of 135 degrees is advocated, although longer bevels have been recommended for improved marginal fit. Special care must be exerted where the bevel meets the interproximal chamfer. The chamfer and bevel should be continuous with each other. Care must be taken not to damage the epithelial attachment during beveling; tissue displacement before preparation of subgingival bevels is recommended.

11. After a satisfactory facial margin has been obtained, round all sharp line angles within the preparation (see Fig. 9-2*S*). This facilitates surface wetting and expedites subsequent procedures (impression making, pouring of casts, waxing, and investing). A fine-grit diamond operating at low speed is particularly useful. However, where access allows, a slightly larger tapered diamond may be preferred because the greater diameter of its tip prevents "ditching" of the chamfer. Blend all surfaces together, and remove any sharp transitions (Figs. 9-18 and 9-19; see also Fig. 9-2*T*).

Evaluation

Areas often missed during finishing are the incisal edges of anterior preparations and the transition from occlusal to axial wall of posterior preparations. The completed chamfer should provide 0.5 mm of space for the restoration at the margin. The chamfer must be smooth and continuous, and when it is evaluated, a distinct resistance to vertical displacement of the tip of an explorer or periodontal probe should be felt. The chamfer should be continuous with the interproximal



Fig. 9-18
Facial (**A**) and lingual (**B**) views of metal-ceramic preparations.



Fig. 9-19
The "wingless" variation does not exhibit the defined transition from chamfer to shoulder seen in Fig. 9-15. Rather, the shoulder gradually narrows toward the lingual side. Interproximally, the same criteria for minimum extension of the shoulder apply as for the wing-type or flange preparation.

shoulder or beveled shoulder. The cavosurface angle of the chamfer should be slightly obtuse or 90 degrees. Under no circumstances should any unsupported tooth structure remain, especially at the facial margin. Care is also needed to avoid creating an undercut between the facial and lingual walls. This aspect of the preparation should be thoroughly evaluated. Excessive convergence should also be avoided, because this may lead to pulpal exposure. All residual debris is removed with thorough irrigation. (Various examples of metal-ceramic preparations are shown in Figs. 9-20 and 9-21.)



Fig. 9-20
A to **F,** Metal-ceramic crowns used to restore maxillary incisor teeth.



Fig. 9-21
A, Metal-ceramic preparations on the maxillary premolars in conjunction with more conservative preparations on the molars. **B**, Buccal view of the preparations. Note that, by comparison, considerable tooth reduction was needed on the premolars to accommodate metal-ceramic restorations. **C,** Except for the molars, all remaining teeth in this patient have been prepared for metal-ceramic restorations. Note the subtle variations and modifications of the same underlying theme: wing-type preparations on the anterior teeth, wingless on the premolars. **D,** Mandibular arch of the same patient. Many of the smaller mandibular teeth were prepared with wingless restorations. Because of previously existing restorations, excessively heavy shoulder-like chamfers resulted on some of the posterior teeth.

STUDY QUESTIONS

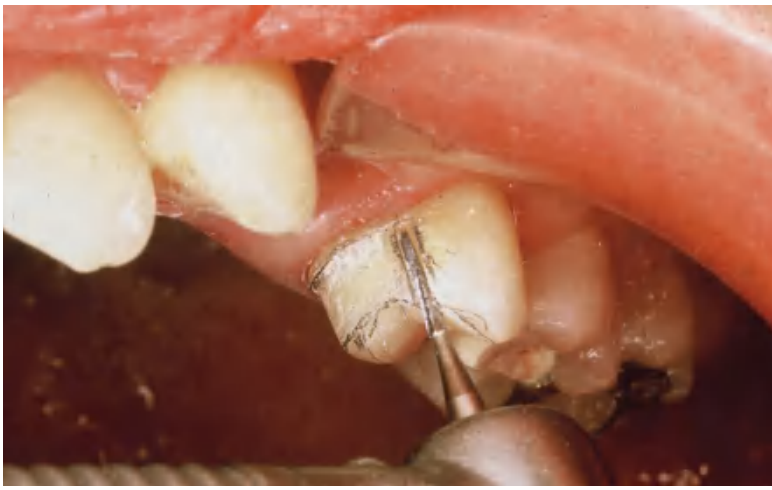
1. What are the indications and contraindications for metal-ceramic crowns?
2. What are the advantages and disadvantages of metal-ceramic crowns?
3. What is the recommended armamentarium, and in what sequence should a maxillary central incisor be prepared, for a metal-ceramic crown?
4. What are the minimal criteria for steps 1, 2, and 3? Why?
5. Discuss how to determine the buccolingual position of a proximal groove to precisely obtain the desired position of the facial finish line.

SUMMARY CHART
METAL-CERAMIC CROWN

Indications	Contraindications	Advantages	Disadvantages
Esthetics	Large pulp chamber	Superior esthetics in comparison with complete cast crown	Removal of substantial tooth structure
If all-ceramic crown is contraindicated	Intact buccal wall	–	Subject to fracture because porcelain is brittle
Gingival involvement	When more conservative retainer is technically feasible	–	Difficult to obtain accurate occlusion in glazed porcelain Shade selection can be difficult Inferior esthetics in comparison with all-ceramic crown Expensive
Esthetics	Large pulp chamber	Superior esthetics as compared to complete cast crown	Removal of substantial tooth structure

Preparation steps	Recommended armamentarium	Criteria
Incisal (occlusal) reduction guide grooves	Tapered, round-tipped diamond	1.5 to 2 mm of clearance in intercuspal positions and all excursions
Incisal (occlusal) reduction	Tapered, round-tipped diamond	1.2 to 1.5 mm of reduction for metal and porcelain (see Fig. 9-1)
Labial reduction guide grooves (two plane)	Tapered, round-tipped diamond	6 degrees of convergence, as measured as the angle between opposing axial walls
Labial reduction (two plane)	Tapered, flat-tipped diamond	Should provide 1 mm of clearance in all excursions and intercuspal positions (≥1.5 mm if occlusal is porcelain)
Axial reduction	Tapered, round-tipped diamond	Shoulder must extend at least 1 mm lingual to proximal contact area; bevel, if selected, should be as far incisal as possible in relation to epithelial attachment
Lingual reduction	Football-shaped diamond	All line angles rounded and preparation surfaces smooth
Finishing of shoulder (or beveled shoulder)	Tapered, flat-tipped diamond	–
Finishing	Hand instrument Tapered, round-tipped diamond or carbide	–
Incisal (occlusal) reduction guide grooves	Tapered, round-tipped diamond	1.5 to 2 mm of clearance in intercuspal positions and all excursions

10



THE PARTIAL VENEER CROWN, INLAY, AND ONLAY PREPARATIONS

An extracoronal metal restoration that covers only part of the clinical crown is considered to be a partial veneer crown. It can also be referred to as a *partial-coverage restoration.* An intracoronal cast metal restoration is called an *inlay* or an *onlay* if one or more cusps are restored. Examples of these restorations are presented in Figure 10-1. Partial veneer crowns generally include all tooth surfaces except the buccal or labial wall in the preparation. Whenever feasible, a partial-coverage restoration should be selected, rather than a complete veneer, because it preserves more of the tooth's coronal surface. However, the preparation is more demanding and is not routinely provided by practitioners. Buccolingual displacement of the restoration is prevented by internal features (e.g., proximal boxes and grooves). The partial veneer can be used as a single-tooth restoration, or it may serve as a retainer for a fixed dental prosthesis (FDP). It can be used on both anterior and posterior teeth. Because it does not cover the entire coronal surface, it tends to be less retentive than a complete crown and is less resistant to displacement. Unless the partial veneer is very carefully prepared, the reduced retention may contraindicate its use. Inlays and onlays are even less retentive than partial veneer crowns and are not recommended for FDP retainers. However, they provide the advantages of a casting, with less enamel removal than for a crown. When carefully prepared, they can produce an exceptionally long-lasting restoration.

PARTIAL VENEER CROWNS

Several types of partial veneers exist: for posterior teeth, three-quarter, modified three-quarter, and seven-eighths crowns; for anterior teeth, three-quarter crowns and pinledges.

The indications, contraindications, advantages, and disadvantages of partial veneer crowns are described first, and any specific deviations that pertain to a given preparation are identified with that type.

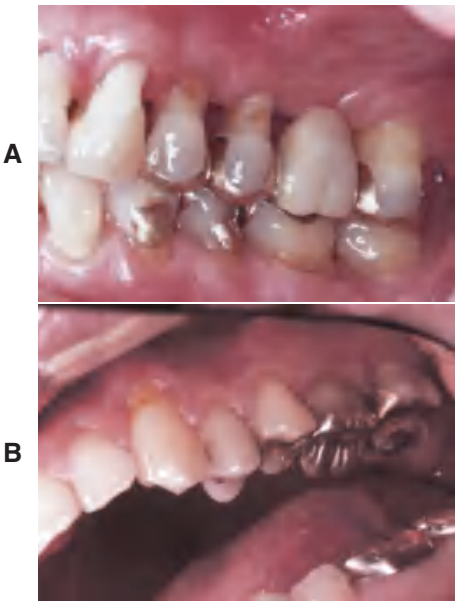


Fig. 10-1
A, Partial veneer crowns serving as retainers on the premolars for a four-unit fixed dental prosthesis replacing the maxillary first molar. **B,** Maxillary premolars restored with gold inlays, and molar restored with gold onlay. These restorations have served for about 35 years.

Indications

Partial veneer crowns often can be used to restore posterior teeth that have lost moderate amounts of tooth structure, if the buccal wall is intact and well supported by sound tooth structure. They are also commonly used as retainers for an FDP or where restoration or alteration of the occlusal surface is needed. Anterior partial veneers are rarely suitable for restoring damaged teeth, but they can be used as retainers, to reestablish anterior guidance, and to splint teeth. They are particularly suitable for teeth with sufficient bulk because they can accommodate the necessary retentive features.

Contraindications

Partial veneer restorations are contraindicated on teeth that have a short clinical crown because retention may not be adequate. They are also contraindicated as retainers for long-span FDPs. They are rarely suitable for endodontically treated teeth, especially anterior teeth, because insufficient supporting tooth structure remains for the retentive features. Likewise, they should not be used on endodontically treated posterior teeth if the buccal cusps are weakened by the access cavity or on teeth with an extensively damaged crown. As is true of all cast restorations, partial veneer restorations are contraindicated in dentitions with active caries or periodontal disease.

The shape and alignment of teeth are important determinants of the feasibility of partial veneer crowns. The alignment of axial surfaces should be evaluated, and partial veneer crowns should not be placed on teeth that are proximally bulbous. Making the necessary proximal grooves on these teeth is likely to leave unsupported enamel. It may be similarly impossible to prepare adequate grooves on thin teeth of restricted faciolingual dimension.

Partial veneer crowns are usually prepared parallel to the long axis of the tooth, and poorly aligned abutment teeth may not be suitable. When poorly aligned teeth are being prepared for a partial-coverage restoration, problems with unsupported enamel often result.

Advantages

The primary advantage associated with partial veneer crowns is conservation of tooth structure. Another advantage is reduced pulpal and periodontal insult during tooth preparation. Access to supragingival margins is rather easy and allows the operator to perform selected finishing procedures that are more difficult or impossible with complete coverage restorations. Access is also better for oral hygiene. Because less of the margin approximates the soft tissues subgingivally, there is less gingival involvement than with complete coverage.

During cementation of a partial veneer, the luting agent can escape more easily, which produces relatively good seating of the restoration. Because of direct visibility, verification of seating and cement removal are simple. When the restoration is in service, the remaining intact facial or buccal tooth structure permits electric vitality testing.

Disadvantages

Partial veneer restorations have less retention and resistance than do complete cast crowns. Preparing the tooth for this type of coverage is difficult, primarily because only limited adjustments can be made in the path of placement. The preparation of grooves, boxes, and pinholes requires dexterity of the operator. Some metal is displayed in the completed restoration, which may be unacceptable to patients with high cosmetic expectations.

Preparation

The following discussions cover the teeth most commonly prepared for partial veneer restorations. The

use of partial veneers on anterior teeth has declined because of the difficulty in achieving an esthetic result. The technique illustrated may be suitable for posterior teeth and, with minimal variation, for other teeth. On both posterior and anterior teeth, meticulous care and precision are required if partial veneer restorations are to be a successful (conservative) alternative to complete-coverage restorations.

Armamentarium

The necessary instruments for a partial veneer crown preparation include the following (Fig. 10-2):

- Narrow (approximately 0.8 mm), round-tipped, tapered diamond (regular or coarse grit)
- Regular-size (approximately 1.2 mm), round-tipped, tapered diamond (fine grit) or carbide
- Football-shaped or wheel-shaped diamond (regular grit)
- Tapered and straight carbide fissure burs
- Small, round carbide bur
- Small-diameter twist drill
- Inverted-cone carbide bur
- Finishing stones
- Mirror
- Explorer and periodontal probe
- Chisels

This is the typical armamentarium for a partial veneer crown preparation. Depending on operator preference, additional instruments can be used. The regular- or coarse-grit diamonds are used for bulk reduction, and the fine-grit diamonds or carbides are used for finishing. Pinholes are prepared with the twist drill and finalized with a tapered carbide. The fissure burs are recommended for preparing boxes and ledges, and the inverted-cone carbide is recommended for preparing incisal offsets. Hand instruments can be used to finish proximal flares and bevels. A periodontal probe is invaluable for assessing the direction and dimension of the various steps.



Fig. 10-2
Armamentarium for a partial veneer crown preparation.

Posterior Partial Veneer Crown Preparations

Maxillary premolar three-quarter crown

The three-quarter crown preparation (Fig. 10-3) derives its name from the number of axial walls involved. Except for a slight bevel or chamfer placed along the bucco-oclusal line angle, the buccal tooth surface remains intact. The other surfaces (including the occlusal surface) are prepared to accommodate a casting in the same manner as a complete crown preparation (see Chapter 8), differing only in the need for axial retention grooves.

Occlusal reduction

Upon the completion of occlusal reduction, a clearance of at least 1.5 mm should exist on the functional cusp and at least 1.0 mm on the nonfunctional cusp and in the central groove. Simultaneously, the tooth should be prepared so that the restoration displays a minimum of metal, with preservation of the buccal wall outline.

1. Before any partial veneer crown preparation, mark the proposed location of the margin of the completed preparation on the tooth with a pencil (Fig. 10-4).
2. Place depth grooves for the occlusal reduction. These should be made with a tapered carbide or narrow diamond in the developmental grooves of the mesial and distal fossae and on the crest of the triangular ridge. In the central groove, they should be slightly less (about 0.2 mm) than 1 mm deep to allow for finishing; on the functional (lingual) cusp they should be slightly less than 1.5 mm deep in the location of the occlusal contacts.
3. Place three depth grooves on the lingual incline of the buccal cusp. Initially, these should be kept somewhat shallow as they approach the buccal cusp ridge (see Fig. 10-3*B*). In the area of occlusal contact, the groove should be about 0.8 mm deep so that there will be at least 1 mm of clearance after finishing.
4. Verify groove depth with a periodontal probe. When this is found to be acceptable, remove the islands of tooth structure remaining between the grooves (see Fig. 10-3*C* and *D*).
5. Assess the amount of occlusal clearance in maximum intercuspation and in all excursive movements of the mandible (Fig. 10-5). Grinding a small concavity on the incline of the buccal cusp may help obtain sufficient clearance while maintaining the original occlusocervical dimension of the buccal tooth surface (Fig. 10-6).

Axial reduction

6. Place grooves for axial alignment in the center of the lingual surface and in the mesiolingual

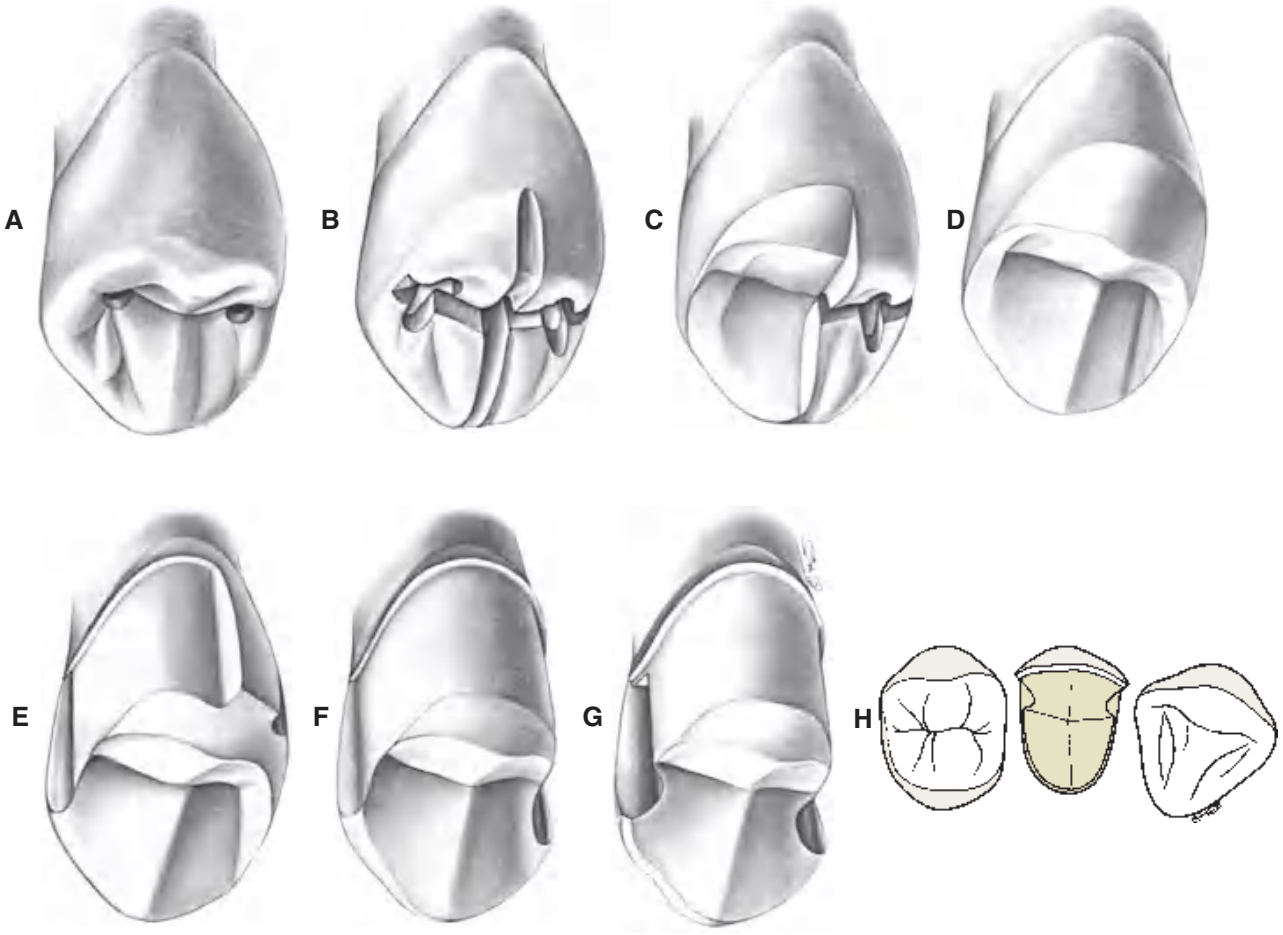


Fig. 10-3
The maxillary premolar three-quarter crown. **A,** Initial depth holes are placed in the mesial and distal fossae approximately 0.8 mm deep. **B,** They are connected by a guiding groove that extends through the central groove. Additional guiding grooves are placed on the lingual cusp similar to those for a complete cast crown (see Fig. 8-8). The depth cut placed on the triangular ridge of the buccal cusp becomes shallower as it approaches the cusp tip. **C,** Half the occlusal reduction is completed. Note the functional cusp bevel. The occlusocervical height of the buccal surface is not reduced at this stage. **D,** Occlusal reduction completed. **E,** After guiding grooves are placed in the lingual surface of the tooth parallel to the proposed path of placement, the proximoaxial and linguoaxial reductions are initiated. Simultaneously, a smooth and even-width cervical chamfer is created. **F,** When the axial reduction of the first half is considered acceptable, the other half can begin. **G,** Proximal grooves are placed perpendicular to the prepared surface, and the buccal wall of each groove is flared to leave no unsupported enamel. The proximal flares are connected with a narrow contrabevel. After rounding of the line angles, the preparation is complete. **H,** The interproximal clearance relative to adjacent teeth extends cervically as well as near the occlusal aspect of the buccal flares of the proximal grooves.



Fig. 10-4
The anticipated location of the completed preparation is marked with a pencil.

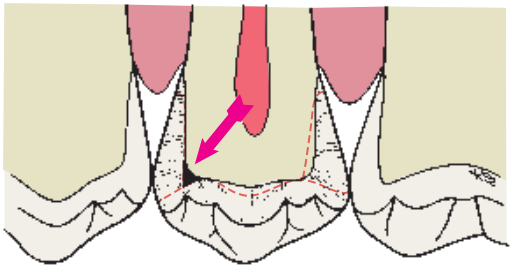


Fig. 10-5
A common error is insufficient reduction of tooth structure in the marginal ridge area (*arrow*).

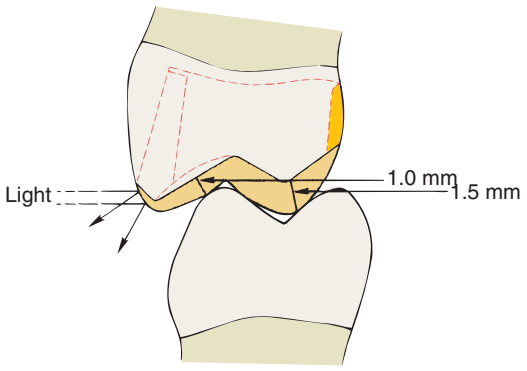


Fig. 10-6
Recommended minimum clearances for reduction of a partial veneer crown preparation. Slight hollow grinding of the lingual incline of the buccal cusp results in an acceptable clearance with the least display of metal. Also, the final restoration retains the normal contours of the cuspal ridge, so that incident light is not reflected and the restoration is less evident.



Fig. 10-7
Proximal and lingual axial reduction is performed with a round-tipped diamond. The proximal reduction is stopped short of the proposed location of the buccal margin.

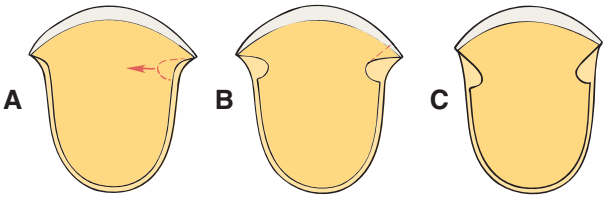


Fig. 10-8
A, Upon completion of the proximal axial reduction, a groove is placed perpendicular to the prepared surface. **B,** Note that some unsupported tooth structure remains at the cavosurface angle. **C,** After the buccal wall of the proximal groove is flared, no unsupported tooth structure remains. *Note:* It is important to anticipate in advance the influence of the buccal extent of the proximoaxial reduction (**A**) on the ultimate location of the margin (**C**).

and distolingual transitional line angles. These should be parallel to the long axis of the tooth and should not exceed half the width of the tip of the diamond used to place them.

7. Because the path of placement of a partial veneer is crucial, assess these grooves carefully when correction is still possible. A common error is to incline the path of placement toward the buccal. This either reduces retention or leads to an excessive display of metal. A periodontal probe placed in each groove should be carefully viewed in both planes (mesiodistal and buccolingual). It often helps to pour an irreversible hydrocolloid (alginate) impression in fast-setting plaster and to evaluate the cast with a dental surveyor, particularly if multiple partial veneers are being used as retainers for an FDP.
8. After verifying the alignment, remove tooth structure between the guide grooves (with a smooth continuous motion) and place a cervical chamfer (Fig. 10-7).
9. Carry the diamond into the proximal embrasure and reduce the proximal wall (see Fig. 10-3*E* and *F*). For proper reduction of the axial tooth surface, it is important to understand the factors that determine correct positioning of the proximal groove. A proximal groove is placed parallel to the path of placement. Normally, unsupported tooth structure remains on the buccal side of the groove, and this side is flared to remove it. Figure 10-8 illustrates the relationship among the initial axial reduction, groove placement, and location of the cavosurface angle where the flare meets the intact buccal wall. The cavosurface angle is especially significant when a tooth is prepared for a partial veneer that should display a minimum of metal; the farther to the buccal the margin is, the more gold is visible. A subtle but extremely important variable that determines the final location of the cavosurface angle is the apical extension of the preparation. As the cervical chamfer extends closer to the cementoenamel junction, more axial tooth structure is removed. Consequently, the deepest portion of the groove (its pulpal wall) is located slightly closer to the center of the tooth. This results in a flare that can extend farther onto the facial or buccal surface than desirable. Marking the location of the intended facial flare on the tooth with a pencil before initiating the proximoaxial reduction is helpful. The intersection of this mark with the reduced occlusal surface is a convenient reference point.
10. Stop the proximal reduction well short of the pencil mark and usually slightly short of break-



Fig. 10-9
The distal proximal reduction is stopped before breaking proximal contact. After groove placement and subsequent flaring, interproximal clearance results.

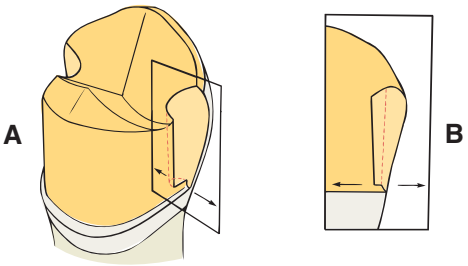


Fig. 10-10
Because of the rotary instrument's taper, the proximal groove is deeper near the occlusal table (**A**). The floor of the groove should be flat and smooth. Often the proximal chamfer extends slightly cervically to the floor of the groove. If only minimal difference exists, as in **B**, the cervical margin adjacent to the groove can be beveled. The recommended occlusocervical height for a proximal groove is 4 mm.

ing the proximal contact (Fig. 10-9). The resulting flange should be parallel to the linguoaxial preparation, with the chamfer placed sufficiently cervical to provide at least 0.6 mm of clearance with the adjacent tooth and the axial wall allowing for a proximal groove of at least 4 mm of length occlusocervically (see Fig. 10-3*F*).

Groove placement

Preparation of the proximal grooves is best done with a tapered carbide bur.

11. Position the bur against the interproximal flange parallel to the path of placement and make a groove perpendicular to the axial surface. The groove need not be deeper than 1 mm at its cervical end but may be deeper near its occlusal end (Fig. 10-10). During this stage, the bur must be held precisely parallel to the selected path of placement. Allowing it to tip axially results in excessive taper between opposing proximal grooves, which is a common error. The criteria that need to be met consist of the following (Fig. 10-11; see also Fig. 10-9):

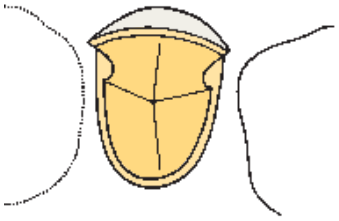


Fig. 10-11
The 90-degree angle between the lingual walls of the proximal grooves and the axial walls resists lingual displacement. Because the buccal aspect of the grooves has been adequately flared, no unsupported tooth structure remains.

- The grooves should resist lingual displacement of a periodontal probe or explorer.
- The walls of the grooves should not be undercut in relation to the selected path of placement.
- The walls should be flared toward the intact buccal surface of the tooth (see Fig. 10-3*G* and *H*).

Depending on available access, it may be feasible to complete the flaring with the same rotary instrument that was used to place the groove (Fig. 10-12). However, removing the last lip of unsupported tooth structure with a chisel is often a better option, because this minimizes the risk of damage to the adjacent tooth.

Bucco-occlusal contrabevel

12. Connect the mesial and distal flares with a narrow contrabevel that follows the buccal cusp ridges. This can be placed with a diamond, a carbide, or even a hand instrument. Its primary purpose is to remove any unsupported enamel and thereby protect the buccal cusp tip from chipping during function. If group function is planned (as opposed to a mutually protected occlusion), a heavier bevel, chamfer, or occlusal offset is needed, because tooth contact occurs in this area during excursive movement. The bevel should remain within the curvature of the cusp tip rather than extend onto the buccal wall (Fig. 10-13). This results in a convex shape of the restoration, and light is prevented from reflecting back to a casual observer (see Fig. 10-6). Thus, the restoration is less obvious, and the outline form of remaining buccal enamel is perceived as the shape of the tooth.

Occlusal offset

If additional bulk is needed to ensure rigidity of the restoration, it can be provided with an occlusal offset. This V-shaped groove extends from the proximal grooves along the buccal cusp. It is not usually necessary for posterior partial veneer crowns but is essential for the structural durability of anterior



Fig. 10-12
A, Initial preparation of the mesial proximal groove. Note that the carbide is oriented parallel to the path of placement as dictated by the lingual surface of the tooth. **B,** Initial flaring has resulted in elimination of most unsupported tooth structure. **C,** Hand or rotary instruments are used to refine these proximal flares and remove all unsupported enamel.

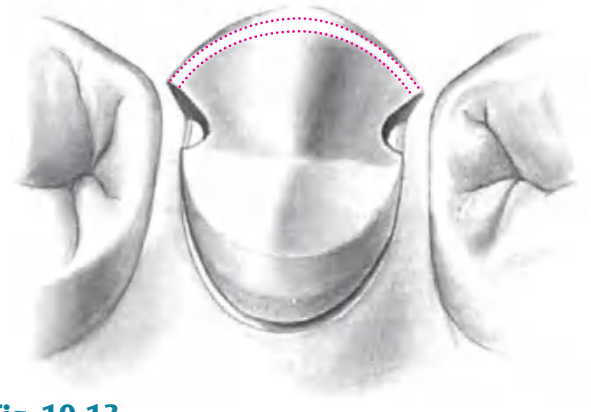


Fig. 10-13
The buccoclusal contrabevel remains within the curvature of the cusp tip rather than extending onto the buccal surface.

partial veneer crowns. This is described in detail on p. 301.

Finishing

13. Round all sharp internal line angles to facilitate subsequent procedures. A fine-grit diamond or carbide can be used to blend the surfaces (Fig. 10-14).
14. Reevaluate the flares, paying particular attention to any remaining undercuts, which must be removed. The flares should be straight and smooth, with sufficient clearance between them and the adjacent tooth. A minimum clearance of 0.6 mm is recommended. The mesial flare cannot extend beyond the transitional line angle. However, because the distal margin is less visible, it may extend slightly farther to the buccal margin, allowing better access for oral hygiene.



Fig. 10-14
A and **B,** A fine-grit diamond in a low-speed contra-angle is used to place the bucco-occlusal contrabevel connecting the mesioproximal and distoproximal flares.

Maxillary molar three-quarter crown

The principles used in a premolar preparation also apply for a maxillary molar (Figs. 10-15 and 10-16). However, some additional leeway may exist for groove placement because more tooth structure is present on molars than on premolars. Also, because of their less prominent position in the dental arch, molars are less visible. As a result, the mesioproximal flare can sometimes be extended onto the buccal surface without spoiling the esthetics.



Fig. 10-15
Three-quarter crown preparation on a maxillary molar. Note that the occlusal reduction follows normal anatomic form.

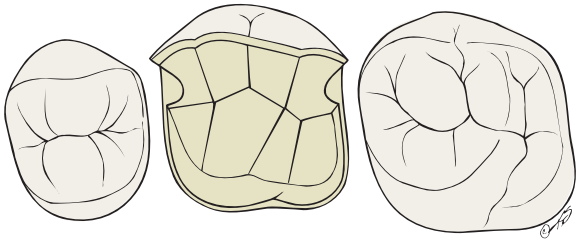


Fig. 10-16
The three-quarter crown preparation on a maxillary first molar.

Maxillary molar seven-eighths crown

The seven-eighths crown preparation (Fig. 10-17) includes, in addition to the surfaces covered by the three-quarter crown, the distal half of the buccal surface. Therefore, the mesial aspect of this preparation resembles that for a three-quarter crown; the distal aspect resembles that for a complete crown. The mesial half of the buccal tooth surface remains intact and is protected by a narrow contrabevel or chamfer similar to the one used in the three-quarter crown preparation. A distal groove may be placed, although generally this is not necessary. A groove in the middle of the buccal surface is placed parallel to the path of placement. Distal to this groove, the buccal surface is reduced in two planes, cervical and occlusal; the cervical plane parallels the path of placement, and the occlusal plane follows the normal anatomic contour. The lingual surface of the tooth also is reduced in two planes, and functional cusp bevels are incorporated.

Occlusal reduction

Upon completion of the occlusal reduction, adequate clearance should exist in all excursive movements of the mandible. Minimum measurements are the same as for the three-quarter crown preparation.

1. Place depth grooves in the central and developmental grooves, as well as on the crests of the triangular ridges. To delineate the extent of the lingual functional cusp bevel, they should extend onto the lingual surface of the tooth. On the lingual incline of the mesiobuccal cusp, they resemble depth cuts for the three-quarter crown preparation. On the distobuccal cusp, they should be approximately 0.8 mm deep to provide sufficient occlusal clearance for this nonfunctional cusp (see Fig. 10-17*A*).
2. Remove the tooth structure between the depth grooves. Concave shaping of the resulting mesiobuccal incline may again prove useful because it enables the occlusocervical height of the cusp to be maintained. When completed, this bevel should provide 1.5 mm of clearance in maximum intercuspation, as well as throughout all excursive movements of the mandible (see Fig. 10-17*B* and *C*).

Axial reduction

In principle, the steps for axial reduction follow those for occlusal reduction.

3. Place three alignment grooves in the lingual wall and transfer the selected path of placement to the distobuccal transitional line angle area, where a fourth alignment groove can be placed.
4. Start the reduction in the middle of the lingual surface. The mesial half is prepared in the same way as for a three-quarter crown and the distal half as for a complete crown (see Fig. 10-17*D*).
5. Carry the facial reduction sufficiently mesial to include the buccal groove. Occlusally the buccal surface of maxillary molars is rather flat, therefore some additional reduction may be necessary in the occlusal third. This follows the normal anatomic configuration of the tooth and often resembles a small version of the functional cusp bevel. If correctly performed, the reduction allows for contouring of the restoration so that when viewed from the mesial aspect, the distal half of the restoration is hidden behind the mesiobuccal cusp. A frequent error is to overtaper the buccal wall segment, with resulting loss of retention.

Groove placement, flaring, and contrabevel

6. Prepare the mesial groove in the same way as for the three-quarter crown (see Fig. 10-17*E* and *F*).
7. Place the buccal groove parallel to the mesial groove and perpendicular to the buccoaxial wall.



Fig. 10-17

The maxillary molar seven-eighths crown preparation. **A,** Occlusal depth grooves. On the lingual of the mesiobuccal cusp, they are identical to grooves for any functional cusp. On the buccal, note their difference from grooves placed on the triangular ridges. The mesial groove becomes shallower as it approaches the cuspal ridge; the distal extends through the cuspal ridge. **B,** Mesial half of the occlusal reduction is completed. Normal occlusal form can be recognized in the reduced area. **C,** Occlusal reduction completed. **D,** Distal half of the axial reduction completed. This is comparable to the preparation for a complete cast crown. The rotary instrument is moved parallel to the guiding grooves placed in the lingual tooth surface. **E,** Mesial half of the axial reduction completed and a proximal groove placed. **F,** The buccal groove, with flaring of the mesial groove. Note the monoplane of the flare, extending from the deepest portion of the groove to the cavosurface angle. **G,** A contrabevel connects the mesial flare with the buccal groove. The mesial wall of the buccal groove is smooth and has a 90-degree cavosurface angle, leaving no unsupported enamel.

It is often not necessary to flare the buccal groove because the flat configuration of this area of the tooth precludes any unsupported enamel after the groove is placed. The buccal groove should resist mesiodistal displacement of a probe.

8. Connect the two grooves with a smooth contrabevel that follows the ridge of the mesiobuccal cusp (see Fig. 10-17G). This bevel should meet the same criteria as described in the three-quarter crown preparation. Adequate clearance must be established interproximally upon completion (Fig. 10-18). All surfaces are finished to the same specifications as the preceding preparations (Fig. 10-19).

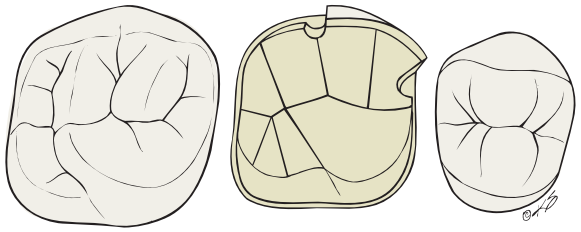


Fig. 10-18
The seven-eighths crown preparation. Note that adequate clearance has been established. From this perspective, it is evident why little or no flaring is necessary for the buccal groove, as opposed to the considerable flaring needed for the mesial groove.

Mandibular premolar modified three-quarter crown

Mandibular partial veneer preparations (Fig. 10-20) are made more often on premolars than on molars. They differ from maxillary molar three-quarter crown preparations in two respects: (1) Additional retention is required because of the shorter crown lengths of mandibular teeth. This can be obtained by extending the preparation buccally, although because of their rather prominent position in the dental arch, these teeth should be modified only distal to their height of contour (Fig. 10-21). (2) The axial surface that is not prepared (the buccal) includes the functional cusp. This means that additional tooth structure must be removed to provide sufficient bulk of metal for strength.

Occlusal reduction

1. Place 0.8-mm depth grooves on the buccal inclines of the lingual cusp and 1.3-mm grooves on the lingual inclines of the buccal cusp (see Fig. 10-20*A* and *B*). These guiding grooves are once again placed to follow the basic groove and fissure pattern of the occlusal surface. Only one depth cut needs to be placed to accommodate the functional cusp bevel on the distal aspect of the distal ridge.

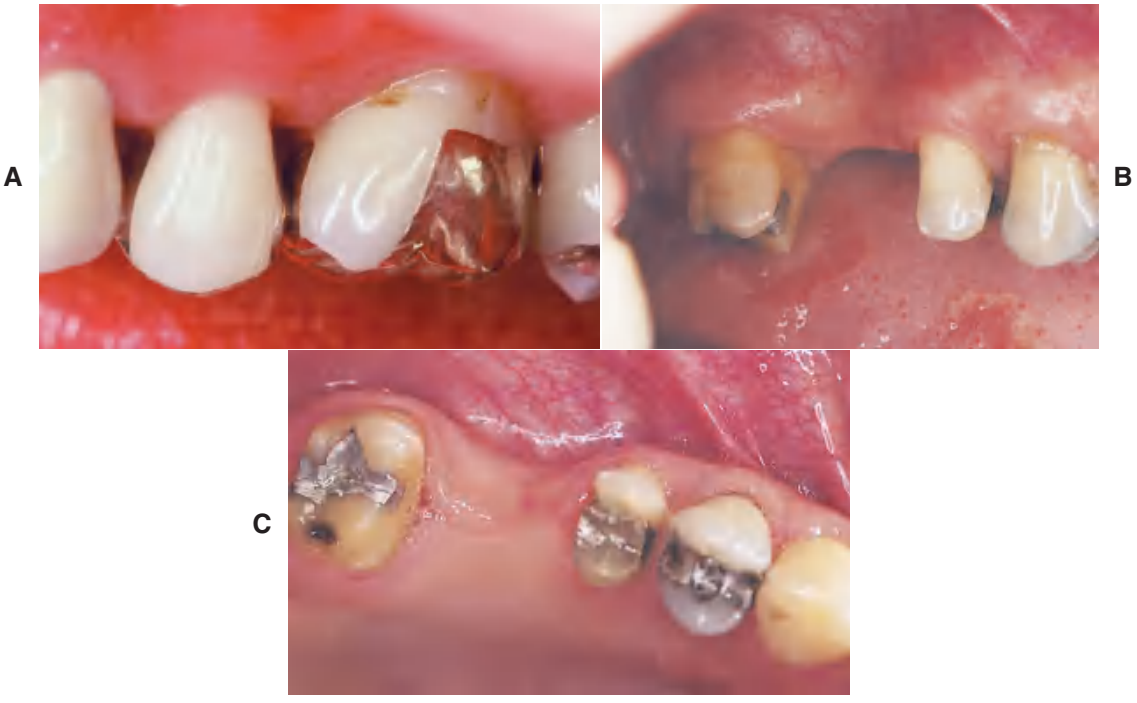


Fig. 10-19
A, Three-quarter crown restoring maxillary premolar and seven-eighths crown restoring maxillary molar. **B** and **C,** Fixed dental prosthetic retainers: a seven-eighths crown as the distal and a three-quarter crown as the mesial.

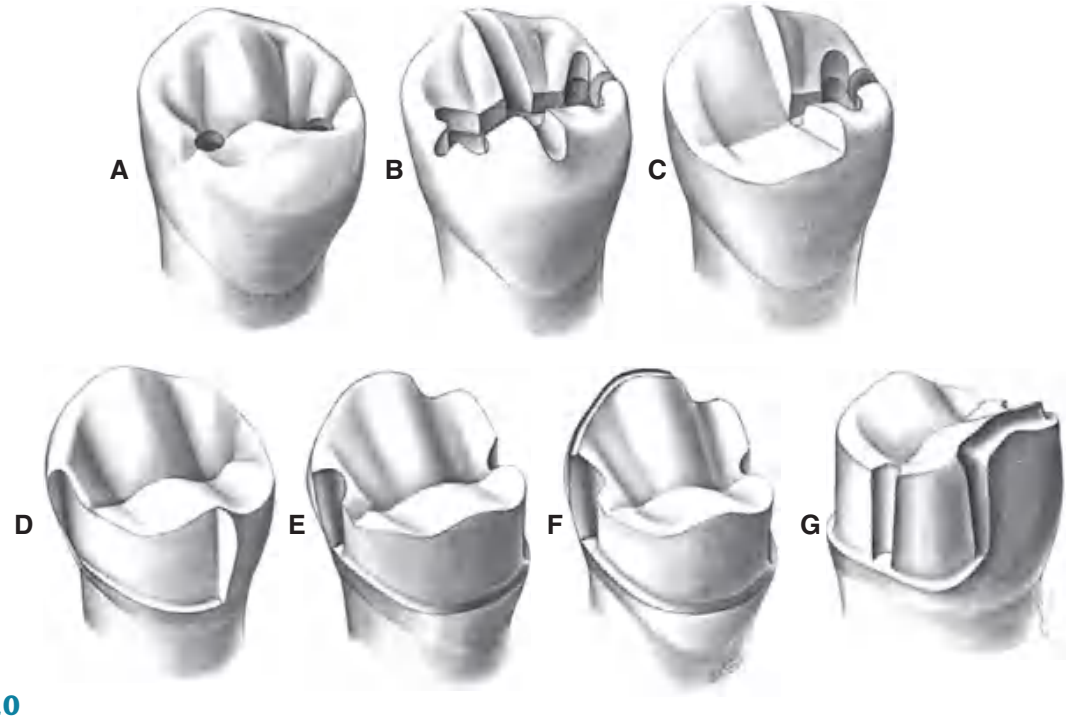


Fig. 10-20
The mandibular premolar modified three-quarter crown preparation. **A,** Depth holes placed in the mesial and distal fossae approximately 0.8 mm deep. **B,** The holes are connected by a guiding groove that extends through the central groove and the mesial and distal marginal ridges. Guiding grooves are also placed in the buccal and lingual triangular ridges, extending through the cuspal ridges on both sides. **C,** Half the occlusal reduction is completed. **D,** Occlusal reduction and mesial half of the axial reduction are completed. **E,** Axial reduction is completed. The proximal grooves have been placed. Note that the distal groove is close to the buccolingual center of the tooth. This enables retention of considerable tooth structure in the area of the distobuccal line angle, enhancing the resistance form of the preparation. **F,** The mesial groove has been flared and the functional cusp chamfer placed. **G,** Facial view. There is considerable width of the chamfer on the functional cusp. Note that the distobuccal cervical margin angles occlusally as it progresses mesially. This enables a more conservative tooth preparation in the area of the distobuccal modification that is placed to improve resistance form.



Fig. 10-21
Modified three-quarter crown restoring a mandibular second premolar. **A, B,** and **C,** The three-quarter crown is serving as the anterior retainer for a three-unit fixed dental prosthesis. Because the distobuccal modification remains in the distal fourth of the buccal preparation, it is hidden behind the normal height of contour of the buccal tooth surface. Note the considerable thickness of gold that protects the buccal cusp.

2. Reduce the occlusal surface by removing the tooth structure between the grooves (see Fig. 10-20*C*).

Axial reduction

3. Place guiding grooves on the lingual surface to parallel the proposed path of placement and the long axis of the tooth.
4. Prepare the mesial half as already described for the three-quarter and seven-eighths crown (see Fig. 10-20*D*).
5. Reduce the distal surface as for a complete crown, extending the preparation to the transitional line angle and onto the buccal surface. However, it should not extend mesially beyond the middle of

the distal half of the buccal surface, and the chamfer should not extend too far cervically; otherwise, the distobuccal line angle is unnecessarily reduced, which would decrease the resistance form (see Fig. 10-20*E*).

Finishing

The modified three-quarter crown preparation can include two or three grooves.

6. Place the mesial and buccal grooves as described for the seven-eighths crown (see Fig. 10-20*F*). Another distal groove may be placed. In general, to gain as much length as possible, the grooves of the three-quarter crown should be slightly buccal. Care must be taken so that the distal groove is slightly closer to the center of the distal wall (so that the distobuccal line angle is not undermined).
7. Connect the mesial and buccal grooves with a functional cusp chamfer after the grooves and mesial flare have been placed and evaluated. The chamfer must be heavy enough to allow 1.5 mm of clearance in the area of occlusal contact (see Fig. 10-20*G*). A regular or thick diamond is used to place the chamfer, which should connect the grooves and provide a protective "staple" linkage of alloy in the completed restoration. Insufficient tooth reduction where this chamfer meets the mesial flare is a common error. Finally, all prepared surfaces are smoothed and the internal line angles rounded.

Anterior Partial Veneer Crown Preparations

As stated, with the advent of metal-ceramic restorations, the use of partial veneer restorations on anterior teeth has become rare. Nevertheless, two anterior partial veneer crown preparations, the maxillary canine three-quarter crown and the pinledge, are worthy of consideration (Figs. 10-22 and 10-23).

Maxillary canine three-quarter crown

The three-quarter crown on a maxillary canine (Figs. 10-24 and 10-25) is probably one of the most demanding of all tooth preparations. As with such preparations on other teeth, on a maxillary canine it involves the proximal and lingual surfaces and leaves the facial surface intact. However, the greater degree of difficulty stems from the different shape of the canine tooth. Unless the placement of grooves is determined very precisely in advance, there is an undesirable display of metal in the interproximal embrasures (see Fig. 10-25*A* and *B*). The relatively short proximal walls do not allow much correction after initial groove placement. Similarly, the greater degree of curvature in each proximal wall immediately adjacent to the contact area significantly influences the location of the preparation's facial margin.

Incisal and lingual reduction

1. Remove enough enamel to allow 1 mm of metal thickness. The design of the incisal bevel should prevent contact between opposing teeth and the incisal margin. However, the original configuration of the facial surface should be preserved without significant incisal reduction of the tooth. Outlining the anticipated location of the margin with a pencil can be helpful.
2. Place depth grooves for both the incisal bevel and the lingual reduction (see Fig. 10-24*A*). The direction of the bevel may vary somewhat, depending on the configuration of the tooth. In general, it makes an angle of approximately 45 degrees with the long axis of the tooth.
3. After the depth has been verified, perform the reduction. A football- or wheel-shaped diamond is



Fig. 10-22

A, Deficient anterior guidance resulting from years of parafunctional activity. **B,** An anterior partial veneer crown has reestablished guidance, allowing the intact sound labial tooth structure to be retained as a conservative alternative to a metal-ceramic restoration.

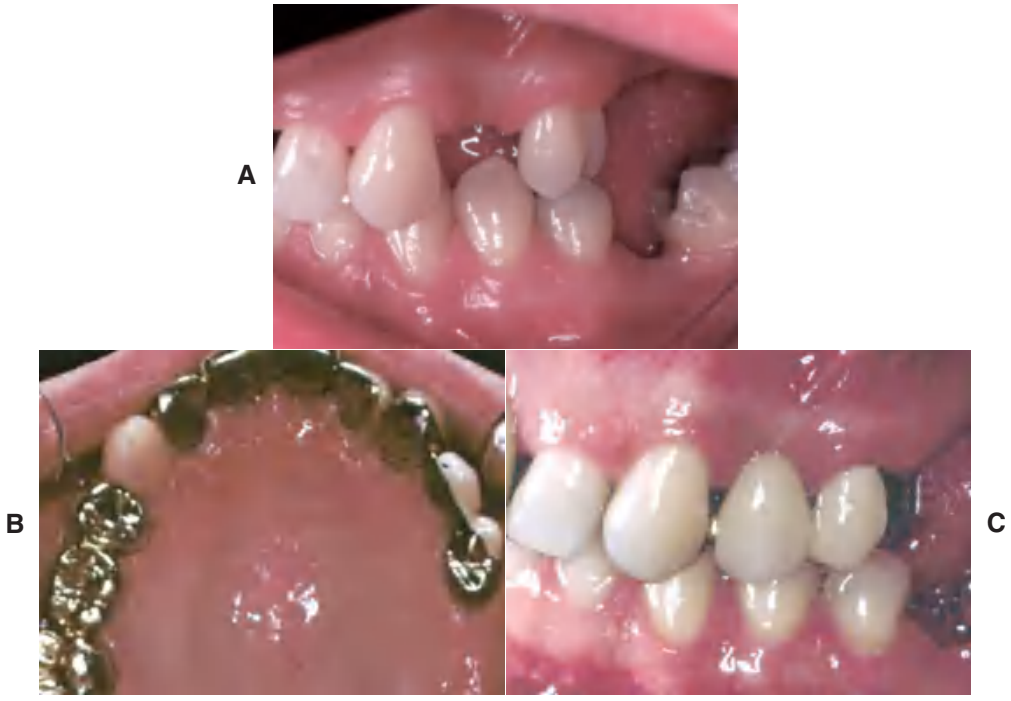


Fig. 10-23

A, Caries-free canine and lateral incisor of adequate bulk: excellent candidates for anterior partial veneer crowns. **B,** The canine restored with a three-quarter crown, serving as the anterior retainer for a three-unit fixed dental prosthesis (FDP) to replace the first premolar. The lateral incisor has been restored with a modified pinledge that serves as a retainer for an anterior four-unit FDP. **C,** Satisfactory esthetics with minimal display of metal are apparent.

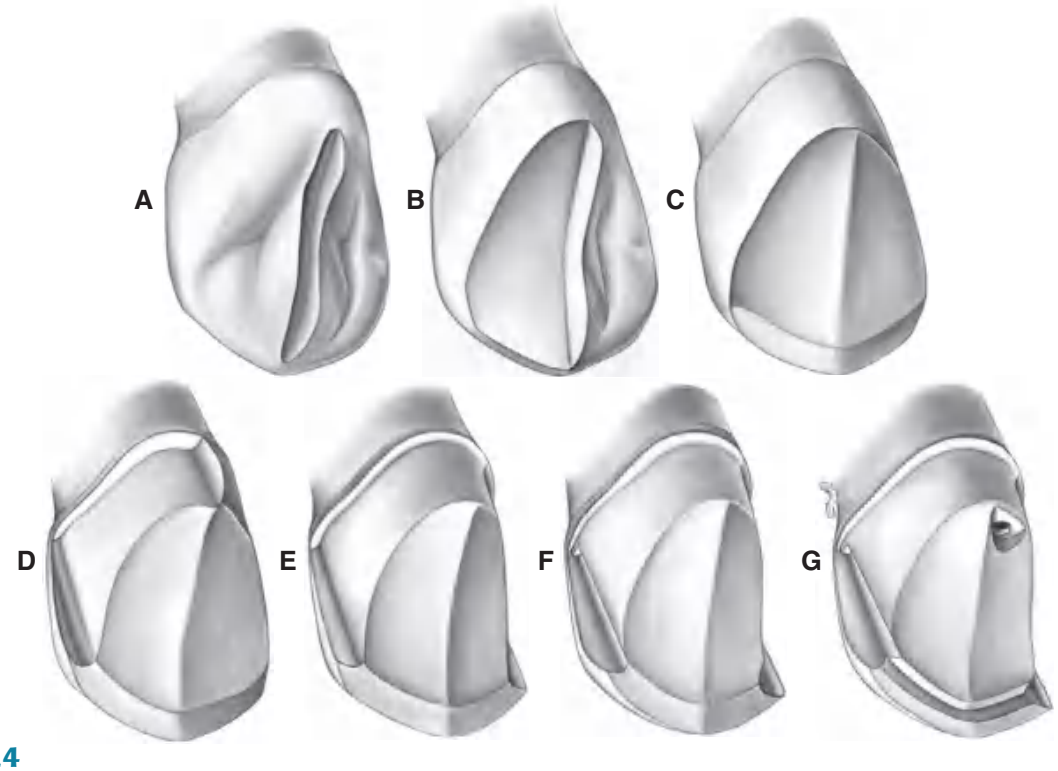


Fig. 10-24

The maxillary canine three-quarter crown preparation. **A,** A guiding groove is placed on the lingual surface. **B,** Half the lingual surface is reduced. Clearance is verified before reduction of the other half. **C,** Lingual reduction is completed, with an incisal bevel placed. No significant change has occurred in the incisocervical height. **D,** After an alignment groove is placed in the center of the cingulum wall, half the axial reduction is complete. Note that the path of placement parallels the incisal or middle third of the labial surface. As a result, the lingual chamfer is quite wide, perhaps even resembling a shoulder. This permits paralleling of the cingulum wall, with the proximal grooves and pinhole providing additional retention. **E,** Axial reduction is completed. Any final modification of the path of placement is done at this time before groove placement. **F,** Proximal grooves. The visible mesial groove has been flared, but unsupported enamel remains on both grooves where they meet the incisal bevel. **G,** Completed preparation. The lingual pinhole is surrounded by adequate dentin. Note the horizontal ledge prepared before pinhole placement.

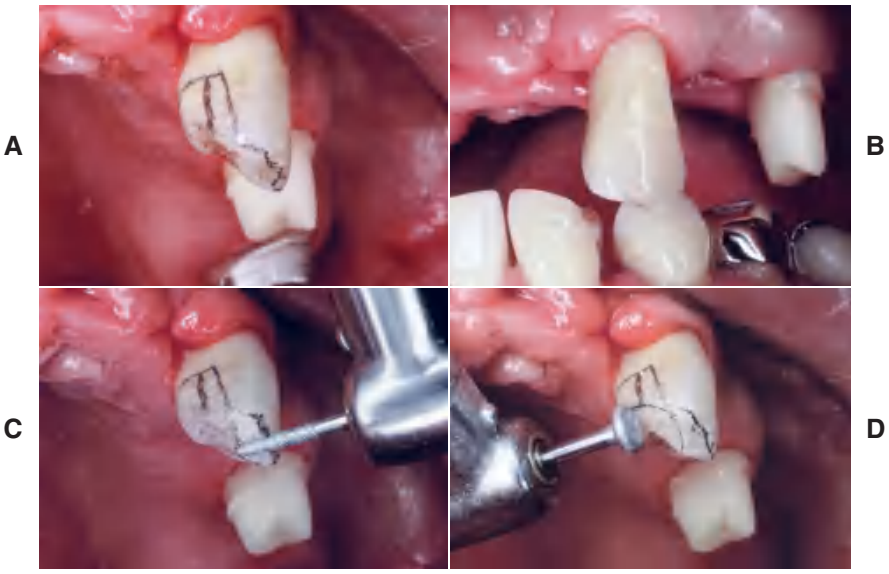


Fig. 10-25
A, Proposed margin location outlined on the tooth with a pencil. **B,** Careful assessment of the anticipated outline from as many directions as possible is valuable at this time. **C,** Preparing the incisal bevel. Typically a lingually tilted bevel is prepared at a 45-degree angle to the long axis of the tooth. **D,** The lingual surface is reduced with a wheel- or football-shaped diamond.

used to reduce the concave lingual wall (see Figs. 10-24*B* and 10-25*D*). The lingual reduction should not extend onto the cingulum itself, which will be prepared as part of the axial reduction. (The completed reduction is shown in Fig. 10-24*C*.)

Axial reduction and groove placement

The path of placement of the restoration must be accurately determined before axial reduction. Mesiodistally, it should parallel the long axis of the tooth; buccolingually, it should parallel the middle third or incisal two thirds of the facial surface. This allows the preparation of proximal grooves of optimum length in an area of the tooth where sufficient bulk is present.

4. To enhance the retention and resistance form of the preparation, place a slightly exaggerated chamfer on the lingual aspect of the tooth (see Fig. 10-24*D*) and a guiding groove in the middle of the lingual wall. When alignment has been verified, the axial reduction can be performed in the same manner as the other preparations (Fig. 10-26). It is important to understand the difference between this phase of the preparation on a canine, with little bulk of lingual tooth structure as opposed to a premolar or molar. After completion, a proximal flange should result; this guides the rotary instrument during groove placement (see Figs. 10-24*E* and 10-26*B*). The technical aspects of the preparation of proximal grooves are like those described for the other partial veneer preparations (Figs. 10-27 and 10-28). The primary difference is the direction in which the groove is prepared. Because the groove is placed perpendicular to the proximal wall, its deepest portion is slightly labial to the proximal flange that results when proximoaxial reduction is completed. As a result, the proximal flares extend

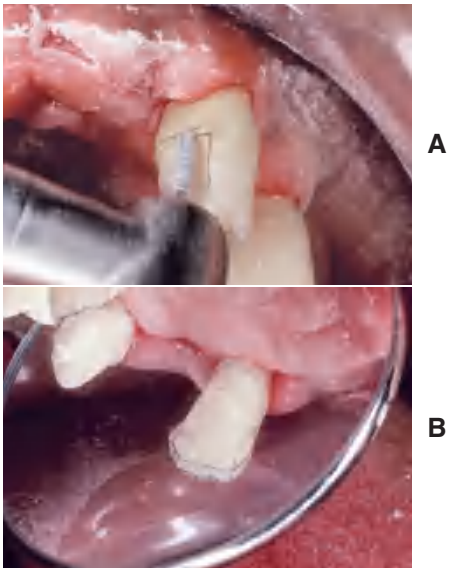


Fig. 10-26
A, A regular-grit diamond is used to complete the axial reduction. Mesiodistally, the diamond is oriented parallel to the long axis of the tooth. **B,** When the reduction is completed, a mesial and distal flange results; this serves as a guide during preparation of the proximal groove.

slightly farther onto the facial surface. This is even more accentuated by the curvature of the proximal wall (Fig. 10-29). Meticulous assessment of the needed extent of the initial axial reduction is a prerequisite for successful preparation (Fig. 10-30; see also Fig. 10-24*F*). (The required interproximal clearance is illustrated in Fig. 10-31.)

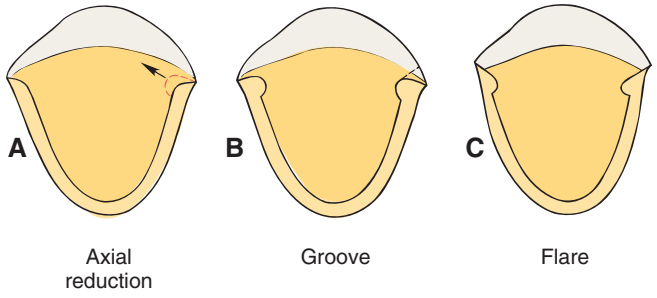


Fig. 10-27

A, Because the groove is prepared perpendicular to the proximal surface of the tooth, its deepest portion is slightly buccal to where axial reduction was halted. **B,** The *dotted line* indicates the proposed flare. Note that the curvature of the tooth causes the final margin to be located a considerable distance facial to where the initial axial reduction stopped. **C,** Completed flares.

Incisal offset and lingual pinhole

Anterior partial veneer crowns require a means of reinforcement for preserving the casting's integrity. Posterior three-quarter crowns usually do not need as much additional reinforcement because the solid "corrugated" occlusal surface provides rigidity. For an anterior tooth, an incisal offset or groove is needed to create a band of thicker metal to provide a "staple" configuration. This provides additional rigidity and resistance against bending of the casting.

5. Connect the mesial and distal grooves with an incisal offset. It should improve the general resistance form of the preparation against lingual displacement and should have a V configuration. Sufficient dentin must be preserved facially to the offset to prevent the metal from being visible through the translucent tooth enamel. This is most effectively accomplished with an offset that is slightly narrower labiolingually than incisocervically. The offset should follow the normal con-

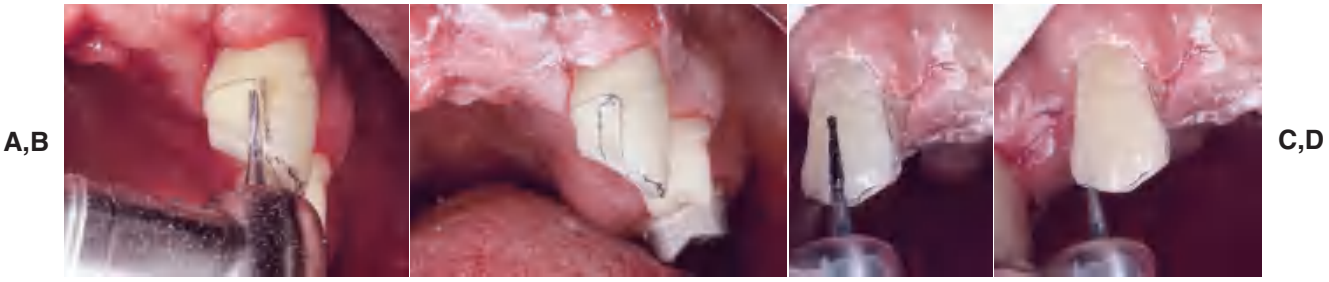


Fig. 10-28

A, A tapered carbide is used to place the proximal groove. **B,** Initial groove preparation is completed. **C,** The carbide is moved parallel to itself. **D,** Mesial and distal grooves must be prepared in strict alignment.

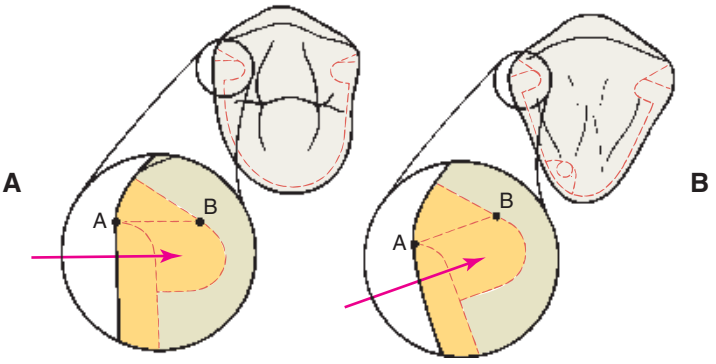


Fig. 10-29

Differences between the proximal flares on premolars and canines. *A* designates where the initial proximal reduction is halted. Because a facial component is present in the direction of groove placement on the canine, as opposed to the premolar, the starting point (*B*) for the flare is located farther to the facial aspect. In conjunction with the greater degree of proximal curvature of canines, it is crucial that the initial axial reduction not be carried too far facially; otherwise, the final margin will extend too far onto the labial surface of the tooth and result in excessive display of metal.

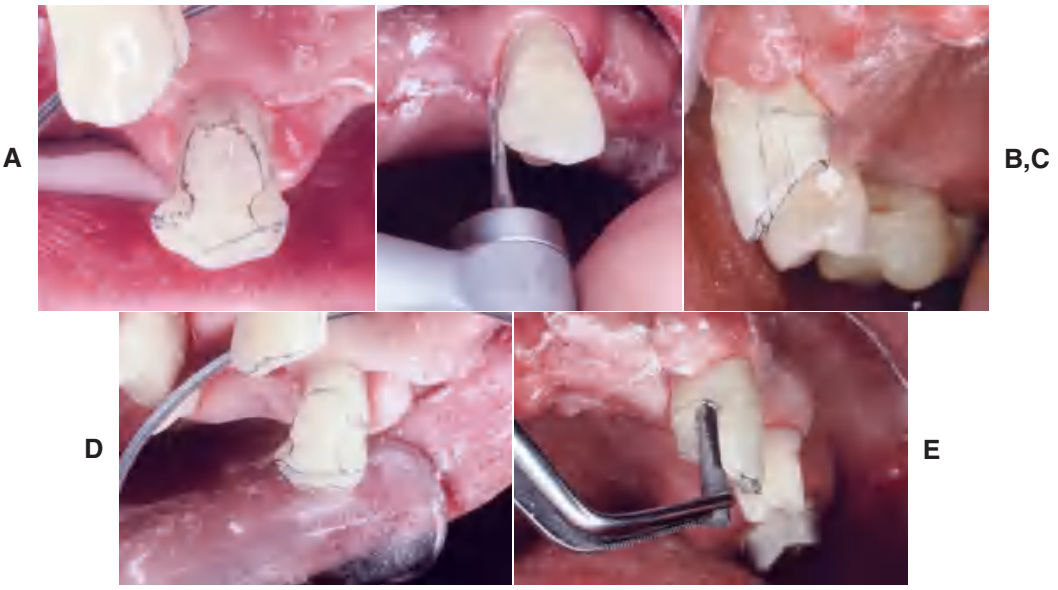


Fig. 10-30
A, Unsupported enamel remaining after initial groove placement. **B,** A carbide bur can be used to flare the grooves. **C,** The flared groove. Note the irregularity of the margin near the cervical aspect of the groove. **D,** After the flaring. Note that a mesial box, rather than a groove, has been prepared. This restoration is designed to contain an intracoronal partial removable dental prosthesis rest; hence, the box. Nevertheless, there is adequate resistance to lingual displacement. **E,** A special mandrel is placed in the box to ensure that it fits within its confines. It is identical in size to the male attachment of the partial removable dental prosthesis.

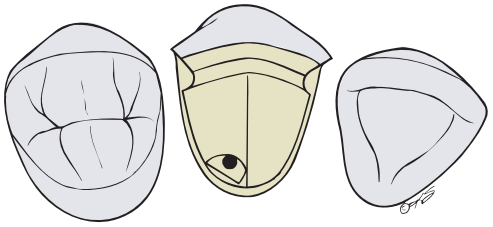


Fig. 10-31
Completed three-quarter crown preparation. Note the location of the facial margin in relation to the adjacent teeth. Sufficient interproximal clearance has been established, but unnecessary display of metal is avoided.

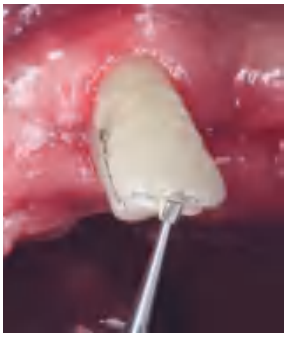


Fig. 10-32
An inverted-cone diamond or carbide can be used to prepare the incisal offset. Note the faciolingual inclination of the rotary instrument.

figuration of the incisal edge, and its transition into the proximal flares should be smooth and continuous. An inverted-cone diamond or carbide (Fig. 10-32) can be used to prepare the offset.

6. Place a pinhole in the cingulum area slightly off center to improve the retention and resistance form of this preparation. The pinhole is prepared in five stages: first, a small horizontal ledge is made with a large, tapered carbide bur; second, a slight "dimple" is created with a round bur at the intended pinhole location; third, a pilot hole is prepared with a small-diameter twist drill* (it must be parallel to the precise path of placement of the restoration); fourth, the preparation is completed with a tapered carbide bur to a pinhole depth of approximately 2 mm; finally, a larger, round bur is used to countersink or bevel the junction between pinhole and ledge.

The technical aspects of pinhole preparation are described in the ensuing paragraphs. The completed preparation (Fig. 10-33) is carefully assessed for any remaining undercuts. The flares are a common area for undercuts, and all surfaces should be smoothed as previously described.

*The twist drills supplied with threaded pin kits for amalgam retention are suitable.



Fig. 10-33

A, Completed three-quarter crown preparation on a maxillary canine. **B,** The contralateral canine. **C,** A three-quarter crown serves as the anterior retainer for a three-unit fixed dental prosthesis (FDP); its female intracoronal rest is incorporated in the mesial box. **D,** Note the connector and the open embrasures on the contralateral side. **E** to **G,** Labial views of the cemented FDP. **H,** The definitive RDP.

Pinledge Preparations

A pinledge (Fig. 10-34) is occasionally used as a single restoration, generally to reestablish anterior guidance, in which case only the lingual surface is prepared. More commonly, however, it is used as a retainer for an FDP (Fig. 10-35) or to splint periodontally compromised teeth (Fig. 10-36). In these cases, one or more of the proximal surfaces are included in the preparation design to accommodate the required connector or connectors. Retention and resistance are provided primarily by pins that extend to a depth of 2 mm into dentin. In comparison with other retainers, the pinledge preparation is very conservative of tooth structure.

The preparation steps themselves are not difficult, but advance planning and a thorough understanding of the various steps are prerequisites to success. Diagnostic preparation on an accurate cast is particularly useful during the planning phase. Preparation of a number of parallel pinholes with a common path of placement can be intimidating. With some practice, however, this can be accomplished freehand by most operators, especially when a tapered bur is used. Paralleling devices are available for practitioners who do not feel comfortable preparing multiple pinholes. In general, pinledges are highly esthetic restorations. Plaque control after treatment is easier because of short margin length and largely supragingival margin location.

Indications

The pinledge is indicated for undamaged anterior teeth in dentitions with low caries activity. The presence of a small proximal carious lesion, however, does not preclude its use. If a high esthetic requirement exists, the advantage of this restoration is that the labial tooth surface remains intact, although this is sometimes offset by the display of a slight amount

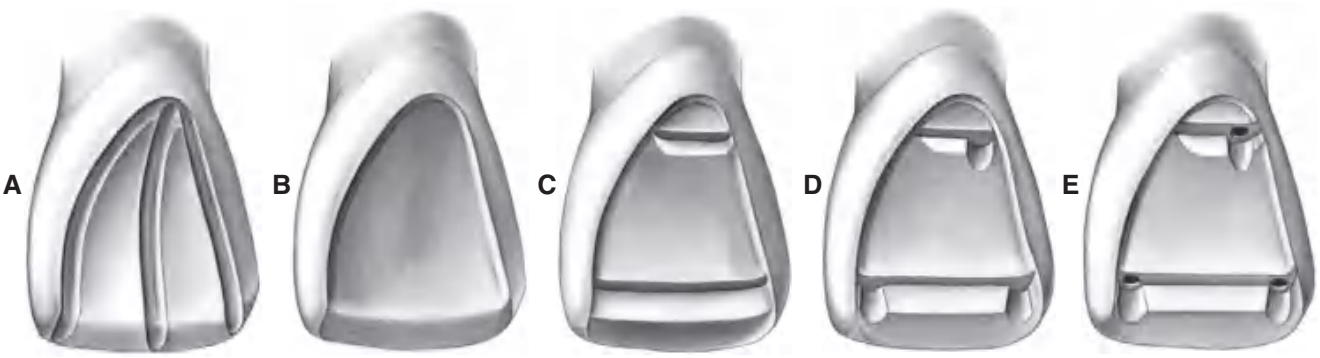


Fig. 10-34

The pinledge preparation on a maxillary central incisor. **A,** Guiding grooves placed for lingual reduction. **B,** The lingual reduction completed and an incisal bevel placed. **C,** Incisal and cervical ledges prepared. **D,** Indentations have been made. Note the spacing of the ledges in relation to each other and to the pulp. All pinholes will be in sound dentin. **E,** Pinholes prepared to a depth of 2 mm. The junction between the ledge and the pinholes has been countersunk.



Fig. 10-35

A, Modified pinledge serving as a retainer for a four-unit fixed dental prosthesis (FDP). An additional pinhole was placed in the cingulum and in the cervical aspect of the proximal groove; in the latter instance, this was done because insufficient tooth structure remained to provide resistance against lingual displacement. **B,** The FDP on the definitive cast. **C,** A four-unit FDP consisting of a modified pinledge, two metal-ceramic pontics, and a metal-ceramic crown.



Fig. 10-36

A, Periodontally compromised but caries-free teeth of adequate buccolingual width are excellent candidates for a pinledge retained fixed splint. **B,** The definitive cast. **C,** Pinledge splint consisting of six separate castings that were soldered together and seated. **D,** A minimum display of metal results. The pinledge preparations allow retention of the intact labial enamel of all six anterior teeth.

of metal along the incisal edge. Pinledges can be prepared on bulbous teeth that are unsuitable for three-quarter crowns, which would result in a significant amount of unsupported enamel interproximally. The lingual concavity of a maxillary anterior tooth can be modified successfully with a pinledge restoration (see Fig. 10-22) to establish the desired anterior guidance.

Contraindications

Patients with poor oral hygiene or a high caries rate are not good candidates for this type of restoration. Young patients with large pulps generally are better served by a resin-retained FDP (see Chapter 26). It is often not possible to place pinholes of adequate size and length in teeth that are thin labiolingually (Fig. 10-37). Pinledges are contraindicated on nonvital teeth and when the alignment of the abutment conflicts with the proposed path of placement of the FDP. Because less surface area is involved in the preparation, pinledges are not as retentive as their less conservative counterparts. Therefore, they should not be used when optimum retention is needed.

Maxillary central incisor pinledge

Three designs of pinledge preparations are discussed here: the conventional pinledge (see Fig. 10-34), involving only the lingual surface of the tooth; the pinledge with a proximal slice (Fig. 10-38); and the pinledge with a proximal groove (Fig. 10-39A). The latter two can serve equally well as retainers for an FDP; the choice of one over the other depends primarily on tooth configuration and the presence or absence of caries. A tooth with a slight proximal convexity can often be prepared successfully with a proximal slice, whereas one with a small carious lesion often lends itself better to the proximal groove variation. The pinledge preparation with proximal slice is described first.

Design

1. Draw the outline of the proposed preparation onto the tooth (Fig. 10-40*D*). A line is marked along the height of contour of the incisal edge and on the proximal wall to include the area needed for a connector. The lingual chamfer is placed immediately adjacent to the crest of the marginal ridge. The cervical extent of the margin is on the height of contour of the cingulum, but it may be extended farther cervically at a later stage to blend into the proximal aspect of the preparation.

Proximal reduction

2. Prepare the proximal slice with a tapered diamond. (Disks may be preferred by some operators.) The diamond is either held parallel to the path of placement or given a slight lingual inclination. The primary purpose of this step is to provide sufficient reduction to allow adequate metal in the area for a subsequent connector. The proximal reduction includes the proximal contact area, but care must be taken not to extend the reduction too far facially, because this alters the outline form of the tooth. For esthetic reasons, the reduction must not extend onto the labial surface.

Incisal and lingual reduction

3. Prepare the incisal bevel with the diamond inclined slightly toward the lingual aspect. It extends just beyond the previously placed pencil line on the crest of the incisal edge, but it must remain within the curvature of the incisal edge to minimize display of metal. Sufficient clearance provides functional contact on metal rather than on the junction between



Fig. 10-37
Where incisors are thin labiolingually and insufficient dentin remains facial to the casting, appearance is compromised by a pinledge restoration.

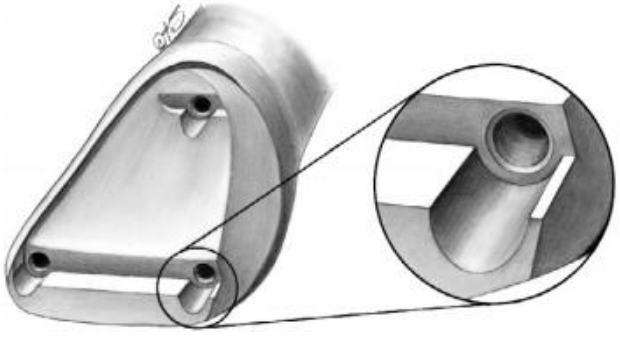


Fig. 10-38
Pinledge preparation with a proximal slice. The slice provides room for a fixed dental prosthesis connector. Sufficient tooth structure should remain between the slice and the pinhole adjacent to it. Note that the junction between pinhole and ledge has been beveled or countersunk.

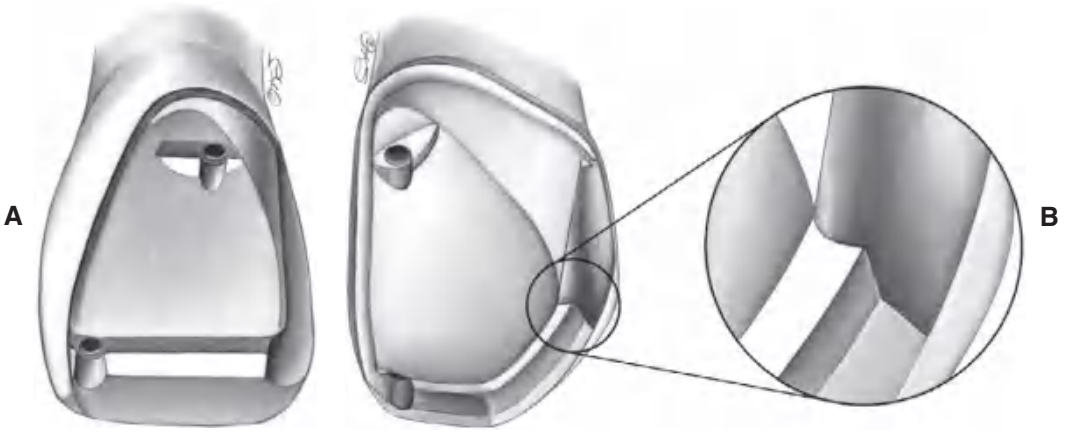


Fig. 10-39

A, Modified pinledge preparation with a proximal groove. The path of placement of this groove is compatible with the preparation as well as with the pinholes. **B,** A similar preparation on a maxillary canine. Note two similarities with the three-quarter crown: the heavy lingual chamfer and the incisal offset blending into the proximal groove to provide additional bulk for reinforcement.



Fig. 10-40

A, Although periodontally compromised and malpositioned, these six caries-free anterior teeth are excellent for pinledge preparations. **B,** Orthodontic repositioning of the teeth. **C,** Stabilization after the repositioning. **D,** Outline of the proposed preparations drawn on the teeth.

metal and tooth structure. The desired metal thickness is 1 mm, except in the area close to the margin.

4. Perform the lingual reduction with a football- or wheel-shaped diamond after placing reduction grooves, as has been described in other anterior preparations. Metal thickness of 1 mm is required in maximum intercuspation and throughout excursive movements. The reduction follows the lingual marginal ridge and continues its chamfer configuration cervically until it runs into the proximal reduction. To facilitate subsequent stages of the preparation, care must be taken to maintain as much tooth structure as possible in the incisal third.
5. Smooth the incisal and lingual reduction with fine-grit diamonds and stones before preparing the ledges and pinholes.

Ledges and indentations

Two ledges are prepared across the reduced lingual surface. They provide room for sufficient bulk of metal to ensure rigidity. The restoration would otherwise not be very strong because it would consist of only a thin sheet of metal.

The ledges are prepared parallel to the incisal edge of the tooth, as viewed from the lingual aspect, and parallel to one another, as viewed from the incisal aspect. In selected areas, they are widened to provide indentations of sufficient size to accommodate the pinholes. The determination of the incisocervical location of the ledges depends on the configuration of the pulp and the available bulk of tooth structure (Fig. 10-41). The incisal ledge is usually prepared 2 to 2.5 mm cervical to the incisal edge, or one fourth of the total height of the preparation from the incisal edge. The cervical ledge is placed on the crest of the cingulum at the center of the cervical one fourth of the preparation.

6. Prepare two ledges with a cylindrical carbide bur. The recommended minimum width for the ledge is 0.7 mm. Drawing the proposed location of the ledges on the lingual surface of the tooth is helpful. The design of the ledges must be compatible with the path of placement of the restoration, which is parallel to the incisal two thirds of the labial surface of the tooth.
7. Make indentations in the left and right sides of the incisal ledge and slightly off center in the cervical ledge to prevent subsequent pulp exposure when the pinholes are placed. These incisal indentations are as widely spaced as possible to retain as much dentin as possible between the pinholes and the pulp. Because the completed pinhole must be surrounded by sound dentin, it is not possible to place holes in the extreme corners because of the tooth's structure. However, every effort should be made to prepare the indentations so that the pinholes are surrounded by dentin and away from the pulp. This is particularly important for younger patients. The relationship between recommended pinhole locations and the pulp is illustrated in Figure 10-42. In general, this means that the indentations are just within the mesial and distal marginal ridges, about 1.5 mm inside the external tooth contour (Fig. 10-43). The same carbide bur can be used to prepare the indentations. When the indentations are completed, their configuration should resemble a half cylinder. Again, their orientation is parallel to the selected path of placement, and their floor should be smooth and continuous with the floor of the ledges. When combined, they should provide a flat area 1 to 1.2 mm wide buccolingually.

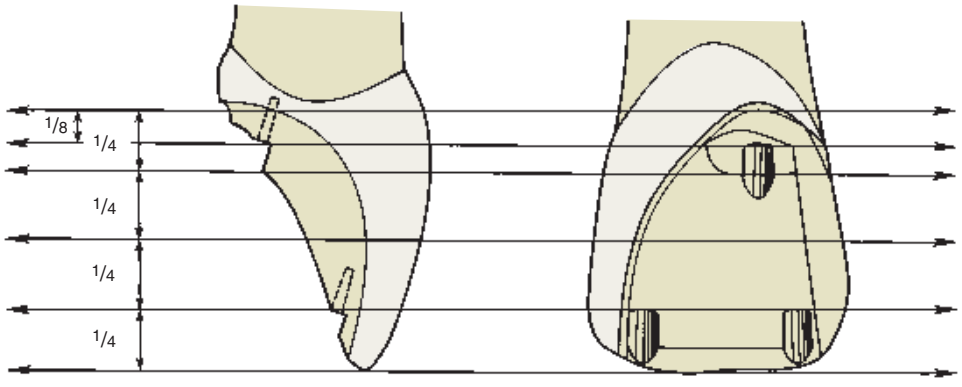


Fig. 10-41

Proximal lingual views of the location of ledges in relation to the height of the crown. The incisal ledge is placed so that its floor is one fourth of the preparation's height from the incisal edge. The cervical ledge is placed so its floor bisects the cervical fourth. Note that the path of insertion is parallel to the incisal two thirds of the labial wall. Adequate offset of the cervical pinhole either mesially or distally is needed to prevent pulpal exposure.

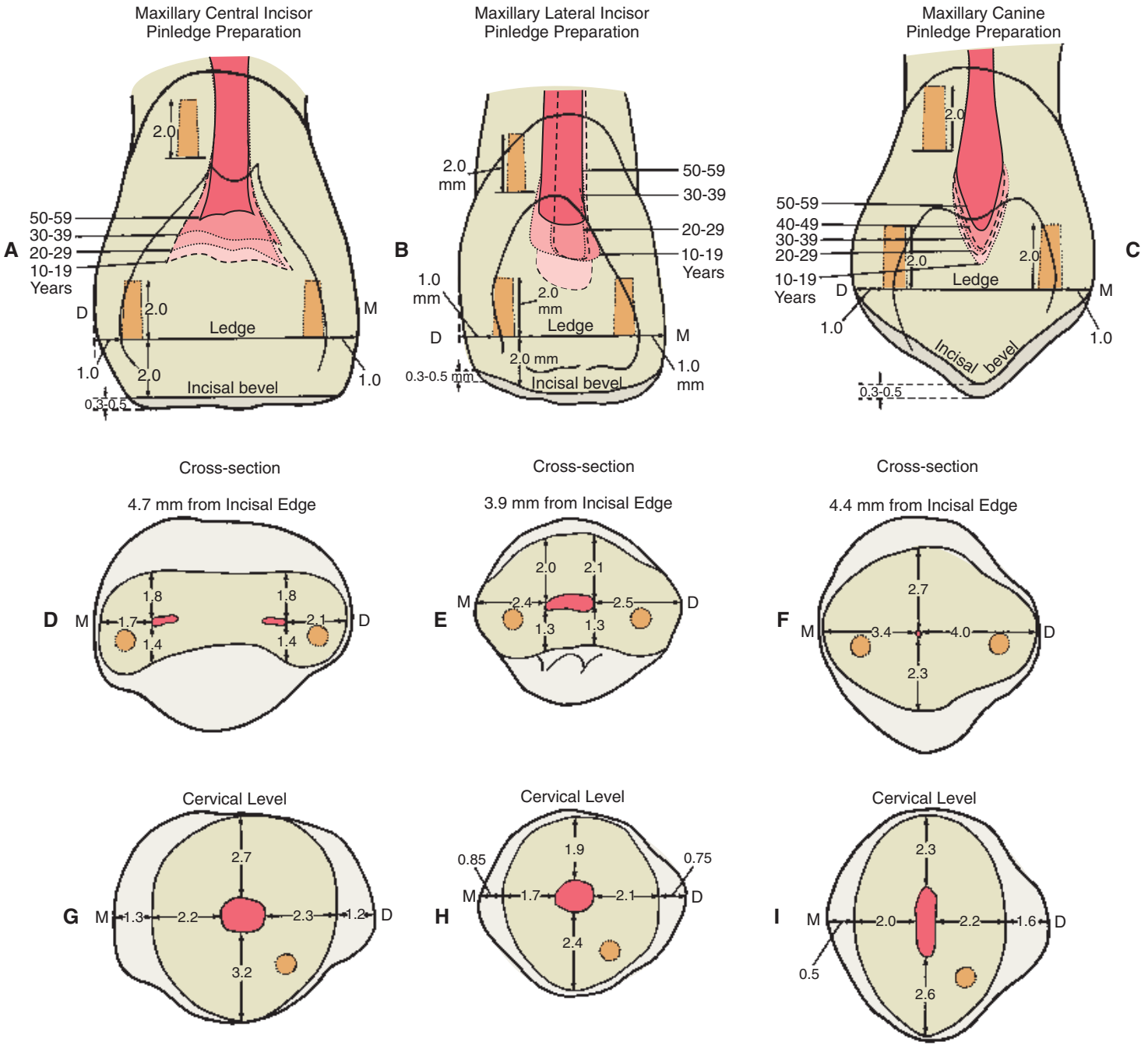


Fig. 10-42

Relationship between pinhole placement and pulp configuration. A to C, Lingual views. **D to F,** Cross-sections through incisal pinholes. **G to I,** Cross-sections through cervical pinholes. *Dotted lines* show the mean pulp chamber size of various age groups. *(Data from Ohashi Y: Shikagakuho 68:726, 1968.)*

Pinhole preparation

8. Sink pilot channels with either a small, round bur or a small twist drill. The shallow indentations prevent skating of the selected bur. The depth of the completed pinhole should be at least 2 mm but can be as much as 3 mm when the placement and orientation of the pilot channels are satisfactory.
9. Enlarge and deepen the pilot channels with a tapered carbide bur when their placement and orientation are satisfactory. At this stage, any small corrections in orientation can be made. Less experienced operators may spend a great deal of time attempting to determine the correct alignment of the bur. However, it should be remembered that the design and location of



Fig. 10-43
A, Proposed location of the ledges marked on the teeth with a pencil. Note the orientation of the carbide in relation to the long axis of the tooth. **B,** Ledge preparation completed on one side. Pilot holes for some pinholes have been placed.

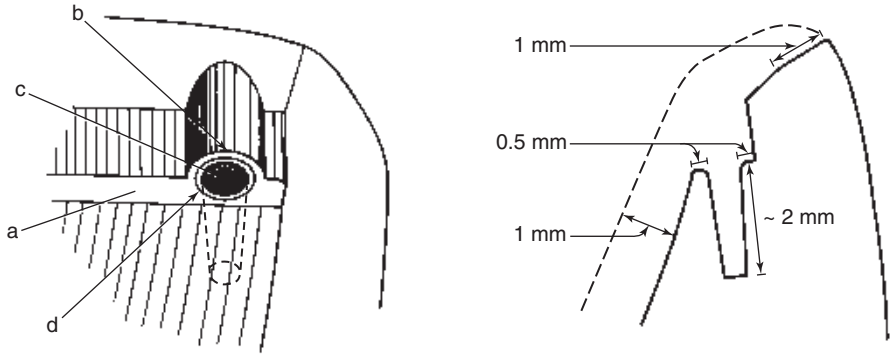


Fig. 10-44
Note the relation among the ledge, the indentation, and the pinhole. Recommended dimensions are given in the buccolingual cross section on the right. *a,* Ledge; *b,* indentation; *c,* pinhole; *d,* countersink.

the pinholes have already been determined by the placement of the ledges and indentations; therefore, the only remaining concern should be verification of the position of the rotary instrument and attainment of the minimum depth of the pinholes. Some operators find it helpful to place a second bur in a prepared pinhole to help transfer the path of placement, although precautions must be taken to prevent its being swallowed or inhaled. Preparing multiple pinholes a little at a time may also be helpful, moving from one to the next and gradually deepening each. This enables alignment verification as the pinholes are prepared.

10. Bevel the junction between pinhole and indentation with a round bur slightly larger than the largest diameter of the pinhole (Fig. 10-44). (The required interproximal clearance is illustrated in Fig. 10-45.)
11. Inspect all surfaces of the preparation for smoothness and evaluate the margin. Correct any area that requires more distinct delineation (Fig. 10-46).

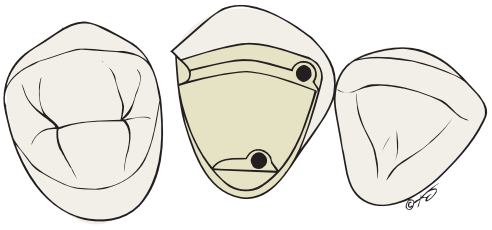


Fig. 10-45
Modified pinledge preparation with a proximal groove. Adequate interproximal clearance has resulted from the proximal flare.

INLAYS AND ONLAYS

Indications

An inlay can be used instead of amalgam for patients with a low caries rate who require a small Class II restoration in a tooth with ample supporting dentin. It is among the least complicated cast restorations to make and can be very durable when it is carefully done. An onlay allows the damaged occlusal surface to be restored with a casting in the most conserva-



Fig. 10-46
A, Ledges and indentations prepared. **B,** Pinhole preparation with low-speed handpiece. **C,** The completed pinledge preparations. Utility wax has been placed over the brackets for impression making.

tive manner. It should be considered in the restoration of a severely worn dentition when the teeth are otherwise minimally damaged or for the replacement of a mesio-occlusal-distal (MOD) amalgam restoration when sufficient tooth structure remains for retention and resistance form.

Contraindications

Because these restorations rely on intracoronal (wedging) retention, inlays and onlays are contraindicated unless there is sufficient bulk to provide resistance and retention form. MOD inlays may increase the risk of cusp fracture and are generally not recommended. Extensive onlays, required where caries or existing restorations extend beyond the facial or lingual line angles, are contraindicated unless pins are used to supplement retention and resistance.

Advantages

Cast inlays and onlays can prove to be extremely long-lived restorations because of the excellent mechanical properties of the gold alloy. Low creep and corrosion mean that if inlay or onlay margins are accurately cast and finished, they will not deteriorate. The lack of corrosion may be an esthetic advantage. Gold does not lead to the tooth discoloration sometimes associated with dental amalgam. Unlike an inlay or amalgam, an onlay can support cusps, reducing the risk of tooth fracture.

Disadvantages

In the restoration of a small carious lesion, an inlay is not very conservative of tooth structure. This is because additional tooth removal is necessary after minimal proximal extension to achieve a cavity preparation without undercuts and to enable access for impression making. This extension may lead to additional display of metal and gingival encroachment, which is undesirable for periodontal health. Because they do not encircle the tooth, inlays rely on the bulk of the buccal and lingual cusps for resistance and retention form. There is concern that high occlusal force will lead to cusp fracture as a result of wedging from the inlay.

Preparation

Armamentarium

Carbide burs are usually used for inlay or onlay preparations (Fig. 10-47), but diamonds can be substituted if preferred:

- Tapered carbide burs
- Round carbide burs

- Cylindrical carbide burs
- Finishing stones
- Mirror
- Explorer and periodontal probe
- Chisels
- Hatchet
- Gingival margin trimmers
- Excavators
- High- and low-speed handpieces
- Articulating film



Fig. 10-47
Armamentarium for inlays and onlays.

Class II Inlay Preparation (Fig. 10-48)

Occlusal analysis

1. Carefully assess the occlusal contact relationship and mark it with articulating film. The margins of the restoration should not be too close (≥1.0 mm) to a centric contact; otherwise, there will be damaging stresses at the gold-enamel junction.
2. Apply rubber dam. Because good visibility and moisture control are essential during tooth preparation and caries excavation, the use of a rubber dam is strongly recommended.

Outline form

3. Penetrate the central groove just to the depth of the dentin (typically about 1.8 mm) with a small round or tapered carbide bur held in the path of placement of the inlay. In general, this is perpendicular to an imaginary line connecting the buccal and lingual cusps, not necessarily perpendicular to the occlusal plane. For example, on mandibular premolars, it is angled toward the lingual aspect.

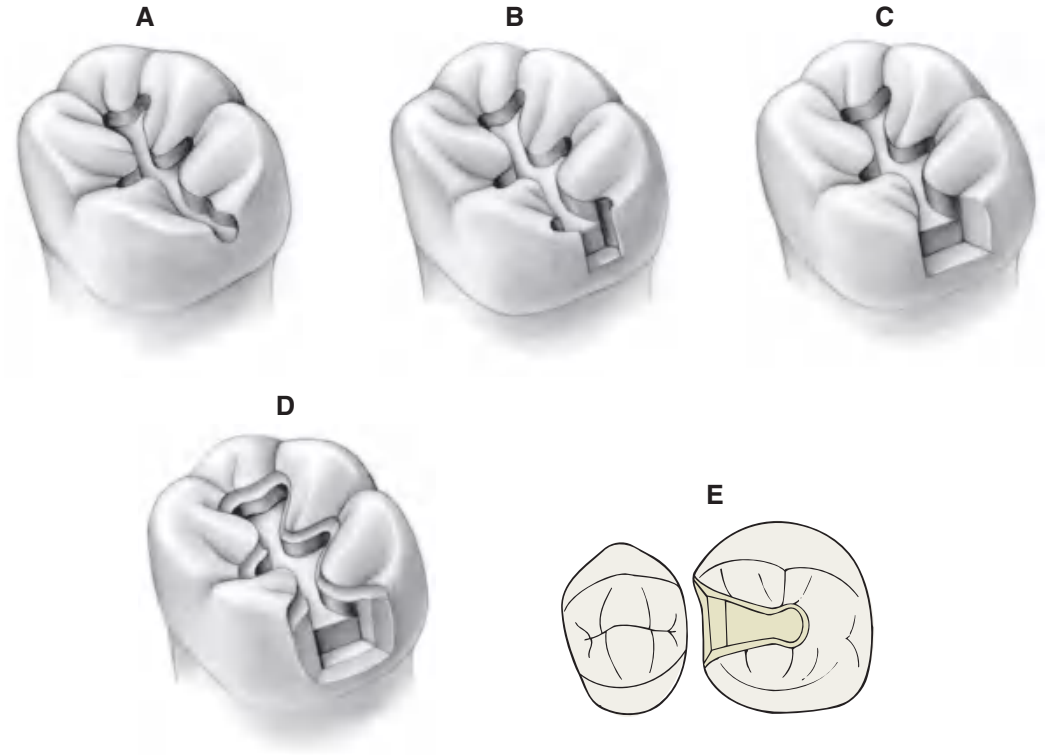


Fig. 10-48
The MO inlay preparation. **A,** An occlusal outline is prepared following the central groove and extended proximally. **B,** Gingival extension undermines the marginal ridge while removing caries. **C,** Unsupported enamel is removed, and the walls of the proximal box are defined. This is easily accomplished with hand instruments. **D,** An occlusal bevel or chamfer completes the preparation. **E,** Occlusal view of the completed preparation.

4. Extend the occlusal outline through the central groove with the tapered carbide. The bur should be held in the same path of placement and kept at the same depth—just into dentin. The buccolingual extension should be as conservative as possible to preserve the bulk of the buccal and lingual cusps. Resistance to proximal displacement is achieved with a small occlusal dovetail or pinhole. The outline should avoid the occlusal contacts.
5. Extend the outline proximally, undermining the marginal ridge, and stop it at the height of contour of the ridge (Fig. 10-49*A*).
6. Advance the bur cervically to the carious lesion and then lingually and buccally, taking care to hold it in the precise path of placement. There should be a thin layer of enamel remaining between the side of the bur and the adjacent tooth (Fig. 10-49*B*). This prevents accidental damage. The bur should move parallel to the original unprepared proximal surface, creating a convex axial wall in the box. The opposing buccal and lingual walls contribute significantly to retention, so great care must be taken not to tilt the bur during this step. It should be held in the path of placement throughout. The width of the gingival floor of the box should be about 1.0 mm (mesiodistally). Correct cervical, lingual, and buccal extension at this stage is just beyond the proximal contact area. The completed inlay will require a minimum of 0.6 mm of proximal clearance to allow an impression to be made, but some of this will be achieved with the proximal flares and gingival bevels. Sharp line angles between the occlusal outline and proximal box are rounded at this time (Fig. 10-49*C*).



Fig. 10-49
Preparation of a mandibular premolar tooth for a disto-occlusal inlay. **A,** Occlusal outline. **B,** Proximal box initiated. **C,** Proximal box extended to remove contact. **D,** Completed preparation. *(Courtesy of Dr. H. Bowman.)*

Caries excavation

7. Identify and remove any caries not eliminated by the proximal box preparation, using an excavator or a round bur in the low-speed handpiece.
8. Place a cement base to restore the excavated tissue in the axial wall and/or pulpal floor. If necessary, the preparation can be extended buccally or lingually. An inlay is not a suitable restoration for extensive caries, and carrying it beyond the line angles will lead to a significant loss of retention and resistance form.

Axiogingival groove and bevel placement

9. Prepare a small, well-defined groove at the junction of axial and gingival walls at the base of the proximal box to enhance resistance form and prevent distortion of the wax pattern during manipulation. It is easily placed with a gingival margin trimmer held in contact with the axial wall to prevent creating an undercut.
10. Place a 45-degree gingival margin bevel with a thin, tapered carbide or fine-grit diamond. Correct orientation is achieved by holding the instrument parallel to the gingival third of the proximal surface of the adjacent tooth. The bur should not be tilted buccally or lingually to the path of placement; otherwise, an undercut will be created at the corners of the box (a commonly seen error in inlay preparations).
11. Prepare proximal bevels on the buccal and lingual walls with the tapered bur oriented in the path of placement. There should be a smooth transition between the proximal and gingival bevels.
12. Place an occlusal bevel to improve marginal fit and allow finishing of the restoration. When the cuspal anatomy is steep, a conventional straight bevel creates too little metal near the margin for strength and durability. A hollow-ground bevel or chamfer is normally preferred and can be conveniently placed with a round bur or stone.
13. As a final step, smooth the preparation where necessary, paying particular attention to the margin (see Fig. 10-49*D*).

Mesio-Occlusal-Distal Onlay Preparation

The occlusal outline and proximal boxes of an onlay preparation (Fig. 10-50) are similar to those of an inlay. The additional steps are the occlusal reduction and a functional (centric) cusp ledge.

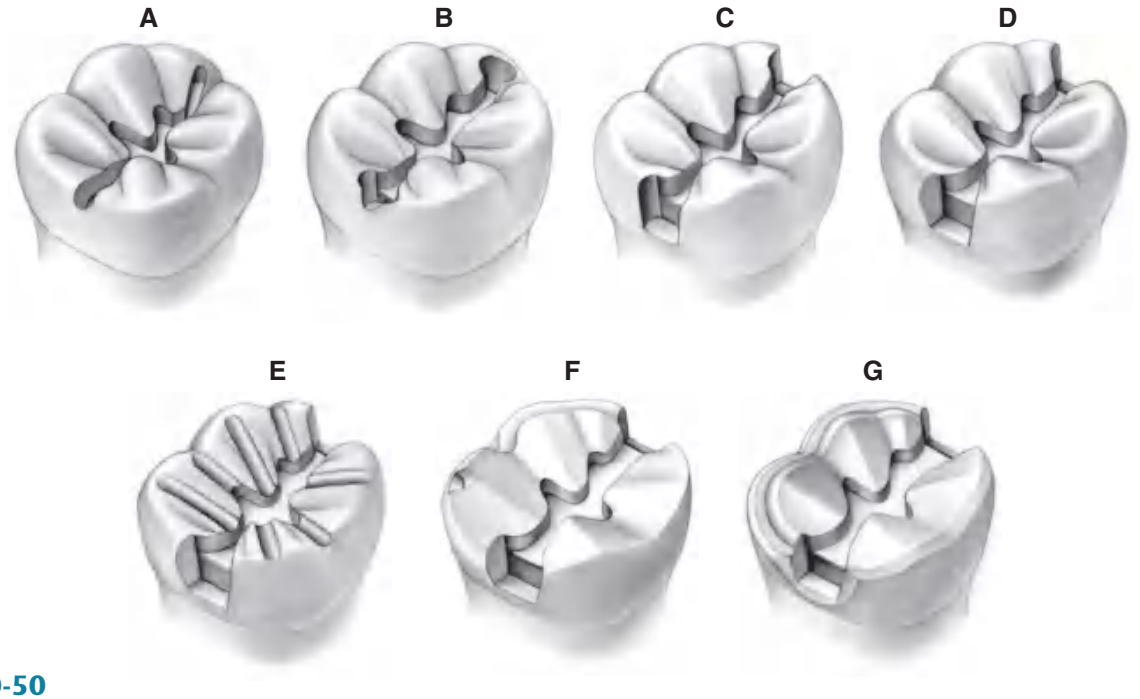


Fig. 10-50

The mesio-occlusal-distal (MOD) onlay preparation. **A,** An occlusal outline is prepared to follow the central fossa. **B,** The marginal ridges are undermined. **C** and **D,** The proximal boxes are refined. They should extend just beyond the proximal contact area. **E,** Depth grooves are placed for occlusal reduction: 0.8 mm on the nonfunctional cusp and 1.3 mm on the functional cusp. **F,** Note the buccal functional cusp bevel as part of the completed occlusal reduction. A buccal shoulder is prepared, approximately at the level of the pulpal floor. **G,** A continuous bevel completes the preparation. The bevel on the buccal shoulder makes a smooth transition into the proximal bevel of the box. A small contrabevel is placed on the lingual cavosurface margin.

Outline form

1. Prepare the occlusal outline with a tapered carbide bur just beyond the enamel-dentin junction (approximately 1.8 mm deep) and extend it through the central groove, incorporating any deep buccal or lingual grooves. Existing amalgam restorations are removed as part of this step (Fig. 10-51*A*).
2. Extend the outline both mesially and distally to the height of contour of the marginal ridge. As with an inlay, the boxes with an MOD onlay are prepared by advancing the bur gingivally and then buccally and lingually, always holding it in the precise path of placement of the preparation. If a thin section of proximal enamel remains as the bur advances, damage to the adjacent tooth will be prevented (Fig. 10-51*B*). Correct gingival, buccal, and lingual extension of the preparation normally depends on the contact area with the adjacent tooth. A minimum clearance of 0.6 mm is needed for impression making. Sometimes existing restorations or caries necessitate that a box be extended beyond optimal. However, if a box requires extension beyond the transitional line angle, the preparation will have little resistance form, and an alternative restoration such as a complete crown should be considered. Preparing the boxes is a key step when an onlay is fabricated (Fig. 10-51*C* and *D*). The tapered bur should be held precisely in the planned path of placement throughout. Tilting, often caused by trying to advance the bur too quickly, is commonly done and is difficult to correct.
3. Round sharp line angles between the occlusal outline and proximal boxes.

Caries excavation

4. Remove any remaining caries by using an excavator or a round bur in the low-speed handpiece.
5. Place a cement base to restore the excavated tissue. Good judgment is needed to ensure that adequate sound dentin is present on the axial walls to provide retention and resistance.

Occlusal reduction

6. Place depth grooves on the functional cusps. To give additional clearance at the cusp tip, the bur must be oriented more horizontally than the intended restoration cusp. The grooves should be 1.3 mm deep, allowing 0.2 mm for smoothing (Fig. 10-51*E*).
7. Place 0.8 mm grooves on the nonfunctional cusps. On nonfunctional cusps, the bur is ori-

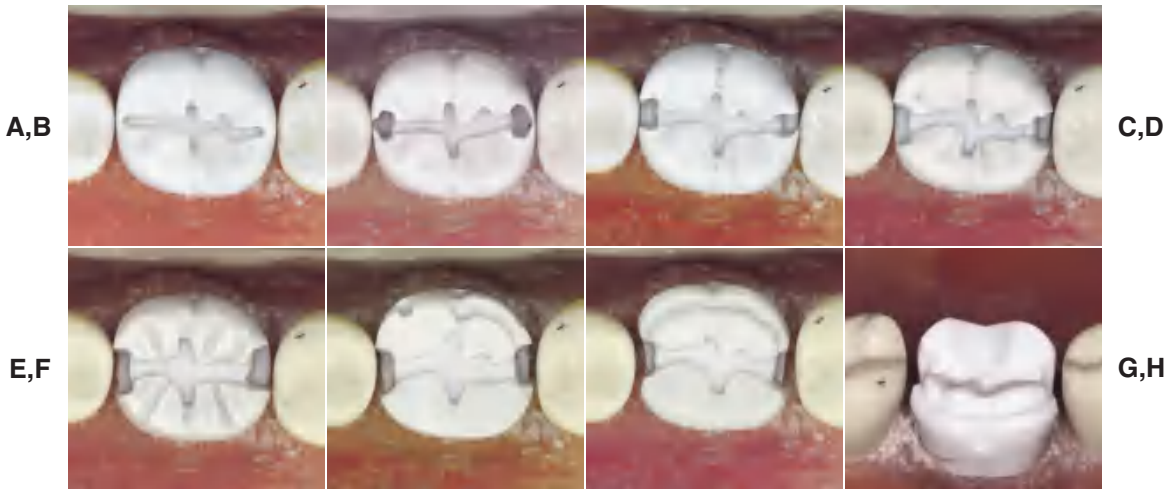


Fig. 10-51
Preparation of a mandibular molar tooth for a mesio-occlusal-distal (MOD) onlay. **A,** Preparation outline. **B,** Proximal boxes extended to remove contacts. **C,** Unsupported enamel removed with hand instruments. **D,** Proximal boxes are extended to form a 90-degree cavosurface angle. **E,** Occlusal reduction grooves. **F,** Functional cusp ledge placed for distal half. **G** and **H,** Completed preparation. *(Courtesy of Dr. H. Bowman.)*

ented parallel to the cuspal inclines. As with all depth grooves, it is assumed that the tooth is in good occlusal relation before preparation. If it is not, a vacuum-formed matrix made from the diagnostic waxing procedure is recommended as a guide.

8. Connect the grooves to form the occlusal reduction, maintaining the general contour of the original anatomy.
9. Prepare a 1.0-mm functional cusp ledge with the cylindrical carbide bur (see Fig. 10-51*F*). This gives the restoration bulk in a high-stress area, preventing deformation during function. The ledge should be placed about 1 mm apical to the opposing centric contacts. It extends into the proximal boxes but should not be positioned too far apically; otherwise, the resistance form from the boxes will be lost.
10. Round any sharp line angles, particularly at the junction of the ledge and occlusal surface.
11. Check for adequate occlusal reduction by having the patient close into soft wax and measuring with a thickness gauge.

Margin placement

12. Establish a smooth, continuous bevel on all margins. The gingival bevel is placed, as for an inlay, with the thin carbide or diamond held at 45 degrees to the path of placement, or approximately parallel to the adjacent tooth contour. This will blend smoothly with the buccal and lingual bevels, which have been prepared with the bur held in the path of placement.
13. Bevel the nonfunctional and functional. Where additional bulk at the margin is needed, a chamfer should be substituted for the straight bevel. This can be placed with a round-tipped diamond.
14. Complete the preparation by rechecking the occlusal clearance in all excursions and assessing for smoothness (see Fig. 10-51*G* and *H*).)

STUDY QUESTIONS

1. What are the indications and contraindications for partial veneer crowns?
2. What are the advantages and disadvantages of partial veneer crowns?
3. What is the recommended armamentarium, and in what sequence should a maxillary premolar be prepared, for a partial veneer crown?
4. What are the minimal criteria for each step just described?
5. What are the indications and contraindications for inlay/onlay restorations?
6. What are the advantages and disadvantages for inlay/onlay restorations?
7. What is the recommended armamentarium, and in what sequence should a mandibular molar be prepared, for an inlay/onlay restoration?
8. What are the minimal criteria for steps 5, 6, and 7? Why?

SUMMARY CHART

PARTIAL VENEER CROWN PREPARATION, POSTERIOR TEETH

Indications	Contraindications	Advantages	Disadvantages
Sturdy clinical crown of average length or longer	Short teeth	Conservative of tooth structure	Less retentive than complete cast crown
Intact buccal surface not in need of contour modification and well supported by sound tooth structure	High caries index	Easy access to margins	Limited adjustment of path of withdrawal
No conflict between axial relationship of tooth and proposed path of placement	Extensive destruction	Less gingival involvement than with complete cast crown	Some display of metal
	Poor alignment	Easy escape of cement and good seating	–
	Bulbous teeth	Verification of seating simple	–
	Thin teeth	Electric vitality test feasible	–

Preparation steps	Recommended armamentarium	Criteria
Depth grooves for occlusal reduction	Tapered carbide fissure bur or tapered round-tipped diamond	0.8 mm on nonfunctional cusps, 1.3 mm on functional cusps
Occlusal reduction	Round-tipped diamond	Clearance of 1 mm on nonfunctional cusps, 1.5 mm on functional cusps
Depth grooves for axial reduction	Round-tipped diamond	Chamfer depth of 0.5 mm (no more than half the width of diamond)
Axial reduction	Round-tipped diamond	Axial reduction parallel to long axis of tooth
Chamfer finishing	Large, round-tipped diamond	Smooth and continuous to minimize marginal length and facilitate finishing; distinct resistance to vertical displacement by periodontal probe
Proximal groove	Tapered carbide fissure bur	Distinct resistance to lingual displacement by probe; parallel to path of placement of restoration; 90-degree angle between prepared axial wall and buccal or lingual aspect of groove
Buccal and occlusal bevel (maxillae), chamfer (mandible)	Round-tipped diamond	Maxillary teeth: bevel extends just beyond cusp tip but remains within curvature of cusp tip
Finishing	Large, round-tipped diamond or carbide	Mandibular teeth: minimum of 1 mm of cast gold in area of centric stops All sharp internal line angles (except grooves) rounded to smooth transitions

SUMMARY CHART

PARTIAL VENEER CROWN PREPARATION, ANTERIOR TEETH

Indications	Contraindications	Advantages	Disadvantages
Sturdy clinical crown of average length or longer	Short teeth	Conservation of tooth structure	Less retentive than complete cast crown
Intact labial surface that is not in need of contour modification and that is supported by sound tooth structure	Nonvital teeth	Easy access to margins for finishing (dentist) and cleaning (patient)	Limited adjustment of path of insertion
No discrepancy between axial relationship of tooth and proposed path of placement of FDP	High caries index	Less gingival involvement than with complete cast crown	Some display of metal
	Extensive destruction	Easy escape of cement and good seating	Not indicated on nonvital teeth
	Poor alignment with path of withdrawal of FDP	Easy verification of complete seating	–
	Cervical caries	Electric vitality test feasible	–
	Bulbous teeth	–	–
	Thin teeth		

FDP, fixed dental prosthesis.

Preparation steps	Recommended armamentarium	Criteria
Depth grooves for lingual reduction	Round-tipped diamond	Should allow for 1 mm of clearance
Lingual reduction	Football-shaped diamond	Should have 1 mm of clearance
Incisal bevel	Round-tipped diamond	Allows for metal thickness ≥0.7 mm
Depth grooves for axial reduction	Round-tipped diamond	Allows for 0.5 mm of metal thickness at margin
–	Round-tipped diamond	Extends into interproximal about 0.4 mm lingual of contact area; parallel to incisal two thirds of labial surface
Axial reduction	Tapered carbide fissure bur and half-round bur	Grooves parallel to incisal two thirds of labial surface; should resist lingual displacement; pinhole should be between 2 and 3 mm deep
Retention form (proximal grooves and lingual pinhole)	Fine-grit, tapered diamonds (large and small) or carbide	Lingual wall of groove meets proximoaxial wall at angle of 90 degrees
Finishing and flare		All surfaces smooth; buccal wall of groove flared to break proximal contact; resulting cavosurface angle is 90 degrees; no unsupported enamel remaining

SUMMARY CHART
PINLEDGE PREPARATION

Indications	Contraindications	Advantages	Disadvantages
Undamaged anterior teeth in caries-free mouth	Large pulps	Minimal tooth reduction	Less retentive than complete coverage
Alteration of lingual contour of maxillary anterior teeth or alteration of occlusion	Thin teeth	Minimal margin length	Alignment can prove difficult
Anterior splinting	Nonvital teeth	Minimum gingival involvement	Technically demanding
	Carious involvement	Optimum access for margin finishing and hygiene	Not usable on nonvital teeth
	Problems with proposed path of placement of FDP	Adequate retention	–

FDP, fixed dental prosthesis.

SUMMARY CHART
CLASS II INLAY PREPARATION

Indications	Contraindications	Advantages	Disadvantages
Small carious lesion in otherwise sound tooth	High caries index	Superior material properties	Less conservative than amalgam
Adequate dentinal support	Poor plaque control	Longevity	May display metal
Low caries rate	Small teeth	No discoloration from corrosion	Gingival extension beyond ideal
Patient's request for gold instead of amalgam or composite resin	Adolescents	Least complex cast restoration	"Wedge" retention summary chart
	MOD restorations	–	–
	Poor dentinal support necessitating a wide preparation	–	–

MOD, mesio-occlusal-distal.

Preparation steps	Recommended armamentarium	Criteria
Reduction of marginal ridge and contact area adjacent to edentulous space	Round-tipped, tapered diamond	Should provide space for adequate bulk of metal in area of connector
Lingual reduction	Football-shaped diamond	Should provide for clearance of at least 0.7 mm
Ledges	Straight carbide fissure bur	Ledges must be parallel to one another when viewed from lingual and from incisal; maximum width, 1 mm
Indentations	Straight carbide fissure bur	Indentation should provide at least 0.5 mm of space for metal reinforcement around opening of pinhole
Pilot channels and pinholes	Tapered carbide bur	Pinholes must be between 2 and 3 mm deep; minimal width of ledge around pinholes is 0.5 mm
Finishing	Finishing stones or carbides	All surfaces must be as smooth as possible (obtain with fine-grit rotary instruments) to facilitate removal of this delicate wax pattern from die

Preparation steps	Recommended armamentarium	Criteria
Occlusal outline	Tapered carbide	Includes central groove, avoids centric contacts, includes dovetail or pinhole for resistance; approximately 1.8 mm deep
Proximal box	Tapered carbide	Follows curvature of original tooth surface
Caries removal	Excavator or round bur	Tissue replaced with base
Axiogingival groove	Gingival margin trimmer	Detectable with explorer tip (0.2 mm deep)
Gingival and proximal bevels	Thin, tapered carbide or diamond	45 degrees; approximately 0.8 mm wide
Occlusal bevel	Round carbide or stone	Hollow ground, avoid centric contacts

SUMMARY CHART

MOD ONLAY PREPARATION

Indications	Contraindications	Advantages	Disadvantages
Worn or carious teeth with intact buccal and lingual cusps	High caries index	Support of cusps	Lacks retention
MOD amalgam requiring replacement	Poor plaque control	High strength	Less conservation than amalgam
	Short clinical crown or extruded teeth	Longevity	May display metal
Low caries rate	Lesions extending beyond transitional line angles	–	Gingival extension beyond ideal
Patient's request for gold instead of amalgam	–	–	–

MOD, mesio-occlusal-distal.

Preparation steps	Recommended armamentarium	Criteria
Occlusal outline	Tapered carbide	Includes central, buccal, and lingual grooves; about 1.8 mm deep
Proximal boxes	Tapered carbide	Follows curvature of original tooth surface
Caries removal	Excavator or round bur	Tissue replaced with base
Occlusal reduction	Tapered carbide	Adequate dentin for resistance and retention
Centric cusp ledge	Tapered carbide	Following anatomic contours
Gingival and proximal bevels	Thin, tapered carbide	1.5-mm functional cusp; 1.0-mm nonfunctional cusp About 1.0 mm wide (before beveling) About 1.0 mm apical to centric contact 45 degrees; about 0.8 mm wide

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11

TOOTH PREPARATION FOR ALL-CERAMIC RESTORATIONS



All-ceramic inlays, onlays, veneers, and crowns are some of the most esthetically pleasing prosthodontic restorations. Because there is no metal to block light transmission, they can resemble natural tooth structure better in terms of color and translucency than can any other restorative option. Their chief disadvantage is their susceptibility to fracture, although this is lessened by use of the resin-bonded technique.

The restorations may be fabricated in several ways. The technique (first developed more than 100 years ago) originally called for a platinum foil matrix to be intimately adapted to a die. This supported the porcelain during firing and prevented distortion. The foil was removed before cementation of the restoration.

Today, popular fabrication processes for the restorations include hot-pressing and slip-casting. These options are discussed in Chapter 25.

COMPLETE CERAMIC CROWNS

Complete ceramic crowns should have relatively even thickness circumferentially. For the hot-pressed ceramic crown (IPS Empress* or OPC†) (Fig. 11-1), usually about 1 to 1.5 mm is needed to create an esthetically pleasing restoration. Incisally, a greater ceramic thickness may be required.

Only minor differences in tooth preparation design exist among the restorations fabricated with the various techniques. Therefore, the hot-pressed crown preparation is described in detail, and the necessary variations are discussed when pertinent.

*Ivoclar Vivadent, Schaan, Liechtenstein.
†Pentron Ceramics, Inc., Somerset, New Jersey.

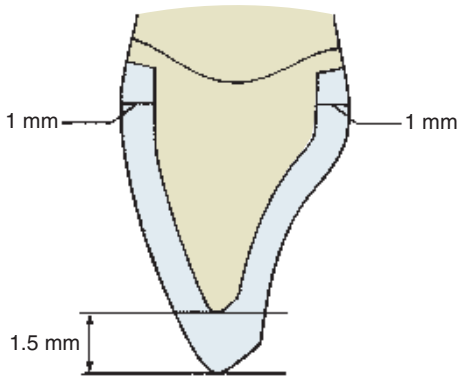


Fig. 11-1
Recommended reduction for the all-ceramic crown.

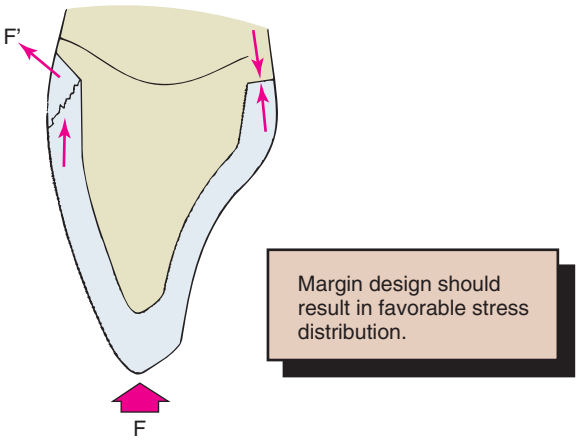


Fig. 11-2
A sloping shoulder is not recommended for the all-ceramic crown. It does not support the porcelain. Incisal loading leads to tensile stresses near the margin.

Advantages

The advantages of a complete ceramic crown include its superior esthetics, its excellent translucency (similar to that of natural tooth structure), and its generally good tissue response. Lack of reinforcement by a metal substructure enables slightly more conservative reduction of the facial surface than is possible with the metal-ceramic crown, although the lingual surface needs additional reduction for strength. The appearance of the completed restoration can be influenced and modified by selecting different colors of luting agent. However, changing cement color under restorations that rely on an opaque core for strength, such as the slip-cast alumina core system (In-Ceram[‡]), is ineffective.

Disadvantages

The disadvantages of a complete ceramic crown include reduced strength of the restoration because of the absence of a reinforcing metal substructure. Because of the need for a shoulder-type margin circumferentially, significant tooth reduction is necessary on the proximal and lingual aspects. Porcelain brittleness, when combined with the lack of a reinforcing substructure, requires the incorporation of a circumferential support with a shoulder. Thus, by comparison, the proximal and lingual reductions are less conservative than those needed for a metal-ceramic crown.

Difficulties may be associated with obtaining a well-fitting margin when certain techniques are used. The "unforgiving" nature of porcelain, if an inadequate tooth preparation goes uncorrected, can result in fracture.

Proper preparation design is critical to ensuring mechanical success. A 90-degree cavosurface angle is needed to prevent unfavorable distribution of stresses and to minimize the risk of fracture (Fig. 11-2). The preparation should provide support for the porcelain along its entire incisal edge, unless a ceramic system that includes a high-strength core is chosen (see Chapter 25).

All-ceramic restorations are not effective as retainers for a fixed dental prosthesis, although the strongest of the slip-cast materials (In-Ceram Zirconia[§]) and the higher-strength pressed systems (IPS Empress 2[¶]) may be suitable for anterior applications. The brittle nature of porcelain necessitates that connectors of large, cross-sectional dimension (a minimum of 4 × 4 mm is recommended) be incorporated in the fixed dental prosthesis design. This typically leads to impingement on the interdental papilla by the connector, with increased potential for periodontal failure.

Wear has been observed on the functional surfaces of natural teeth that oppose porcelain restorations. This also applies to teeth opposed by metal-ceramic restorations, especially the mandibular incisors, which can exhibit significant wear over time (see Fig. 19-1).

Indications

The complete ceramic crown is indicated in areas with a high esthetic requirement where a more conservative restoration would be inadequate (Fig. 11-3). Usually such a tooth has proximal and/or facial caries that can no longer be effectively restored with composite resin.

[‡]VITA Zahnfabrik, Bad Säckingen, Germany.

[§]VITA Zahnfabrik, Bad Säckingen, Germany.
[¶]Ivoclar Vivadent, Schaan, Liechtenstein.



Fig. 11-3
A, Inadequately fitting all-ceramic crowns have led to recurrent caries and gingival recession around these central incisors. The patient was a professional model and therefore had exceptionally high esthetic requirements. **B,** The gingival defect was corrected by minor periodontal recontouring, the teeth were reprepared, and new all-ceramic crowns were provided.

The tooth should be relatively intact with sufficient coronal structure to support the restoration, particularly in the incisal area, where it is important not to exceed a maximum porcelain thickness of 2 mm; otherwise, failure of the brittle material will occur.

Because of the relative weakness of the restoration, the occlusal load should be favorably distributed (Fig. 11-4). In general, this means that centric contact must be in an area where the porcelain is supported by tooth structure (e.g., in the middle third of the lingual wall).

Contraindications

The ceramic crown is contraindicated when a more conservative restoration can be used. Rarely is it recommended for molar teeth. Because of the increased occlusal load and the reduced esthetic demand, metal-ceramic restorations are the treatment of choice. If occlusal loading is unfavorable (Fig. 11-5) or if it is not possible to provide adequate support or an even shoulder width of at least

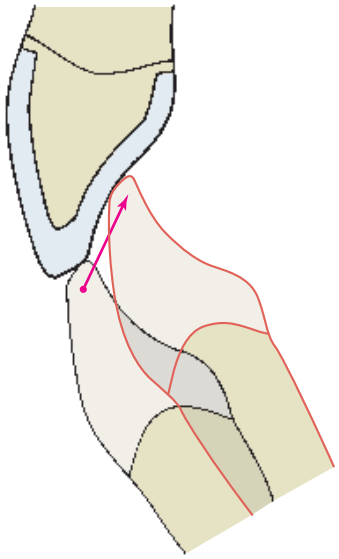


Fig. 11-4
The design of the occlusion on an all-ceramic crown is crucial to avoid fracture. Centric contacts are best confined to the middle third of the lingual surface. Anterior guidance should be smooth and consistent with contact on the adjacent teeth. Leaving the restoration out of contact is not recommended. Future eruption may lead to protrusive interferences, precipitating fracture.



Fig. 11-5
Unfavorable occlusal loading such as this edge-to-edge relationship on the lateral incisor is a contraindication to the all-ceramic crown, particularly in view of the parafunctional activity of this patient.

1 mm circumferentially, a metal-ceramic restoration should be considered instead.

Preparation

Armamentarium

The instruments needed for preparing an all-ceramic crown (Fig. 11-6) include the following:

- Narrow, round-tipped, tapered diamonds, regular and coarse grit (0.8 mm)



Fig. 11-6
Armamentarium for an all-ceramic crown preparation.

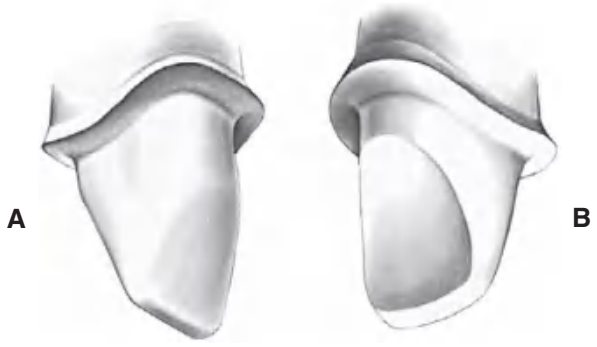


Fig. 11-7
All-ceramic crown preparation. **A,** Labial view. **B,** Lingual view. To prevent stress concentrations in the ceramic, all internal line angles should be rounded. The shoulder should be as smooth as possible to facilitate the technical aspects of fabrication.

- Square-tipped, tapered diamond, regular grit (1.0 mm)
- Football-shaped diamond
- Finishing stones and carbides
- Mirror
- Periodontal probe
- Explorer
- Chisels and hatchets
- High- and low-speed handpieces

Step-by-step procedure

The preparation sequence for a ceramic crown (Fig. 11-7) is similar to that for a metal-ceramic crown; the principal difference is the need for a 1-mm-wide chamfer circumferentially (Fig. 11-8).

Incisal (occlusal) reduction

The completed reduction of the incisal edge should provide 1.5 to 2 mm of clearance for porcelain in all excursive movements of the mandible. This enables fabrication of a cosmetically pleasing restoration with adequate strength. If the restoration is used for posterior teeth (rare), 1.5 to 2 mm of clearance is needed on all cusps.

1. Place three depth grooves in the incisal edge, initially keeping them approximately 1.3 mm deep to allow for additional loss of tooth structure during finishing. The grooves are oriented perpendicular to the long axis of the opposing tooth to provide adequate support for the porcelain crown.
2. Complete the incisal reduction, reducing half the surface at a time, and verify its adequacy upon completion.

Facial reduction

3. After placing depth grooves, reduce the facial or buccal surface and verify that adequate clearance exists for 1 mm of porcelain thickness. One depth groove is placed in the middle of the facial wall, and one each in the mesiofacial and distofacial transitional line angles. The reduction is then performed with a cervical component parallel to the proposed path of placement and an incisal component parallel to the original contour of the tooth. The depth of these grooves should be approximately 0.8 mm to allow finishing. The reduction is performed on half of the facial surface at a time.
4. Accomplish the bulk reduction with the round-tipped tapered diamond (which results in a heavy chamfer margin). Be sure to maintain copious irrigation throughout.

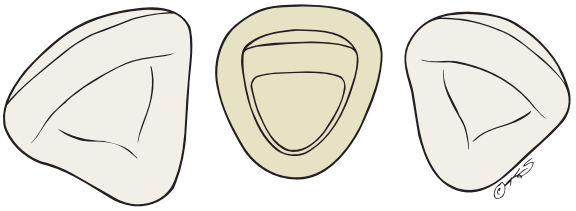


Fig. 11-8
Note the uniform chamfer width of 1 mm on this all-ceramic crown preparation.

Lingual reduction

5. Use the football-shaped diamond for lingual reduction after placing depth grooves approximately 0.8 mm deep. The lingual reduction is done in the same way as the other anterior tooth preparations (see Chapters 9 and 10) until a clearance of 1 mm in all mandibular excursive movements has been obtained. Adequate space must exist for the porcelain in all load-bearing areas.
6. After the selected path of placement has been transferred from the cervical wall of the facial

preparation, place a depth groove in the middle of the cingulum wall.

7. Repeat the shoulder preparation, this time from the center of the cingulum wall into the proximal aspect, until the lingual shoulder meets the facial shoulder. This margin should follow the free gingival crest and should not extend too far subgingivally.

Chamfer preparation

For subgingival margins, displace the tissue with cord before proceeding with the chamfer preparation. The ultimate objective is to direct stresses optimally in the completed porcelain restoration. This is accomplished when the chamfer or rounded shoulder margin completely supports the crown; any forces exerted on the crown are then in a direction parallel to its path of placement. A sloping shoulder results in unfavorable loading of the porcelain, with a greater likelihood of tensile failure. A 90-degree cavosurface angle is optimal. Care must be taken, however, that no residual unsupported enamel is overlooked, because it easily chips off.

The completed chamfer should be 1 mm wide, smooth, continuous, and free of any irregularities.

Finishing

8. Finish the prepared surfaces to a final smoothness as described for the other tooth preparations. Be sure to round any remaining sharp line angles to prevent a wedging action, which can cause fracture.
9. Perform any additional margin refinement as needed, using either the diamond or a carbide rotary instrument of choice.

CERAMIC INLAYS AND ONLAYS

For patients demanding esthetic restorations, ceramic inlays and onlays provide a durable alternative to posterior composite resins. The procedure consists of bonding the ceramic restoration to the prepared tooth with an acid-etch technique. The bonding mechanism relies on acid etching of the enamel and the use of composite resin, as seen in the resin-retained fixed dental prosthesis technique (see Chapter 26). Bonding to porcelain is achieved by etching with hydrofluoric acid and the use of a silane coupling agent (materials are identical to those marketed as porcelain repair kits). A similar restoration entails the use of laboratory-processed composite resin instead of the ceramic.

Indications

A ceramic inlay can be used instead of amalgam or a gold inlay for patients with a low caries rate who require a Class II restoration and wish to restore the tooth to its original appearance. It is the most conservative ceramic restoration and enables most of the remaining enamel to be preserved.

Contraindications

Because these restorations are time consuming and expensive, they are contraindicated in patients with poor oral hygiene or active caries. Because of their brittle nature, ceramic restorations may be contraindicated in patients with excessive occlusal loading, such as those with bruxism.

Advantages

Ceramic inlays and onlays can be extremely esthetic restorations. The restoration wear associated with posterior composite restorations is not a problem with the ceramic restorations. Marginal leakage associated with polymerization shrinkage and high thermal coefficient of expansion of the resin is reduced, because the luting layer is very thin.

Disadvantages

Accurate occlusion can be difficult to achieve with ceramic inlays and onlays. Because they are fragile, intraoral occlusal adjustment is impractical before they are bonded in place. Therefore, any areas of adjustment need careful finishing and polishing, which is a time-consuming procedure. Rough porcelain is extremely abrasive of the opposing enamel. Castable glass-ceramic restorations (see Chapter 25) are less abrasive than the traditional feldspathic porcelain. Wear of the composite resin-luting agent can be a problem, leading to marginal gaps. These eventually allow chipping or recurrent caries. Accuracy is important with these restorations, because accurately fitting restorations (marginal gaps less than 100 μm) have been shown to reduce this problem significantly. Finishing of the margins can be difficult in the less accessible interproximal areas. Resin flash or overhangs are difficult to detect and can initiate periodontal disease.

Bonded ceramic inlays are a relatively new concept, and long-term clinical performance is hard to judge. The patient should always be made aware that unforeseen problems may surface over time when a newer procedure is used.

Preparation

Armamentarium

As for metal inlays, carbide burs are used in the preparation (Figs. 11-9 and 11-10), but diamonds may be substituted:



Fig. 11-9
Maxillary first molar preparation for a mesio-occlusal-distal (MOD) ceramic inlay. **A,** Defective restoration. **B,** The restoration and caries removed. **C,** Unsupported enamel removed and glass ionomer base placed. **D,** The completed ceramic restoration. *(Courtesy of Dr. R. Seghi.)*



Fig. 11-10
Armamentarium for the ceramic inlay preparation.

- Tapered carbide burs
- Round carbide burs
- Cylindrical carbide burs
- Finishing stones
- Mirror
- Explorer and periodontal probe
- Chisels
- Gingival margin trimmers
- Excavators
- High- and low-speed handpieces
- Articulating film

Step-by-step procedure

Rubber dam isolation is recommended for visibility and moisture control. Before applying the dam, mark and assess the occlusal contact relationship with articulating film. To avoid chipping or wear of the luting resin, the margins of the restoration should not be at a centric contact.

Outline form

1. Prepare the outline form. Preparation is generally governed by the existing restorations and caries and is broadly similar to that for conventional metal inlays and onlays (see Chapter 10). Because of the resin bonding, axial wall undercuts can sometimes be blocked out with resin-modified glass ionomer cement, which preserves additional enamel for adhesion. However, undermined or weakened enamel should always be removed. The central groove reduction (typically about 1.8 mm) follows the anatomy of the unprepared tooth rather than a monoplane. This provides additional bulk for the ceramic. The outline should avoid occlusal contacts. Areas to receive onlays need 1.5 mm of clearance in all excursions to prevent ceramic fracture.
2. Extend the box to allow a minimum of 0.6 mm of proximal clearance for impression making. The margin should be kept supragingival, which makes isolation during the crucial luting procedure easier and improves access for finishing. If necessary, electrosurgery or crown lengthening (p. 190) can be performed. The width of the gingival floor of the box should be approximately 1.0 mm.
3. Round all internal line angles. Sharp angles lead to stress concentrations and increase the likelihood of voids during the luting procedure.

Caries excavation

4. Remove any caries not included in the outline form preparation with an excavator or a round bur in the low-speed handpiece.

5. Place a resin-modified glass ionomer cement base to restore the excavated tissue in the gingival wall.

Margin design

6. Use a 90-degree butt joint for ceramic inlay margins. Bevels are contraindicated because bulk is needed to prevent fracture. A distinct heavy chamfer is recommended for ceramic onlay margins.

Finishing

7. Refine the margins with finishing burs and hand instruments, trimming back any glass ionomer base. Smooth, distinct margins are essential in an accurately fitting ceramic restoration.

Occlusal clearance (for onlays)

8. Check the occlusal clearance after the rubber dam is removed. A 1.5-mm clearance is needed to prevent fracture in all excursions. This can be easily evaluated by measuring the thickness of the resin interim restoration with a dial caliper.

PORCELAIN LAMINATE VENEERS

Laminate veneering (Fig. 11-11) is a conservative method of restoring the appearance of discolored, pitted, or fractured anterior teeth. It consists of bonding thin ceramic laminates onto the labial sur-



Fig. 11-11

Esthetic facial veneers. **A** and **B,** Unesthetic maxillary incisors with crowding. The 50-year-old patient was not prepared to pursue an orthodontic option. **C,** Diagnostic waxing to optimal incisor form. **D,** Vacuum-formed matrix used to place interim restoration resin directly on the unprepared teeth to simulate the final esthetics. **E,** Tooth preparations. **F,** Restorations in place.

faces of affected teeth. The bonding procedure is the same as that for ceramic inlays except that a photopolymerize luting resin is usually used.

Advantages and Indications

The main advantage of laminate veneers is that they are conservative of tooth structure. Typically, only about 0.5 mm of facial reduction is needed. Because this is confined to the enamel layer, local anesthesia is not usually required. The main disadvantage of the procedure relates to difficulty in obtaining restorations that are not excessively contoured. This is almost inevitable in the gingival area if enamel is left for bonding. Little has been reported about the effect of the restorations on long-term gingival health and whether or how often they need replacement over a patient's lifetime.

Esthetic veneers should always be considered as a conservative alternative to cemented crowns. In many practices, they have largely replaced metal-ceramic crowns for the treatment of multiple discolored but otherwise sound teeth.

Preparation

Armamentarium

The instruments needed for preparing a porcelain laminate veneer include the following:

- 1-mm round bur or 0.5-mm depth cutter
- Narrow, round-tipped, tapered diamonds, regular and coarse grit (0.8 mm)
- Finishing strip
- Finishing stones
- Mirror
- Periodontal probe
- Explorer

Step-by-step procedure

The gingival third and proximal line angles are often overcontoured with these restorations (Fig. 11-12). Therefore, maximum reduction should be achieved with minimum penetration into the dentin.

1. Make a series of depth holes with a round bur to avoid penetrating abnormally thin enamel. The amount of reduction required depends somewhat on the extent of discoloration. A



Fig. 11-12

Porcelain facial veneer preparation. **A,** The proximal contact areas and incisal edge are preserved, and the preparation is limited to enamel. Normally, a reduction depth of about 0.5 mm is recommended, but making a series of depth holes with a round bur guards against penetrating thin enamel. **B,** Tetracycline-stained teeth. Composite resin veneers were placed earlier but failed to mask the discoloration satisfactorily. Six maxillary porcelain labial veneers will be provided. **C** and **D,** Completed tooth preparations. **E,** Interim restorations made directly with composite resin, which are retained by etching small areas of enamel (see Chapter 15).

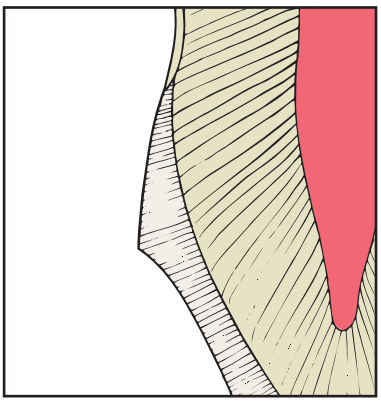


Fig. 11-13
The recommended margin ("long chamfer") for facial veneers has an obtuse cavosurface angle, and so the ends of the enamel prisms are exposed for differential etching.

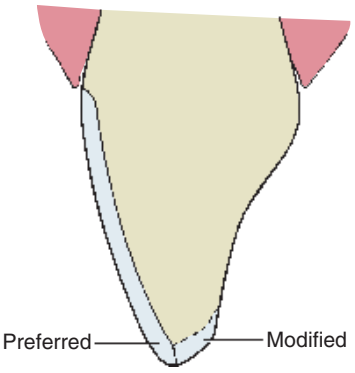


Fig. 11-14
The preferred design for porcelain laminate veneers maintains part of the incisal edge in enamel. If the edge is to be lengthened, a modified preparation with lingual extension is needed (*dotted line*).

minimum of 0.5 mm is usually adequate. The reduction should follow the anatomic contours of the tooth.

2. Place the "long chamfer" margin (Fig. 11-13). This design has an obtuse cavosurface angle, which exposes the enamel prism ends at the margin for better etching. The margin should closely follow the gingival crest so that all discolored enamel prisms are veneered without undue encroachment on the gingival sulcus.
3. Wherever possible, place the preparation margin labial to the proximal contact area to preserve it in enamel. However, slight clearance for separating the definitive cast and for accessing the proximal margins for finishing and polishing is essential. A diamond finishing strip helps create the necessary clearance. Sometimes the proximal margins are extended lingually to include existing restorations. This can necessitate considerable tooth reduction to avoid creating an undercut. Some authorities advocate placing the ceramic margin on composite material rather than extending the preparation to enamel, but this is not recommended. Extensive existing restorations are a contraindication for porcelain laminate veneers.
4. If possible, do not reduce the incisal edge (Fig. 11-14); this helps support the porcelain and makes chipping less likely. If the incisal edge length is to be increased, the preparation should extend to the lingual aspect. Care is needed to avoid undercuts with this modification. Visualizing the path of placement of the restoration is important, because an undercut prevents placement of the veneer.
5. To prevent areas of stress concentration in the porcelain, be sure that all prepared surfaces are rounded (see Fig. 11-12*C* and *D*).

STUDY QUESTIONS

1. What are the indications and contraindications for all-ceramic crowns and porcelain laminate veneers?
2. What are the advantages and disadvantages for all-ceramic crowns and porcelain laminate veneers?
3. What is the recommended armamentarium, and in what sequence should a maxillary central incisor be prepared, for an all-ceramic crown and porcelain laminate veneer?
4. What are the minimal criteria for steps 1 to 3? Why?
5. Discuss the advantages, disadvantages, indications, and contraindications for ceramic inlays and onlays.
6. What is the recommended armamentarium, and in what sequence should a mandibular molar be prepared, for a ceramic inlay and onlay?
7. What are the minimal criteria for steps 5 and 6? Why?

SUMMARY CHART

ALL-CERAMIC CROWN PREPARATION

Indications	Contraindications	Advantages	Disadvantages
High esthetic requirement	When superior strength is warranted and metal-ceramic crown is more appropriate	Esthetically unsurpassed	Reduced strength in comparison with metal-ceramic crown
Considerable proximal caries	High caries index	Good tissue response even for subgingival margins	Proper preparation extremely crucial
Incisal edge reasonably intact	Insufficient coronal tooth structure for support	Slightly more conservative of facial wall than metal ceramic	Among least conservative preparations
Endodontically treated teeth with post and cores	Thin teeth faciolingually	–	Brittle nature of material
Favorable distribution of occlusal load	Unfavorable distribution of occlusal load	–	Can be used only as single restoration
	Bruxism	–	–

Preparation steps	Recommended armamentarium	Criteria
Depth grooves for incisal reduction	Tapered diamond	Approximately 1.3 mm deep to allow for additional reduction during finishing; perpendicular to long axis of opposing tooth
Incisal reduction	Tapered diamond	Clearance of 1.5 mm; check excursions
Depth grooves for facial reduction	Tapered diamond	Depth of 0.8 mm needed for additional reduction during finishing
Facial reduction	Tapered diamond	Reduction of 1.2 mm needed; two planes, as for metal-ceramic crown preparation
Depth grooves and lingual reduction	Tapered and football-shaped diamonds	Initial depth, 0.8 mm; recreate concave configuration; do not maintain any convex configurations (stress)
Depth grooves for cingulum reduction	Tapered diamond	Parallel to cervical aspect of facial preparation; 1 mm of reduction; shoulder follows free gingival margin
Lingual shoulder preparation	Square-tipped diamond	Rounded shoulder 1 mm wide; minimize "peaks and valleys"; 90-degree cavosurface angle
Finishing	Fine-grit diamond or carbide	All surfaces smooth and continuous; no unsupported enamel; 90-degree cavosurface angle

SUMMARY CHART
CERAMIC INLAY AND ONLAY PREPARATION

Indications	Contraindications	Advantages	Disadvantages
Demand for esthetics	High caries index	Superior esthetics	Abrasive of opposing tooth
Low caries rate	Poor plaque control	Conservative	Occlusion difficult to adjust
Intact buccal and lingual enamel	Bruxism	Durable	Wear of luting agent
			Expensive
			Long-term success rate unknown

SUMMARY CHART
PORCELAIN LAMINATE VENEERS

Indications	Contraindications	Advantages	Disadvantages
Discolored or damaged anterior teeth	High caries index	Superior esthetics	Increased tooth contour
	Poor plaque control	Wear and stain resistant	Expensive
	Extensive existing restorations	–	–
	Bruxism	–	–

Preparation steps	Recommended armamentarium	Criteria
Outline	Tapered carbide	Includes existing restorations and caries; about 1.8 mm deep; small undercuts tolerated
Proximal box	Tapered carbide	Gingival floor 1 mm wide
Caries removal	Excavator or round bur	Clearance for impression 0.6 mm
Margins	Finishing burs	Block out undercuts with glass ionomer
Occlusal clearance	Hand instruments	90-degree butt joint
Finishing	Round-tipped diamond Finishing burs Fine-grit diamonds	Heavy chamfer for onlays Clearance in all excursions of 1.5 mm Rounded internal angles Smooth margins

Preparation steps	Recommended armamentarium	Criteria
Depth cuts	1-mm round bur or 0.5-mm depth cutter	A series of depth cuts to determine dentin exposure
Facial reduction	Round-tipped diamond	Follows curvature of original tooth surface
Proximal reduction	Round-tipped diamond	Extended to gingival crest, leaving contact area intact
Incisal and lingual reduction	Round-tipped diamond	None unless incisal margin is extended to lingual to allow lengthening
Margins	Round-tipped diamond	Long chamfer
Finishing	Fine-grit diamonds, carbides, or finishing stones	No sharp internal margins

12



RESTORATION OF THE ENDODONTICALLY TREATED TOOTH

KEY TERMS

canal shape
ferrule
multipiece cast cores
post shape
post removal
post type
post and core
post length
prefabricated posts
root
root diameter
stress distribution
surface texture

An endodontically treated tooth should have a good prognosis. It can resume full function and serve satisfactorily as an abutment for a fixed dental prosthesis (FDP) or a removable partial dental prosthesis. However, special techniques are needed to restore such a tooth. Usually a considerable amount of tooth structure has been lost because of caries, endodontic treatment, and the placement of previous restorations. The loss of tooth structure makes retention of subsequent restorations more problematic and increases the likelihood of fracture during functional loading.

Two factors influence the choice of technique: the type of tooth (whether it is an incisor, canine, premolar, or molar) and the amount of remaining coronal tooth structure. The latter is probably the most important indicator in determining the prognosis.

A number of different clinical techniques have been proposed to solve these problems, and opinions vary about the most appropriate one. Experimental data have improved the understanding of the difficulties inherent in restoring endodontically treated teeth. This chapter offers a rational and practical approach to the challenge.

TREATMENT PLANNING

Because of extensive caries or periodontal disease, removal of a tooth may be more sensible than endodontically treating it, although a severely damaged tooth occasionally can be restored after orthodontic repositioning or root resection (Fig. 12-1; see also Fig. 16-7). This should be done if loss of the tooth will significantly jeopardize the patient's occlusal function or the total treatment plan, particularly if dental implants are not an option. When the

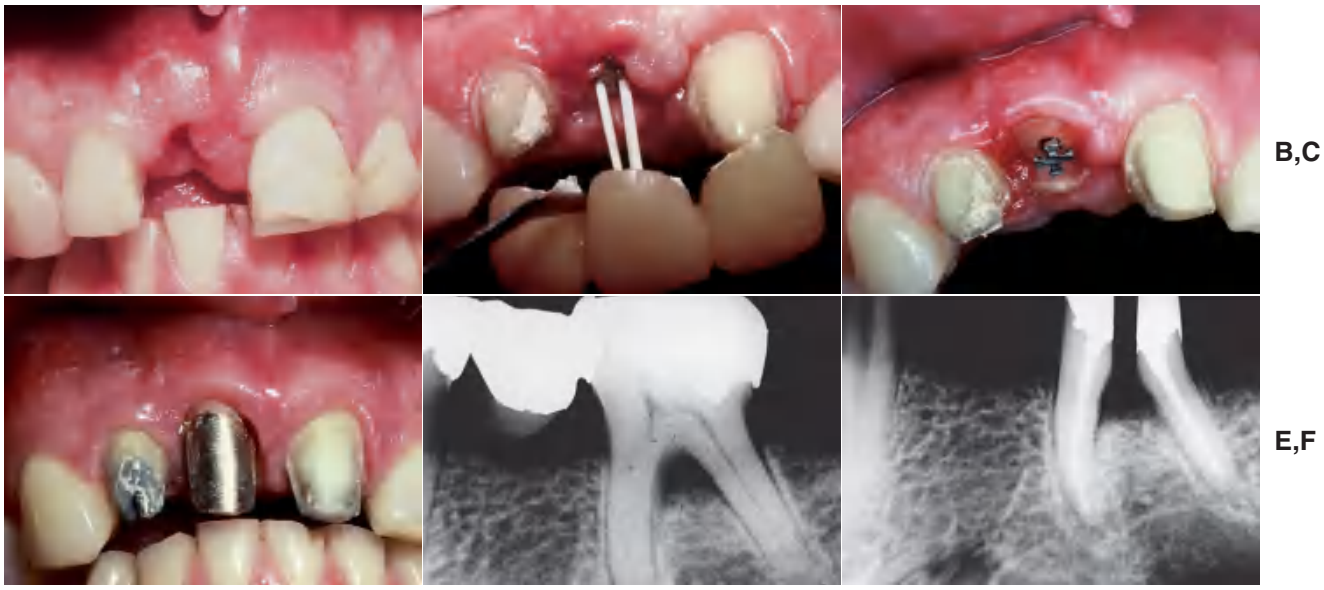


Fig. 12-1
A to **D,** A severely damaged tooth can sometimes be retained after orthodontic extrusion (see Chapter 6). **E** and **F,** Plaque control around periodontally compromised teeth may be improved after hemisectioning (see Chapter 5). *(**E** and **F**, Courtesy of Dr. H. Kahn.)*

decision is made to treat the tooth endodontically, consideration must have been given to its subsequent restoration. Before being restored, teeth that have been endodontically treated must be carefully evaluated for the following[1]:

- Good apical seal
- No sensitivity to pressure
- No exudate
- No fistula
- No apical sensitivity
- No active inflammation

Inadequate root fillings should be re-treated before fixed prosthodontic treatment is begun. If doubt remains, the tooth should be observed for several months until there is definite evidence of success or failure.

If the coronal structures are largely intact and loading is favorable, as on anterior teeth that are farther removed from the fulcrum (see Chapter 4), a simple filling can be placed in the access cavity (Fig. 12-2*A*). However, if a substantial amount of coronal structure is missing, a cast **post and core** is indicated instead (Fig. 12-2*B*). Molars are often restored with amalgam or a combination of one or more cemented posts and amalgam or composite resin (Fig. 12-2*C* and *D*).

Although one-piece post-crowns were once made, such prostheses are of only historical interest. Superior results are obtained with a two-step technique (Fig. 12-3) consisting of initial placement of a post and core foundation followed by placement of a

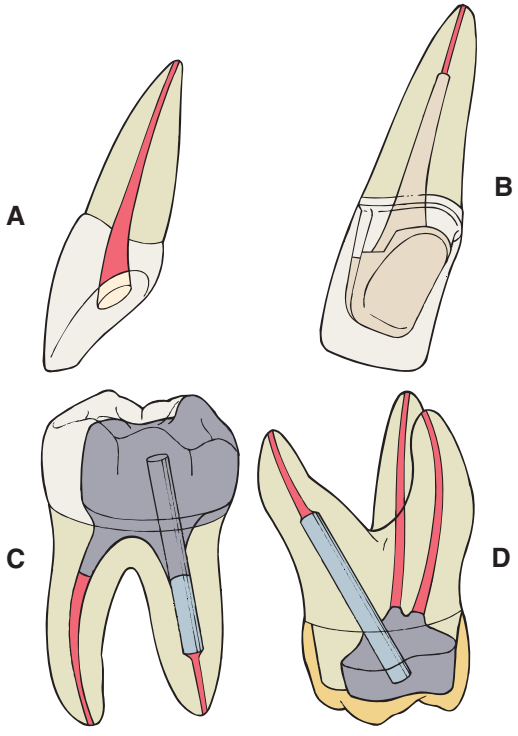


Fig. 12-2
A, An anterior tooth with an intact clinical crown can be predictably restored with a composite restoration in the access cavity. **B,** When most coronal tissue is missing, a cast post and core is indicated to obtain optimal tooth preparation form. **C,** In mandibular molars, an amalgam foundation is retained by a cemented prefabricated post in the distal canal. **D,** In maxillary molars, the palatal canal is most often used.



Fig. 12-3
The first molar and second premolar have been restored with post and cores. Note the margins, optimally located on sound tooth structure, cervical to the castings.



Fig. 12-4
The second premolar has been restored with a cast post and core, before a metal-ceramic crown. *(Courtesy of Dr. R. Webber.)*

separately fabricated crown. Most often a metal post is used, which provides the necessary retention for the core. The core replaces any lost coronal tooth structure, allowing optimal tooth preparation geometry to be achieved. Thus, the shape of the residual coronal tooth structure, combined with the core, should result in an ideal shape for the preparation (Fig. 12-4).

Prefabricated metal, carbon fiber, ceramic, and glass fiber posts are available. The last two options provide esthetic alternatives to metal posts.[2,3] Typically, **prefabricated posts** are used in a two-step procedure: first the post is cemented, after which a plastic core material such as composite resin, amalgam, or glass ionomer is applied. After shaping of the core and remaining tooth structure to optimal crown preparation form, a crown is fabricated in the conventional manner.

A cast post and core needs to be slightly undersized compared with the canal to achieve optimal internal seating, whereas the crown needs to be slightly larger to achieve optimal seating (see Chapter 7). Thus, it is easier to achieve a satisfactory marginal adaptation because the expansion rate of the two castings can be controlled individually. An added benefit is that it is possible to fabricate a replacement crown, if necessary, without the need for **post removal,** which may jeopardize the prognosis of the tooth. Finally, a path of placement different from the one selected for the post and core may be selected for the crown. This is often helpful when the tooth is restored to serve as an abutment for an FDP.

Clinical Failure

Morphologic and functional differences between anterior teeth and posterior teeth necessitate that they be treated differently after endodontic therapy, mainly because different loading considerations apply.

In one retrospective analysis[4] involving 638 patients, investigators evaluated 788 post and cores: 456 custom cast post and cores and 332 foundations with ParaPosts. Four to five years after cementation, reported failure rates in male patients were significantly higher than in female patients, and failure rates after age 60 were three times as high as failure rates for younger patients. Maxillary failure rates (15%) were three times as high as mandibular failure rates (5%) and more prevalent in lateral incisors, canines, and premolars than in central incisors and molars. Failure rate under FDPs was significantly lower than under single crowns. The latter finding may have been caused by load reduction resulting from bracing by the FDP. No correlation was apparent between failure and reduced marginal height of the encasing bone. Custom cast post and cores exhibited slightly higher failure rates than did amalgam foundations. This observation was also made by Sorensen and Martinoff.[5] However, Torbjörner and colleagues[4] suggested that custom cast post and cores tend to be used more often in teeth that already have considerably weakened root structure. Thus, regardless of the technique selected for subsequent restoration, the teeth themselves are already more prone to failure. Distal cantilevers appear to contribute to post and core failure in endodontically treated abutment teeth that support the cantilever.

Most of the failures just discussed are influenced by load. In general, as loading increases, failure rates appear to increase concomitantly. Failure has been shown to occur at lower loads as teeth are loaded less parallel to their long axes,[6] which suggests that clinical failure occurs more readily under lateral loading.

In the planning of the restoration of endodontically treated teeth, the practitioner must account for the strength of the remaining tooth structure, weighed carefully against the load to which the restored tooth will be subjected.

Considerations for Anterior Teeth

Endodontically treated anterior teeth do not always need complete coverage by placement of a complete crown, except when plastic restorative materials have limited prognosis (e.g., if the tooth has large proximal composite restorations and unsupported tooth structure). Many otherwise intact teeth function satisfactorily with a composite resin restoration.

Although it is commonly believed, it has not been demonstrated experimentally that endodontically treated teeth are weaker or more brittle than vital teeth. Their moisture content, however, may be reduced.[7] Laboratory testing[8] has actually revealed a resistance to fracture similar between untreated and endodontically treated anterior teeth. Nevertheless, clinical fracture does occur, and attempts have been made to strengthen the tooth by removing part of the root canal filling and replacing it with a metal post. In reality, placement of a post requires the removal of additional tooth structure (Box 12-1), which is likely to weaken the tooth.

Cementing a post in an endodontically treated tooth is a fairly common clinical procedure, despite the paucity of data to support its success. In fact, a laboratory study[9] and two stress analyses[10,11] have determined that no significant reinforcement results. This might be explained by the hypothesis that when the tooth is loaded, stresses are greatest at the facial and lingual surfaces of the root and an internal post, being only minimally stressed, does not help prevent fracture (Fig. 12-5). Results of other studies, however, contradict this assumption.[8,12]

Box **12-1** **Disadvantages to the Routine Use of a Cemented Post**

- Placing the post requires an additional operative procedure.
- Preparing a tooth to accommodate the post entails removal of additional tooth structure.
- It may be difficult to restore the tooth later, when a complete crown is needed, because the cemented post may have failed to provide adequate retention for the core material.
- The post can complicate or prevent future endodontic re-treatment that may be necessary.

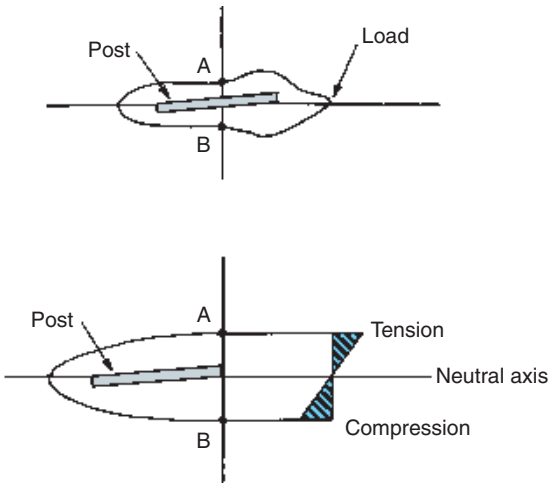


Fig. 12-5
Experimental stress distributions in an endodontically treated tooth with a cemented post. When the tooth is loaded, the lingual surface (A) is in tension, and the facial surface (B) is in compression. The centrally located cemented post lies in the neutral axis (i.e., not in tension or compression). *(Redrawn from Guzy GE, Nicholls JI: In vitro comparison of intact endodontically treated teeth with and without endo-post reinforcement. J Prosthet Dent 42:39, 1979.)*

Cemented posts may further limit or complicate endodontic re-treatment options if these are necessary. In addition, if coronal destruction occurs, post removal may be necessary to provide adequate support for a future core.

For these reasons, a metal post is not recommended in anterior teeth that do not require complete coverage restorations. This view is supported by a retrospective study[13] that did not show any improvement in prognosis for endodontically treated anterior teeth restored with a post. In another study, post placement did not influence the position or angle of radicular fracture.[14] A conflicting report however, suggests that endodontically treated teeth not crowned after obturation were lost six times more frequently than teeth that were crowned after obturation.[15]

Discoloration in the absence of significant tooth loss may be more effectively treated by bleaching[16] than by the placement of a complete crown, although not all stained teeth can be bleached successfully. Resorption can be an unfortunate side effect of nonvital bleaching.[17] However, when loss of coronal tooth structure is extensive or the tooth will be serving as an FDP or partial removable dental prosthetic abutment, a complete crown becomes mandatory. Retention and support then must be derived from within the canal, because a limited amount of coronal dentin remains once the reduction for complete coverage has been completed.

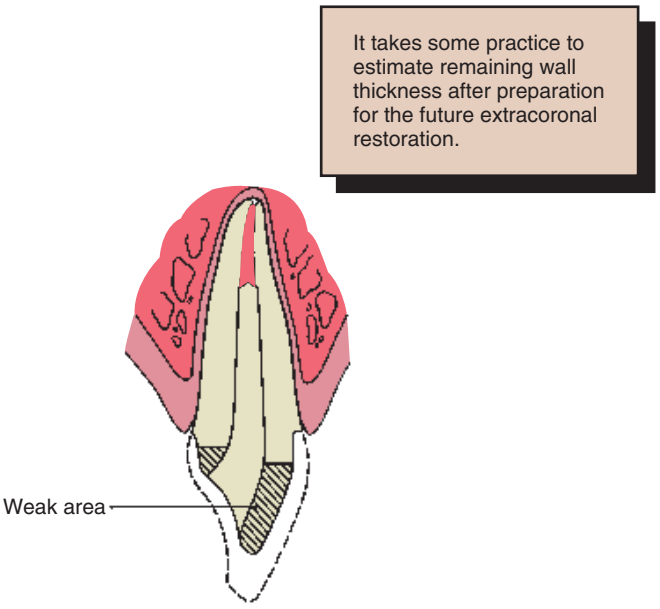


Fig. 12-6
Cross section through a central incisor. The *dotted line* indicates the original tooth contour before preparation for a metal-ceramic restoration. Even with minimum reduction for the extracoronal restoration, the facial wall is weakened and would not be able to support a prosthesis successfully. The sharp lingual wall complicates pattern fabrication.

Coupled with the loss of internal tooth structure necessary for endodontic treatment, the remaining walls become thin and fragile (Fig. 12-6), which often necessitates their reduction in height.

Considerations for Posterior Teeth

Posterior teeth are subject to greater loading than are anterior teeth because of their closer proximity to the transverse horizontal axis. This, combined with their morphologic characteristics (having cusps that can be wedged apart), makes them more susceptible to fracture. Careful occlusal adjustment reduces potentially damaging lateral forces during excursive movements. Nevertheless, endodontically treated posterior tooth should receive cuspal coverage to prevent biting forces from causing fracture. Possible exceptions are mandibular premolars and first molars with intact marginal ridges and conservative access cavities not subjected to excessive occlusal forces (i.e., posterior disclusion in conjunction with normal muscle activity).

Complete coverage is recommended on teeth with a high risk of fracture. This is especially true for maxillary premolars, which have been shown to have fairly high failure rates if restored with two or three surface amalgam restorations.[18] Complete coverage gives the best protection against fracture, because the tooth is completely encircled by the

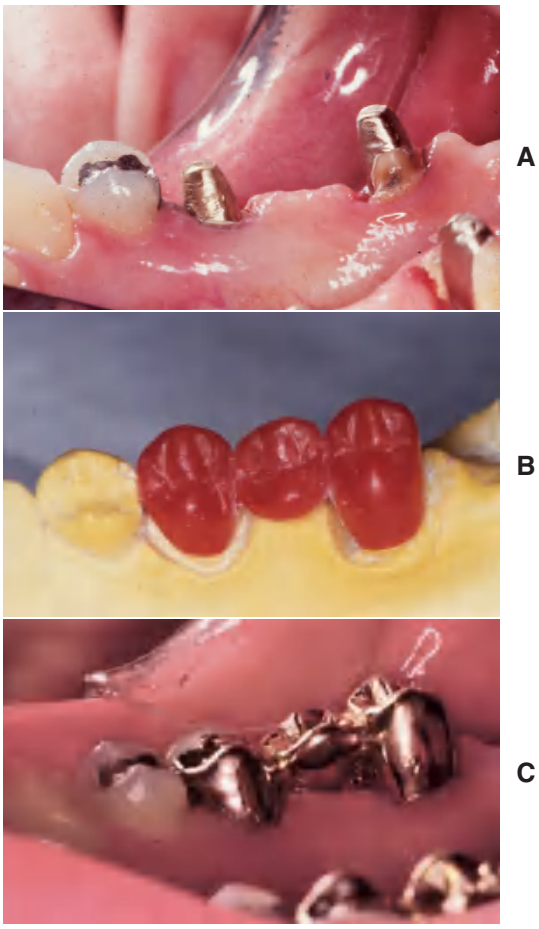


Fig. 12-7
A, Mandibular premolar and hemisected molar restored with cast post and cores. **B,** Waxed three-unit fixed dental prosthesis (FDP). **C,** The FDP cemented in place. *(Courtesy of Dr. F. Hsu.)*

restoration. However, when a metal-ceramic crown is to be used, considerable tooth reduction is required, which results in further weakening of the remaining tooth structure. In general, when significant coronal tooth loss has occurred, a cast post and core (Fig. 12-7) or an amalgam foundation restoration is needed.

PRINCIPLES OF TOOTH PREPARATION

Many of the principles of tooth preparation discussed in Chapter 7 apply equally to the preparation of endodontically treated teeth, although certain additional concepts must be understood in order to avoid failure.

Conservation of Tooth Structure

Preparation of the canal

In creating post space, great care must be used to remove only minimal tooth structure from the canal

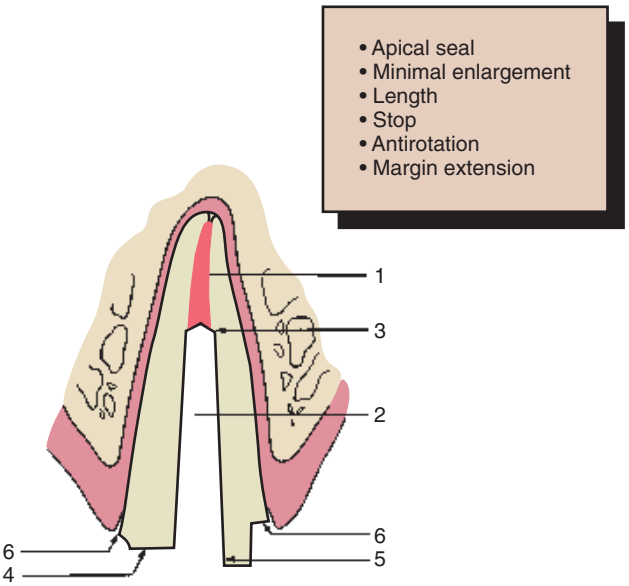


Fig. 12-8

Faciolingual cross-section through a maxillary central incisor prepared for a post and core. Six features of successful design are identified: *1*, adequate apical seal; *2*, minimum canal enlargement (no undercuts remaining); *3*, adequate post length; *4*, positive horizontal stop (to minimize wedging); *5*, vertical wall to prevent rotation (similar to a box); and *6*, extension of the final restoration margin onto sound tooth structure.

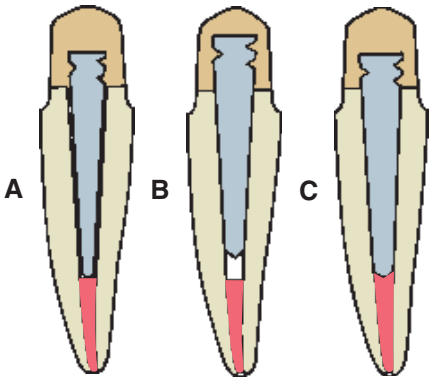


Fig. 12-9

Use of a prefabricated post entails enlarging the canal one or two file sizes to obtain a good fit at a predetermined depth. **A,** Incorrect; the prefabricated post is too narrow. **B,** Incorrect; the prefabricated post does not extend to the apical seal. **C,** Correct; the prefabricated post is fitted by enlarging the canal slightly.

(Fig. 12-8). Excessive enlargement can perforate or weaken the root, which then may split during post cementation or subsequent function. The thickness of the remaining dentin is the prime variable in fracture resistance of the root. Experimental impact testing of teeth with cemented posts of different diameters[7] showed that teeth with a thicker (1.8 mm) post fractured more easily than those with a thinner (1.3 mm) one.

Photoelastic stress analysis also has shown that internal stresses are reduced with thinner posts. The root can be compared to a ring. The strength of a ring is proportional to the difference between the fourth powers of its internal and external radii. This implies that the strength of a prepared root comes from its periphery, not from its interior, and so a post of reasonable size should not weaken the root significantly.[19] Nevertheless, it is difficult to enlarge a root canal uniformly and to judge with accuracy how much tooth structure has been removed and how thick the remaining dentin is. Most roots are narrower mesiodistally than faciolingually and often have proximal concavities that cannot be seen on a standard periapical radiograph. Experimentally, most root fractures originate from these concavities, because the remaining dentin thickness is minimal.[20] Therefore, the root canal should be enlarged only enough to enable the post to fit accurately and yet passively while ensuring strength and retention. Along the length of a tapered post space, enlargement seldom needs to exceed what would have been accomplished with one or two additional file sizes beyond the largest size used for endodontic treatment. Because of the more coronal position of the post space, a much larger file must be used to accomplish this (Fig. 12-9).

Preparation of coronal tissue

Endodontically treated teeth often have lost much coronal tooth structure as a result of caries, as a result of previously placed restorations, or in preparation of the endodontic access cavity. However, if a cast core is to be used, further reduction is needed to accommodate a complete crown and to remove undercuts from the chamber and internal walls. This may leave very little coronal dentin. Every effort should be made to save as much of the coronal tooth structure as possible, because this helps reduce stress concentrations at the gingival margin.[21] The amount of remaining tooth structure is probably the most important predictor of clinical success. If more than 2 mm of coronal tooth structure remains, the post design probably has a limited role in the fracture resistance of the restored tooth.[22,23] The once common clinical practice of routine coronal reduction to the gingival level before post and core fabrication is outmoded and should be avoided (Fig. 12-10). Extension of the axial wall of the crown apical to the missing tooth structure provides what is known as a restoration with a **ferrule,** which is defined as a metal band or ring used to fit the root or crown of a tooth, as opposed to a crown that merely encircles core material (Fig. 12-11). This is



Fig. 12-10

A, It is preferable to maintain as much coronal tooth structure as possible, provided it is sound and of reasonable strength. **B,** Extensive caries has resulted in the loss of all coronal tooth structure. This is less desirable than the situation in **A,** because greater forces are transmitted to the root.

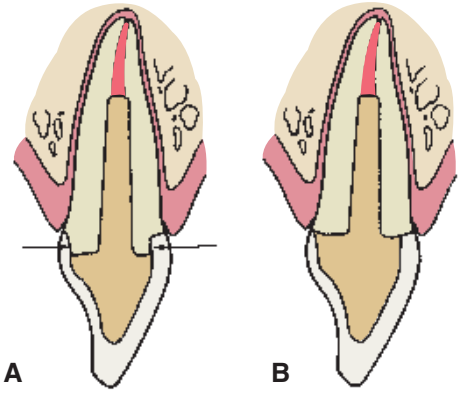


Fig. 12-11

Extending a preparation apically creates a ferrule and helps prevents fracture of an endodontically treated tooth during function. **A,** Preparation with a ferrule (*arrows*). **B,** Preparation without a ferrule.

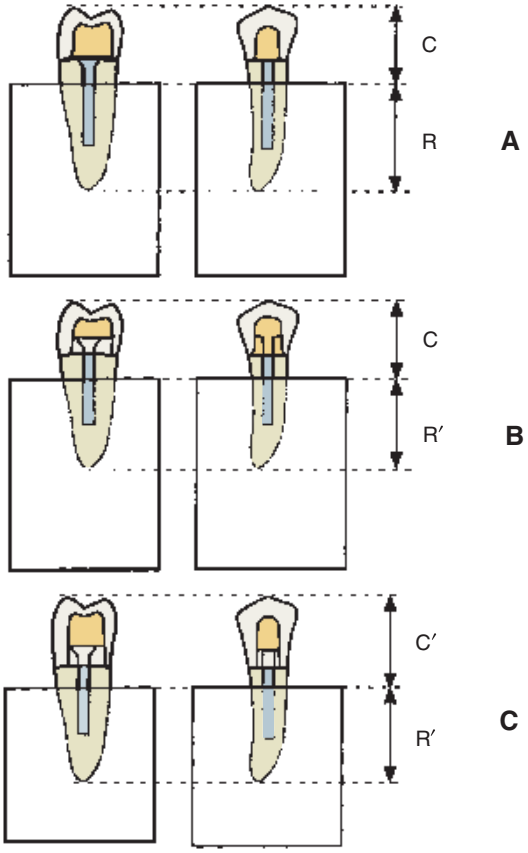


Fig. 12-12

Effect of apical preparation on crown/root ratio. **A,** Schematic of extensively damaged premolar tooth. Apical extension of the gingival margin would encroach on the biologic width (Chapter 5). This preparation has no ferrule. *C,* crown length; *R,* root length. **B,** Creating a ferrule with orthodontic extrusion (see Fig. 6-21) reduces root length (R′), whereas crown length remains unchanged. **C,** Surgical crown lengthening also reduces root length (R′) but increases crown length (C′). This results in a much less favorable crown/root ratio, which may, in fact, weaken the restoration. *(Courtesy of Dr. A. G. Gegauff. From Gegauff AG: Effect of crown lengthening and ferrule placement on static load failure of cemented cast post-cores and crowns, J Prosthet Dent 84:169, 2000.)*

thought to help bind the remaining tooth structure together, simultaneously preventing root fracture during function.[24-26] Although there is evidence that preserving as much coronal tooth structure as possible enhances prognosis, it is less clear whether the prognosis is improved by creation of a ferrule in an extensively damaged tooth through a surgical crown-lengthening procedure. In this latter circumstance, although the crown lengthening allows fabrication of a crown with a ferrule, it also leads to a much less favorable crown/root ratio and therefore to increased leverage on the root during function (Fig. 12-12).

One laboratory study showed that creating a ferrule through surgical crown lengthening resulted in a weaker, rather than a stronger, restored tooth.[27] In comparison, creating a ferrule with orthodontic extrusion may be preferred, because even though the root is effectively shortened, the crown is not lengthened (see Fig. 12-12*B*).

Retention Form

Anterior teeth

Simultaneous dislodgment of an anterior crown with the post and core that retains it is frequently seen clinically and results from inadequate retention form of the prepared tooth.[13,28] The normal faciolingual convergence of anterior teeth, coupled with smaller tooth size, complicates achieving such retention form. Post retention is affected by the

preparation geometry, post length, post diameter, post **surface texture,** and the luting agent.

Preparation geometry

Some canals, particularly in maxillary central incisors, have a nearly circular cross-section (see Table 12-3). These can be prepared with a twist drill or reamer to provide a cavity with parallel walls or minimal taper, allowing the use of a preformed post of corresponding size and configuration. Conversely, canals with elliptical cross-sections must be prepared with a restricted amount of taper (usually 6 to 8 degrees) to ensure adequate retention and eliminate undesired undercuts. This is analogous to an extracoronal preparation (see Chapter 7). With extracoronal preparations, retention increases rapidly as vertical wall taper is reduced (see Chapter 7). Although retention can be further increased by use of a threaded post, which screws into dentin, this procedure is not recommended because of residual stress in the dentin. If the procedure is used, however, threaded posts must be "backed off" to ensure passivity; otherwise, the root will fracture.

In accordance with this explanation, laboratory testing[29-31] has confirmed that parallel-sided posts are more retentive than tapered posts and that threaded posts are the most retentive (Fig. 12-13). However, these comparisons are relevant only if the post fits the root canal properly, because retention is proportional to the total surface area.

Circular parallel-sided post systems are effective only in the most apical portion of the post space, because the majority of prepared post spaces demonstrate considerable flare in the occlusal half. Similarly, when the root canal is elliptical, a parallel-sided post is not effective unless the canal is considerably enlarged, which would significantly weaken the root unnecessarily (Fig. 12-14).

Post length

Studies[29,31,32] have shown that as **post length** increases, so does retention. However, the relationship is not necessarily linear (Fig. 12-15). A post that is too short will fail (Fig. 12-16), whereas one that is too long may damage the seal of the root canal fill or risk root perforation if the apical third is curved or tapered (Fig. 12-17). Absolute guidelines for optimal post length are difficult to define. Ideally, the post should be as long as possible without jeopardizing the apical seal or the strength or integrity of the remaining root structure. Most endodontic texts advocate maintaining a 5-mm apical seal. However, if a post is shorter than the coronal height of the clinical crown of the tooth, the prognosis is considered unfavorable, because stress is distributed over a smaller surface area, thereby increasing the probability of radicular fracture. A short root and a tall clinical crown present the clinician with the dilemma of having to compromise the mechanics, the apical seal, or both. Under such circumstances, an apical seal of 3 mm is considered acceptable.

Post diameter

Increasing the post diameter in an attempt to increase retention is not recommended because the results are minimal retentive gain and unnecessary weakening of the remaining root. Although one group of investigators[33] reported that increasing the post diameter increased retention, other reports do not confirm this.[29,30] Empirical evidence suggests that the overall prognosis is good when post diame-

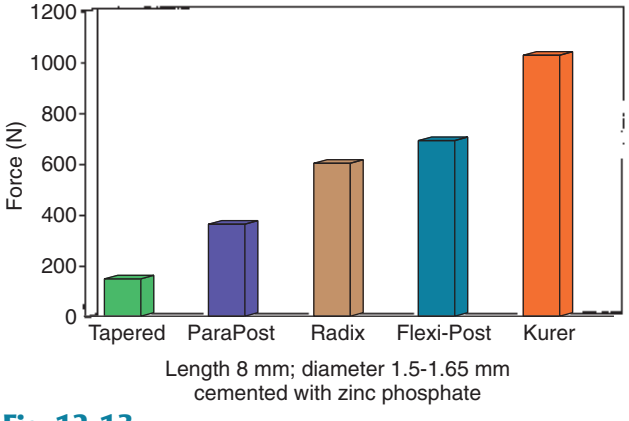


Fig. 12-13

Comparison of forces needed to remove different prefabricated post systems. *(Redrawn from Standlee JP, Caputo AA: The retentive and stress distributing properties of split threaded endodontic dowels. J Prosthet Dent 68:436, 1992.)*



Fig. 12-14

The use of a parallel-sided post in a tapered canal requires considerable enlargement of the post space, which can weaken the root significantly. *(Courtesy of Dr. R. Webber.)*

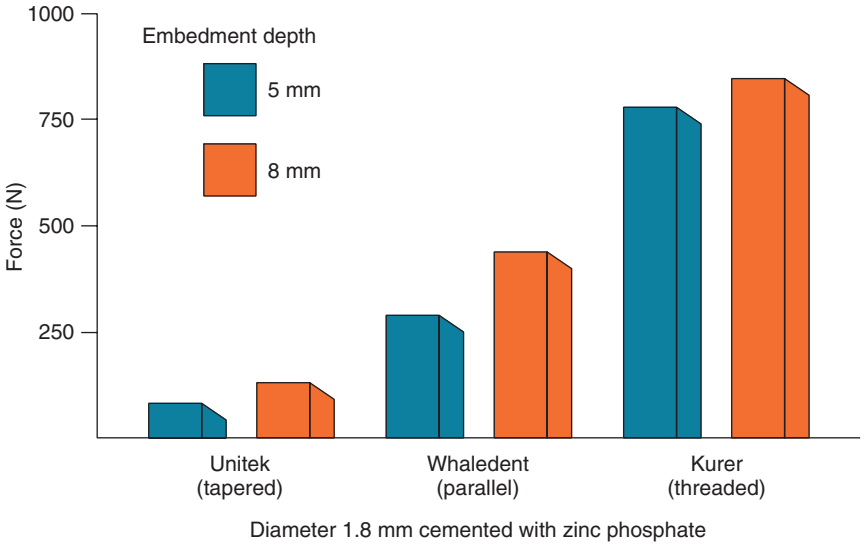


Fig. 12-15

Effect of the depth of embedding a post on its retentive capacity. *(Data from Standlee JP, et al: Retention of endodontic dowels: effects of cement, dowel length, diameter, and design. J Prosthet Dent 39:401, 1978.)*

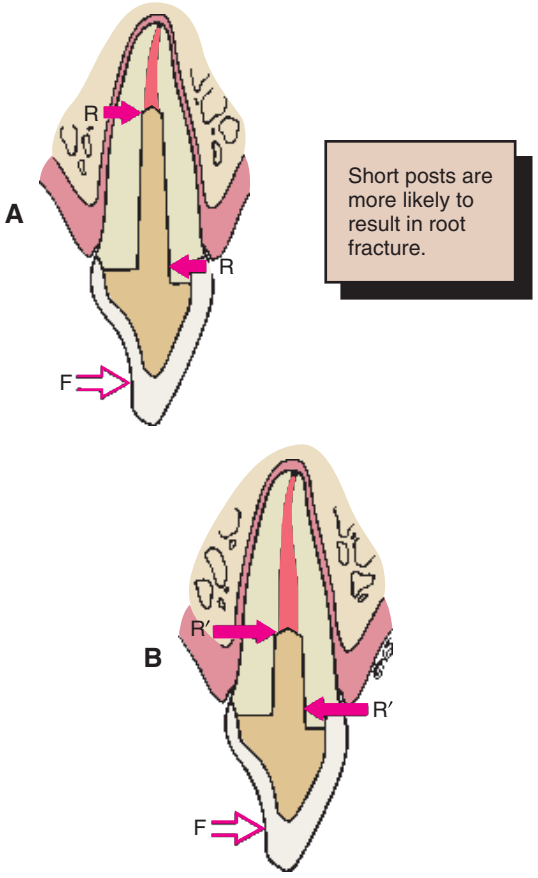


Fig. 12-16

Faciolingual longitudinal sections through a maxillary central incisor. **A,** With a post of the correct length, a force (*F*) applied near the incisal edge of the crown generates a resultant couple (*R*). **B,** When the post is too short, this couple is greater (*R′*), which leads to the increased possibility of root fracture.

ter does not exceed one third of the cross-sectional **root diameter.**

Post surface texture

A serrated or roughened post is more retentive than a smooth one,[30] and controlled grooving of the post and root canal[34] (Fig. 12-18) considerably increases the retention of a tapered post.

Luting agent

In considering traditional cements, the choice of luting agent seems to have little effect on post retention[35,36] or the fracture resistance of dentin.[37] However, adhesive resin luting agents (see Chapter 31) have the potential to improve the performance of post and core restorations; laboratory studies have shown improved retention.[38,39] Resin cements may be indicated if a post becomes dislodged. Resin cements are affected by eugenol-containing root canal sealers, which should be removed by irrigation with ethanol or etching with 37% phosphoric acid if the adhesive is to be effective.[40] Zinc phosphate and glass ionomer have comparable retentive properties, whereas polycarboxylate and composite resin cements have slightly less.[41] Some resin and glass ionomer cements have demonstrated significantly higher retention than resin-ionomer cements,[42] although the choice of luting agent may become more important if the post has a poor fit within the canal.[43] A post and core should be remade if any rotation or wobble is present.

Posterior teeth

Relatively long posts with a circular cross-section provide good retention and support in anterior teeth

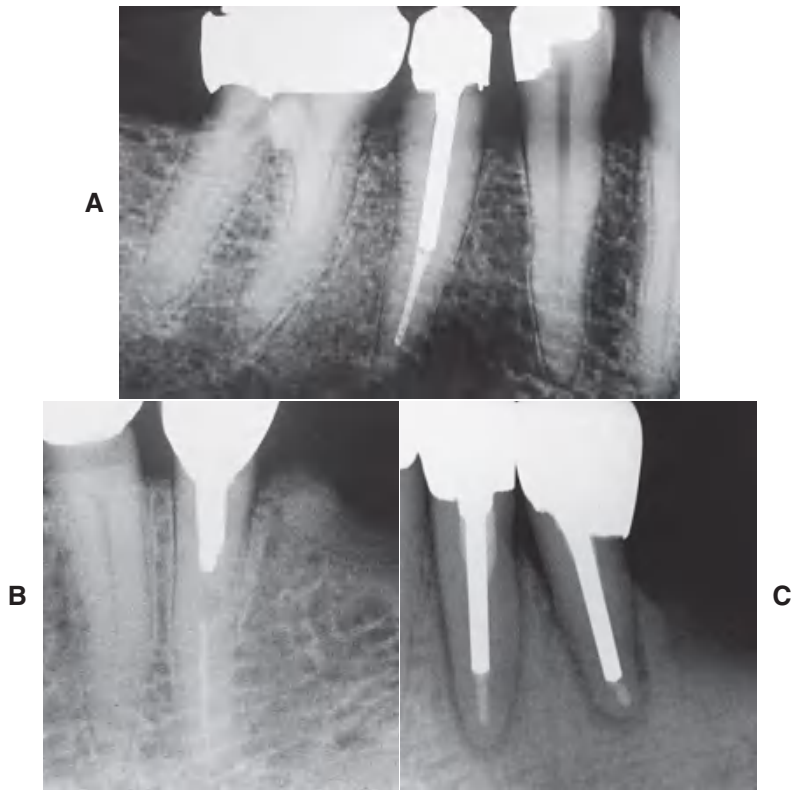


Fig. 12-17

A, Correct post length. **B,** The post is too short; the consequences are inadequate retention and increased risk of root fracture. **C,** These posts are too long, jeopardizing the apical seal.

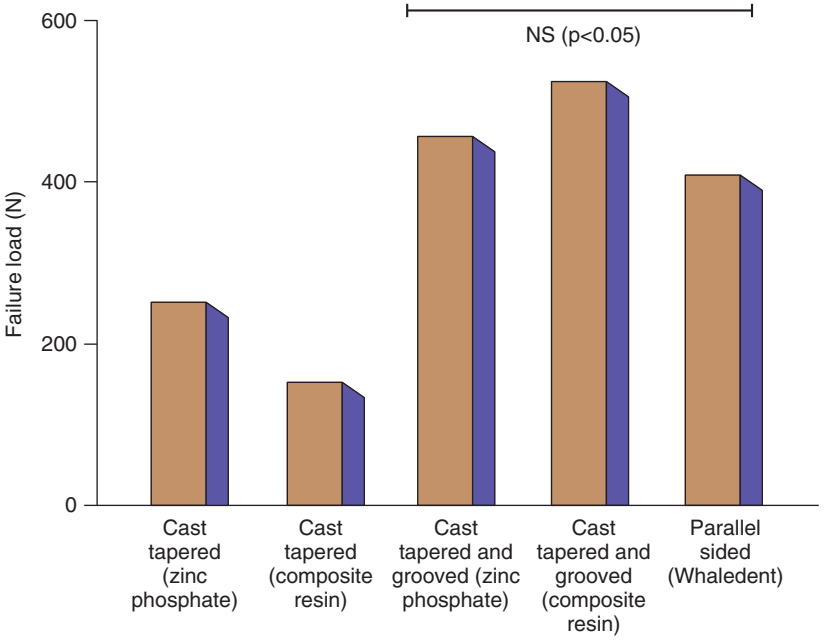


Fig. 12-18

Effect of horizontal grooving on the retention of tapered posts. NS, Not significant. *(Modified from Wood WW: Retention of posts in teeth with nonvital pulps. J Prosthet Dent 49:504, 1983.)*



Fig. 12-19
When preparing posterior teeth for intracoronal retention, the practitioner must be careful to avoid perforation, especially on the distal surface of mesial roots and the mesial surface of distal roots, where residual tooth structure is normally thinnest and where concavities are often present (*arrows*).

but should be avoided in posterior teeth, which often have curved roots and elliptical or ribbon-shaped canals (Fig. 12-19). For these teeth, retention is better provided by two or more relatively short posts in the divergent canals.

When amalgam is used as the core material, it can be condensed either around cemented metal posts or directly into short, prepared post spaces. If a reasonable amount of coronal tissue remains, use of a single metal post that is cemented in the largest canal can provide adequate retention for the core material. When more than 3 to 4 mm of coronal tooth structure with reasonable wall thickness remains, use of a post in the root canals for retention is not necessary, and this reduces the risk of perforation.[44] When a post is not used, the chamber must provide adequate retention for the core material. It may then be advantageous to prepare several short divergent post spaces into which the core material extends. Use of the canals for retention can provide good results,[45] although once a complete crown has been provided, the strength of the tooth is not dramatically influenced by differences in technique.

Mandibular premolars and molars with a reasonable amount of remaining coronal tooth structure, when coupled with a circumferential cervical band of tooth structure with restricted taper of about 2 mm, can often be restored with amalgam directly condensed into the chamber. Core buildups in molars with one or more missing cusps benefit from one or more cemented posts around which the amalgam can be condensed. The posts provide the additional retention, which was compromised because of the missing tooth structure. In mandibular molars, the larger distal canal is recommended for post placement. In maxillary molars, the palatal canal is used (see Fig. 12-2*C* and *D*).

Although it is possible to restore a severely compromised molar with three or more missing cusps with multiple posts and amalgam, the tooth's overall importance must be assessed, as the prognosis of such teeth is often guarded. If retaining the tooth is crucial and optimal strength is needed, a multipiece cast core can be used (made in sections that have different paths of withdrawal) (Fig. 12-20). An alternative preparation method for a posterior tooth is selecting the canals that are widest (normally the palatal of maxillary molars and the distal of mandibular molars) for the major post and then preparing short auxiliary post spaces in the other canals with the same path of withdrawal (Fig. 12-21).

Resistance Form

Stress distribution

One of the functions of a post and core is to improve resistance to laterally directed forces by distributing them over as large an area as possible. However, excessive internal preparation of the root weakens it, and the risk of failure increases. The post design should distribute stresses as evenly as possible. The incidence of radicular fracture increases with the use of threaded posts that actively engage radicular dentin, and threaded flexible posts do not appear to reduce stress concentrations during function.

The influence of post design on **stress distribution** has been tested with photoelastic materials,[20,32,46-48] strain gauges,[49,50] and finite element analysis.[51,52] From these laboratory studies, the following conclusions have been drawn:

1. The greatest stress concentrations are found at the shoulder, particularly interproximally, and at the apex. Dentin should be conserved in these areas if possible.
2. Stresses are reduced as post length increases.
3. Parallel-sided posts may distribute stress more evenly than do tapered posts, which may have a wedging effect. However, parallel-sided posts generate high stresses at the apex.
4. Sharp angles should be avoided because they produce high stresses during loading.
5. High stress can be generated during insertion, particularly with smooth, parallel-sided posts that have no vent for cement escape.



Fig. 12-20
A to **F,** Cast cores for posterior teeth can be made in interlocking sections, with each section having its own path of withdrawal.

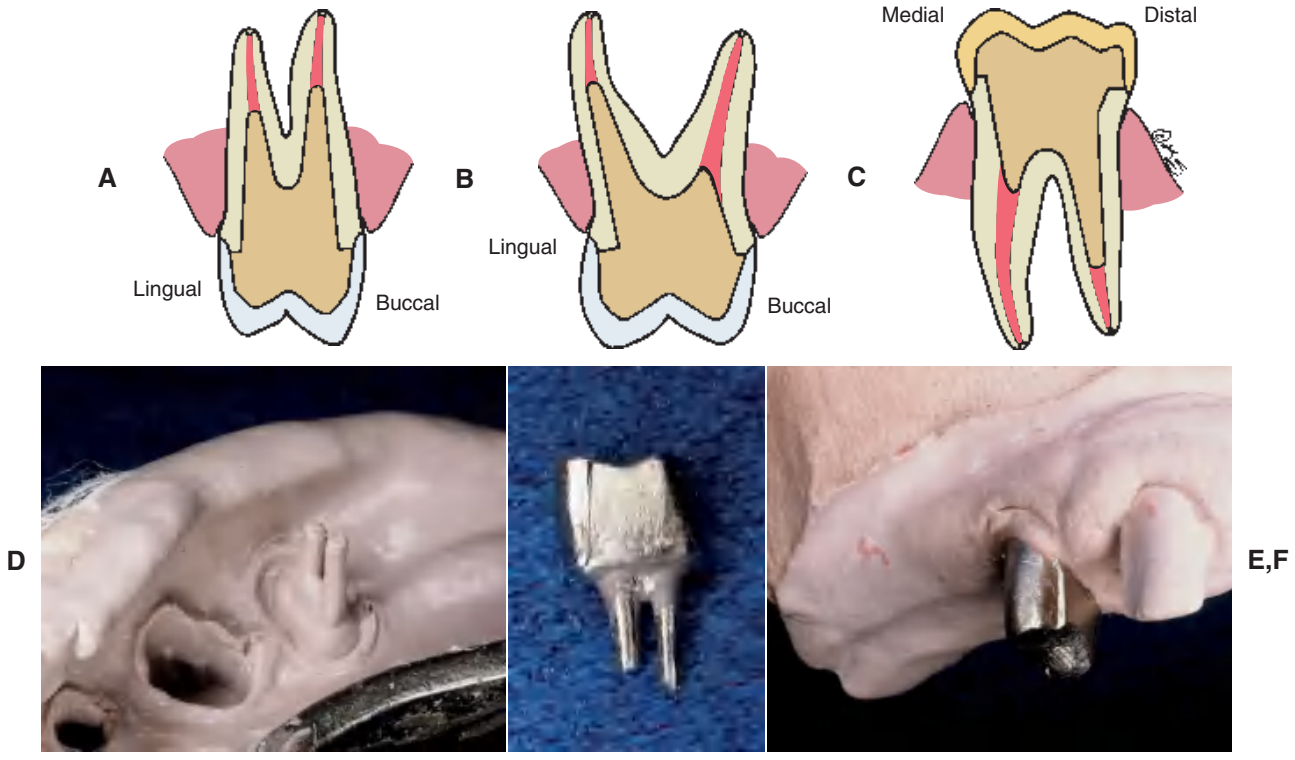


Fig. 12-21
Single-piece castings can be made by selecting the larger-diameter canal and extending a second post for a limited distance into the smaller canal. **A,** A maxillary first premolar. **B,** A maxillary first molar. **C,** A mandibular first molar. **D** to **F,** Post and core provided for a maxillary first premolar by the indirect technique.

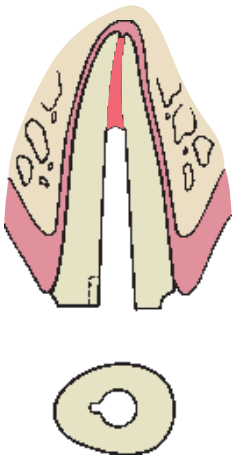


Fig. 12-22
Rotational resistance in an extensively damaged tooth can be obtained by preparing a small groove in the root canal. This must be in the path of placement of the post and core.

6. Threaded posts can produce high stress concentrations during insertion and loading, but they have been shown to distribute stress evenly if the posts are backed off a half-turn and when the head contact area is of sufficient size.[38]
7. The cement layer results in a more even stress distribution to the root with less stress concentrations.

Rotational resistance

To minimize the risk of dislodgment, it is important that preparation geometry prevents a post with a circular cross-section from rotating during function (Fig. 12-22). This usually does not present a problem when sufficient coronal tooth structure remains, because rotation is prevented by a vertical coronal wall. Where coronal dentin has been completely lost, a small groove placed in the canal wall can serve as an antirotational element. The groove is normally located where the root is bulkiest, usually on its lingual aspect. Alternatively, rotation can be prevented by an auxiliary pin in the root face. Rotation of a threaded post can also be prevented[31] by preparing a small cavity (half in the post, half in the root) and condensing amalgam into it after the post is cemented.

PROCEDURES

Tooth preparation for endodontically treated teeth can be considered a three-stage operation:
1. Removal of the root canal filling material to the appropriate depth.
2. Enlargement of the canal.
3. Preparation of the coronal tooth structure.

Removal of the Endodontic Filling Material

The root canal system should first be completely filled; space should then be made for a post, thus ensuring that lateral canals are sealed. A post cannot be placed if the canal is filled with a full-length silver point, so these must be removed and the tooth retreated with gutta-percha. It is not advisable to shorten previously cemented silver points, because leakage will result even if only a short portion is removed.[53,54]

There are two commonly used methods to remove gutta-percha (Fig. 12-23): (1) using a warmed endodontic plugger, and (2) using a rotary instrument, sometimes in conjunction with chemical agents. Although more time consuming, the warmed endodontic plugger is preferred because it eliminates the possibility that the rotary instrument will inadvertently damage the dentin. If it is more convenient, the gutta-percha can be removed with a warmed condenser immediately after obturation. This does not disturb the apical seal.[55,56] This method offers the additional advantage of allowing the operator to work in an area where the root canal anatomy is still familiar.

1. Before removing gutta-percha, calculate the appropriate length of the post. It should be adequate for retention and resistance but not long enough to weaken the apical seal. As a guide, make the post length *equal to the height of the anatomic crown* (or two-thirds the length of the root), but *leave 5 mm of apical gutta-percha*. On short teeth, it is not possible to meet both these restrictions, and a compromise must be made. An absolute minimum of 3 mm of apical fill is needed. If this cannot be achieved without having a very short post, the tooth's prognosis is seriously impaired.
2. Avoid the apical 5 mm if possible. Curvatures and lateral canals may be found in this segment. Average values for crown and root length are given in Table 12-1. If the working length of the root canal is known, the length of the post space can be easily determined. Therefore, the incisal or occlusal reference point must not be lost as a result of premature removal of coronal tooth structure.
3. To prevent the patient's aspiration of an endodontic instrument, apply a rubber dam before preparing the post space.
4. Select an endodontic condenser large enough to hold heat well but not so large that it binds against the canal walls.
5. Mark it at the appropriate length (normally endodontic working length minus 5 mm), heat

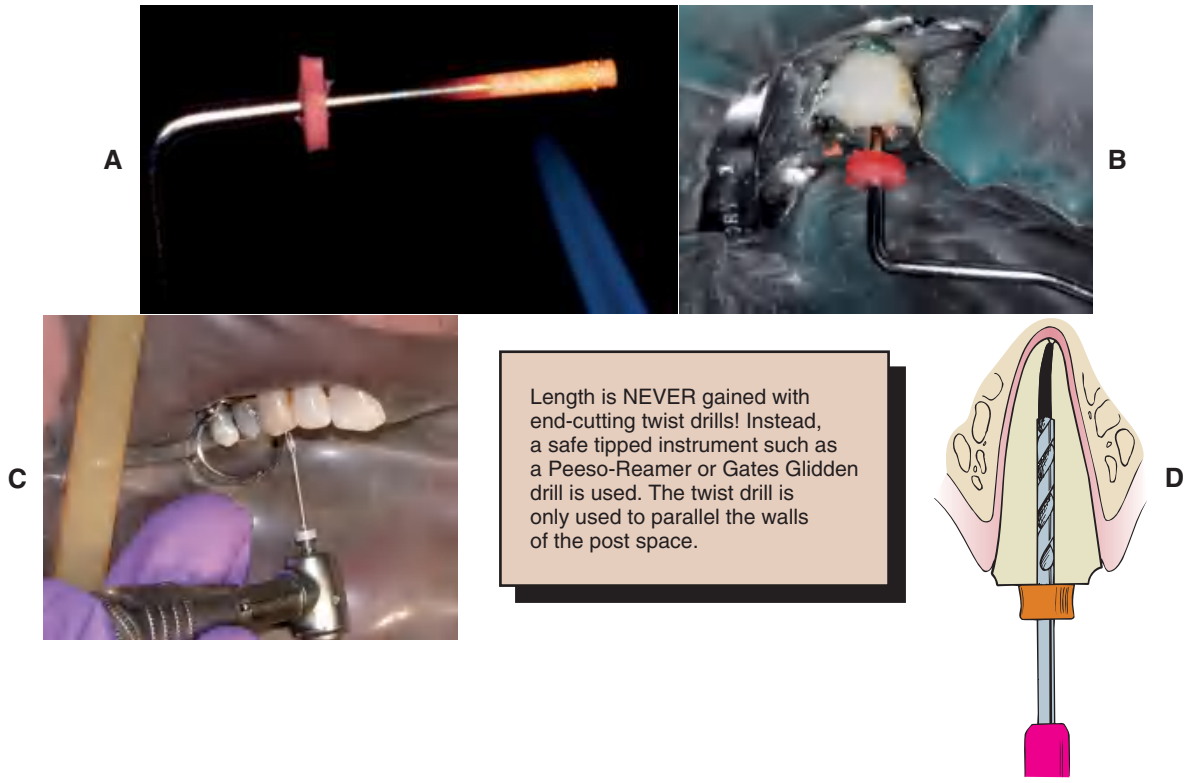


Fig. 12-23
Gutta-percha can be removed from the canal with a heated endodontic plugger. (**A** and **B**), a non-end-cutting bur (**C**) (e.g., a Gates Glidden drill). A ParaPost drill (**D**) can be used to parallel the post space wall (with a rubber stop to ensure accuracy of the preparation depth). *(**A** and **B**, Courtesy of Dr. D. A. Miller.)*

Table **12-1** **AVERAGE CROWN AND ROOT LENGTHS (IN MILLIMETERS)**

	Mean Crown Length*	Mean Root Length*	Two-Thirds Root Length	Root Length (to 4 mm from apex)
MAXILLARY TEETH				
Central incisor	10.8 ± 0.7	12.5 ± 1.6	8.3	8.5
Lateral incisor	9.7 ± 0.9	13.1 ± 1.4	8.7	9.1
Canine	10.2 ± 0.8	15.8 ± 2.1	10.5	11.8
First premolar	8.6 ± 0.8	12.7 ± 1.7	8.5	8.7
Second premolar	7.5 ± 0.6	13.5 ± 1.4	9.0	9.5
First molar	7.4 ± 0.5	MF 12.5 ± 1.2	8.3	8.5
		DF 12.0 ± 1.3	8.0	8.0
		L 13.2 ± 1.4	8.8	9.2
Second molar	7.4 ± 0.5	MF 12.8 ± 1.5	8.5	8.8
		DF 12.0 ± 1.4	8.0	8.0
		L 13.4 ± 1.3	8.9	9.4
MANDIBULAR TEETH				
Central incisor	9.1 ± 0.5	12.4 ± 1.4	8.3	8.4
Lateral incisor	9.4 ± 0.7	13.0 ± 1.5	8.7	9.0
Canine	10.9 ± 0.9	14.3 ± 1.4	9.5	10.3
First premolar	8.7 ± 0.7	13.4 ± 1.3	8.9	9.4
Second premolar	7.8 ± 0.6	13.6 ± 1.7	9.1	9.6
First molar	7.4 ± 0.5	M 13.5 ± 1.3	9.0	9.5
		D 13.4 ± 1.3	8.9	9.4
Second molar	7.5 ± 0.5	M 13.4 ± 1.2	8.9	9.4
		D 13.3 ± 1.3	8.9	9.3

Data from Shillingburg HT, et al: Root dimensions and dowel size. Calif Dent Assoc J 10(10):43, 1982.
$n = 50$ for each tooth.
*SD listed after mean length.
D, distal; DF, distofacial; L, lingual; M, mesial; MF, mesiofacial.

it, and place it in the canal to soften the gutta-percha.

6. If the gutta-percha is old and has lost much of its thermoplasticity, use a rotary instrument, making sure that it follows the gutta-percha and does not engage dentin (this causes a root perforation). For this reason, high-speed instruments and conventional burs are contraindicated. Special post preparation instruments are available (Fig. 12-24). Peeso-Reamers and Gates Glidden drills are often used for this purpose. The football shape of the cutting head of the Gates-Glidden drill often results in small concavities in the wall of the post space. These are avoided with the more cylindrically shaped Peeso-Reamer. Both are considered "safe-tip" instruments because they are not end-cutting burs. The friction generated between the fill and the tip of these burs softens the gutta-percha, allowing the rotary instrument to track the canal with reasonable predictability. In one comparison of rotary instruments,[57] investigators concluded that the Gates Glidden drill conformed to the original canal more consistently than did the ParaPost drill, which is an end-cutting instrument. The latter is a twist drill and should be used only to parallel the walls of the post space. Considerable heat can be generated by these rotary instruments, especially during the ParaPost preparation stage.[58]

Of importance: End-cutting instruments should *never* be used to gain length because root perforation *will* result!

7. If using a rotary instrument, choose it to be slightly narrower than the canal.
8. Make sure the instrument follows the center of the gutta-percha and does not cut dentin. Often, only a part of the root canal fill needs to be removed with a rotary instrument, and the remainder can be removed with the heated condenser.
9. When the gutta-percha has been removed to the appropriate depth, shape the canal as needed. This can be accomplished by using an endodontic file or a low-speed drill. This procedure removes undercuts and prepares the canal to receive an appropriately sized post without excessively enlarging the canal. Files are a conservative approach to shaping the canal walls and enable simultaneous removal of any small residual undercuts in the chamber. If a parallel-sided post is desired, a matching-size low-speed twist drill that is set to the same length as the most recently used Peeso-Reamer can be used.

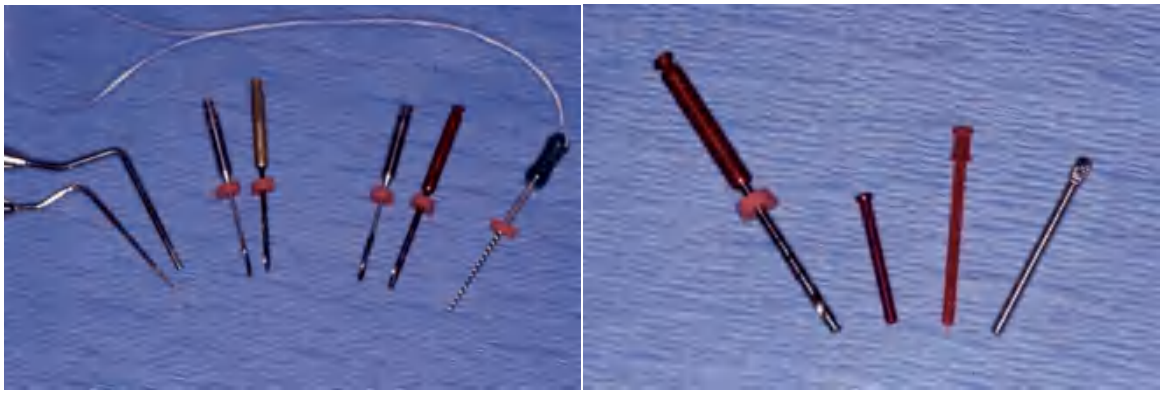


Fig. 12-24

Commonly used instruments for gutta-percha removal and canal enlargement. A, Endodontic pluggers, two sizes of Peeso-Reamers with corresponding twist drills, and endodontic file. Note attached floss as a safety precaution. **B,** The ParaPost twist drill corresponds in size to an aluminum post used to fabricate interim restorations, a plastic post for patterns, and a stainless-steel or titanium post. *(Courtesy of Dr. J. A. Nelson.)*

The post should be no more than one-third the root diameter,[1,59] with the root and walls at least 1 mm thick. Obviously, for deciding on appropriate post diameters, a knowledge of average root dimensions is important. These have been calculated[60] and are presented in Table 12-2. Knowledge of root canal cross-section also is significant in post selection. Prefabricated posts are circular in cross-section, but many root canals are elliptical, which makes uniform reduction with a drill impossible. Canal shapes are summarized in Table 12-3.

Table 12-2 AVERAGE ROOT DIAMETERS AND RECOMMENDED POST SIZES (IN MILLIMETERS)*

	CEJ	Furcation†	Midpoint	Diameter 4 mm from Apex‡	Recommended Post Diameter
MAXILLARY TEETH					
Central incisor	MD 6.3 ± 0.5	–	5.2 ± 0.5	3.8 ± 0.4	1.5
	FL 6.4 ± 0.4	–	5.8 ± 0.4	4.3 ± 0.4	
Lateral incisor	MD 4.9 ± 0.5	–	4.0 ± 0.5	3.2 ± 0.5	1.3
	FL 5.7 ± 0.5	–	5.4 ± 0.5	4.2 ± 0.4	
Canine	MD 5.4 ± 0.5	–	4.4 ± 0.5	3.3 ± 0.5	1.5
	FL 7.7 ± 0.6	–	7.2 ± 0.6	4.8 ± 0.6	
First premolar	MD 4.1 ± 0.3	Facial MD	3.6 ± 0.4	2.6 ± 0.4	0.9
	FL 8.1 ± 0.7	– FL –	3.4 ± 0.4	2.4 ± 0.4	
		Lingual MD	3.3 ± 0.3	2.5 ± 0.4	0.9
		– FL –	3.3 ± 0.4	2.4 ± 0.5	
Second premolar	MD 4.9 ± 0.3	–	3.8 ± 0.4	3.2 ± 0.6	1.1
	FL 7.9 ± 0.5	–	7.0 ± 0.7	5.0 ± 0.7	
First molar	MD 7.7 ± 0.4	Mesio- MD	3.1 ± 0.3	2.9 ± 0.4	1.1
	FL 10.5 ± 0.5	3.4 ± 0.3			
		Facial FL	5.8 ± 0.7	4.8 ± 0.7	
		6.8 ± 0.5			
		Disto- MD	2.8 ± 0.3	2.6 ± 0.4	1.1
		3.1 ± 0.2			
		Facial FL	4.4 ± 0.5	3.8 ± 0.5	
		5.0 ± 0.4			
		Lingual MD	5.0 ± 0.5	4.4 ± 0.5	1.3
		5.7 ± 0.5			
		FL 4.3 ± 0.4	3.7 ± 0.4	3.3 ± 0.4	
Second molar	MD 7.3 ± 0.4	Mesio- MD	3.1 ± 0.3	2.7 ± 0.4	1.1
	FL 10.4 ± 0.6	3.4 ± 0.3			
		Facial FL	5.6 ± 0.7	4.5 ± 0.7	
		6.6 ± 0.5			
		Disto- MD	2.8 ± 0.3	24 ± 0.4	0.9
		3.1 ± 0.4			
		Facial FL	3.8 ± 0.4	3.2 ± 0.4	
		4.3 ± 0.4			
		Lingual MD	4.2 ± 0.5	3.6 ± 0.5	1.3
		4.9 ± 0.5			
		FL 4.5 ± 0.4	3.9 ± 0.4	3.1 ± 0.4	
MANDIBULAR TEETH					
Central incisor	MD 3.3 ± 0.3	–	2.7 ± 0.3	2.1 ± 0.2	0.7
	FL 5.5 ± 0.5		5.6 ± 0.4	4.3 ± 0.6	
Lateral incisor	MD 3.6 ± 0.3	–	2.7 ± 0.4	2.0 ± 0.2	0.7
	FL 5.9 ± 0.4		5.7 ± 0.5	4.3 ± 0.5	

Table **12-2—cont'd**

	CEJ	Furcation†	Midpoint	Diameter 4 mm from Apex‡	Recommended Post Diameter
Canine	MD 5.2 ± 0.6 FL 7.8 ± 0.8	–	4.0 ± 0.5 7.3 ± 0.6	3.2 ± 0.7 5.0 ± 0.5	1.5
First premolar	MD 5.1 ± 0.4 FL 6.6 ± 0.4	–	4.0 ± 0.4 6.0 ± 0.5	3.2 ± 0.4 4.3 ± 0.5	1.3
Second premolar	MD 5.3 ± 0.3 FL 7.0 ± 0.5	–	4.3 ± 0.3 6.0 ± 0.6	3.5 ± 0.5 4.4 ± 0.5	1.3
First molar	MD 8.9 ± 0.6	Mesio- MD 3.7 ± 0.2	3.2 ± 0.3	2.8 ± 0.3	1.1
	FL 8.3 ± 0.6	Facial FL 3.4 ± 0.3	3.1 ± 0.3	2.8 ± 0.4	
		Mesio- MD 3.4 ± 0.3	2.9 ± 0.3	2.5 ± 0.3	0.9
		Lingual FL 3.5 ± 0.4	3.2 ± 0.3	2.7 ± 0.4	
		Distal MD 3.5 ± 0.4	2.8 ± 0.4	2.7 ± 0.4	1.1
		FL 7.6 ± 0.8	6.6 ± 1.2	5.4 ± 0.8	
Second molar	MD 9.3 ± 0.7 FL 8.3 ± 0.7	Mesio- MD 3.6 ± 0.3	3.1 ± 0.3	2.6 ± 0.3	0.9
		Facial FL 3.2 ± 0.3	2.8 ± 0.3	2.4 ± 0.4	
		Mesio- MD 3.6 ± 0.4	3.0 ± 0.4	2.5 ± 0.4	0.9
		Lingual FL 3.2 ± 0.5	2.8 ± 0.4	2.3 ± 0.4	
		Distal MD 4.1 ± 0.4	3.5 ± 0.4	3.0 ± 0.4	1.1
		FL 6.8 ± 0.8	5.9 ± 0.9	4.7 ± 0.7	

Data from Shillingburg HT, et al: Root dimensions and dowel size. Calif Dent Assoc J 10(10):43, 1982.
*N = 50 for each tooth.
†Furcation distance from the CEJ: maxillary first molar, 4.1 mm; maxillary second molar, 3.2 mm; mandibular first molar, 3.1 mm; mandibular second molar, 3.3 mm.
‡Because of greater root length, the mean distance from the apex on maxillary canine measurements is 5.1 mm.
CEJ, cementoenamel junction; FL, faciolingual; MD, mesiodistal.

Table **12-3 Root Canal Configurations**

Circular	Elliptical	
	Buccolingual	**Mesiodistal**
Maxillary central incisor	Maxillary lateral incisor Maxillary canine Mandibular incisors Mandibular canine	
Maxillary first premolar (two roots)	Maxillary first premolar (single root) Mandibular first premolar	
Mandibular second premolar	Maxillary second premolar	
Maxillary molars (distobuccal roots)	Maxillary molars (mesiobuccal roots) Mandibular molars (mesial and distal roots)	Maxillary molars (palatal roots)

From Weine FS: Endodontic Therapy, 4th ed, pp 225-269. St. Louis, Mosby, 1989.

Enlargement of the Canal

Before enlargement of the canal, the type of post system to be used for fabrication of the post and core must be chosen.

The advantages and disadvantages of different **post types** are summarized in Table 12-4. Because no system has universal application, being familiar with more than one technique is a significant advantage. A wide range of prefabricated posts are available. They come in many shapes and sizes and have varying radiopacity that may assist in their identification (Table 12-5 and Figs. 12-25 and 12-26).

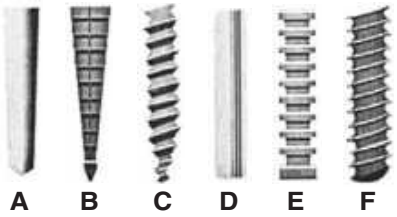


Fig. 12-25
Classification of prefabricated posts. **A,** Tapered smooth posts. **B,** Tapered serrated posts. **C,** Tapered threaded posts. **D,** Parallel-sided smooth posts. **E,** Parallel-sided serrated posts. **F,** Parallel-sided threaded posts. *(Redrawn from Shillingburg HT, Kessler JC: Restoration of the Endodontically Treated Tooth. Chicago, Quintessence Publishing, 1982.)*

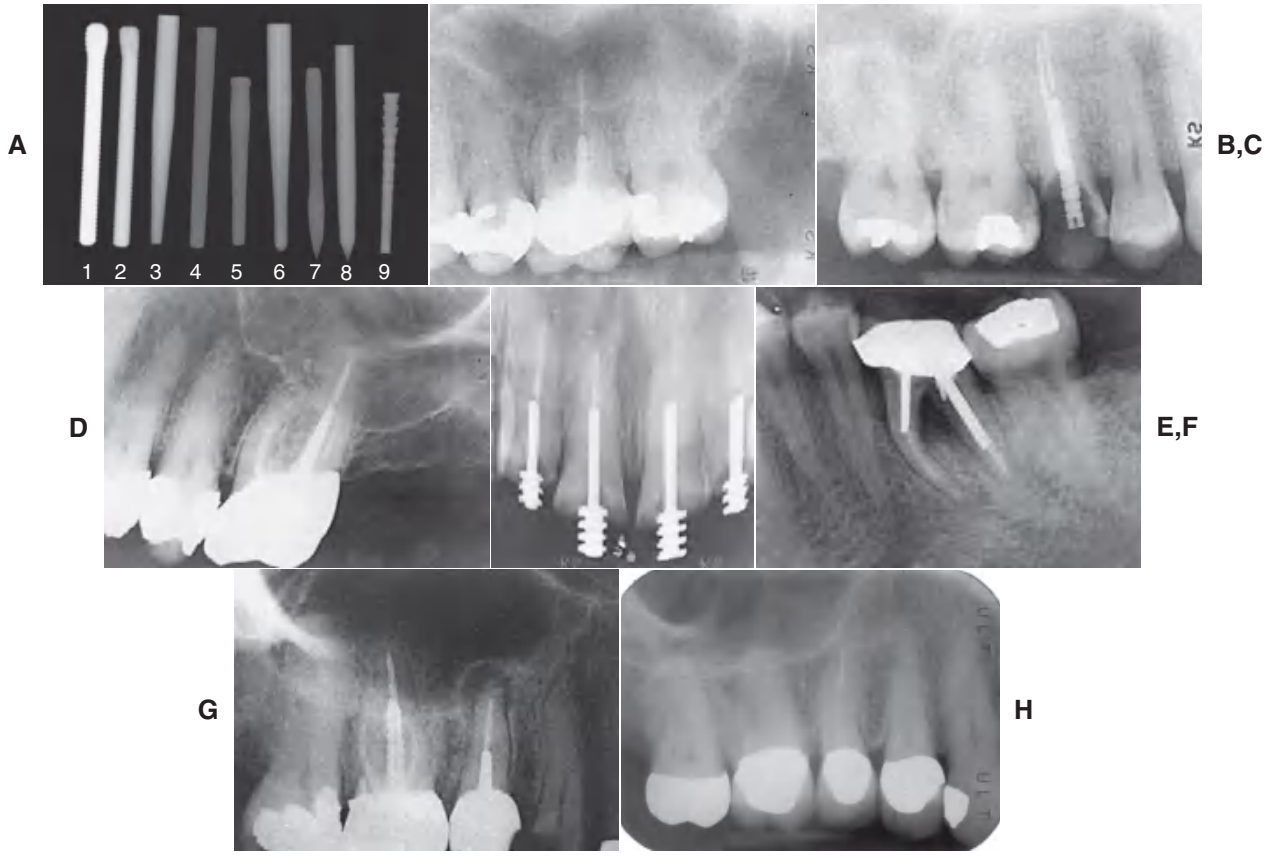


Fig. 12-26
The various endodontic posts encountered in clinical practice present with varying degrees of radiopacity. Dentists accustomed to seeing traditional stainless steel and titanium posts may be deceived by more recently introduced systems. **A,** Nine representative posts: (1) ParaPost stainless steel (Coltène/Whaledent); (2) ParaPost titanium (Coltène/Whaledent); (3) FRC Postec Plus (Ivoclar Vivadent); (4) Glass Fiber Post (Ellman International); (5) Glass Fiber C-I Post (Parkell); (6) D. T. Light-Post (Bisco); (7) Twin Luscent Anchors (Dentatus USA); (8) Unicore (Ultradent Products); (9) PeerlessPost (SybronEndo). The pure carbon fiber posts (not included in **A**) are completely radiolucent. The type of cement that is used plays a role in the radiopacity of the post (see Fig. 31-6). **B** to **I,** Radiographs of the six categories: **B,** Endowel (Star Dental), tapered and smooth sided. **C,** Unimetric (DENTSPLY), tapered and serrated. **D,** Surtex (Dentatus USA), tapered and threaded. **E,** CTH Beta Post (CTH), parallel-sided and smooth. **F,** ParaPost (Coltène/Whaledent) (two sizes), parallel-sided and serrated. **G,** Flexi-Post (Essential Dental Systems) (in the right maxillary first molar), parallel-sided and threaded (note the split shank). **H,** ParaPost Fiber Lux (Coltène/Whaledent) cemented with RelyX Luting (3M ESPE). Note the radiolucency of the post in comparison with the radiopacity of the gutta-percha endodontic fill. *(**B,** Courtesy of Dr. D. A. Miller and Dr. H. W. Zuckerman; **C,** courtesy of Dr. I. A. Roseman; **D,** courtesy of Dr. F. S. Weine and Dr. S. Strauss; **E,** courtesy of Dr. J. F. Tardera; **F,** courtesy of Dr. J. L. Wingo; **G,** courtesy of Dr. L. R. Farsakian; **H,** courtesy of Dr. D. A. Miller and Dr. G. Freebeck.)*

Text continues on page 358

Table **12-4 AVAILABLE POST AND CORE SYSTEMS**

	Advantages	Disadvantages	Recommended Use	Precautions
Amalgam	Conservative of tooth structure Straightforward technique	Low tensile strength Corrosion with base metal	Molars with adequate coronal tooth structure	Not recommended in teeth under lateral load (anteriors)
Glass ionomer	Conservative of tooth structure Straightforward technique	Difficult condensation Low strength	Teeth with minimum tooth structure missing	Not recommended in teeth under lateral load
Composite resin	Conservative of tooth structure Straightforward technique	Low strength Continued polymerization Microleakage	Teeth with minimum tooth structure missing	Not recommended in teeth under lateral load
Custom cast post and core	High strength Better fit than prefabricated	Less stiff than wrought Time consuming, complex procedure	Elliptical or flared canals	Care to remove nodules before try-in
Wire post and cast core	High strength High stiffness	Corrosion of base metal Pt-Au-Pd wire expensive	Small circular canals	Care to avoid perforation during preparation
Tapered prefabricated post	Conservative of tooth structure High strength and stiffness	Less retentive than parallel-sided or threaded systems	Small circular canals	Not recommended for excessively flared canals
Parallel-sided prefabricated post	High strength Good retention Comprehensive system	Precious metal post expensive Corrosion of stainless steel Less conservative of tooth structure	Small circular canals	Care during preparation
Threaded post	High retention	Stresses generated in canal may lead to fracture Not conservative of coronal and radicular tooth structure	Only when maximum retention is essential	Care to avoid fracture during seating
Carbon fiber post	Dentin bonding Easy removal	Low strength Microleakage Black color	Minimal missing tooth structure Uncertain endodontic prognosis	Not recommended for teeth under lateral load
Zirconia ceramic posts	Esthetics High stiffness	Uncertain clinical performance	High esthetic demand	
Woven fiber posts	Esthetics Dentin bonding	Low strength Uncertain clinical performance	High esthetic demand	Not recommended for teeth under lateral load
Glass fiber posts	Esthetics Dentin bonding	Low strength Uncertain clinical performance	High esthetic demand	Not recommended for teeth under lateral load

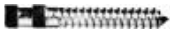
Pt-Au-Pd, platinum-gold-palladium.

Table **12-5 CURRENTLY AVAILABLE PREFABRICATED POSTS***

Example†	Product (vendor)	Composition‡	Characteristics	Shank Diameter (mm)§
	TAPERED SMOOTH-SIDED POSTS			
	FibreKleer Post System (Pentron)	GF (unidirectional, LT)	Flat tip	1.2 to 1.5
	FRC Postec Plus (Ivoclar Vivadent)	GF (unidirectional, LT)	Flat tip	1.5 to 1.7
	Glass Fiber Post (Ellman International)	GF (unidirectional, LT)	Flat tip	0.9 to 2.0
	Fibio (Dental Anchor Systems)	GF (unidirectional)	Flat tip	1.2 to 1.5
	ER Casting Post (Brasseler USA)	PB	Flat tip	1.1 to 1.7
	Endodontic Post (Sterngold)	PB	Blunt tip	1.7 and 1.8
	Plastic Sprue Post (Miltex)	PB	Blunt tip	1.4 and 1.7
	C-I Plastic Pattern Post (Parkell)	PB	Blunt tip	1.3 and 1.6
	Stress-Free Post (Denovo)	SS	Blunt tip, ISO‖ sizes: 50 to 130	0.7 to 1.5
	Filpost (Filhol Dental USA)	Ti	Blunt tip	1.3 and 1.6
	Cerapost (Brasseler USA)	ZrO_2	Blunt tip	1.1 to 1.7
	C-I White Glass Fiber Post (Parkell)	GF (braided)	Blunt tip	1.3 and 1.6
	D. T. Light-Post (Bisco)	QF (unidirectional, LT)	Blunt tip	1.0 to 1.6
	Luscent Anchors (Dentatus USA)	GF (unidirectional, LT)	Blunt tip	1.1 to 1.6
	Twin Luscent Anchors (Dentatus USA)	GF (unidirectional, LT)	Tappered tip, hourglass shape	1.4 to 1.8
	Unicore (Ultradent Products)	QF (unidirectional, LT)	Pointed tip	1.1 to 1.7
	Endowel (Star Dental)	PB	Pointed tip, ISO‖ sizes: 80 to 140	1.0 to 1.6
	TAPERED SERRATED POSTS			
	PeerlessPost (SybronEndo)	GF (unidirectional)	Inverse ledges, flat tip	1.1 to 1.2
	C-I Stainless Steel Post (Parkell)	SS	Shallow narrow grooves, flat tip	1.3 and 1.6
	NuBond (Ellman International)	SS	Shallow narrow grooves, blunt tip	0.9 to 2.0
	Tri-R Post System (Miltex)	SS	Spiraling grooves, pointed tip	1.0 to 1.6
	TAPERED THREADED POSTS			
	Surtex (Dentatus USA)¶	Ti, SS, Brass	Tightly threaded	1.1 to 1.8
	Ancorex (E. C. Moore)¶	Ti	Tightly threaded	1.1 to 1.8
	PARALLEL SMOOTH-SIDED POSTS			
	FibreKleer Post System (Pentron)	GF (unidirectional, LT)	Flat tip	1.0 to 1.5
	IntegraPost System (Premier)	Ti alloy	Fine diamond shape grooves, flat tip	0.9 to 1.5
	CTH Beta Post (CTH)	SS	Vertical grooves, flat tip	1.1 to 1.6

Table **12-5—cont'd**

			SHANK	
Example[†]	**Product (vendor)**	**Composition**[‡]	**Characteristics**	**Diameter (mm)**[§]
	CTH R Series (CTH)	SS	Vertical grooves, flat tip	1.1 to 1.6
	GT Post (Dentsply Tulsa Dental)	SS	Flat tip	0.9 to 1.7
	ProPost (Dentsply Tulsa Dental)	SS	Tapered apical end, flat tip	0.8 to 1.4
	CosmoPost (Ivoclar Vivadent)	ZrO_2	Tapered apical end, flat tip	1.4 and 1.7
	CarboPost (Danville Materials)	CF	Tapered apical end, blunt tip	1.0 to 1.6
	Snowlight (Danville Materials)	GF (unidirectional, LT)	Tapered apical end, blunt tip	1.0 to 1.6
	Snowpost (Danville Materials)	GF (unidirectional)	Tapered apical end, blunt tip	1.0 to 1.6
	Core-Post (Den-Mat)	GF (unidirectional), CF	Pointed tip	1.0 to 2.0
	Mirafit White and Black (Hager Worldwide)	GF (braided), CF	Pointed tip	1.2 to 1.5
	GF Glass Fiber Post (J. Morita USA)	GF (braided)	Blunt tip	1.1 to 1.6
	CF Carbon Fiber Post (J. Morita USA)	CF	Blunt tip	1.1 to 1.6
	Vario Cast Passive Post (Brasseler USA)	PB	Blunt tip	1.2 to 1.6
	PARALLEL SERRATED POSTS			
	PermaPost (Ultradent Products)	Ti alloy	Numerous shallow grooves, blunt tip	0.9 to 1.5
	ParaPost (Coltène/Whaledent)	Ti alloy, PB, SS	Numerous shallow grooves, flat tip	0.9 to 1.8
	ParaPost XP (Coltène/Whaledent)	Ti alloy, PB, SS	Diamond shape grooves, flat tip	0.9 to 1.8
	Unity (Coltène/Whaledent)	Ti alloy, PB	Diamond shape grooves, flat tip	0.9 to 1.8
	ParaPost XH (Coltène/Whaledent)	Ti alloy	Diamond shape grooves, flat tip	0.9 to 1.8
	ParaPost Plus (Coltène/Whaledent)	Ti alloy, SS	Inverse ledges, flat tip	0.9 to 1.8
	ParaPost Fiber Lux (Coltène/Whaledent)	GF (unidirectional, LT)	Inverse ledges, flat tip	1.1 to 1.5
	ParaPost Fiber White (Coltène/Whaledent)	GF (unidirectional)	Inverse ledges, flat tip	1.1 to 1.5
	FibreKor Post System (Pentron)	GF (unidirectional)	Inverse ledges, flat tip	1.0 to 1.5
	Achromat (Axis Dental)	GF (unidirectional, LT)	Wide grooves, flat tip	1.3 and 1.6
	Achromat–HP (Axis Dental)	GF (unidirectional, LT)	Wide grooves, flat tip	1.1 to 1.6
	Vario Passive Post (Brasseler USA)	Ti alloy	Wide grooves, flat tip	1.2 to 1.6
	Vlock Passive Post (Brasseler USA)	Ti alloy	Wide grooves, flat tip	1.2 to 1.6
	Luminex (Dentatus USA)	PB	Wide grooves, tapered tip	1.1 to 1.8
	SB Post (J. Morita USA)	SS	Shallow grooves, tapered tip	0.8 to 1.6
	AccessPost (Essential Dental Systems)	SS	Deep spiraling groove, flat tip	0.8 to 1.6
	AccessPost Overdenture (Essential Dental Systems)	SS	Deep spiraling groove, flat tip	1.1 to 1.6

	ERA Direct Overdenture (Sterngold)	SS	Numerous shallow grooves, flat tip	1.4 and 1.7
	Locator attachment (Zest Anchors)	SS	Numerous shallow grooves, flat tip	1.8
	PARALLEL THREADED POSTS			
	Surtex (Dentatus USA)¶	Ti, SS, Brass	Tightly threaded, threaded tapered tip	1.1 to 1.8
	Ancorex (E. C. Moore)¶	Ti	Tightly threaded, threaded tapered tip	1.1 to 1.8
	AZtec (Dentatus USA)	Ti	Tightly threaded, smooth tapered tip	1.5 to 1.8
	Boston Post (Roydent Dental Products)	Ti	Tightly threaded, pointed tip	1.0 to 1.6
	Titanium Screw Post (E. C. Moore)	Ti	Tightly threaded, pointed tip	1.1 to 1.8
	Golden Screw Post (E. C. Moore)	Brass	Tightly threaded, pointed tip	1.1 to 1.8
	Compo-Post (Sullivan-Schein)	Brass	Tightly threaded, pointed tip	1.1 to 1.8
	Obturation Screws (Miltex)	SS	Tightly threaded, pointed tip	1.3
	Kurer K4 Ready Core Anchor (Marie Reiko)	SS, Ti alloy	Tightly threaded, flat tip	1.6 to 2.0
	Kurer K4 Universal Anchor (Marie Reiko)	SS, Ti alloy	Tightly threaded, flat tip	1.5 to 2.0
	Kurer K4 Custom Core Anchor (Marie Reiko)	SS, Ti alloy	Tightly threaded, flat tip	1.7 to 2.0
	Kurer K4 Denture Anchor (Marie Reiko)	SS, Ti alloy	Tightly threaded, flat tip	1.8 to 2.0
	Europost, Headless (Dental Anchor Systems)	Ti alloy	Sparsely threaded, blunt tip	1.1 to 1.8
	Europost, Headed (Dental Anchor Systems)	Ti alloy	Sparsely threaded, blunt tip	1.1 to 1.8
	Vlock Active Post (Brasseler USA)	Ti alloy	Sparsely threaded, blunt tip	1.3 to 1.8
	Vario Active Post (Brasseler USA)	Ti alloy	Sparsely threaded, blunt tip	1.3 to 1.8
	Vario ELO Active Post (Brasseler USA)	Ti alloy	Sparsely threaded, flat tip	1.3 to 1.8
	Radix-Anchor (Dentsply Maillefer)	Ti alloy	Sparsely threaded, flat tip	1.2 to 1.6
	ParaPost XT (Coltène/Whaledent)	Ti alloy	Sparsely threaded, grooves, flat tip	0.9 to 1.5
	Flexi-Post (Essential Dental Systems)	Ti alloy, SS	Sparsely threaded, split shank	1.0 to 1.9
	Flexi-Flange (Essential Dental Systems)	Ti alloy, SS	Sparsely threaded, split shank	1.1 to 1.9
	Flexi-Overdenture (Essential Dental Systems)	Ti alloy, SS	Sparsely threaded, split shank	1.4 to 1.9
	Cytco-K (Dentsply Maillefer)	Ti alloy	4 coronal threads, long tapered tip	0.9 and 1.2

*Posts are categorized by their radiographic silhouette from the apical 8 mm of the shank.
†Posts are not photographed to scale.
‡Composition key: Brass, alloy of copper and zinc (brass posts are gold plated); CF, carbon fibers bound by resin matrix; GF, glass fibers bound by resin matrix (glass fibers are either braided or unidirectional in orientation); LT, light transmission through the post; PB, plastic burnout for a cast post; QF, quartz fibers bound by resin matrix (quartz fibers are unidirectional in orientation); SS, stainless-steel; Ti, titanium (Ti indicates approximately 99% pure titanium, Ti alloy indicates a content of approximately 90% titanium); ZrO_2, zirconium oxide or zirconia.
§Shank diameter includes the threads of relevant posts; diameters of tapered posts are taken 8 mm from the apical tip.
‖ISO indicates that the post corresponds to standardized file sizes (set by the International Standards Organization).
¶Surtex and Ancorex post categorization is dependent on the length of the post: the medium and longer sizes are parallel-sided threaded posts; the shorter sizes are tapered threaded posts.

The diameters of popular prefabricated posts are given in Table 12-6. Parallel-sided prefabricated posts are recommended for conservatively prepared root canals in teeth with roots of circular cross-section. Excessively flared canals (e.g., those found in young persons or in individuals after re-treatment of an endodontic failure) are most effectively managed with a custom post. However, situations should be evaluated on an individual basis.

Prefabricated posts

1. Enlarge the canal one or two sizes with a drill, endodontic file, or reamer that matches the configuration of the post (Fig. 12-27*A* and *B*). When using rotary instruments, alternate between the Peeso-Reamers and twist drills that correspond in size. In the case of a threaded post, the appropriate drill is followed by a tap that prethreads the internal wall of the post space. Parallel-sided posts are more retentive and distribute stresses better than do tapered posts, but they do not conform well to the shape of a canal that has been flared to facilitate condensation of gutta-percha. In this situation, it may not be possible to enlarge the canal sufficiently to provide adequate retention for the post; in that case, a tapered custom-made post is preferred.
2. Use a prefabricated post (Fig. 12-27*C*) that matches standard endodontic instruments. A tapered post conforms better to the canal than a parallel-sided post and requires less removal of dentin to achieve an adequate fit. However, it is slightly less retentive and causes greater stress concentrations, although retention may be improved by controlled grooving.[34]
3. Be especially careful not to remove more dentin at the apical extent of the post space than is necessary (see Figs. 12-14 and 12-27).

Of importance: If careful measurement techniques have been followed, radiographs are not normally necessary to verify the post space preparation.

Most of the time, a preformed parallel-sided post fits only in the most apical portion of the canal. Modified posts are available with tapered ends, and these conform better to the shape of the canal, although they have slightly less retention than parallel-sided posts do, particularly when restoring shorter roots.[32] In the absence of a vertical stop on sound tooth struc-

Table 12-6 **DIAMETERS OF EIGHT COMMONLY USED PREFABRICATED POSTS (IN MILLIMETERS)**

Post	0.80	0.90	0.95	1.00	1.05	1.15	1.20	1.25	1.35	1.40
Boston*				X			X			
Surtex*					X		X		X	
Flexi-Post*			X		X					X
Stress-free post size 70	†	‡								
K4 Universal Anchor										
ParaPost		X		X				X		
Radix*						X			X	
Vlock Passive Post						X			X	

Post	1.45	1.50	1.60	1.65	1.75	1.80	1.85	1.90	2.00
Boston*			X						
Surtex*	X		X		X				
Flexi-Post*				X				X	
Stress-free post size 70									
K4 Universal Anchor	X		X	X			X		X
ParaPost		X			X				
Radix*			X	X					
Vlock Passive Post			X						

*Diameter includes threads.
†5 mm from tip.
‡10 mm from tip.

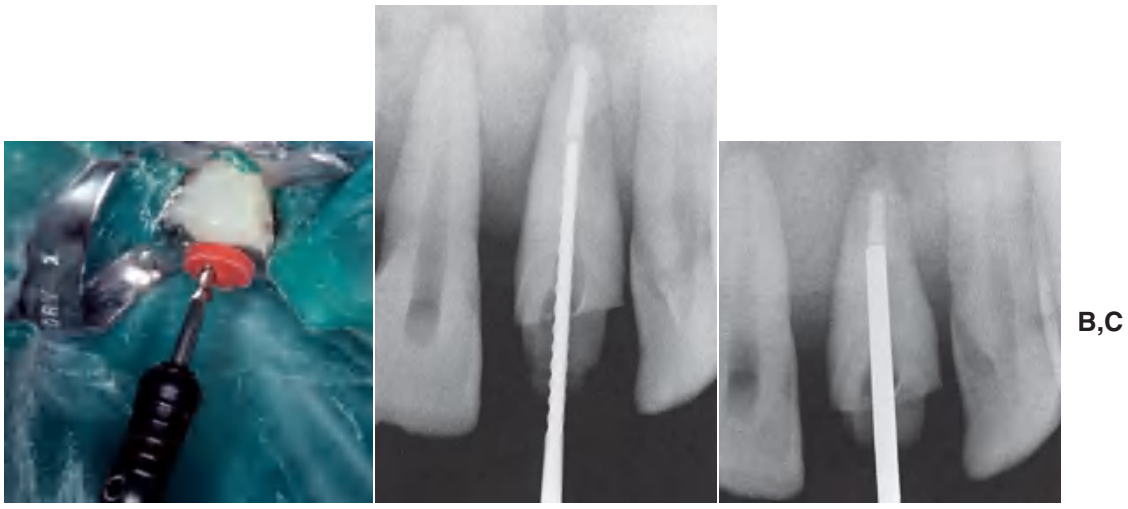


Fig. 12-27
A to **C,** Enlargement of the root canal for a prefabricated post.

ture, such posts can also create an undesirable wedging effect.

Custom-made posts

1. Use custom-made posts (Fig. 12-28) in canals that have a noncircular cross-section or extreme taper. Enlarging canals to conform to a preformed post may lead to perforation. Often very little preparation is needed for a custom-made post. However, undercuts within the canal must be removed, and some additional shaping usually is necessary.
2. Be most careful on molars to avoid root perforation. In mandibular molars, interradicular root concavities make the distal wall of the mesial root and the mesial wall of the distal root. particularly susceptible. In maxillary molars, the curvature of the mesiobuccal root makes mesial or distal perforation more likely[61] (Fig. 12-29). Therefore, neither post size nor length should be excessive.

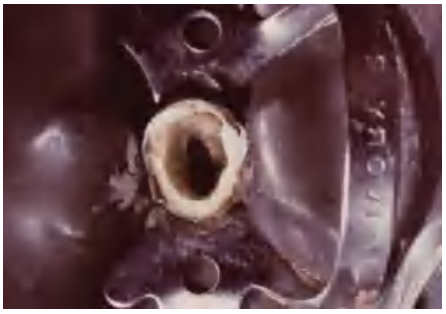


Fig. 12-28
Custom-made posts are indicated for teeth with root canals whose cross-section is not circular or is extremely tapered. Further enlargement of the root canal is often not necessary on these teeth.

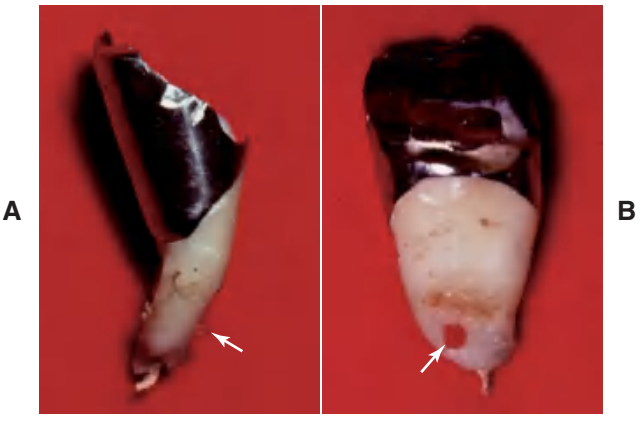


Fig. 12-29
A and **B,** Distal root curvature contributed to this mesial perforation (*arrow*) of a mandibular molar and necessitated removal of the distal root segment. *(Courtesy of Dr. J. Davila.)*

Preparation of the Coronal Tooth Structure

After the post space has been prepared, the remaining coronal tooth structure is reduced for the extracoronal restoration. Specific reduction depends on the type of crown that is planned. When esthetic requirements apply, as for anterior teeth, metal-ceramic crowns or all-ceramic crowns are indicated. (see Chapters 9, 11, 24, and 25).

1. Ignore missing coronal tissue (from previous restorative procedures, caries, fracture, or endodontic access) and prepare the remaining tooth structure as if the crown is intact. Meeting

the same specifications that would be applied otherwise (i.e., if a metal-ceramic crown with a porcelain labial margin is planned, a facial shoulder and lingual chamfer are placed). The prepared walls are the starting point for the core materials, and ensuring that the configuration is correct facilitates achieving correct preparation form in the core.
2. Be sure that the facial structure of the tooth is adequately reduced for good esthetics.
3. Remove all internal and external undercuts that will prevent withdrawal of the pattern.
4. Remove any unsupported tooth structure, but preserve as much of the crown as possible. Because tooth structure has been removed internally and externally, the remaining walls often are thin and weakened. Defining absolute measurements for the dimensions of the residual coronal walls is difficult, but ideally they should probably be at least 1 mm wide. Wall height is reduced proportionally to the remaining wall thickness, because tall, thin walls have a tendency to fracture when the interim restoration is removed and during evaluation and seating of the casting.
5. In addition, be sure that part of the remaining coronal tissue is prepared perpendicular to the post (see step 4 in Fig. 12-8), because this creates a positive stop to minimize wedging and subsequent splitting of the tooth. Similarly, rotation of the post must be prevented by preparing a flat surface parallel to the post (see step 5 in Fig. 12-8). If insufficient tooth structure for this feature remains, an antirotation groove should be placed in the canal (see Fig. 12-22).
6. Complete the preparation by eliminating sharp angles and establishing a smooth finish line.

Post Fabrication

Prefabricated posts

Technique simplicity and treatment expediency are advantages of prefabricated posts. A post is selected to match the dimensions of the canal, and only minimum adjustment is needed to seat it to the full depth of the post space. The coronal part of the post may have an inadequate fit because the root canal has been flared. This can be corrected by adding material when the core is made.

Available materials (see Table 12-5)

Prefabricated parallel-sided posts are made of platinum-gold-palladium (Pt-Au-Pd), nickel-chromium (Ni-Cr), cobalt-chromium (Co-Cr), or stainless steel wire. Serrated posts come in stainless steel, titanium, or nonoxidizing noble alloy. Tapered posts are available in Au-Pt, Ni-Cr, and titanium alloys. All these posts have a high modulus of elasticity and an elongated grain structure, which contribute to their more suitable physical properties in comparison to cast posts. Essentially, they are more rigid.

Failure of posts cast in type III gold when loaded at a 45-degree angle has been attributed to bending.[62] Although posts cast in stiffer (type IV) gold or Ni-Cr alloys can be expected to resist bending better, prefabricated posts should possess even more desirable physical properties, although their properties can deteriorate when a core is cast to a wrought post.[63]

Fiber composite posts have increased in popularity. These posts consist of bundles of stretched aligned glass or carbon fibers* embedded in a resin matrix. The resulting post is strong but has significantly less stiffness and strength than do ceramic and metal posts.[64] Preliminary retrospective study of the carbon fiber system appears promising[65] (Fig. 12-30). However, in a laboratory study in which teeth restored with carbon fiber posts and composite-resin foundations were compared with teeth restored with custom post and cores cast in type III alloy, there were significantly higher fracture thresholds for the cast post and cores.[66] One advantage of a fiber composite posts is their ease of its removal for re-treatment. The preferred technique involves drilling in an apical direction. The very strong carbon fibers prevent the drill from tracking laterally, avoiding penetration of the dentin and preventing the post from shattering easily into small fragments (Fig. 12-31).

Manufacturers have developed high-strength ceramic[67,68] (zirconia) posts† (Fig. 12-32) and ceramic composite‡ (Fig. 12-33) and woven fiber (e.g., polyethylene) posts,§ all of which have excellent esthetic properties (see also Chapters 25 and 27). Ceramic is very strong and rigid; woven fiber is less strong and more flexible.[69] Because the systems are relatively new, judging how well the foundations will perform in clinical practice is difficult, but they should be considered when esthetic demands are high.

Corrosion resistance

Several reports[70-72] have linked root fracture to corrosion of base metal prefabricated post and core systems. In one study,[67] a report on 468 teeth with vertical or oblique root fracture, investigators attributed 72% of these failures to electrolytic action of

*C-Posts, Bisco Co., Schaumburg, Illinois.
†CosmoPost, Ivoclar Vivadent, Amherst, New York.
‡Æstheti-Post, Bisco Co., Schaumburg, Illinois.
§FibreKor, Jeneric/Pentron Inc., Wallingford, Connecticut.



Fig. 12-30

Fiber composite posts. A and B, The ParaPost Fiber Lux system is available in various sizes. **C,** Gutta-percha is removed with hot instruments or a Gates Glidden drill. The canal is prepared sequentially with the drills provided by the manufacturer. **D,** The post is seated in the canal. **E,** The canal is prepared by etching and priming according to the manufacturer's recommendations. **F,** The luting resin is introduced into the canal with a paper point. **G,** The post is coated with resin luting agent, seated and the resin polymerized (**H**). The translucent post allows light transmission to the luting agent. **I,** The core is built up with the recommended core resin. **J,** The preparation is finalized. *(Courtesy of Coltène/Whaledent AG, Altstatten, Switzerland.)*

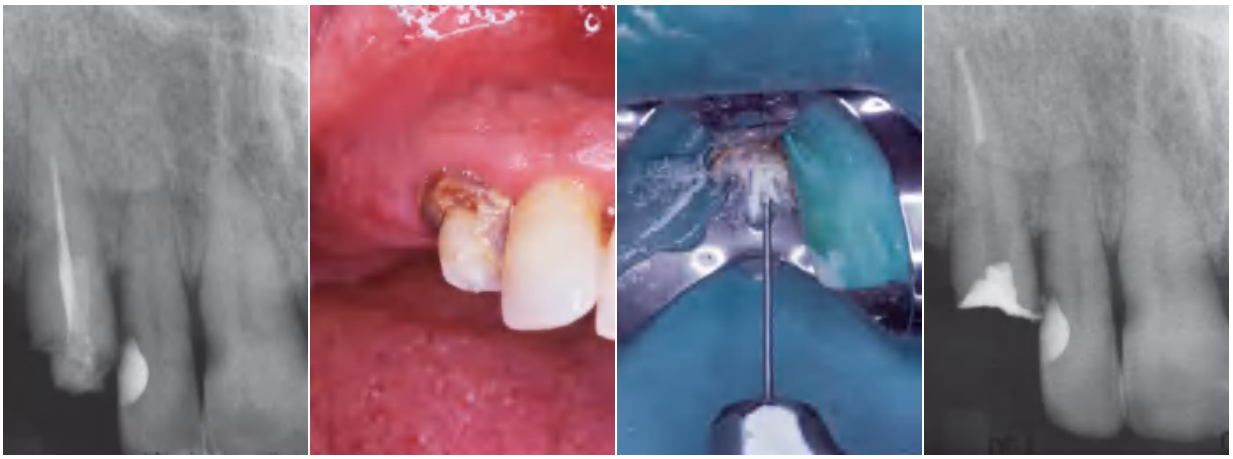
dissimilar metals used for the post and the core (reaction occurring between tin in the amalgam core and stainless steel, German silver, or brass in the post). The authors suggested that volume changes produced by corrosion products split the root. Although possible fracture mechanisms have been suggested,[68,69] these studies are confusing cause with effect: The corrosion may have occurred after root fracture rather than causing it.

Further study is needed to answer the question conclusively. However, in the meantime, avoiding the use of potentially corrodible dissimilar metals for post, core, and crown is recommended.

Custom-made posts

A custom-made cast post and core can be cast from a direct pattern fabricated in the patient's mouth, or an indirect pattern can be fabricated in the dental

A,B



C,D

Fig. 12-31

A, Maxillary canine requires fiber post removal for endodontic re-treatment **B,** Composite resin core is removed first. **C,** Gates Glidden drill used to remove the fiber post. **D,** Endodontically re-treated tooth before fabrication of new post and core and extracoronal restoration. If concern exists about the long-term prognosis of an endodontically treated tooth, a carbon fiber post should be considered. The chief disadvantage of a carbon fiber post is its black appearance, which presents an esthetic problem (as can metal posts). *(Courtesy Dr. D.A. Miller.)*



Fig. 12-32

Zirconia posts, such as the CosmoPost, shown with the corresponding rotary instruments, are esthetic and strong. Special pressable ceramics are available to form the core (composite resin can also be used). *(Courtesy of Ivoclar Vivadent, Amherst, New York.)*

laboratory. A direct technique with autopolymerizing or light-polymerized resin is recommended for single canals with good clinical access, whereas an indirect procedure is more appropriate for multiple canals or when access is more problematic. As an alternative to autopolymerizing resin, thermoplastic resin can be used.

Direct procedure

1. Lightly lubricate the canal and notch a loose-fitting plastic dowel (Fig. 12-34*A*). It should extend to the full depth of the prepared canal.
2. Use the bead-brush technique (Fig. 12-34*B*) to add resin to the dowel (Fig. 12-34*C*) and seat it in the prepared canal. This should be done in two steps: Add resin only to the canal orifice first. An alternative is to mix some resin and roll it into a thin cylinder. This is introduced into the canal and pushed into place with the monomer-moistened plastic dowel.
3. Do not allow the resin to harden fully within the canal. Loosen and reseat it several times while it is still rubbery.
4. Once the resin has polymerized, remove the pattern (Fig. 12-34*D*).
5. Form the apical part of the post by adding additional resin and reseating and removing the post, taking care not to lock it in the canal.
6. Identify any undercuts that can be trimmed away carefully with a scalpel.

The post pattern is complete when it can be inserted and removed easily without binding in the canal. Once the pattern has been made, additional resin or light-polymerized resin* is added for the core.

Pattern fabrication with thermoplastic resin. (Fig. 12-35)

1. Fit the plastic rod to the prepared post space. Trim the rod until the bevel area is approximately 1.5 to 2 mm occlusal to the finish line for the core.

*LX Gel, Dentatus, New York, New York; Palavit G LC, Heraeus Kulzer, Inc., South Bend, Indiana.

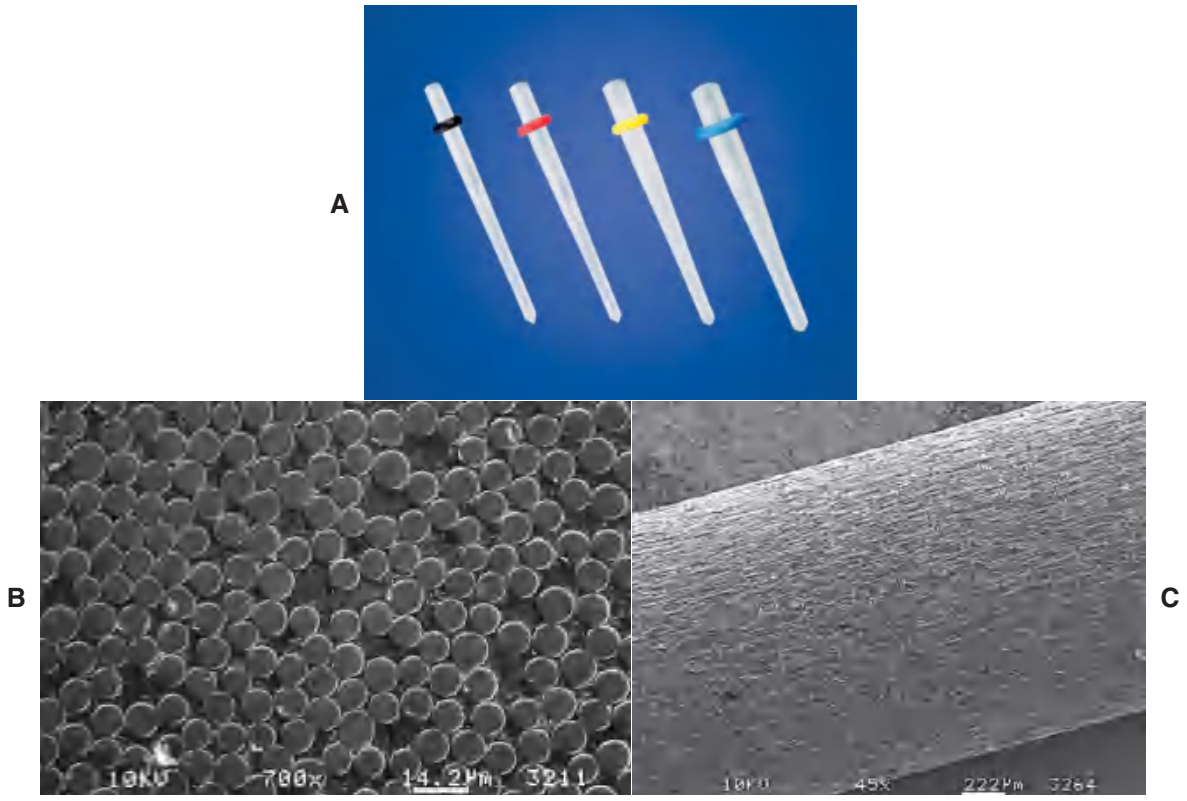


Fig. 12-33
Ceramic composite post. A, The D.T. LIGHT-POST system uses quartz fibers in an epoxy resin matrix. Cross-sectional (B) and longitudinal (C) sections of the fiber composite. *(Courtesy of Bisco, Inc., Schaumburg, Illinois.)*



Fig. 12-34
A to D, Fabrication of an acrylic resin pattern for a custom-made post. *(Courtesy of Dr. R. Webber.)*

2. Lubricate the canal with a periodontal probe and petroleum jelly.
3. Heat the thermoplastic resin over a flame until the material turns clear, or heat the resin in a low-temperature glue gun.*
4. Apply a small amount of the heated resin to the apical end of the rod to cover two thirds of the anticipated length of the post pattern.
5. Fully insert the rod into the prepared post space. Lift after 5 to 10 seconds and reseat. Inspect the post pattern for completeness and, with a scalpel blade, remove any projections that result from undercuts in the canal.
6. For the direct technique, fabricate the core with conventional autopolymerizing resin, using the brush-bead technique, or use a syringe to apply a light polymerized pattern resin (an easier technique).
7. If the indirect technique is preferred, pick up the pattern with an elastomeric impression material, which can be poured in the conventional manner. Soak the cast in warm water to help release the pattern. Reseat the post pattern, and wax the core.

*Thermogrip, Black & Decker, Inc., Towson, Maryland.



Fig. 12-35
The Merritt EZ Cast Post system. **A,** The canal is lubricated and excess lubricant removed with paper points. The post was previously trimmed until its beveled portion protruded about 1.5 to 2 mm above the tooth preparation. **B,** A stick of the thermoplastic material is heated. **C,** The plastic rod is covered for about two thirds of the anticipated post length. **D,** The coated post is inserted and can be removed in 5 to 10 seconds. **E,** After any protrusions have been removed, the core is built from autopolymerizing resin and trimmed to ideal tooth preparation form. **F,** The completed custom post and core. (From Rosenstiel SF, et al: Custom-cast post fabrication with a thermoplastic material. J Prosthet Dent 77:209, 1997.)

8. Invest and cast the post and core. Phosphate-bonded investment is recommended because of its higher strength.

Indirect procedure

Any elastomeric material will make an accurate impression of the root canal (Fig. 12-36*A*) if a wire reinforcement is placed to prevent distortion.

1. Cut pieces of orthodontic wire to length and shape them like the letter J (Fig. 12-36*B*).
2. Verify the fit of the wire in each canal. It should fit loosely and extend to the full depth of the post space. If the fit is too tight, the impression material will strip away from the wire when the impression is removed.
3. Coat the wire with tray adhesive. If subgingival margins are present, tissue displacement may be helpful. Lubricate the canals to facilitate removal of the impression without distortion (die lubricant is suitable).
4. Using a lentulo spiral, fill the canals with elastomeric impression material. Before loading the impression syringe, verify that the lentulo will spiral material in an apical direction (clockwise). Pick up a small amount of material with the largest lentulo spiral that fits into the post space. Insert the lentulo with the handpiece set at low rotational speed to slowly carry material into the apical portion of the post space. Then increase

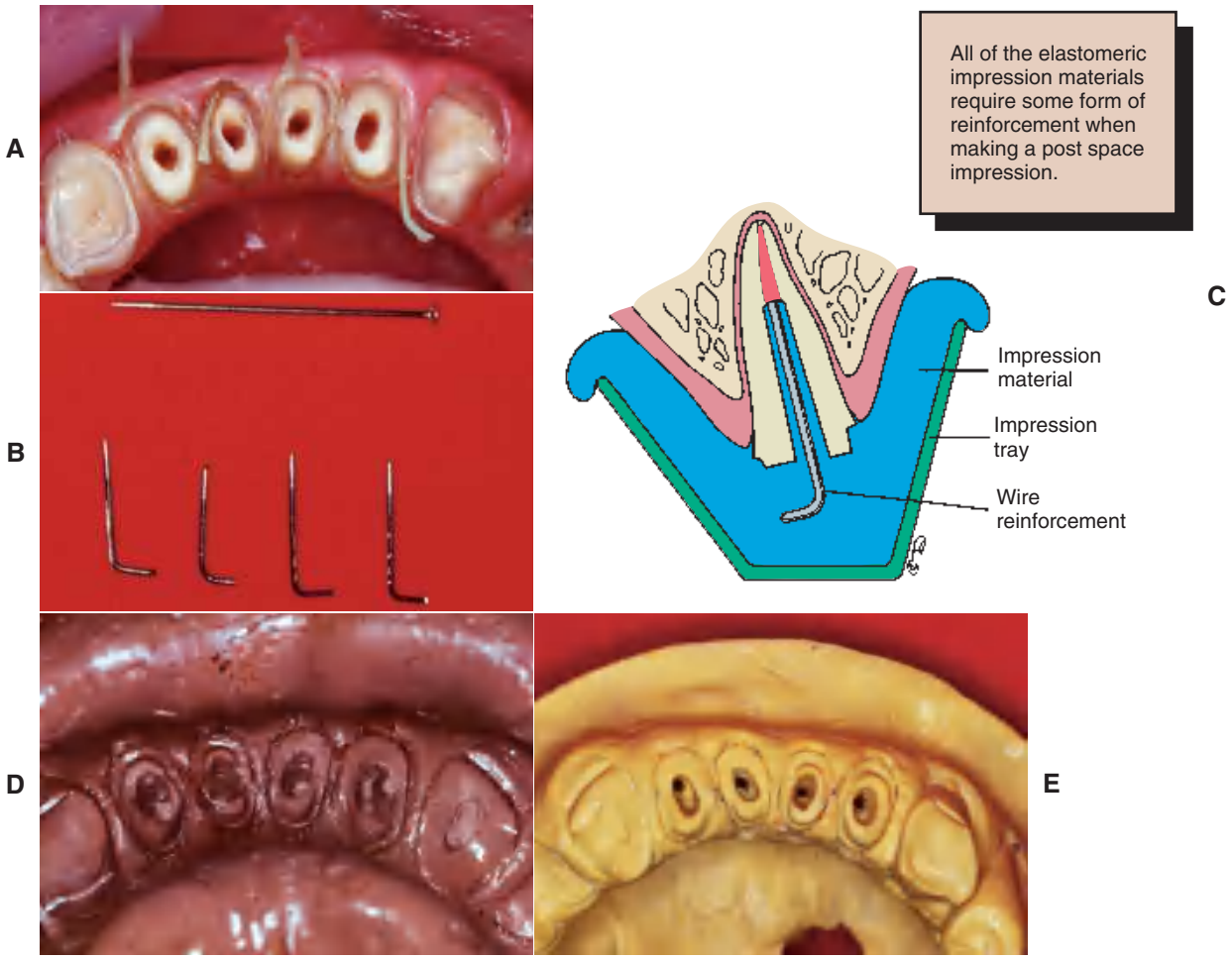


Fig. 12-36
A to **E,** Indirect procedure for post-and-cores.

handpiece speed and slowly withdraw the lentulo from the post space. This technique prevents the impression material from being dragged out. Repeat until the post space is filled.

5. Seat the wire reinforcement to the full depth of each post space, use a syringe to fill in more impression material around the prepared teeth, and insert the impression tray (see Fig. 12-36*C*).
6. Remove the impression (see Fig. 12-36*D*), evaluate it, and pour the definitive cast (see Fig. 12-36*E*) as usual (see Chapter 17).

Access for waxing is generally adequate without placement of dowel pins or sectioning of the cast.

7. Roughen a loose-fitting plastic post (a plastic toothpick is suitable) and, using the impression as a guide, make sure that it extends into the entire depth of the canal.
8. Apply a thin coat of sticky wax to the plastic post and, after lubricating the stone cast, add soft inlay wax in increments (Fig. 12-37). Start from the most apical and make sure that the post is correctly oriented as it is seated to adapt the wax. When this post pattern has been fabricated, the wax core can be added and shaped.
9. Use the impression to evaluate whether the wax pattern is completely adapted to the post space.

Core Fabrication

The core of a post and core restoration replaces missing coronal tooth structure and, combined with the remaining coronal tissue, forms the shape of the optimal tooth preparation. It can be shaped in resin or wax and added to the post pattern before the assembly is cast in one piece. It is cast directly onto a prefabricated post. Some concern arises that the casting process may unfavorably affect the physical properties of wrought metal posts. A third alternative is to make the core from a plastic restorative material, such as amalgam, or from composite resin or glass ionomer.



Fig. 12-37
A and **B,** Post and core patterns made by adding wax to prefabricated plastic posts.

Plastic filling materials

The advantages of amalgam, glass ionomer, or resin[62,73,74] include the following:

1. Maximum tooth structure can be conserved, because undercuts do not need to be removed.
2. Treatment requires one fewer patient visit.
3. There are fewer laboratory procedures.
4. Testing generally shows good resistance to fatigue testing[75] and good strength characteristics,[76] possibly because of the good adaptation to tooth structure. However, these plastic restorative materials, especially the glass ionomers, have lower tensile strength than do cast metals.

Disadvantages include the following:

1. Long-term success may be affected by corrosion of amalgam cores, the low strength of glass ionomer,[77] or the continued polymerization[78] and high thermal expansion coefficients of composite resin cores.
2. Microleakage with temperature fluctuations (thermocycling) is greater under composite resin and amalgam cores than under conventional crown preparations[79] (however, the extent of leakage under cast cores has yet to be determined).
3. Difficulty may be encountered with certain operative procedures such as rubber dam or matrix application (particularly on badly damaged teeth).

Amalgam cores are suitable for restoring posterior teeth, particularly when some coronal structure remains. The procedure described by Nayyar and associates,[45] with amalgam also used for the posts, is conservative of tooth structure. The cores are placed during the same appointment as the root canal obturation, because then the teeth are still isolated by the rubber dam, the practitioner is still familiar with the root canal structure, and the cores can serve as a support for the interim restoration (Fig. 12-38).

Step-by-step procedure for amalgam (see also Chapter 6)

1. Apply the rubber dam and remove gutta-percha from the pulp chamber, as well as 2 to 4 mm into each root canal, if less than 4 mm of coronal height remains. Use a warmed endodontic instrument.
2. Remove any existing restoration, undermined enamel, or carious or weakened dentin. Establish the cavity form, using conventional principles of resistance and retention form. Even if cusps are missing, pins are not normally required, because adequate retention can be gained by extending the amalgam into the root canals.
3. If it is suspected that the floor of the pulp chamber is thin, protect it from condensing pressures with a cement base.
4. Fit a matrix band. Where lack of tooth structure makes the application of a conventional matrix system difficult, an orthodontic or annealed copper band may be used.
5. Condense the first increments of amalgam (select a material with high early strength) into the root canals with an endodontic plugger.
6. Fill the pulp chamber and coronal cavity in the conventional manner.
7. Carve the alloy to shape. The impression can be made immediately. Alternatively, the amalgam can be built up to anatomic contour and later prepared for a complete crown. Under these circumstances, the patient must be cautioned to avoid forces that would fracture the tooth or the newly placed restoration.

Cast metal

Cast metal cores have the following advantages:

1. They can be cast directly onto a prefabricated post, providing a restoration with good strength characteristics.
2. Conventional high noble-metal content alloys can be used.

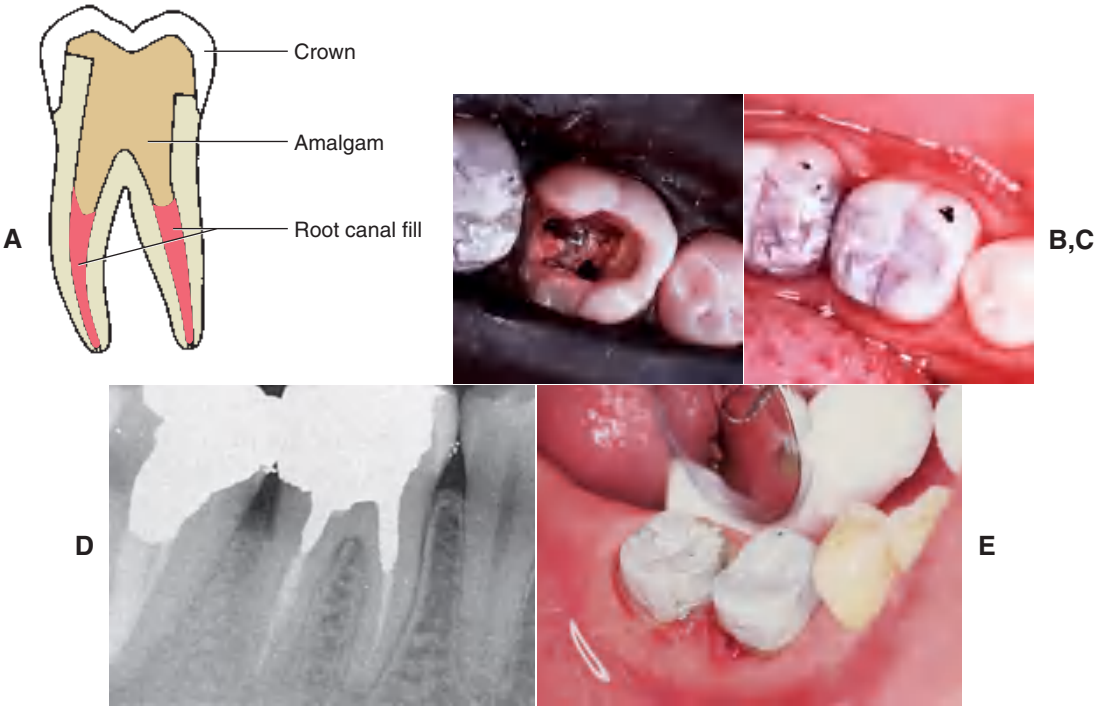


Fig. 12-38
A to **E,** Retention for an amalgam core can be obtained from the root canal system, preserving as much tooth structure as possible. (***B*** to ***D***, *Courtesy Dr. M. Padilla.)*

3. An indirect procedure can be used, making restoration of posterior teeth easier.

Direct procedure for single-root teeth

Direct patterns can be formed by combining a prefabricated post with autopolymerizing resin. Alternatively, a thermoplastic material can be used to create a post pattern,[80] and the core portion can be developed in autopolymerizing resin, light polymerized resin, or wax.

Pattern fabrication with autopolymerizing resin

1. Use a prefabricated metal or custom acrylic resin post.
2. Add resin by the "bead" technique, dipping a small brush in monomer and then into polymer and applying it to the post. Alternatively, light-cured resin can be used to facilitate this step.[81]
3. Slightly overbuild the core and let it polymerize fully (Fig. 12-39*A*).
4. Shape the core with carbide finishing burs or diamonds (Fig. 12-39*B*). Use water spray to prevent overheating of the acrylic resin. Correct any small defects with wax.
5. Remove the pattern (Fig. 12-39*C*); sprue and invest it immediately.

Direct pattern for multiroot teeth

A direct pattern (Fig. 12-40) can be used for multiroot posterior teeth, although limited access may make the indirect approach easier. A single-piece core with auxiliary posts is used, as opposed to the multisection core recommended for indirect posterior cast post and cores. The core is cast directly onto the post of one canal. (The other canals already have prefabricated posts that pass through holes in the core.)

The procedure is simple, as long as smooth parallel-sided or tapered posts are used:

1. Fit prefabricated posts into the prepared canals. One post is roughened; the others are left smooth and lubricated. All posts should extend occlusally beyond the eventual core.
2. Build up the core with autopolymerizing resin, using the bead technique.
3. Shape the core to final form with carbide finishing burs.
4. Grip the smooth, lubricated posts with hemostatic forceps, and remove them.
5. Remove, invest, and cast the core with the roughened single post. When this has been done, the holes for the auxiliary posts can be refined with the appropriate twist drill.
6. After verifying the fit at evaluation, cement the core and auxiliary posts to place.

Indirect pattern for posterior teeth (Fig. 12-41)

1. Wax the custom-made posts as described previously.
2. Build part of the core around the first post.



Fig. 12-39
A to **C,** Direct pattern for a single-root tooth.

3. Remove any undercuts adjacent to other post holes and cast the first section.
4. Wax additional sections and cast them.

Using dovetails to interlock the sections makes the procedure more complicated and is probably of limited benefit, especially because the final buildup is held together by the fixed cast restoration.

Interim Restorations (see Chapter 15)

To reduce the need for endodontic re-treatment, endodontically treated teeth should be restored as soon as practical after completion of the endodontic procedure. Zinc oxide-eugenol (ZOE) luting materials have been used for many years to achieve a seal before initiation of prosthetic treatment, However, such ZOE materials have been shown to leak at the dentin-material interface.[83]



Fig. 12-40
A direct post and core for posterior teeth can be made by cementing a prefabricated post through a casting. Here the two buccal canals (**A** and **B**) had a common path of withdrawal and could be incorporated into the core casting. More typically, only one canal has a fixed post, and the others are cemented through the core.

Thus, if definitive restoration of the tooth is delayed, it is appropriate to etch and seal the access cavity with an adhesive resin to reduce the risk of microleakage. However, teeth in the esthetic zone often require a well-adapted interim restoration.

Such interim restorations prevent drifting of the tooth itself and of opposing or adjacent teeth after completion of endodontics (Fig. 12-42). Of particular importance are good proximal contacts to prevent tooth migration that leads to unwanted root proximity. If a cast post and core is made, the tooth will require an interim restoration while the post and core is being fabricated. This can be retained by fitting a wire (e.g., a paper clip or orthodontic wire) into the prepared canal. The restoration is then conveniently fabricated with autopolymerizing resin by the direct technique.

Investing and Casting

A cast post and core should fit somewhat loosely in the canal. A tight fit may cause root fracture. The casting should be slightly undersized, which can be accomplished by restricting expansion of the investment (i.e., by omitting the usual ring liner or casting at a lower mold temperature [see Chapter 22]). An accelerated casting technique may facilitate the laboratory phase.[83] The casting alloy should have suitable physical properties. Extra-hard partial dental prosthetic gold (American Dental Association type IV) or Ni-Cr alloys have high moduli of elasticity and are suitable for cast posts (see Chapter 19). A sound casting technique is essential because any undetected porosity could lead to a weakened casting that might fail in function (Fig. 12-43).

Casting a core onto a prefabricated post avoids such problems of porosity, but the preheating tem-

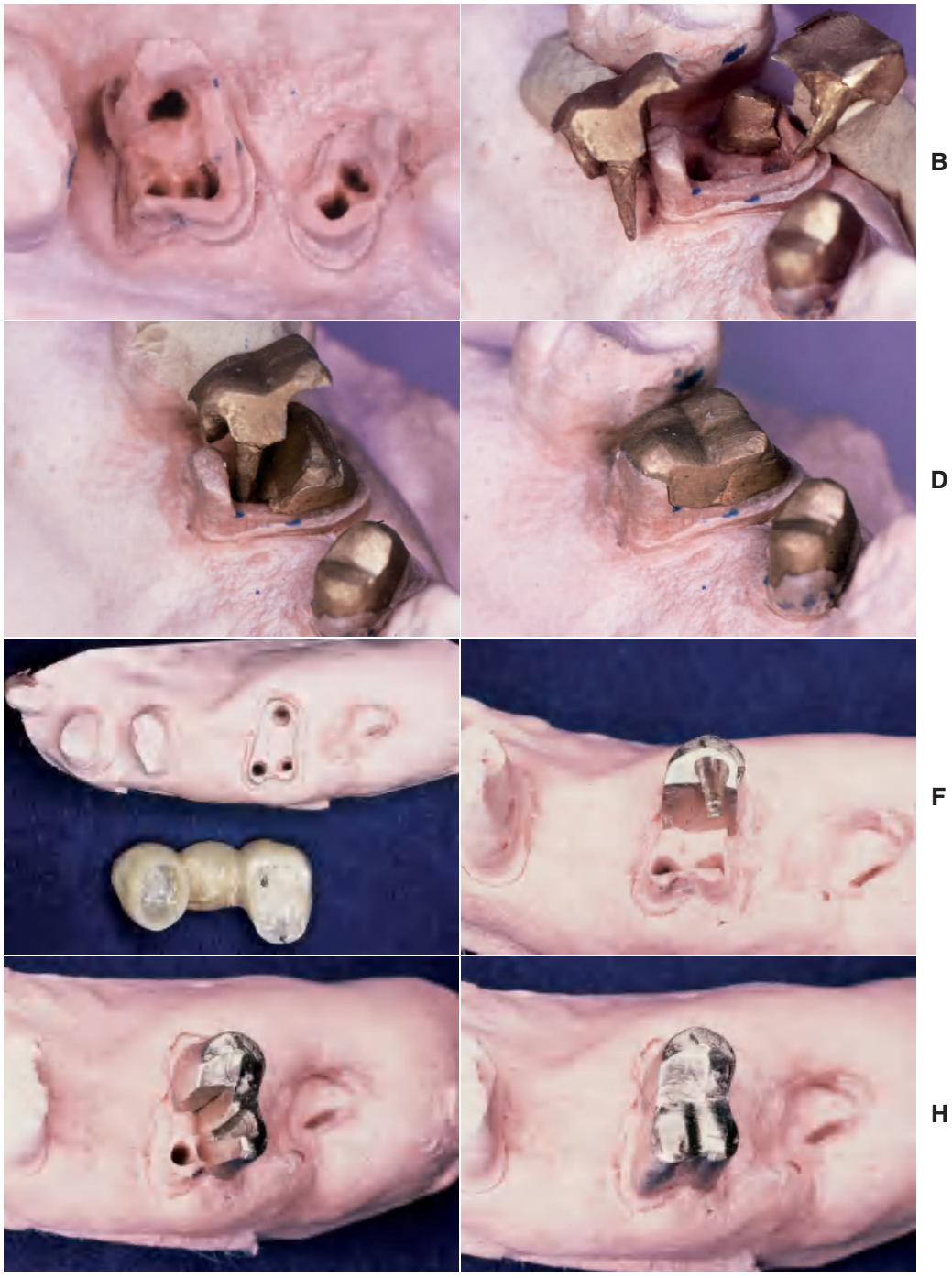


Fig. 12-41
A to **D**, Multipiece post and cores can be made by the indirect technique, waxing each section to ensure that no undercuts are created. **E** to **H**, Alternatively, interlocking sections can be made, but this complicates the laboratory phase.

It is not essential that the reline material extend all the way down the post space. By engaging the apical portion of the post space, the wire will enhance resistance of the provisional.

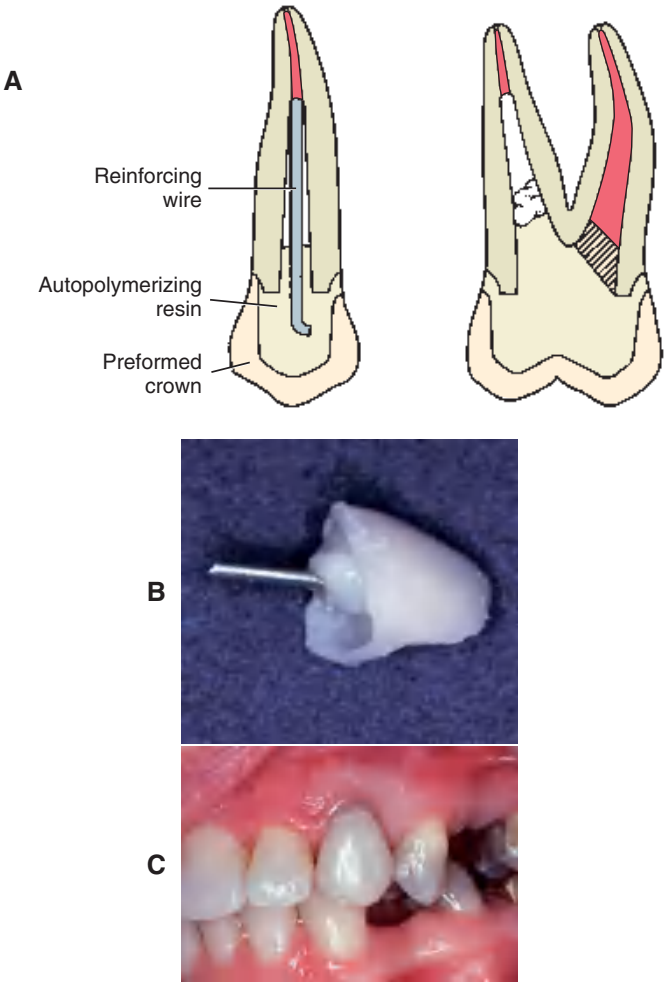


Fig. 12-42
A to C, Interim restorations made for endodontically treated teeth by lining a polycarbonate crown with autopolymerizing resin. The post is made of metal wire (orthodontic wire or a paper clip; see Chapter 15). (**A,** *From Taylor GN, Land MF: Restoring the endodontically treated tooth and the cast dowel. In Clark JW, ed: Clinical Dentistry, vol 4. New York, Harper & Row, 1985.*)

perature of the investment mold should be restricted if recrystallization of the wrought post[84] is to be avoided. The latter would adversely affect its physical properties.

Evaluation

The practitioner must be particularly careful that casting defects do not interfere with seating of the post; otherwise, root fracture will result. Post and cores should be inserted with gentle pressure. However, the marginal fit of a cast foundation is not as crucial as that of other cast restorations, because the margins will be covered by the final casting. Air-abrading the surface to a matte finish may help detect interferences at try-in (Fig. 12-44).

The shape of the foundation is evaluated and adjusted as necessary.



Fig. 12-43
Fractured post. *(Courtesy of Dr. D. Francisco.)*



Fig. 12-44
A, The fitting surface of the casting must be carefully evaluated. **B,** Nodules, as can be seen here, could easily lead to root fracture and tooth loss.

Cementation

The luting agent must fill all dead space within the root canal system (Fig. 12-45). Voids may be a cause of periodontal inflammation via the lateral canals.

A rotary (lentulo) paste filler or cement tube (Fig. 12-46) is used to fill the canal with cement. The post and core is inserted gently to reduce hydrostatic pressure, which could cause root fracture. If a parallel-sided post is being used, a groove should be



Fig. 12-45
Residual voids after cementation can cause inflammation. *(Courtesy of Dr. D. Francisco.)*

placed along the side of the post to allow for improved escape of excess cement. Use of venting procedures has also been shown to reduce the necessary seating force, although the latter is probably cement specific.[85]

Removal of Existing Posts

On occasion, an existing post and core must be removed (e.g., for re-treatment of a failed root canal filling). Patients must understand in advance that post removal is a risky process and occasionally results in radicular fracture. If sufficient length of post is exposed coronally, the post can be retrieved with thin-beaked forceps. Vibrating the post first with an ultrasonic scaler weakens brittle cement and facilitates removal. A thin scaler tip or special post removal tip is recommended (Fig. 12-47). Although histologic examination with animal models reveals

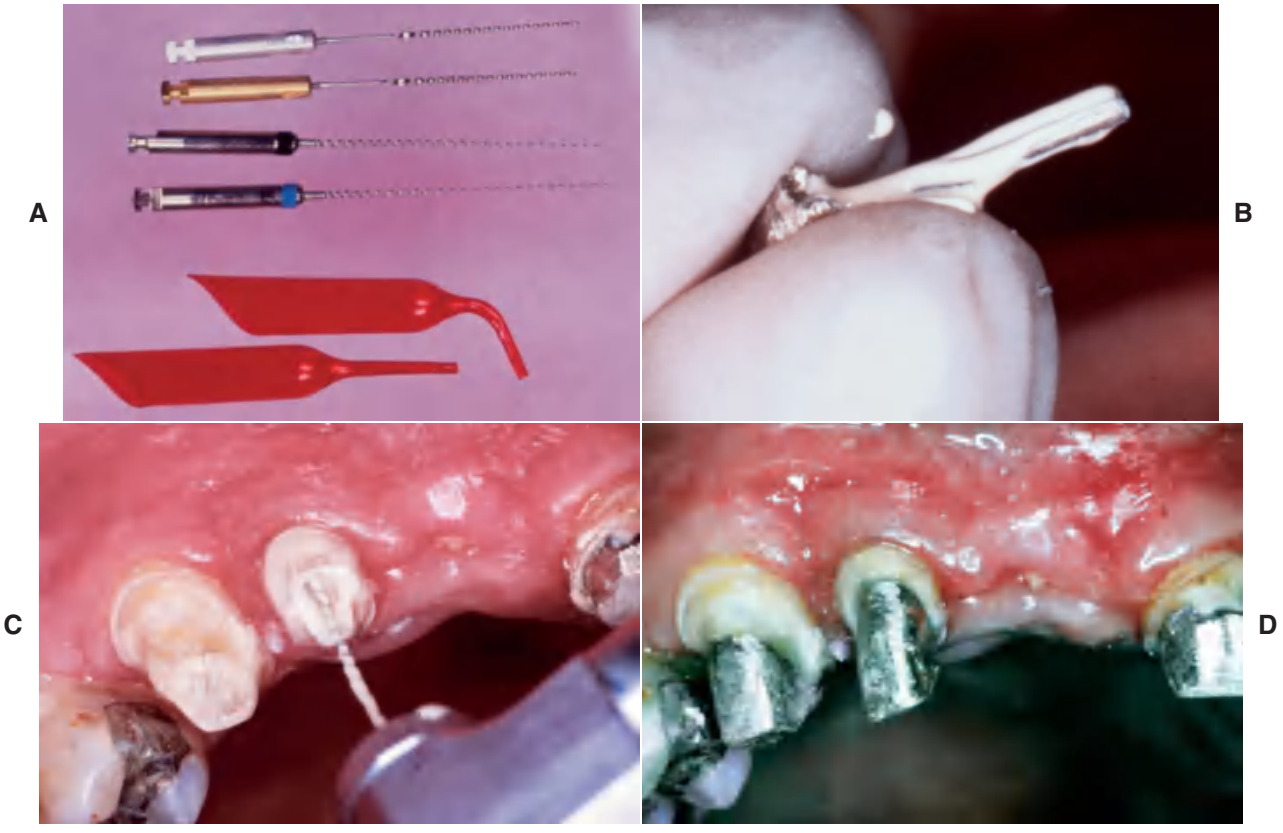


Fig. 12-46
A, Lentulo rotary paste fillers or a cement tube are used to fill the post space completely. **B,** The post is first coated with cement. **C,** The canal is filled with cement. **D,** To avoid the risk of fracture, the post and core is very gently seated. A small cement line is not usually significant, because dissolution is prevented by the presence of the definitive restoration. *(**B** to **D,** Courtesy of Dr. M. Padilla.)*

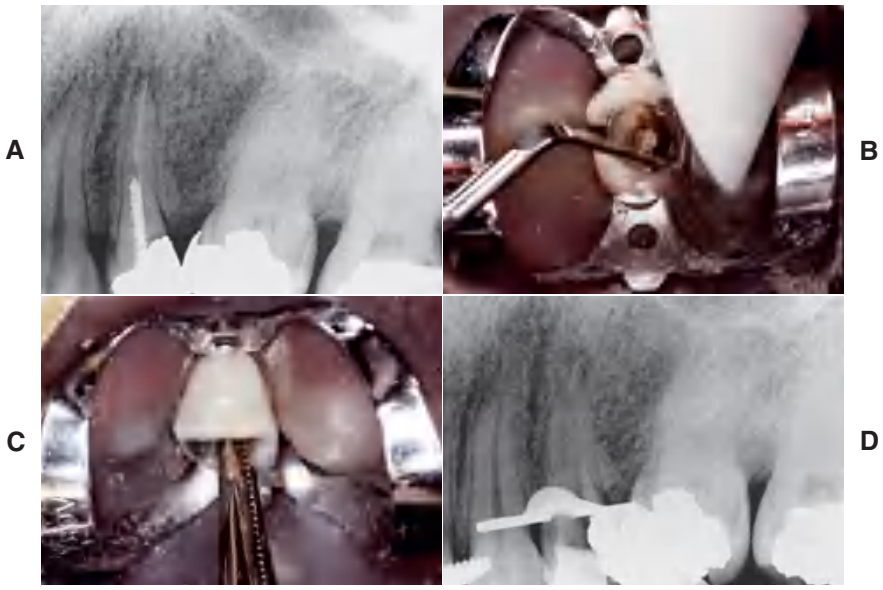


Fig. 12-47
Post removal by ultrasonic device. **A,** Preoperative radiograph of the left maxillary first premolar with a parallel-sided threaded post that had to be removed for endodontic retreatment. **B,** After the coronal portion of the post has been well isolated, the tip of the ultrasonic device is placed against it, and energy is applied to disrupt the cement interface. Note the suction tip, which removes water spray used with the ultrasonic handpiece. **C,** After a time, the post becomes loose within the canal and can be retrieved by forceps. **D,** Radiograph of the premolar after post removal. *(Courtesy of Dr. L. L. Lazare.)*

no harmful effect in the periodontal tissues,[86] ultrasonic removal is slower than other methods and may result in an increased number of canal and intradentin cracks.[87] Alternatively, a post puller can be used.[88] This device consists of a vise to grip the post and legs that bear on the root face. A screw activates the vise and extracts the post.

A post that has fractured within the root canal cannot be removed with a post puller or forceps. The post can be drilled out, but great care is needed to avoid perforation. The technique is best limited to relatively short fractured posts (Fig. 12-48).

Another means of handling an embedded fractured post (described by Masserann[89] in 1966) is to use special hollow end-cutting tubes (or trephines) to prepare a thin trench around the post (Fig. 12-49). This technique has shown success.[90] Retrieval can be facilitated by using an adhesive to attach a hollow tube extractor[91] or by using a threaded extractor[92] (Fig. 12-50).

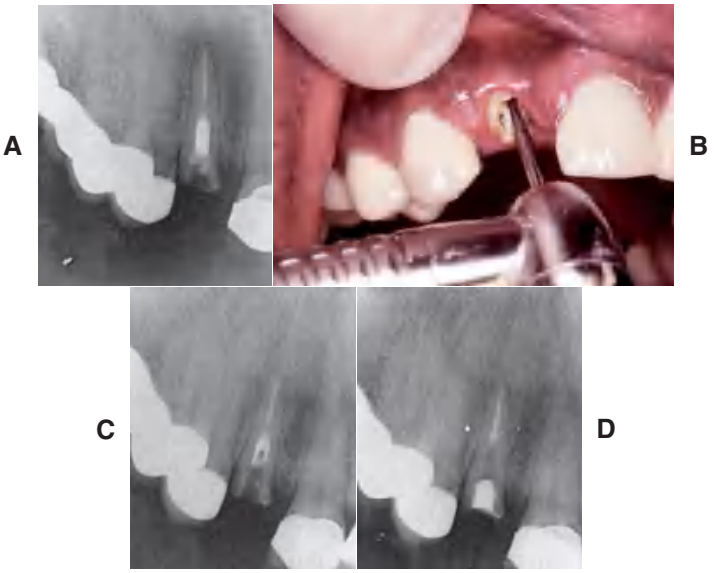


Fig. 12-48
Post removal by high-speed bur. **A,** Preoperative radiograph of the right maxillary lateral incisor, in which both the crown and part of a post have been fractured off. A portion of the Kurer-type, parallel-sided, threaded post remains within the canal. **B,** Because of the large diameter of the post and its position within the canal, a high-speed handpiece was chosen to drill it out. **C,** Radiograph to verify the correct orientation of the bur's progress inside the canal. With this method of post removal, the operator must be extremely careful not to let the high-speed bur contact the canal wall, which would seriously compromise tooth structure. **D,** Radiograph of the incisor after post removal and re-treatment. *(Courtesy of Dr. D. A. Miller.)*

SUMMARY

Although the restoration of endodontically treated teeth has been rationalized considerably by laboratory research data, information from controlled long-term clinical trials is still necessary and difficult to obtain. Different clinical procedures have been advocated, many of which are successful if properly used. Where the crown is preserved and circumferentially

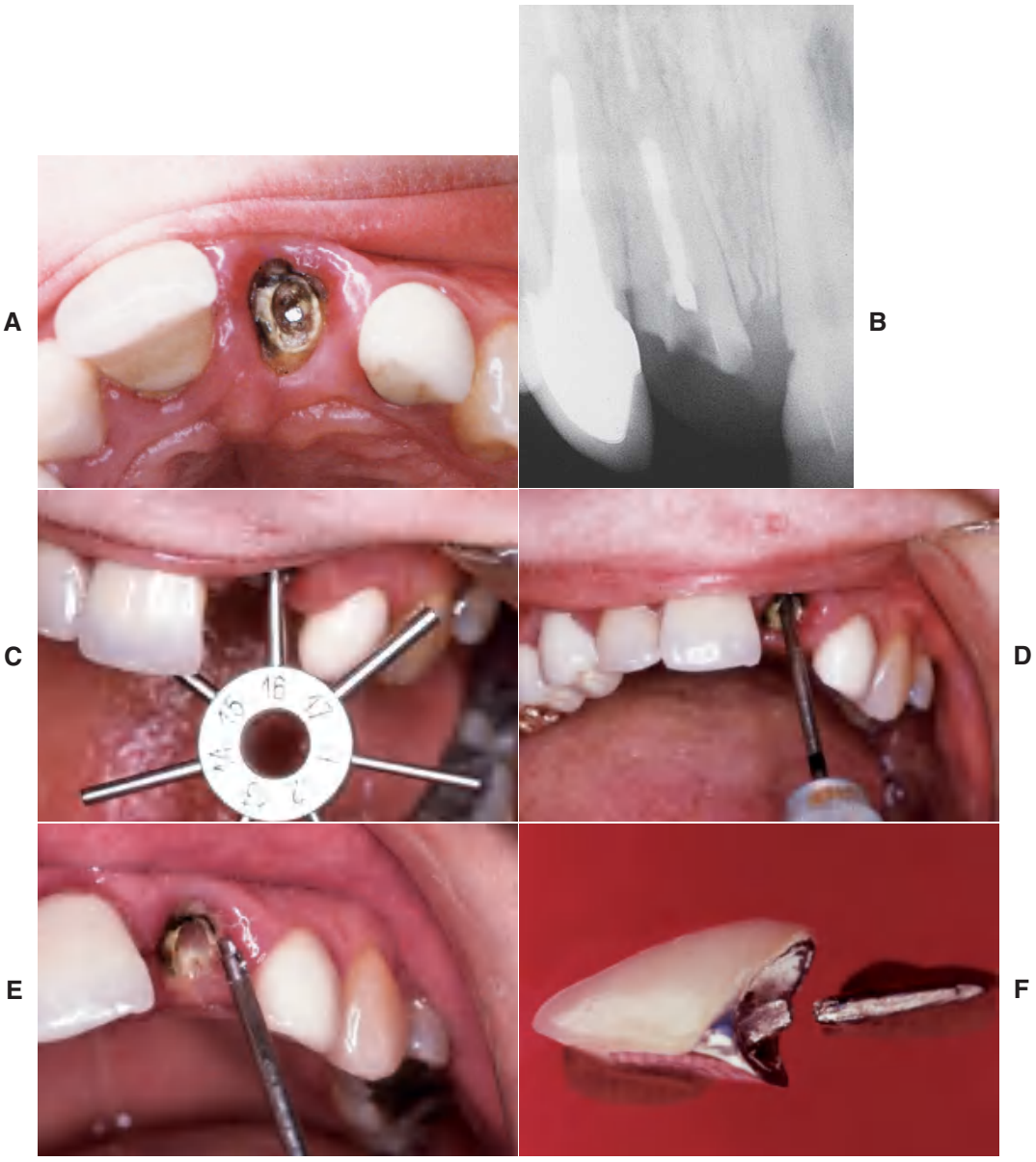


Fig. 12-49

Masserann technique for the removal of fractured posts. **A** and **B,** Maxillary incisor with a post that has fractured inside the canal. **C,** The diameter of the post is gauged with a sizing tool. **D,** The selected trephine is carefully rotated counterclockwise to create a narrow channel around the post. **E,** When the instrument has removed sufficient material, the post is recovered. **F,** The fractured crown and post after removal.

largely intact, an *anterior* tooth can be safely restored with a plastic filling. To prevent fracture of *posterior* teeth, cast restorations providing cuspal coverage are recommended.

Preserving as much tooth structure as possible is important, particularly within the root canal, in which the amount of remaining dentin may be difficult to assess.

A post and core is used to provide retention and support for a cast restoration. It should be of adequate length for good stress distribution but not so long that it jeopardizes the apical seal. The safest method to create post space is to use a heated endodontic plugger to remove the gutta-percha. Anterior teeth, particularly those with flared or elliptical canals, should be built up with a custom cast post and core, which offers great strength, although prefabricated posts can be used successfully when adequate retention and resistance form for the plastic material can be obtained. Esthetic post materials should be considered if a dark post would prevent fabrication of an esthetic restoration. Amalgam core material can be used satisfactorily on posterior teeth when one or more cusps have been lost, although a casting may be preferred if substantial coronal tooth structure is missing.

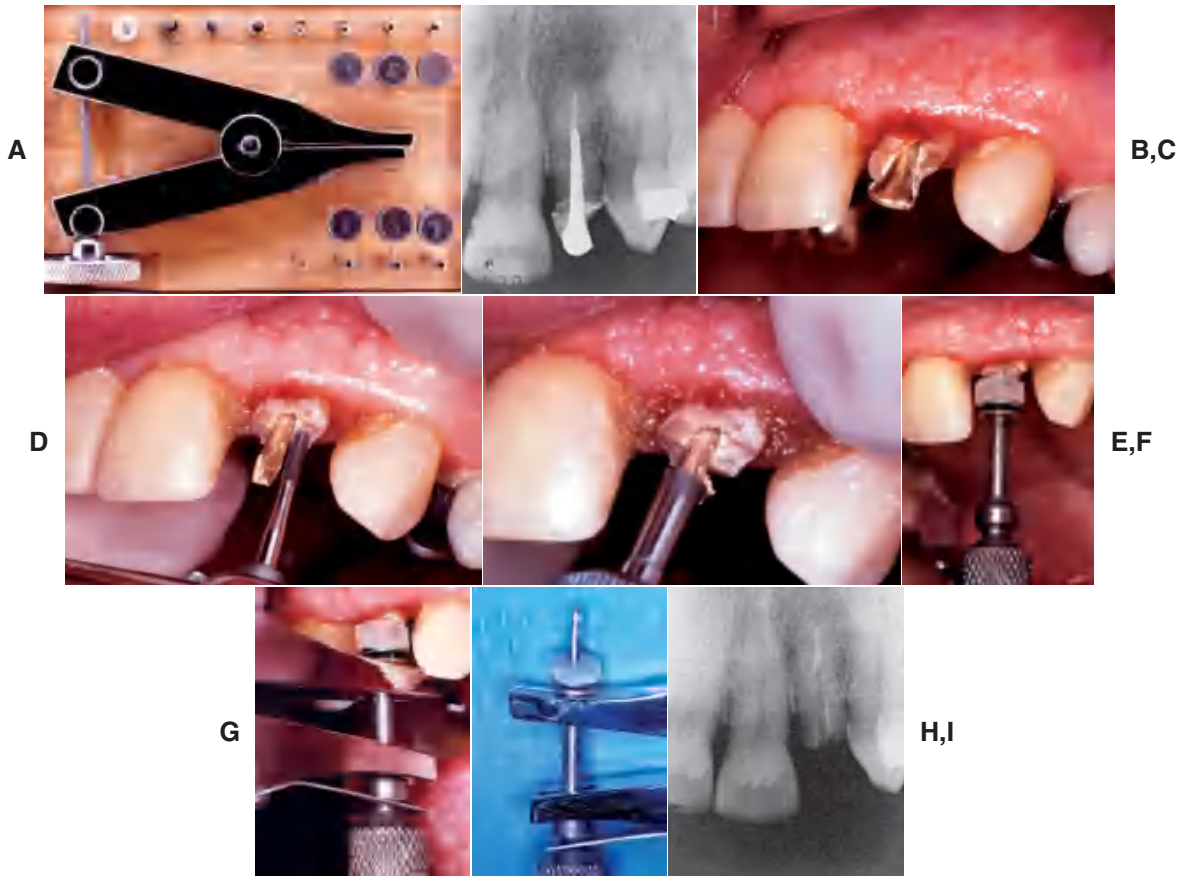


Fig. 12-50
Post removal by extractor. **A,** The Thomas (Gonon) post-removing system. It includes pliers, trephine burs, mandrels, and washers. **B,** Preoperative radiograph of the left maxillary lateral incisor with a post. **C,** Note the flared shape of the post in this preoperative view and the height of the surrounding tooth structure. **D,** A high-speed bur is used to free the post from coronal tooth structure and parallel its sides. (Note: An ultrasonic device may be used at this point to disturb the cement interface.) **E,** A trephine bur machines the post to the correct diameter and places threads for the mandrel. **F,** The mandrel is threaded onto the post with special washers, which distribute the forces from the extractor evenly over the tooth. **G,** The beaks of the pliers are fitted onto the mandrel; the knob of the pliers is then rotated, which separates the beaks, and the post is extruded from the tooth. **H,** The removed post, still attached to the mandrel and pliers. **I,** Radiograph of the lateral incisor after post removal. *(Courtesy of Dr. D. A. Miller.)*

STUDY QUESTIONS

1. What must be determined to ensure that an endodontically treated tooth is ready for subsequent restorative treatment?
2. What six features must be incorporated in the tooth preparation for a cast post and core?
3. Discuss five variables that have an impact on retention form for cast post and cores.
4. Discuss four different post and core systems, their advantages and disadvantages, and typical indications and precautions.
5. Which canal configurations are circular? Which are elliptical?
6. Describe recommended step-by-step procedures for the following: (1) Custom-made direct procedure post and core pattern fabrication for a maxillary second premolar. (2) Amalgam post and core on a mandibular molar.
7. How is an interim restoration fabricated for a mandibular second premolar that has been prepared for a cast post and core?

GLOSSARY*

anatomic crown \ăn′a-tŏm′ĭk kroun\: the portion of a natural tooth that extends coronal from the cementoenamel junction—called also *anatomical crown*

an·nu·lar \ăn′ya-ler\ *n* (1571): a term used to describe a ring like anatomic structure

apex \ā′pĕks′\ *n, pl* **apex·es** or **api·ces** (1601): **1:** the uppermost point; the vertex **2:** in dentistry, the anatomic end of a tooth root

autopolymerizing resin \ô′tō-pŏl-a-mĕr-ī′zing rĕz′ĭn\: a resin whose polymerization is initiated by a chemical activator

avul·sion \a-vŭl′shun\ *n* (1622): a forcible separation or detachment, as in a tearing away of a body part surgically or accidentally

dow·el \dou′al\ *n, obs* (13c): a post usually made of metal that is fitted into a prepared root canal of a natural tooth. When combined with an artificial crown or core, it provides retention and resistance for the restoration—See POST

e·las·tic \ĭ-lăs′tĭk\ *adj* (1653): susceptible to being stretched, compressed, or distorted and then tending to resume the original shape

elastic modulus \ĭ-lăs′tĭk mŏj′a-lus\: the stiffness or flexibility of a material within the elastic range. Within the elastic range, the material deforms in direct proportion to the stress applied as represented by Hooke's law

ex·po·sure \ĭk-spō′zher\ *n* (1606): **1:** the act of laying open, as a surgical or dental exposure **2:** in radiology, a measure of the roentgen rays or gamma radiation at a certain place based on its ability to cause ionization. The unit of exposure is the roentgen, called also exposure dose—see ROENTGEN RAY

fer·rule \fĕr′al\ *n* (15c): **1:** a metal band or ring used to fit the root or crown of a tooth **2:** any short tube or bushing for making a tight joint

mon·o·mer \mŏn′a-mar\ *n* (1914): a chemical compound that can undergo polymerization; any molecule that can be bound to a similar molecule to form a polymer

polymerization \pa-lĭ′ar-ī-zā′shun\ *n* (1872): the forming of a compound by the joining together of molecules of small molecular weights into a compound of large molecular weight

rad·ic·u·lar \ră-dĭ-kyōō′lar\ *adj* (1830): pertaining to the root of a tooth

res·in \rĕz′ĭn\ *n* (14c): **1:** any of various solid or semisolid amorphous natural organic substances that usually are transparent or translucent and brown to yellow; usually formed in plant secretions; are soluble in organic solvents but not water; are used chiefly in varnishes, inks, plastics, and medicine; and are found in many dental impression materials **2:** a broad term used to describe natural or synthetic substances that form plastic materials after polymerization. They are named according to their chemical composition, physical structure, and means for activation of polymerization—see AUTOPOLYMERIZING R., COPOLYMER R.

root \rōōt, rŏŏt\ *n* (bef. 12c): the portion of the tooth apical to the cementoenamel junction that is normally covered by cementum and is attached to the periodontal ligament and hence to the supporting bone

stress \strĕs\ *n* (14c): force per unit area; a force exerted on one body that presses on, pulls on, pushes against, or tends to invest or compress another body; the deformation caused in a body by such a force; an internal force that resists an externally applied load or force. It is normally defined in terms of mechanical stress, which is the force divided by the perpendicular cross sectional area over which the force is applied—see COMPRESSIVE S., SHEARING S., TENSILE S.

wax pattern \wăks păt′urn\: a wax form that is the positive likeness of an object to be fabricated

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REFERENCES

1. Johnson JK, et al: Evaluation and restoration of endodontically treated posterior teeth. J Am Dent Assoc 93:597, 1976.
2. Kakehashi Y, et al: A new all-ceramic post and core system: clinical, technical, and in vitro results. Int J Periodontics Restorative Dent 18:586, 1998.
3. Blitz N: Adaptation of a fiber-reinforced restorative system to the rehabilitation of endodontically treated teeth. Pract Periodont Aesthet Dent 10:191, 1998.
4. Torbjörner A, et al: Survival rate and failure characteristics for two post designs. J Prosthet Dent 73:439, 1995.
5. Sorensen JA, Martinoff JT: Clinically significant factors in dowel design. J Prosthet Dent 52:28, 1984.
6. Loney RW, et al: The effect of load angulation on fracture resistance of teeth restored with cast post and cores and crowns. Int J Prosthodont 8:247, 1995.

7. Helfer AR, et al: Determination of the moisture content of vital and pulpless teeth. Oral Surg Oral Med Oral Pathol 34:661, 1972.
8. Trabert KC, et al: Tooth fracture: a comparison of endodontic and restorative treatments. J Endodont 4:341, 1978.
9. Guzy GE, Nicholls JI: In vitro comparison of intact endodontically treated teeth with and without endo-post reinforcement. J Prosthet Dent 42:39, 1979.
10. Hunter AJ, et al: Effects of post placement on endodontically treated teeth. J Prosthet Dent 62:166, 1989.
11. Ko CC, et al: Effects of posts on dentin stress distribution in pulpless teeth. J Prosthet Dent 68:421, 1992.
12. Kantor ME, Pines MS: A comparative study of restorative techniques for pulpless teeth. J Prosthet Dent 38:405, 1977.
13. Sorensen JA, Martinoff JT: Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth. J Prosthet Dent 51:780, 1984.
14. Lu YC: A comparative study of fracture resistance of pulpless teeth. Chin Dent J 6:26, 1987.
15. Aquilino SA, Caplan DJ: Relationship between crown placement and the survival of endodontically treated teeth. J Prosthet Dent 87:256, 2002.
16. Warren MA, et al: In vitro comparison of bleaching agents on the crowns and roots of discolored teeth. J Endodont 16:463, 1990.
17. Madison S, Walton R: Cervical root resorption following bleaching of endodontically treated teeth. J Endodont 16:570, 1990.
18. Hansen EK, et al: In vivo fractures of endodontically treated posterior teeth restored with amalgam. Endod Dent Traumatol 6:49, 1990.
19. McKerracher PW: Rational restoration of endodontically treated teeth. I. Principles, techniques, and materials. Aust Dent J 26:205, 1981.
20. Felton DA, et al: Threaded endodontic dowels: effect of post design on incidence of root fracture. J Prosthet Dent 65:179, 1991.
21. Henry PJ: Photoelastic analysis of post core restorations. Aust Dent J 22:157, 1977.
22. Assif DF, et al: Photoelastic analysis of stress transfer by endodontically treated teeth to the supporting structure using different restorative techniques. J Prosthet Dent 61:535, 1989.
23. Milot P, Stein RS: Root fracture in endodontically treated teeth related to post selection and crown design. J Prosthet Dent 68:428, 1992.
24. Sorensen JA, Engelman MJ: Ferrule design and fracture resistance of endodontically treated teeth. J Prosthet Dent 63: 529, 1990.
25. Libman WJ, Nicholls JI: Load fatigue of teeth restored with cast posts and cores and complete crowns. Int J Prosthodont 8:155, 1995.
26. Isidor F, et al: The influence of post length and crown ferrule length on the resistance to cyclic loading of bovine teeth with prefabricated titanium posts. Int J Prosthodont 12:78, 1999.
27. Gegauff AG: Effect of crown lengthening and ferrule placement on static load failure of cemented cast post-cores and crowns. J Prosthet Dent 84:169, 2000.
28. Turner CH: Post-retained crown failure: a survey. Dent Update 9:221, 1982.
29. Standlee JP, et al: Retention of endodontic dowels: effects of cement, dowel length, diameter, and design. J Prosthet Dent 39:401, 1978.
30. Ruemping DR, et al: Retention of dowels subjected to tensile and torsional forces. J Prosthet Dent 41:159, 1979.
31. Kurer HG, et al: Factors influencing the retention of dowels. J Prosthet Dent 38:515, 1977.
32. Cooney JP, et al: Retention and stress distribution of tapered-end endodontic posts. J Prosthet Dent 55:540, 1986.
33. Krupp JD, et al: Dowel retention with glass-ionomer cement. J Prosthet Dent 41:163, 1979.
34. Wood WW: Retention of posts in teeth with nonvital pulps. J Prosthet Dent 49:504, 1983.
35. Hanson EC, Caputo AA: Cementing mediums and retentive characteristics of dowels. J Prosthet Dent 32:551, 1974.
36. Chapman KW, et al: Retention of prefabricated posts by cements and resins. J Prosthet Dent 54:649, 1985.
37. Driessen CH, et al: The effect of bonded and nonbonded posts on the fracture resistance of dentin. J Dent Assoc S Afr 52:393, 1997.
38. Mendoza DB, Eakle WS: Retention of posts cemented with various dentinal bonding cements. J Prosthet Dent 72:591, 1994.
39. O'Keefe KL, et al: In vitro bond strength of silica-coated metal posts in roots of teeth. Int J Prosthod 5:373, 1992.
40. Tjan AH, Nemetz H: Effect of eugenol-containing endodontic sealer on retention of prefabricated posts luted with adhesive composite resin cement. Quintessence Int 23:839, 1992.
41. Radke RA, et al: Retention of cast endodontic posts: comparison of cementing agents. J Prosthet Dent 59:318, 1988.
42. Love RM, Purton DG: Retention of posts with resin, glass ionomer and hybrid cements. J Dent 26:599, 1998.

43. Assif D, et al: Retention of endodontic posts with a composite resin luting agent: effect of cement thickness. Quintessence Int 19:643, 1988.
44. Kane JJ, et al: Fracture resistance of amalgam coronal-radicular restorations. J Prosthet Dent 63:607, 1990.
45. Nayyar A, et al: An amalgam coronal-radicular dowel and core technique for endodontically treated posterior teeth. J Prosthet Dent 43:511, 1980.
46. Mentink AG, et al: Qualitative assessment of stress distribution during insertion of endodontic posts in photoelastic material. J Dent 26:125, 1998.
47. Standlee JP, et al: The retentive and stress-distributing properties of a threaded endodontic dowel. J Prosthet Dent 44:398, 1980.
48. Thorsteinsson TS, et al: Stress analysis of four prefabricated posts. J Prosthet Dent 67:30, 1992.
49. Dérand T: The principal stress distribution in a root with a loaded post in model experiments. J Dent Res 56:1463, 1977.
50. Leary JM, et al: Load transfer of posts and cores to roots through cements. J Prosthet Dent 62:298, 1989.
51. Peters MCRB, et al: Stress analysis of a tooth restored with a post and core. J Dent Res 62:760, 1983.
52. Yaman SD, et al: Analysis of stress distribution in a maxillary central incisor subjected to various post and core applications. J Endodont 24:107, 1998.
53. Zmener O: Effect of dowel preparation on the apical seal of endodontically treated teeth. J Endodont 6:687; 1980.
54. Neagley RL: The effect of dowel preparation on the apical seal of endodontically treated teeth. Oral Surg Oral Med Oral Pathol 28:739, 1969.
55. Schnell FJ: Effect of immediate dowel space preparation on the apical seal of endodontically filled teeth. Oral Surg Oral Med Oral Pathol 45:470, 1978.
56. Bourgeois RS, Lemon RR: Dowel space preparation and apical leakage. J Endodont 7:66, 1981.
57. Gegauff AG, et al: A comparative study of post preparation diameters and deviations using Para-Post and Gates-Glidden drills. J Endodont 14:377, 1988.
58. Hussey DL, et al: Thermographic assessment of heat generated on the root surface during post space preparation. Int Endodont J 30:187, 1997.
59. Caputo AA, Standlee JP: Pins and posts: why, when, and how. Dent Clin North Am 20:299, 1976.
60. Shillingburg HT, et al: Root dimensions and dowel size. Calif Dent Assoc J 10(10):43, 1982.
61. Abou-Rass M, et al: Preparation of space for posting: effect on thickness of canal walls and incidence of perforation in molars. J Am Dent Assoc 104:834, 1982.
62. Perez Moll JF, et al: Cast gold post and core and pin-retained composite resin bases: a comparative study in strength. J Prosthet Dent 40:642, 1978.
63. Phillips RW: Skinner's Science of Dental Materials, 9th ed, p 550. Philadelphia, WB Saunders, 1991.
64. Asmussen E, et al: Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent 27:275, 1999.
65. Frederiksson M, et al: A retrospective study of 236 patients with teeth restored by carbon fiber epoxy resin posts. J Prosthet Dent 80:151, 1998.
66. Martinez-Insua A, et al: Comparison of the fracture resistances of pulpless teeth restored with a cast post and core or carbon-fiber post with a composite core. J Prosthet Dent 80:527, 1998.
67. Kakehashi Y, et al: A new all-ceramic post and core system: clinical, technical, and in vitro results. Int J Periodontics Restorative Dent 18:586, 1998.
68. Ahmad I: Zirconium oxide post and core system for the restoration of an endodontically treated incisor. Pract Periodont Aesthet Dent 11:197, 1999.
69. Sirimai S, et al: An in vitro study of the fracture resistance and the incidence of vertical root fracture of pulpless teeth restored with six post-and-core systems. J Prosthet Dent 81:262, 1999.
70. Rud J, Omnell KA: Root fractures due to corrosion: diagnostic aspects. Scand J Dent Res 78:397, 1970.
71. Angmar-Manansson B, et al: Root fracture due to corrosion. I. Metallurgical aspects. Odontol Rev 20:245, 1969.
72. Silness J, et al: Distribution of corrosion products in teeth restored with metal crowns retained by stainless steel posts. Acta Odontol Scand 37:317, 1979.
73. Chan RW, Bryant RW: Post-core foundations for endodontically treated posterior teeth. J Prosthet Dent 48:401, 1982.
74. Lovdahl PE, Nicholls JI: Pin-retained amalgam cores vs. cast-gold dowel-cores. J Prosthet Dent 38:507, 1977.
75. Reagan SE, et al: Effects of cyclic loading on selected post-and-core systems. Quintessence Int 30: 61, 1999.
76. Foley J, et al: Strength of core build-up materials in endodontically treated teeth. Am J Dent 10:166, 1997.
77. Kovarik RE, et al: Fatigue life of three core materials under simulated chewing conditions. J Prosthet Dent 68:584, 1992.

78. Oliva RA, Lowe JA: Dimensional stability of composite used as a core material. J Prosthet Dent 56:554, 1986.
79. Larson TD, Jensen JR: Microleakage of composite resin and amalgam core material under complete cast crowns. J Prosthet Dent 44:40, 1980.
80. Rosenstiel SF, et al: Custom-cast post fabrication with a thermoplastic material. J Prosthet Dent 77: 209, 1997.
81. Waldmeier MD, Grasso JE: Light-cured resin for post patterns. J Prosthet Dent 68:412, 1992.
82. Zmener O, et al: Coronal microleakage of three temporary restorative materials: an in vitro study. J Endodont 30:582, 2004.
83. Campagni WV, Majchrowicz M: An accelerated technique for the casting of post and core restorations. J Prosthet Dent 66:155, 1991.
84. Brunell G: Casting and microstructure of post and core at different mold temperatures. Acta Odontol Scand 40:241, 1982.
85. Wilson PR: Low force cementation. J Dent 24:269, 1996.
86. Yoshida T, et al: An experimental study of the removal of cemented dowel-retained cast cores by ultrasonic vibration. J Endodont 23:239, 1997.
87. Altshul JH, et al: Comparison of dentinal crack incidence and of post removal time resulting from post removal by ultrasonic or mechanical force. J Endodont 23:683, 1997.
88. Warren SR, Gutmann JL: Simplified method for removing intraradicular posts. J Prosthet Dent 42:353, 1979.
89. Masserann J: The extraction of posts broken deeply in the roots. Actual Odontostomatol 75:329, 1966.
90. Williams VD, Bjorndal AM: The Masserann technique for the removal of fractured posts in endodontically treated teeth. J Prosthet Dent 49:46, 1983.
91. Gettleman BH, et al: Removal of canal obstructions with the Endo Extractor. J Endodont 17:608, 1991.
92. Machtou P, et al: Post removal prior to retreatment. J Endodont 15:552, 1989.

13



IMPLANT-SUPPORTED FIXED PROSTHESES

Edwin A. McGlumphy

KEY TERMS

complete metal-resin fixed dental prosthesis
dental implant
healing cap
healing screw
implant abutment
implant analog
implant angulation
implant body
implant placement
implant prosthodontics
implant surgery
interim abutment
osseous integration
transosteal implant

Today the continued high rate of success achieved with osseous integrated **dental implants** allows a greater number of patients to enjoy the benefits of fixed rather than removable dental prostheses.[1-3] The main indications for implant-supported restorations in the partially edentulous patient are the free-end distal extension, in which no posterior abutment is available (Fig. 13-1), and the long edentulous span. In both these situations, the conventional dental treatment plan would include a partial removable dental prosthesis. However, with the advent of dental implants, the patient can benefit from fixed restorations. In addition, in the short edentulous span, the single dental implant is a popular option (Fig. 13-2).

IMPLANT TYPES

There are three major subgroups of dental implants: subperiosteal, transosteal, and endosteal (Fig. 13-3). The first two, subperiosteal and transosteal, are designed primarily to anchor dentures in the completely edentulous patient, and thus they are outside the scope of this chapter. The third, endosteal dental implants, are surgically placed within alveolar or basal bone and are most commonly used for the treatment of partially edentulous patients, either singly or in multiples. They can be further subdivided by shape into blade form (plate form) and root form. Blades are wedge-shaped or rectangular in cross-section and are generally 2.5 mm wide, 8 to 15 mm deep, and 15 to 30 mm long. Root forms are 3 to 6 mm in diameter and 8 to 20 mm long, often with external threads (Fig. 13-4). Endosteal dental implants are also categorized as one-stage or two-stage. The one-stage dental implant is designed to be placed in the bone and to immediately project

through mucosa into the oral cavity. The two-stage dental implant requires two surgical procedures. First, the implant is placed in bone to the level of the cortical plate and the oral mucosa is sutured over it; this is left for a prescribed healing period (usually 3 months in the mandible and 6 months in the maxilla), depending on the quality of bone. Then, in a second surgery, the mucosa is reflected from the superior surface of the implant, and an extension collar or abutment that projects into the oral cavity is fastened to the implant. Some authors have suggested shortening the time before implant loading, but the long-term consequences of this are still being investigated.[4,5]



Fig. 13-1
Implant-supported fixed prosthesis. Four dental implants (**A**) supporting a fixed dental prosthesis (**B**).

Plate Implants (Blades)

Blades were the first endosteal dental implant to be used with reasonable success in a large number of patients. In all the original studies on blades, the researchers used one-stage systems, but the success rates were considerably lower than those of current root-form implants. It has been suggested[6] that many of the problems of blade implants can be traced to the high temperature at which the bone sites were prepared and the routine immediate loading of this type of implant. Both these practices have been linked to the fibrous encapsulation that occurred with many of the original blade implants. Consequently, submersible titanium blades are now available, and in more recent blade studies,[7] investigators have reported success rates above 80% for 5 years. However, the drawbacks to blade implants remain: difficulty of preparing precision slots for blade placement in comparison with placing holes accurately for root-form implants and the disastrously large circumferential area of the jaw that can be affected when a blade fails.

Root-Form Implants

Root-form endosteal dental implants are considered to be state-of-the-art implant dentistry. Advantages include adaptability to multiple intraoral locations, uniformly precise implant site preparation, and comparatively low adverse consequences similar to those experienced when a tooth is lost. Most root forms are made of titanium or titanium alloy with or



Fig. 13-2
A, Single-tooth implant with an internal anti-rotational feature. **B,** Implant crown replacing a single missing tooth (cement retained).

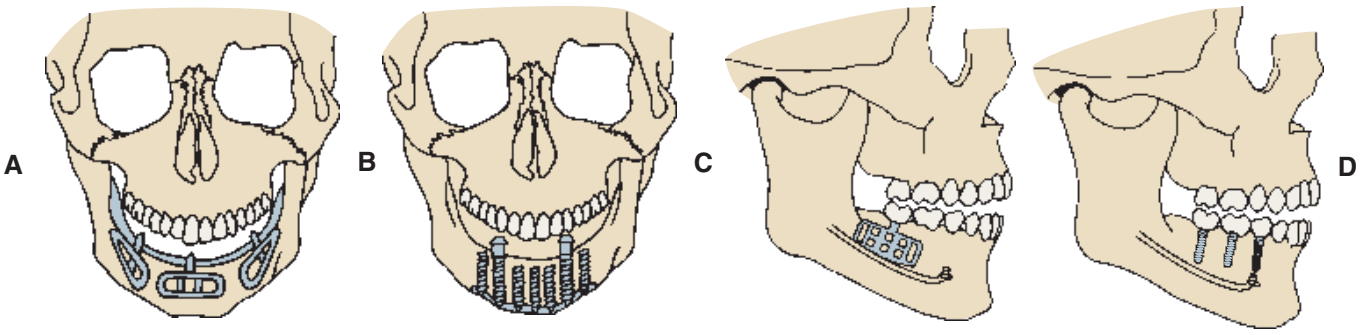


Fig. 13-3
The three major subgroups of dental implants. **A,** Subperiosteal. **B,** Transosteal. **C** and **D,** Endosteal. Endosteal implants can be further subdivided into plate form (**C**) and root form (**D**).

without hydroxyapatite coating; these materials are perceived to have the highest biofunctionality. Both threaded and nonthreaded designs are available and are quite popular. Today many of the titanium implants are grit blasted or acid etched to roughen the surface and increase the area for bone contact. Even the theaded dental implants can be further subdivided into "straight" and "tapered" (see Fig. 13-4).

In the National Institutes of Health (NIH) Consensus Conference[1] in 1988, root-form implants were reported to have already constituted 78% of the dental implant market. This trend is credited to the Brånemark system, which set the precedent for surgical techniques and restorative procedures that result in predictably successful implants. Two of the most important additions from the Swedish research team, led by P. I. Brånemark, were atraumatic **implant placement** and delayed implant loading. These factors contributed to a remarkably increased degree of implant predictability. The original Brånemark success rate of 91% in the mandible over 15 years[2] has become the standard against which other implant systems are judged.[8] Many of the other root-form implant systems are also believed to have reached or exceeded this high level of long-term success.

TREATMENT PLANNING FOR THE IMPLANT PATIENT

Implant success reported from major research institutions is quite high. However, meticulous attention to the procedures of patient selection, diagnosis, and treatment planning is necessary to duplicate this success. Indications for dental implant treatment in the partially edentulous patient are provided in BOX 13-1.

Box 13-1 Indications for Implant Placement in the Partially Edentulous Patient

1. Inability to wear a removable partial dental prosthesis or complete denture
2. Need for long-span fixed dental prosthesis with questionable prognosis
3. Unfavorable number and location of potential natural tooth abutments
4. Single tooth loss that would necessitate preparation of minimally restored teeth for fixed prosthesis

A combined surgical and restorative treatment plan must be devised for prospective implant recipients. Feasible nonimplant alternatives should be included in the overall treatment discussions. Patients need to be evaluated preoperatively and assessed if they will be able to tolerate the procedure. The predictable risks and expected benefits should be weighed for each person. Although the placement of dental implants does entail some risks, they are relatively minor. Absolute contraindications, based on immediate surgical and anesthetic risks, are limited to individuals who are acutely ill, individuals with uncontrolled metabolic disease, and pregnant women (these contraindications apply to virtually all elective surgical procedures).

Local and systemic contraindications that threaten long-term implant retention must also be evaluated. Implants may be contraindicated in patients with abnormal bone metabolism, poor oral hygiene, and previous irradiation of the implant site. Most potential implant placement patients became edentulous or partially edentulous from caries or periodontal disease resulting from poor oral hygiene. Suspicion that inadequate hygiene will continue is a relative contraindication to implant placement.

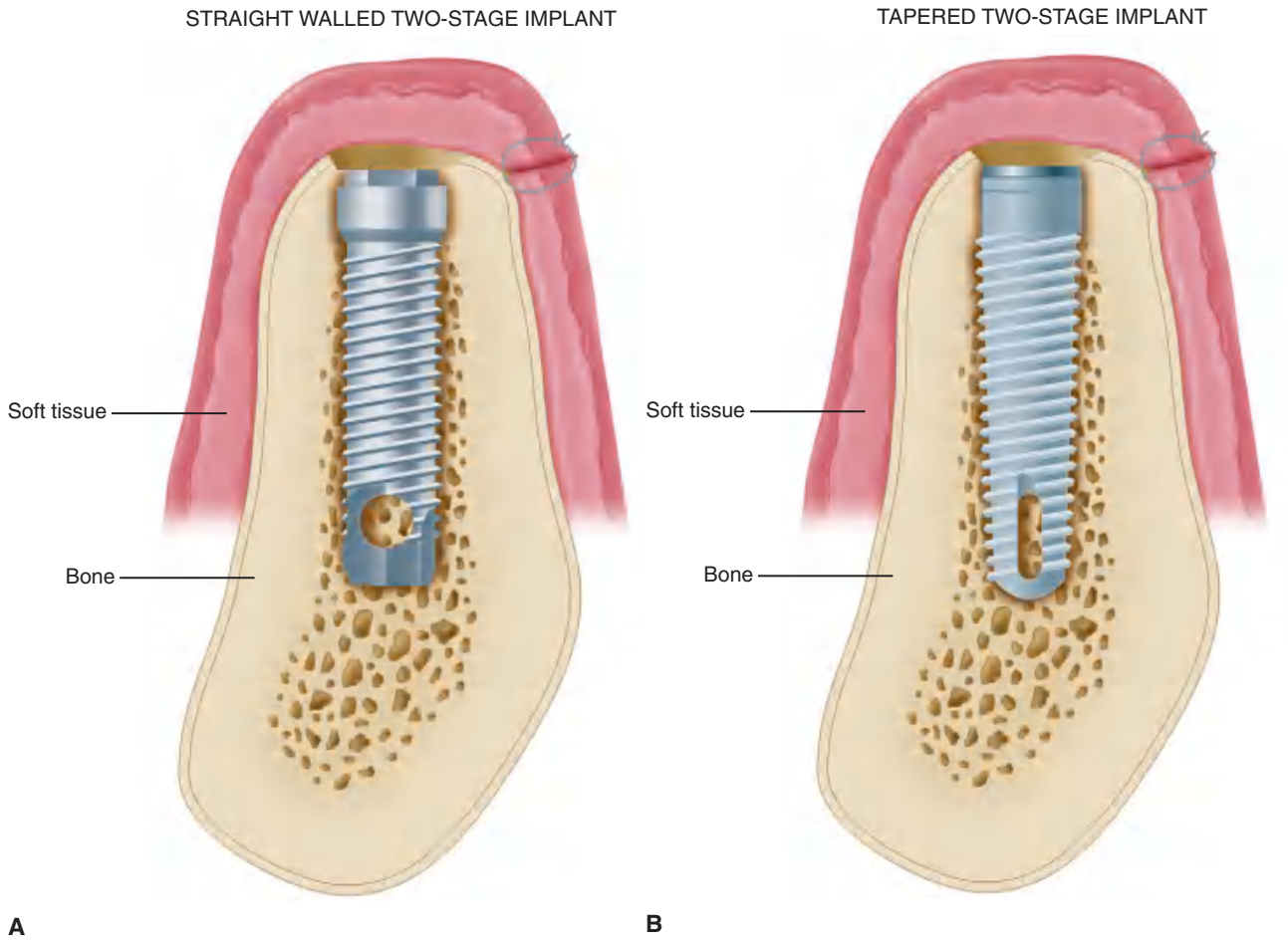


Fig. 13-4

A, Straight walled two-stage implant. **B**, Tapered two-stage implant. **C**, One-stage implant.

Patients must be motivated and educated in oral hygiene techniques as part of their preparation for implants. Some individuals, such as those suffering from paralysis of the arms, debilitating arthritis, cerebral palsy, and severe mental retardation, may not be able to improve their hygiene. Implants are contraindicated in these patients unless adequate oral hygiene will be provided by caregivers. A summary of contraindications to implant placement is presented in BOX 13-2.

Clinical Evaluation

Evaluation of the planned implant site begins with a thorough clinical examination. This examination determines whether there is adequate bone and identifies anatomic structures that could interfere with ideal implant placement. Visual inspection and palpation allow the detection of flabby excess tissue, bony ridges, and sharp underlying osseous formations and undercuts that would limit implant insertion. However, clinical inspection alone may not be adequate if there is thick overlying soft tissue that is dense, immobile, and fibrous.

Box 13-2 Contraindications to Implant Placement (National Institutes of Health Consensus Conference)

1. Acute illness
2. Terminal illness
3. Pregnancy
4. Uncontrolled metabolic disease
5. Tumoricidal irradiation of the implant site
6. Unrealistic patient expectation
7. Improper patient motivation
8. Lack of operator experience
9. Inability to restore with a prosthesis

Radiographic Evaluation

Radiographic evaluation is also necessary. The best initial film is the panoramic view. However, there can be variations in magnification (5% to 35%); a small radiopaque reference object should therefore be placed near the proposed implant placement site during the exposure (Fig. 13-5). Measurement of this image on the actual radiograph enables the practitioner to correct for any magnification error (Fig. 13-6). A ball bearing placed in wax on a denture baseplate or in polyvinyl siloxane impression putty works well. Some new panoramic radiography machines have standardized enlargement ratios, which makes correction markers less necessary.



Fig. 13-5
Ball bearings (5-mm diameter) placed on the diagnostic cast at the proposed implant site.

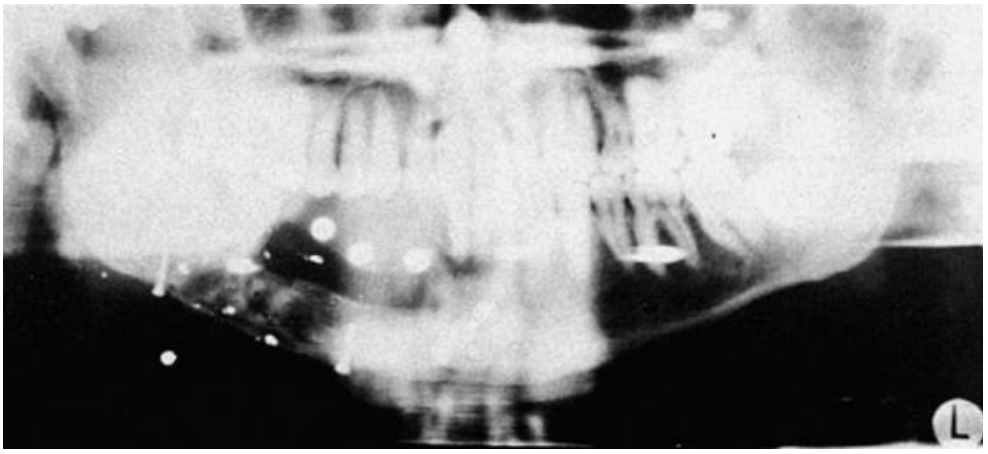


Fig. 13-6
A panoramic radiograph exposed with the ball bearings positioned intraorally with a wax or resin baseplate.

The widths of the posterior mandible and maxilla are determined primarily by clinical examination. Bone width not revealed on a panoramic film can be evaluated in the anterior maxilla and mandible with a cephalometric film (Fig. 13-7). The location of the inferior alveolar canal and maxillary sinus can be determined by specialized computed tomography (CT) scans (Fig. 13-8), although high radiation exposure and considerable expense may limit their routine use. However, significant advances being made in this technology may change this trend.

Diagnostic Casts

Accurately mounted diagnostic casts (see Chapter 2) are essential for treatment planning. They are used to study the remaining dentition, evaluate the residual bone, and analyze maxillomandibular relationships. They can be helpful to the surgeon for fixture placement. A diagnostic waxing is performed on the cast or on a duplicate. Proposed fixture installation sites are checked for proper alignment, direction, location, and relation to the remaining dentition. The waxing helps determine the most esthetic placement of the teeth to be restored and the potential for functional speech disturbances. After adjustments and the diagnostic waxing are completed, a resin template can be made from the cast to guide the surgeon during implant placement (Fig. 13-9). Diagnostic waxings and surgical templates are essential when implants are planned as part of a full-mouth reconstruction or when the anterior esthetic zone is restored (Fig. 13-10).

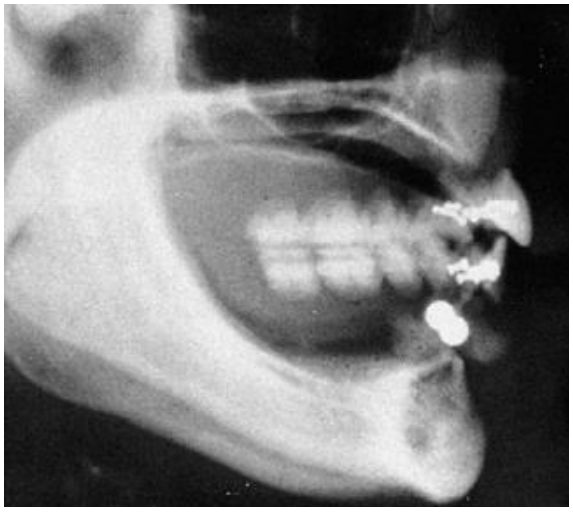


Fig. 13-7
The lateral cephalometric radiograph can indicate bone width in the anterior midline.

Bone Sounding

When the results of clinical and radiographic examinations are equivocal and additional information is needed, sounding of the bone with a probe may be attempted. Under local anesthesia, a needle or sharp caliper is pushed through the tissue until it contacts bone. This can help the examiner judge soft tissue thickness at the planned implant sites.

PRINCIPLES OF IMPLANT LOCATION

Anatomic Limitations

To maximize the chance of success, the implant should be placed entirely within bone and away from

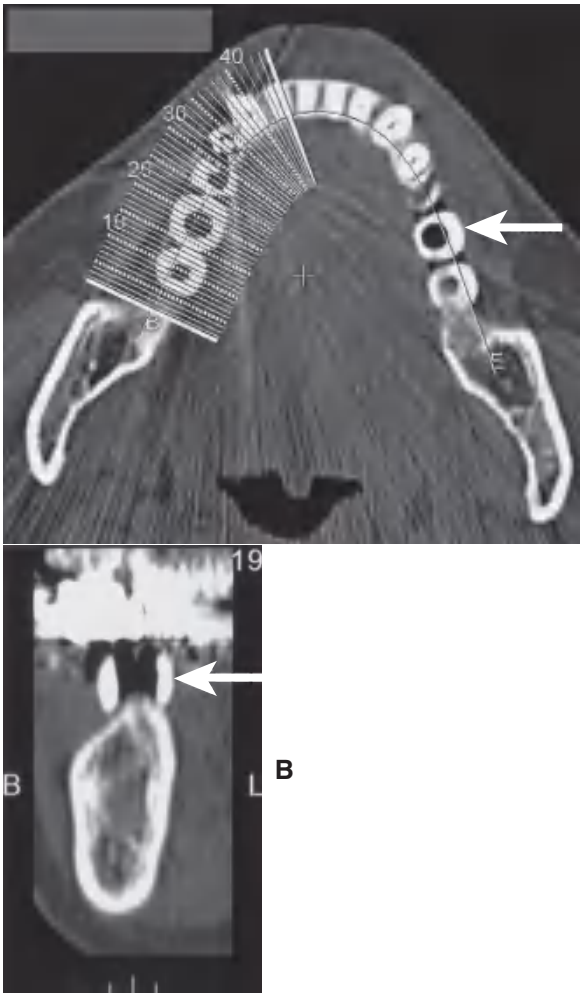


Fig. 13-8
The computed tomography (CT) scan. **A,** CT scan with lines orienting the position of transverse mandibular cross-sections. **B,** reformatted CT cross-section of the posterior mandible. *Arrows* in **A** and **B** denote position of barium-impregnated resin in the surgical guide.



Fig. 13-9

A, Patient with bilateral missing posterior teeth planned for posterior implant-supported restorations. **B,** Diagnostic cast. **C,** Diagnostic denture tooth arrangement to simulate three-unit fixed prostheses on each side of the mandible. **D,** Vacuumed matrix formed over the cast with 1.5-mm (0.060-inch) thermoplastic sheet. **E,** The matrix is marked with the most appropriate implant locations and alignments and then removed from the cast. **F,** The completed surgical guide with holes drilled to guide the surgeon during implant site preparation.

significant anatomic structures (e.g., the inferior alveolar canal). Ideally, 10 mm of vertical bone dimension and 6 mm of horizontal should be available for implant placement. Placement at these dimensions prevents encroachment on anatomic structures and allows 1.0 mm of bone on both the lingual and the facial aspects of the implant. There should also be adequate space between adjacent implants. The minimum recommended distance varies slightly among implant systems but is generally accepted as 3.0 mm (Fig. 13-11). This space is needed to ensure bone viability between the implants and to allow adequate oral hygiene once the restorative dentistry is complete. Specific limitations resulting from anatomic variations among different areas of the jaws also must be considered. These include implant length, diameter, proximity to adjacent structures, and time required for integration.

The anterior maxilla, posterior maxilla, anterior mandible, and posterior mandible each require special considerations in placing implants. Some common guidelines include staying 2.0 mm above the superior aspect of the inferior alveolar canal, 5.0 mm anterior to the mental foramen, and 1.0 mm from the periodontal ligament of adjacent natural teeth.

After tooth loss, resorption of the ridge follows a pattern that results in crestal bone thinning and a change in angulation of the residual ridge. These sequelae most often cause problems in the anterior

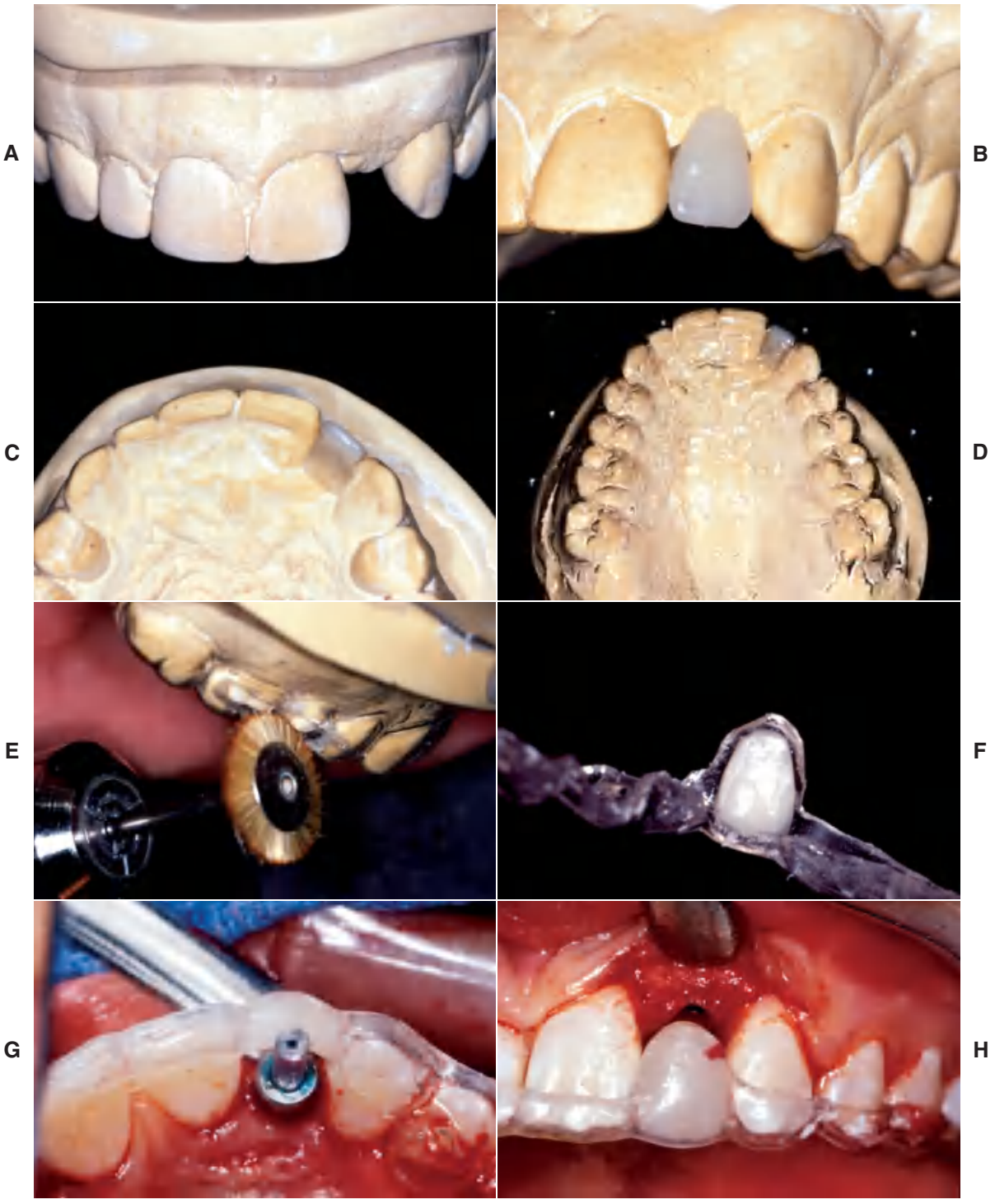


Fig. 13-10

A, Diagnostic cast with missing maxillary left lateral incisor. **B,** The denture tooth is positioned for optimum esthetics. **C,** The denture tooth is trimmed from the lingual side until it is 2 mm thick. **D,** If the tooth is held in position with light-cured composite, a vacuum matrix can be performed directly without duplicating the cast. **E,** The matrix can be trimmed to the height of contour with a stiff bristle brush. **F,** The denture tooth can be glued back into the matrix. **G** and **H,** The surgeon can use this template to guide both horizontal and vertical positioning.

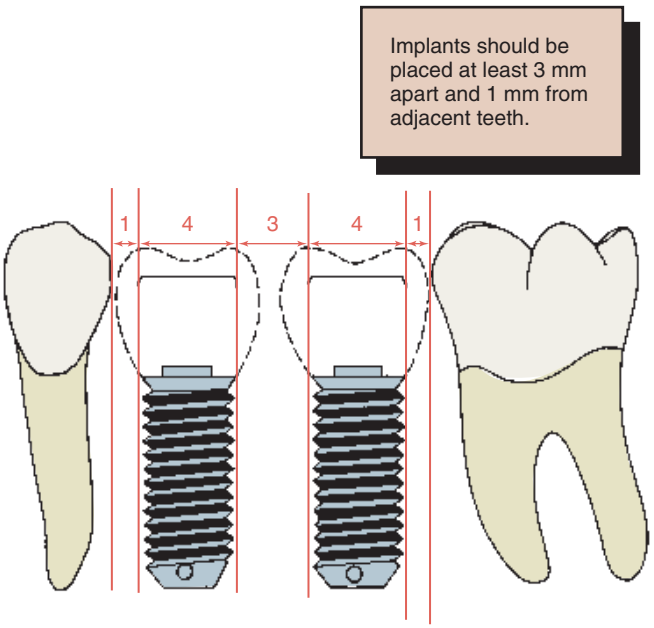


Fig. 13-11
Recommended minimum distances (in millimeters) between implants and between implants and natural teeth.

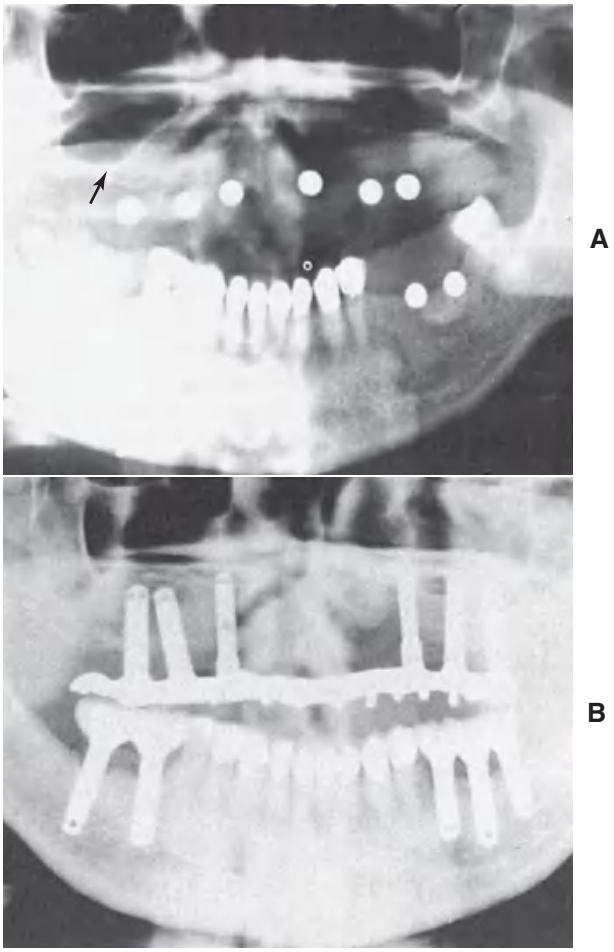


Fig. 13-12
A, The *arrow* denotes thin maxillary bone inferior to the sinus, which would be inadequate for implant placement without additional grafting procedures. **B,** Radiograph showing successful treatment with dental implants after graft placement.

mandible and maxilla. The irregular anatomy of the residual ridge may lead to problems with achieving ideal **implant angulation** or adequate bone thickness along the labial aspect of the implant. Techniques for the management of these problems during surgery are discussed in this chapter, but they must be anticipated in the preoperative phase.

Anterior maxilla

The anterior maxilla must be evaluated for proximity to the nasal cavity. A minimum of 1.0 mm of bone should remain between the apex of the implant and the nasal vestibule. Because of resorption of the anterior maxilla, the incisive foramen may be located near the residual ridge, especially in patients whose edentulous maxilla has been allowed to function against a natural mandibular anterior dentition. Anterior maxillary implants should be located slightly off midline, on either side of the incisive foramen.

Posterior maxilla

Implant placement in the posterior maxilla poses two specific concerns. First, the bone of the posterior maxilla is less dense than that of the posterior mandible. It has larger marrow spaces and a thinner cortex, which can affect treatment planning, inasmuch as increased time must be allowed for integration of the implants and additional implants may be needed. A minimum of 6 months is usually needed for adequate integration of implants placed in the maxilla. In addition, one implant for every tooth that is being replaced is normally recommended, especially in the posterior maxilla.

The second concern is that the maxillary sinus is close to the edentulous ridge in the posterior maxilla. Frequently, because of the resorption of bone and increased pneumatization of the sinus, only a few millimeters of bone remain between the ridge and the sinus (Fig. 13-12*A*). In treatment planning for implants in the posterior maxilla, the surgeon should leave 1.0 mm of bone between the floor of the sinus and the implant so the implant can be anchored apically into cortical bone of the sinus floor. Adequate bone height for implant stability can usually be found between the nasal cavity and the maxillary sinus. If there is not adequate bone for implant placement and support, bony augmentation through the sinus should be considered (see Fig. 13-12).

Anterior mandible

With regard to anatomic limitations, the anterior mandible is usually the most straightforward area for treatment planning. It usually has adequate height and width for implant placement, and the bone quality is normally excellent; therefore, it requires the least amount of time for integration. Success with immediate loading of implants in the anterior mandible has been reported. This seems to be possible because the implants can have good initial stability.

When possible, an implant in the anterior mandible should be placed through the entire cancellous bone so that the apex of the implant engages the cortex of the inferior mandibular border (Fig. 13-13). In the premolar area, care must be taken that the implant does not impinge on the inferior dental nerve. Because this nerve courses as much as 3.0 mm anterior to the mental foramen before turning posteriorly and superiorly to exit at the foramen, an implant should be at least 5.0 mm anterior to the foramen.

Posterior mandible

The posterior mandible poses some limitations on implant placement. The inferior alveolar nerve traverses the mandibular body in this region, and treatment planning must allow for a 2.0-mm margin from the apex of the implant to the superior aspect of the inferior alveolar canal. This is an important guideline: Disregarding it can cause damage to the nerve and numbness of the lower lip. If adequate length is not present for even the shortest implant, nerve repositioning, onlay grafting, or a conventional nonimplant-supported prosthesis must be considered.

Implants placed in the posterior mandible are usually shorter, do not engage cortical bone inferiorly, and must support increased biomechanical occlusal forces once they are loaded, because of their location in the posterior area. Consequently, allowing slightly more time for integration may be beneficial. In addition, if short implants (8 to 10 mm) are used, "overengineering" and placing more implants than usual to withstand the occlusal load is recommended. Short implants are often necessary because of bone resorption, which thus increase the crown/implant ratio when the normal plane of occlusion is reestablished (Fig. 13-14).

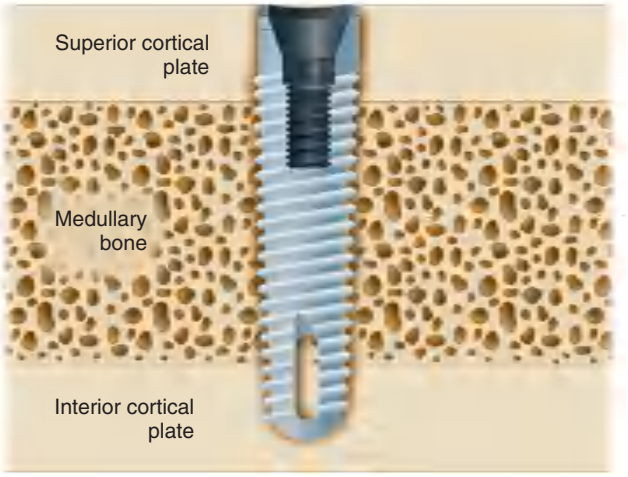


Fig. 13-13
Whenever possible, implants should engage two cortical plates of bone.

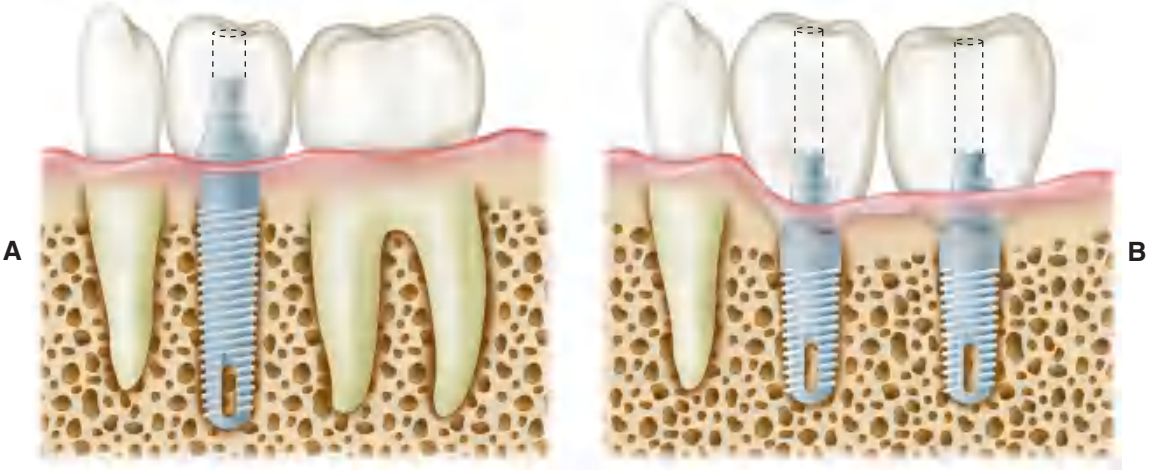


Fig. 13-14
Shorter implants usually have two problems: (1) less bone contact and (2) longer crowns, which increase the forces acting on the implant. More favorable crown-to-implant ratios (**A**) have a better prognosis than less favorable ratios (**B**).

The width of the residual ridge must be carefully evaluated in the posterior mandible. Attachments of the mylohyoid muscle maintain it along the superior aspect of the ridge, and a deep (lingual) depression exists immediately below it. This area should be palpated at the time of evaluation and examined at the time of surgery.

Restorative Considerations

Implant placement

Implant placement is crucial in the design of the restoration. Thus, the treatment-planning aspects of implant placement must begin with a restorative dentistry consultation. Implant placement dictates the appearance, contour, and long-term function of the prosthesis. To prevent damage, staying at least 1.0 mm away from the adjacent natural tooth is essential, but staying as close to the natural tooth as possible is also important; therefore, acceptable contours can be created by the restorative dentist. For proper access during oral hygiene procedures, a minimum of 3.0 mm should be left between implants. In addition, implants must not encroach on the embrasure spaces or be angled so that screw access is necessary through the facial surfaces of the completed restoration (Fig. 13-15).

To minimize harmful lateral forces, the long axis of the implant should be positioned in the central fossa of the restoration. This dictates placing the implant accurately in all three planes of space. Superoinferior placement is important to ensure the optimal emergence profile of the restoration. Ideally, the superior surface of the implant should be 2.5 to 3.0 mm directly inferior to the emergence position of the planned restoration, particularly when the restoration is to be located in the anterior esthetic zone (Fig. 13-16).

Implant and restoration size

The choice of implant and its superoinferior placement location are modified by the diameter of the intended restoration and can be adjusted for different sizes of teeth. For example, the typical root diameter of a maxillary central incisor is 8.0 mm; the average implant diameter is 4.0 mm. Therefore, a distance of 2.5 to 3.0 mm is needed to make the transition gradually from 4.0 to 8.0 mm. If this is done over too short a distance, the restoration will be overcontoured or look unnatural. In contrast, many mandibular central and lateral incisors are smaller than 4.0 mm at the cementoenamel junction. Therefore, an esthetic restoration on a 4.0-mm implant is impossible. Smaller-diameter implants (about

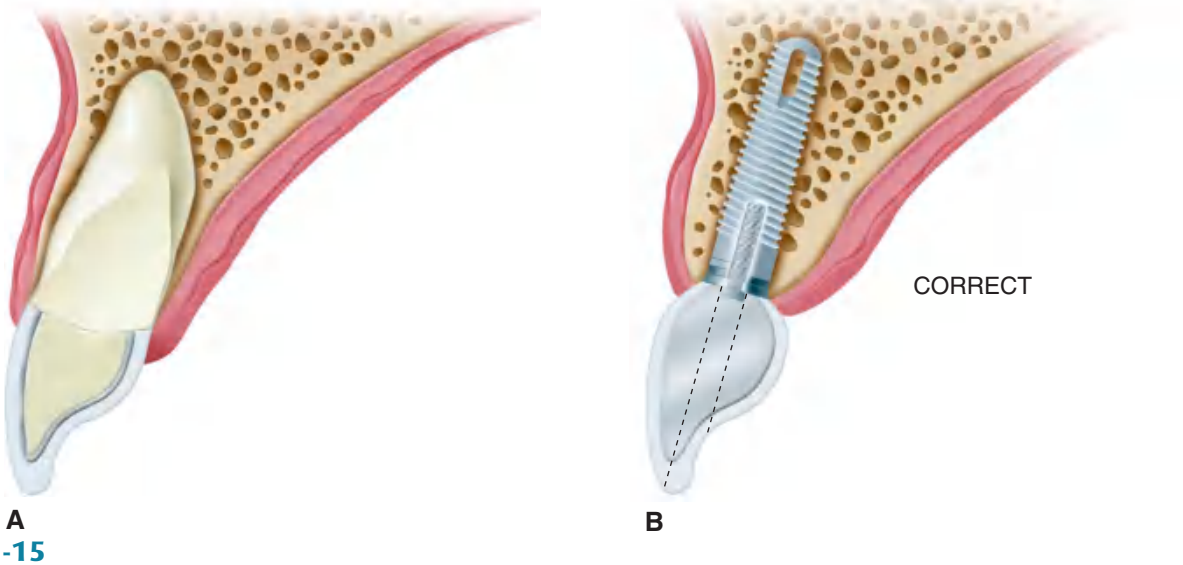


Fig. 13-15

Implant placement and angulation dictate the screw emergence position and crown contours. Esthetics and access for hygiene can be greatly affected. **A,** A restored tooth. **B,** Ideal implant location with acceptable crown contours and lingual screw emergence.

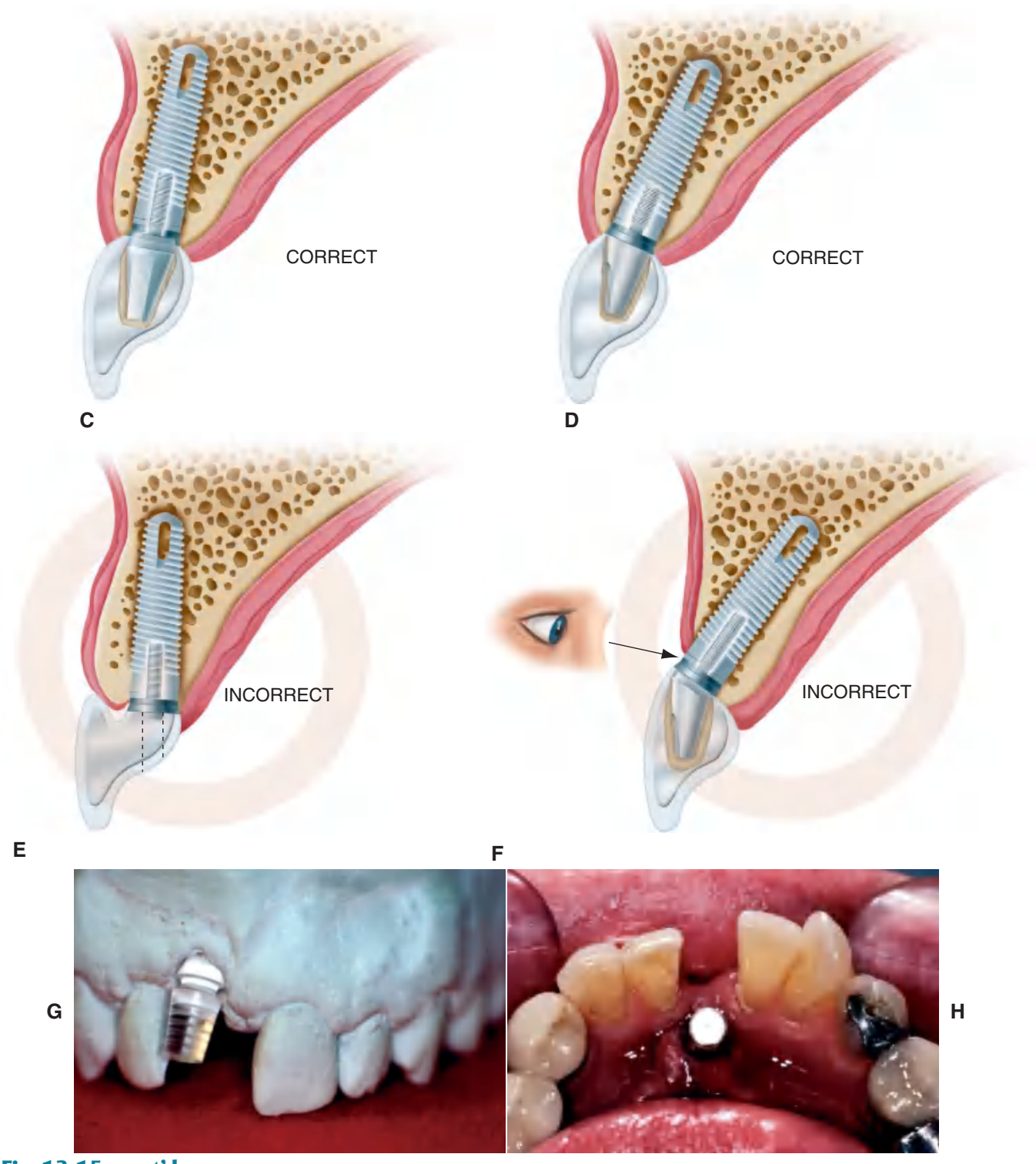
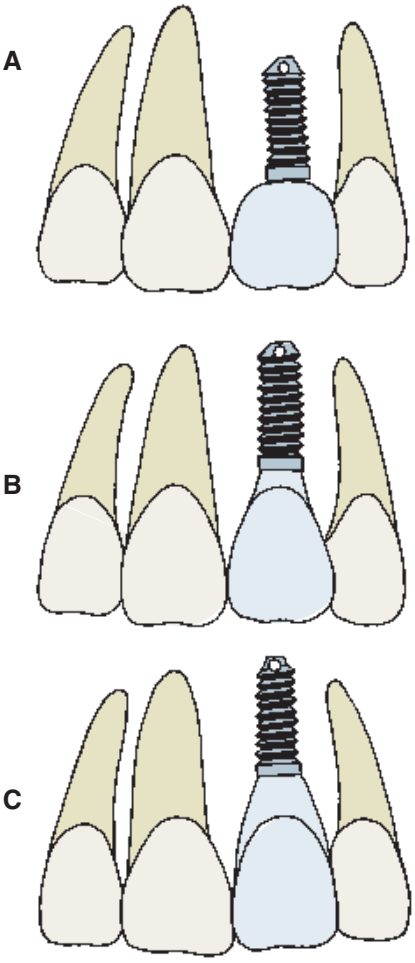


Fig. 13-15, cont'd

C, Acceptable implant location for a cement retained crown. **D,** If the implant is more facially inclined, an angled abutment for a cement retained crown may be necessary. **E,** If the implant is too lingual and too shallow, inadequate crown contours for hygiene will result. **F,** If the implant is angled too far facially and too shallow, the implant and/or abutment may become an esthetic failure.

Accurate implant depth is critical to a successful result.



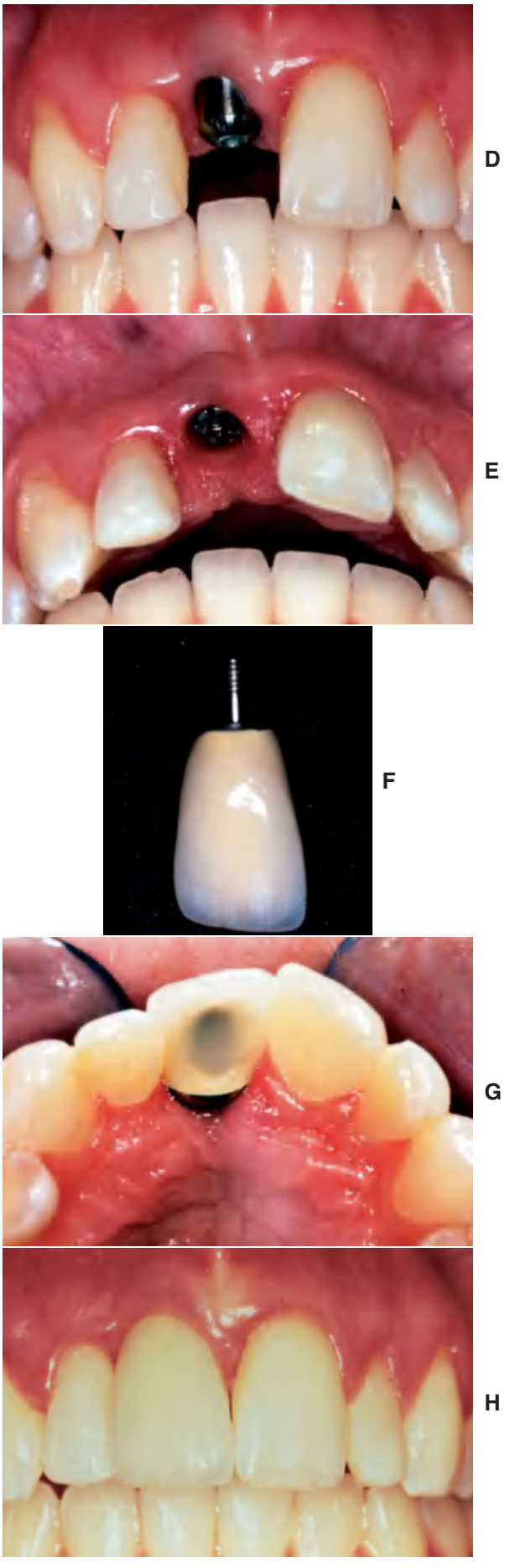


Fig. 13-16

Superior or inferior positioning may affect crown contours and pocket depth. **A,** The implant is not placed deep enough. This creates a short, overcontoured crown. **B,** Placement 2 to 3 mm apical to the tooth emergence position is ideal. **C,** Placing the implant 4 mm apical to the crown contours may create an excessively deep gingival sulcus. **D** to **H,** Clinical example of a properly positioned implant, both facially and apically, which results in good esthetics.

3.0 mm) are available to allow esthetic restoration in these areas. It is also possible to use a larger implant (5.0 to 6.0 mm) for molar restorations in patients with adequate bone (Fig. 13-17).

Restoration size must always be considered during the treatment planning stage so that a properly sized implant is placed in the ideal location.

Single tooth implant

Treatment planning for the single tooth restoration, particularly in the anterior esthetic zone, is one of the most challenging problems faced by the implant restorative dentist. Placement of the implant for both esthetics and biomechanical loading (to minimize screw loosening) is especially crucial. In addition, at the treatment planning stage, the decision to place an implant with an antirotational feature built into the system (e.g., a spline or a hexagon) is essential (Fig. 13-18).

Soft tissue contours

For implant treatment planning in the anterior esthetic zone, it is important to look closely at the soft tissues that will frame the restoration. It can be

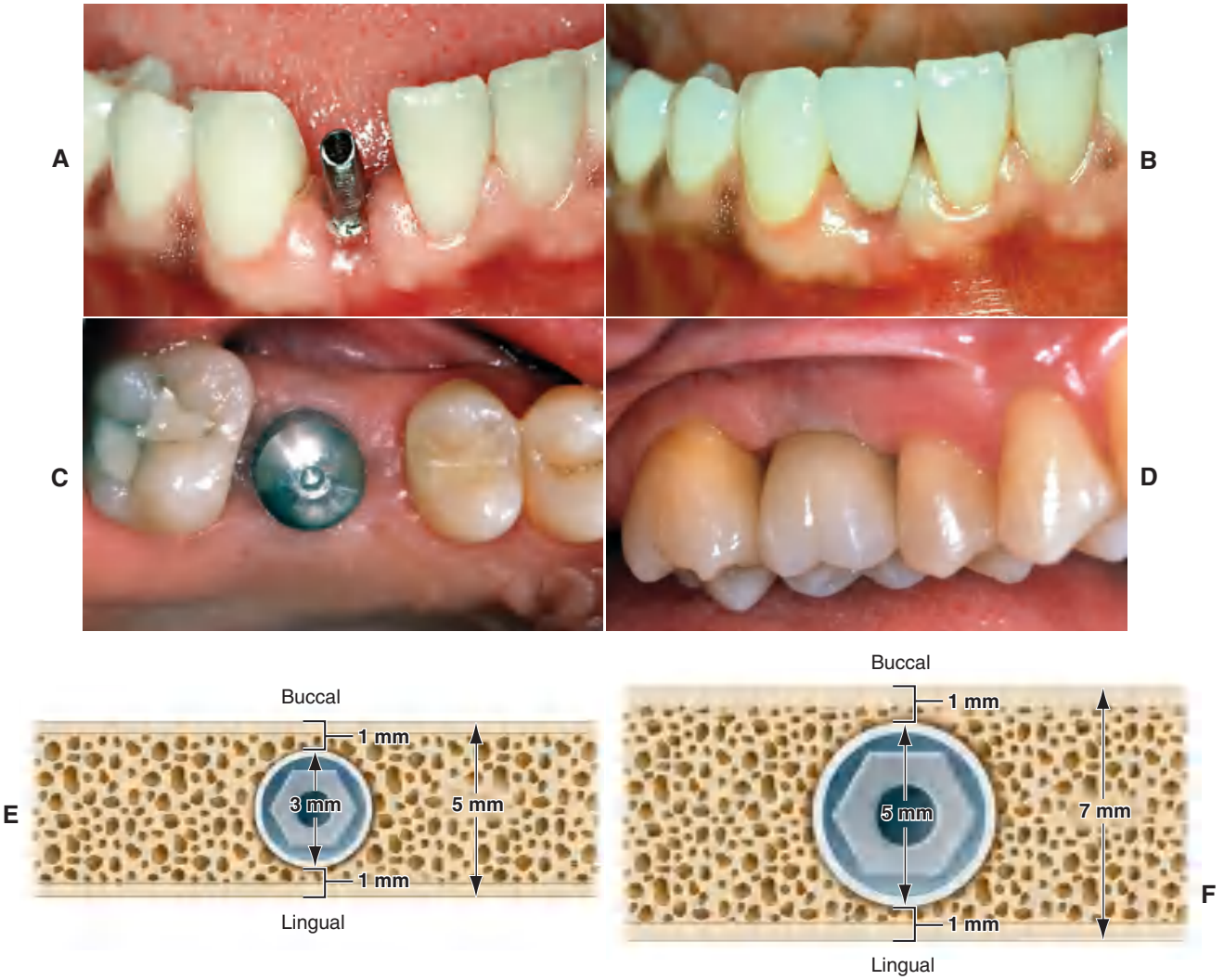


Fig. 13-17

A, Small-diameter implant and abutment positioned to restore a mandibular lateral incisor. The fixed abutment can be custom prepared and narrowed to allow restoration of a small-diameter tooth. **B,** Completed implant restoration of the mandibular lateral incisor. **C,** Wide-diameter (5.0 mm) implant in position to replace maxillary first molar. **D,** Completed implant restoration of the maxillary first molar. **E,** The minimum bone dimension for a small diameter implant is 5 mm. Ideally, at least 1 mm of bone is still left on either side of the implant site after the osteotomy has been prepared. **F,** The minimum bone dimension for a wider (5 mm) implant is approximately 7 mm. At least 1 mm of bone should still remain laterally after the site has been prepared.

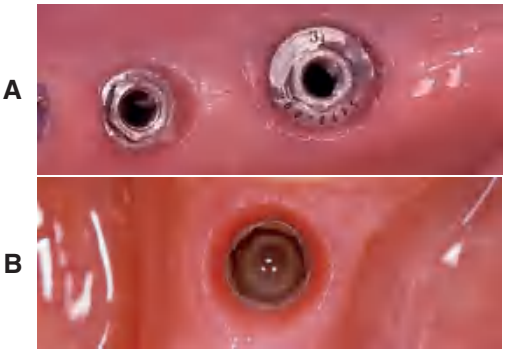


Fig. 13-18
A, Standard external hexagon in use. **B,** Internal hexagon connection implant.



Fig. 13-19 Relationship of interdental bone to position of interproximal contacts seems to predict whether interdental papilla will be present or not. If the distance between the bone and the contact is <5 mm (**A**), a papilla if usually present; if the distance is >8 mm (**B**), there is usually no interdental papilla present.

challenging to achieve a completely formed papilla between the implant restoration and the adjacent teeth in the final outcome. If the interdental tissue and underlying bone have already been lost before implant placement, it may not be possible to achieve ideal papillary contours. The literature contains guidelines that help in predicting whether adequate soft tissue contour can be maintained. As diagrammed (Fig. 13-19), the relationship of interdental bone to the interproximal contact seems to predict whether an interdental papilla will be present or not. If the distances between the bone and the contact is short (~5 mm), a papilla is usually present. If the distance is long ~8 mm), a papilla would not normally be present without additional soft tissue grafting.[9,10]

SURGICAL GUIDE

The coordination of surgical and prosthetic procedures through proper treatment planning is one of the more crucial factors in obtaining ideal esthetic results for the implant restoration. A surgical guide template is extremely useful for anterior implants because slight variations in angulation can significantly affect the appearance of the final restoration. Fabrication of the surgical guide template has become a requirement in patients in whom it is necessary to optimize fixed replacement and ensure correct emergence profiles. Surgical templates can also be beneficial in areas where esthetics is less important. The objectives for using a surgical template in partially edentulous patients are as

follows: (1) delineate the embrasures, (2) locate the implant within the restoration contour, (3) align implants with the long axis of the completed restoration, and (4) identify the level of the cementoenamel junction or tooth emergence from the soft tissue.

A clear resin facial veneer template is recommended for anterior implant placement to allow the surgeon access to the osseous receptor site and an unimpeded view of the frontal and sagittal angulations as the site is being prepared. This type of template is fabricated from a diagnostic waxing or denture tooth arrangement on a mounted cast. The waxing is duplicated with alginate or polyvinyl siloxane and poured in quick-setting stone. Then 1.5-mm (0.060-inch)–thick of vacuum-formed matrix material is adapted to the replicated cast. For accurate orientation, the vacuum-formed matrix should be trimmed to extend over the full facial surface of the teeth being restored and about a third of the facial surface of the remaining dentition. This template is removed from the duplicate cast and returned to the original cast. A 2-mm thickness of autopolymerizing resin is added to the lingual surface to compensate for the space occupied by the porcelain on the implant restoration (Fig. 13-20). (The total thickness, including an additional millimeter from the vacuum-formed matrix, is about 3.0 mm.) To make surgical guides appear radiopaque, barium powder is often added to the resin during its fabrication (see Fig. 13-8). The surgeon must stay as close as possible to this guide during implant placement, which allows maximum flexibility in selecting an implant site without violating the facial surface or forcing screw access holes to be located inappropriately in the facial surface of the restoration. Following this guide enables the surgeon to place a fixture in the best location with minimum undesirable sagittal angulation. If a cement-retained restoration is desired, the orientation of the implant can be slightly more facial.

Although the use of a guide is most necessary in the maxillary anterior region, where bony dimensions are sometimes surprising and often unfavorable, the guide may also be useful in posterior areas with wide edentulous ridges. However, a different type of guide or template may be fabricated in this area. Holes are drilled through the resin into the underlying cast and are paralleled with a milling machine or dental surveyor. Such templates locate the placement of an implant and direct the inclination of its long axis with maximum accuracy.

Surgical templates also can be fabricated for a maxillary edentulous arch that is to be restored with a fixed prosthesis. Such templates are described later in the chapter, but the same preoperative planning and interspecialty cooperation are as important as just described.

IMPLANT SURGERY

Peter E. Larsen

Implant surgery can be performed in an ambulatory setting with the patient under local anesthesia. However, it requires more time than do other surgical procedures, and so conscious sedation may be preferred. Patients expect implant placement to be more traumatic than extracting a tooth. In fact, it is less traumatic. Preoperative education and conscious sedation should lessen the anxiety.

A complete description of the surgical procedures involved in implant placement can be found in one of the current standard texts.[11,12]

Surgical Access

Several types of incision can be used to gain access to the residual ridge for implant placement. The incision chosen should allow retraction of the soft tissue for unimpeded implant placement and should preserve attached tissue esthetics and quantity.

When the quantity of attached tissue is adequate and the underlying bone is expected to be of sufficient width, a simple crestal incision is recommended. However, closure must be performed carefully, because the implant lies directly beneath. In the posterior mandible, an incision may be placed toward the buccal aspect of the ridge to allow the flap to be retracted by a suture. This may be a disadvantage, however, because the incision line is thus immediately over the area where the bone may be thinnest, and a dehiscence can occur during surgery. An incision slightly to the palatal side is particularly effective in the maxillary anterior zone. After the bone is exposed, the surgical template is positioned, and a periodontal probe is used to make a preliminary assessment of the potential implant site. The residual ridge may have areas that are uneven or with sharp ridges. These areas should be smoothed before implant placement.

Implant Placement

Placement procedures for all implant systems require atraumatic preparation of the recipient site. Thermal injury to bone is minimized by using a low-speed, high-torque handpiece, along with copious

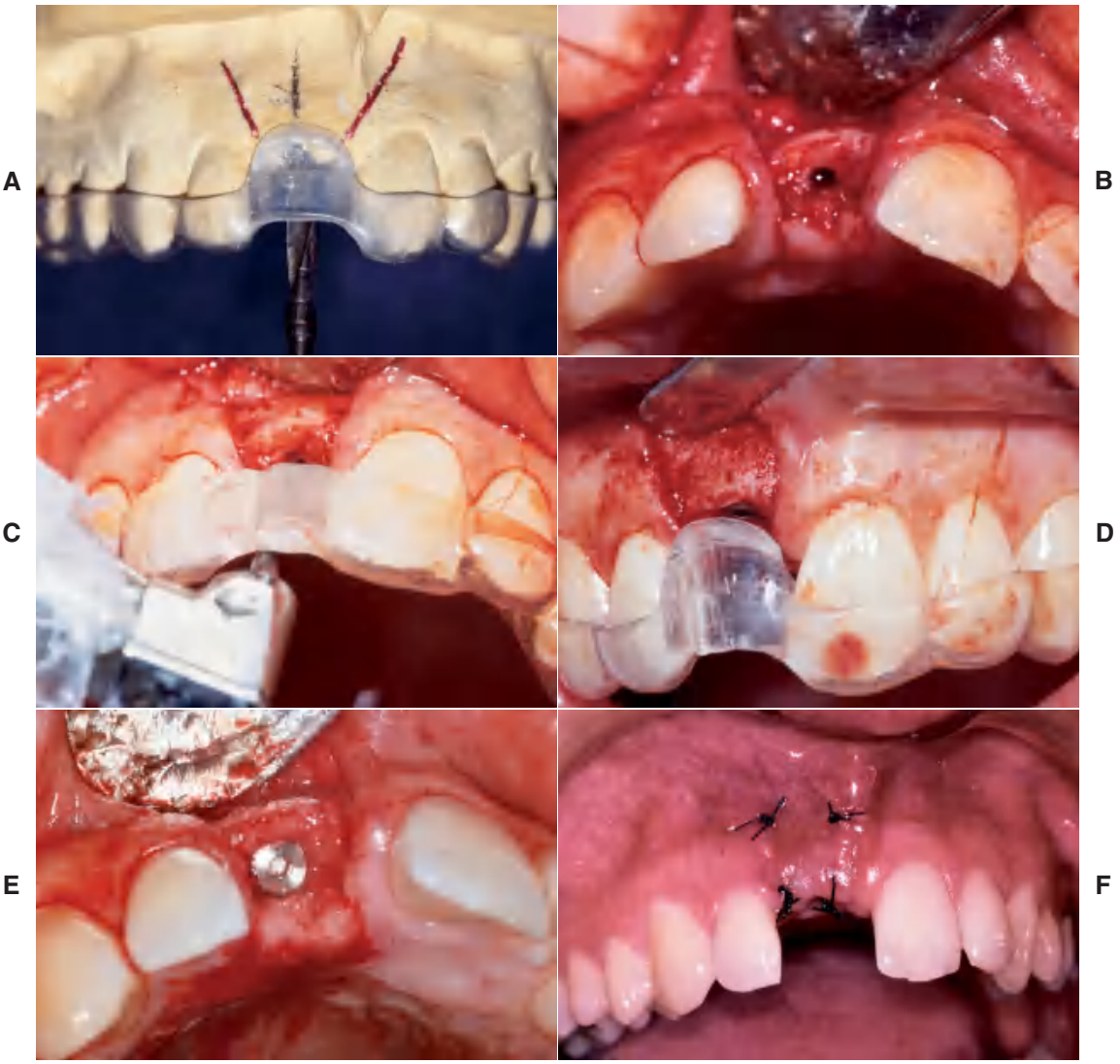


Fig. 13-20

Anterior implant placement with a surgical guide template. A, The apical extent of the template is not removed, which allows the superoinferior orientation of implant placement to be determined. **B,** Full-thickness flap incisions are made, preserving the interdental papilla. The flap is reflected to expose bone for preparation of the implant site. **C,** Resin (2.0 mm) has been added to the lingual aspect of the matrix; the rest of the lingual area was left open so the surgeon can choose the best available bone. The site should be prepared as close to the template as possible. **D,** The implant is positioned 2.5 to 3.0 mm apical to the desired emergence position of the final restoration. **E,** The implant is positioned at an angle and depth that allows optimum esthetics and access for hygiene. **F,** The surgical site is sutured. A 4 to 6-month healing time is allowed. *(Courtesy of Dr. J. A. Holloway.)*

irrigation. The irrigation is either externally or internally applied and directed through channels in the drill. Manufacturer recommendations relating to the type of irrigation and speed of the drilling equipment should be followed. Threaded implants often require final thread preparation in the bone at very low speeds.

The implant recipient site is prepared with a series of gradually enlarged burs. All implant systems have an initial small-diameter drill used to mark the implant site. The implant site is located through use of the surgical template, which may also assist in directing angulation of the implant. The center of the implant recipient site is marked with the initial drill, and a pilot hole is prepared. A paralleling pin is then placed in the preparation to check alignment and angulation.

At this point, a final determination is made regarding the adequacy of the recipient site for implant placement. Although implant placement is

a surgical procedure, it is influenced by critical restorative parameters. The template communicates the range of acceptable implant positions and angulations. At this step, if it is apparent that supporting bone will not allow proper positioning of the implant, further osseous augmentation may be necessary, either simultaneously with implant placement or as a separate procedure with implant placement delayed until proper osseous support is available.

After the desired depth and diameter of the recipient site are achieved, the implant is placed. For titanium implants, an uncontaminated surface oxide layer is required for **osseous integration.** Hydroxyapatite-coated implants are also sensitive to contamination.

Nonthreaded implants are positioned in the recipient site and gently tapped into place with a mallet and seating instrument. Threaded implants are screwed into place, which also requires cutting the screw threads in the recipient site. Self-tapping implants are available for use in the maxilla, where the bone is soft enough to make prethreading unnecessary. After all implants are placed, tension-free closure prevents wound dehiscence.

Postoperative Evaluation

A radiograph should be taken postoperatively to evaluate the position of the implant in relation to adjacent structures (e.g., the sinus and the inferior alveolar canal) and other implants. Any significant problems noticed at this time should be corrected.

Patients are given mild analgesics and 0.12% chlorhexidine gluconate rinses for 2 weeks after surgery to keep bacterial populations to a minimum during healing. Weekly evaluations are recommended until soft tissue healing is complete (2 to 3 weeks). If possible, complete or partial removable dental prostheses should not be worn for 1 week after surgery. The resin over the implant can then be reduced by 2.0 or 3.0 mm and replaced with a soft liner, so that the denture can be worn without injuring the healing implant site.

Implant Uncovering

If a two-stage system is used, implant uncovering is performed after complete implant fixture integration has been achieved. The time interval for integration to occur varies and depends on the particular site and patient. Longer times may be required if the bone quality and surgery were less than ideal or if the bone-implant interface was questionable at the time of placement. In general, recommended integration times are 6 months in the maxilla, 3 months in the anterior mandible, and 4 months in the posterior mandible.

The goals of surgical uncovering are to accurately attach the abutment to the implant, to preserve attached tissue, and to recontour tissue as necessary. These goals may be accomplished with any of these three techniques: the tissue punch, crestal incision, or flap repositioning.

After the implant is exposed, the **implant abutment** is placed. There are two approaches for this procedure. The first approach is to place the same abutment as will be used in the restoration. The second approach is to place an interim **healing cap** that will remain until the tissue heals and will then be replaced by the abutment during the restorative treatment procedures.

When the abutment is placed, the superstructure must be completely seated on the **implant body** without gaps or intervening tissue. In systems with antirotational facets in the implant (see Fig. 13-18), these features must be aligned to allow complete seating of the abutment. Thesuperstructure–implant body interface should be evaluated radiographically immediately after the uncovering. If a gap is present, the superstructure must be repositioned.

IMPLANT RESTORATIONS

Osseous integrated implants are generally designed to support screw- or cement-retained dental prostheses. These implant systems offer many advantages over conventional dental restorations and one-stage implants (BOX 13-3).

Fabrication of screw-retained prostheses requires a number of components unique to implant dentistry. For less experienced clinicians, the large number of parts included within one system might create problems. This section describes in generic terms the component parts typically needed to restore an osseous integrated implant. There are many dental implant systems, and although all the major components are available for each system, many differ slightly in specific design and materials. The basic steps for implant restoration fabrication are described in Figure 13-21.

Clinical Implant Components

Terms used to describe similar implant components vary widely among manufacturing companies. A list

Box **13-3** **Advantages of Osseous Integrated Implants**

1. SURGICAL

a. Documented success rate
b. In-office procedure
c. Adaptable to multiple intraoral locations
d. Precise implant site preparation
e. Reversibility in the event of implant failure

2. PROSTHETIC

a. Multiple restorative options
b. Versatility of second-stage components
   - Angle correction
   - Esthetics
   - Crown contours
   - Screw- or cement-retained options
c. Retrievability in the event of prosthodontic failure

of terms used in this book and a partial list of alternative terms are provided in Table 13-1.

Implant body

The dental implant body is the component placed within the bone during first-stage surgery. It may be a threaded or nonthreaded root form and is ordinarily made of either titanium or titanium alloy of varying surface roughnesses, with or without a hydroxyapatite coating (Fig. 13-22). Although some controversy exists regarding the optimum shape and surface coating for an implant in different parts of the mouth, the significant factors for success are precise placement, atraumatic surgery, unloaded healing, and passive restoration.

All contemporary dental implants have an internally threaded portion that can accept second-stage screw placements. These implants also may incorporate an antirotational feature within the design of the fixture body. If it is incorporated, the antirotational feature may be either internal or external.

Implant bodies can also be classified as *one-stage* or *two-stage*. One-stage implants project through the soft tissue immediately after stage I surgery. Two-stage implants are typically covered with soft tissue at this point. When a tall **healing screw** or cap is placed on a two-stage implant to project it through the tissue at the time of placement, this is referred to as "using a two-stage implant with a one-stage protocol."

Healing Screw

During the healing phase after first-stage surgery, a screw is normally placed in the superior aspect of the fixture. It is usually low in profile to facilitate the suturing of soft tissue in the two-stage implant or to minimize loading in the one-stage implant (Fig. 13-23). At second-stage surgery, it is removed and replaced by subsequent components. In some systems the screw is made slightly larger than the diameter of the implant, which facilitates abutment placement by ensuring that bone does not grow over the edge of the implant. The implant surgeon should always be sure that the healing screw is completely seated after stage-one surgery to prevent bone from growing between the screw and the implant. If this occurs, removing the bone may damage the superior surface of the implant and affect the fit of subsequent components.

Interim abutment

Interim abutments are dome-shaped screws placed after second-stage surgery and before insertion of the prosthesis. They range in length from 2 to 10 mm and project through the soft tissue into the oral cavity. They may screw directly into the fixture or, in some systems, onto the abutment immediately after second-stage surgery. Those that screw onto the abutment are commonly referred to as *healing caps* (Fig. 13-24). Both interim abutments are made of titanium or titanium alloy. In areas where esthetics is paramount, healing should be sufficiently completed around an interim abutment to stabilize the gingival margin. At this time, abutments of appropriate length are selected to ensure that the metal-porcelain interface of the restoration will be located subgingivally. In areas where tissue esthetics is not crucial, adequate healing for impressions usually takes 2 weeks. In esthetic zones, 3 to 5 weeks may be required before abutment selection. In addition, knowing the length of the healing cap can expedite abutment selection.

Abutments

Abutments are the component of the implant system that screw directly into the implant. They eventually support the prosthesis in screw-retained restorations, inasmuch as they accept the retaining screw of the prosthesis. For cement-retained restorations, they may be shaped like a conventional crown prepara-

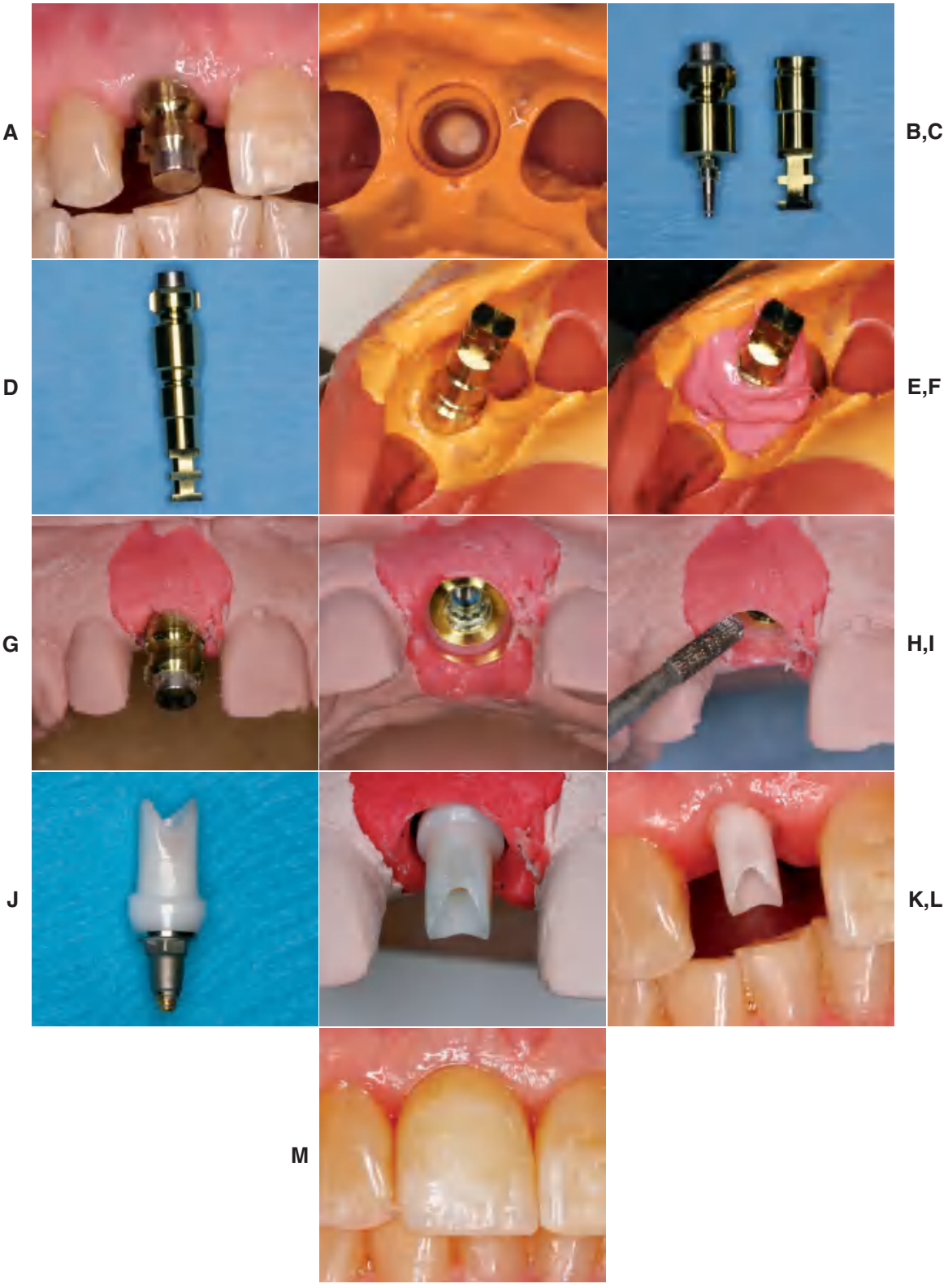


Fig. 13-21

A, A single-unit implant-supported prosthesis will replace the maxillary right central incisor. The impression post is tightened into the implant. **B,** A closed tray impression of the impression coping. **C,** Impression coping removed from the mouth. Pictured adjacent to implant analog. **D,** Impression coping attached to implant analog and inserted into impression (**E**). **F,** Polyether soft tissue cast material (Permadyne, 3M-ESPE North America, St. Paul, Minnesota) injected around analog before pouring. **G,** Poured cast. After an impression is made, the impression post is removed from the mouth and attached to the implant analog. Impression coping and analog are relocated in the impression before pouring. **H,** The impression coping locates the analog in the same position on the cast as the implant is in the mouth. **I,** Soft tissue cast material can be contoured to mimic adjacent tooth emergence profile. **J,** Abutment for cement-retained restoration selected. **K,** Zirconia abutment seated on the cast and ready for fabrication of all-ceramic restoration (*see* Chapter 25). **L,** Zirconia abutment seated in the mouth. **M,** All-ceramic restoration.

Table **13-1 IMPLANT TERMINOLOGY**

Text term	Also known as	Function
Implant body (see Fig. 13-22)	Implant fixture screw or cylinder	Portion of the implant system within the bone
Healing screw (see Fig. 13-23)	Sealing screw Cover screw First-stage cover screw	Seals the occlusal surface of the implant during osseointegration, if a two-stage procedure is used
Interim abutment (see Fig. 13-24)	Temporary gingival cuff Healing collar Implant healing cap Healing abutment	A cover, attached to the implant, that is used to maintain the opening through the tissue until the restoration is completed. Is placed immediately onto the implant if a one-stage protocol is used.
Healing cap (see Fig. 13-24*B*)	Temporary screw Comfort cap Abutment healing cap	A cover that is attached to the top of a transmucosal abutment, protecting the internal threads and interface surfaces of the abutment while the restoration is being completed
Standard abutment (see Fig. 13-25*A*)	Transmucosal abutment Tissue extension Permucosal extension	An intermediate component placed between the implant and metal framework/restoration, providing support and retention for a fixed-removable restoration Excellent for bar overdentures
Tapered abutment (see Fig. 13-25*B*)	Conical abutment Transmucosal abutment Tissue extension Permucosal abutment	An intermediate component placed between the implant and restoration, providing support and retention for a fixed-removable restoration The abutment is cone shaped for maximum esthetics Excellent for screw-retained fixed prostheses
Hex driver (see Fig. 13-33*C*)	Hex tool Screwdriver	Used for placing and removing all hex screws (i.e., abutment fastening screws), impression post-retaining screws, and healing abutments Available in two lengths—short (19 mm, for posterior) and long (24 mm, for anterior)—and three hex sizes (0.048, 0.050, and 0.062 inch)
Abutment driver or seating tool	Name of each driver/tool is specific, based on its use	Used to seat the abutment directly onto the implant
Impression coping (see Fig. 13-33*A*, *B*, and *D*)	Impression post Impression pin Transfer pin Transfer post	Component used during the impression procedure to transfer the position of the implant to the cast
Implant analog (see Fig. 13-33*G*)	Implant fixed analog Laboratory analog Abutment analog Implant body analog Fixture replica	Replicates the implant for use in the cast

Table **13-1—cont'd**

Text term	Also known as	Function
Interim abutment sleeve (see Fig. 13-47*H*)	Temporary cylinder Temporary coping Temorary abutment sleeve Provisional abutment	Provides support and retention for acrylic temporary/interim restorations May also be used for occlusal rim and wax setup try-in procedures for overdentures
Fixed abutment (see Fig. 13-25*B* and *C*)	Straight abutment Coping abutment Abutment post Crown and bridge abutment (slang)	An abutment used for a cement-retained restoration (also available in 15- and 25-degree angles)
Waxing sleeve (see Fig. 13-37)	Plastic sheath Plastic sleeve Plastic coping Castable abutment Castable coping Gold sleeve Gold coping Gold cylinder	A castable plastic pattern usually attached to a premachined metal base used to form an abutment during the laboratory waxing procedure It interfaces directly onto the implant or onto the transmucosal abutment
Prosthesis-retaining screw (see Fig. 13-38)	Gold screw Coping screw Implant fixture screw Fastening screw	Screw used to secure a screw-retained metal (bar) framework or restoration to transmucosal abutments (i.e., conical or standard abutments)

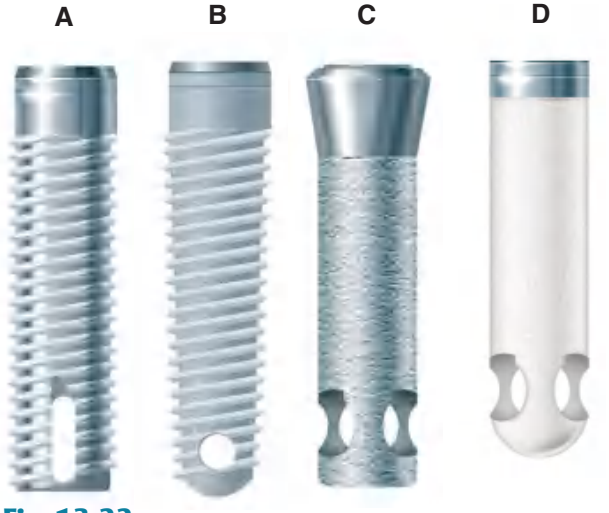


Fig. 13-22
Four main categories of osseous integrated implants. **A,** Titanium screw. **B,** Hydroxyapatite-coated screw. **C,** Hydroxyapatite-coated cylinder. **D,** Titanium plasma-sprayed cylinder.

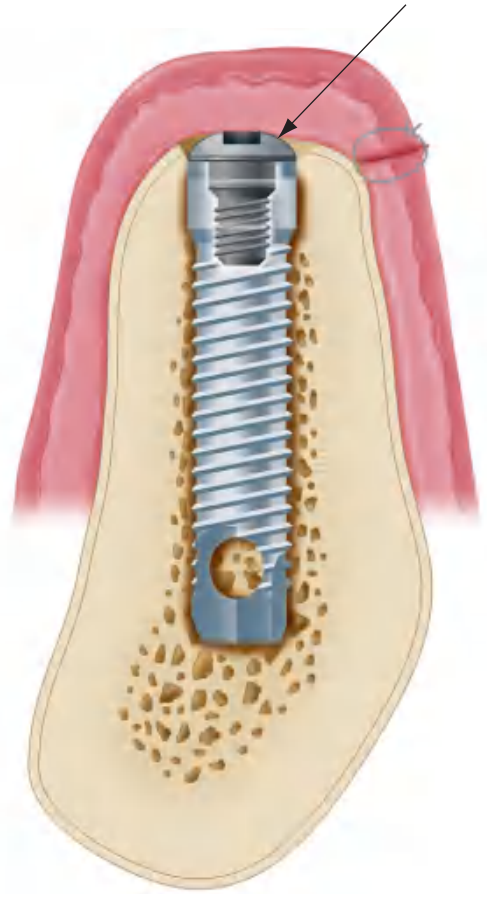


Fig. 13-23
Healing screw (arrow) in place during the initial implant-healing phase. Soft tissue is sutured over the implant. A removable prosthesis can be worn over this area during healing.

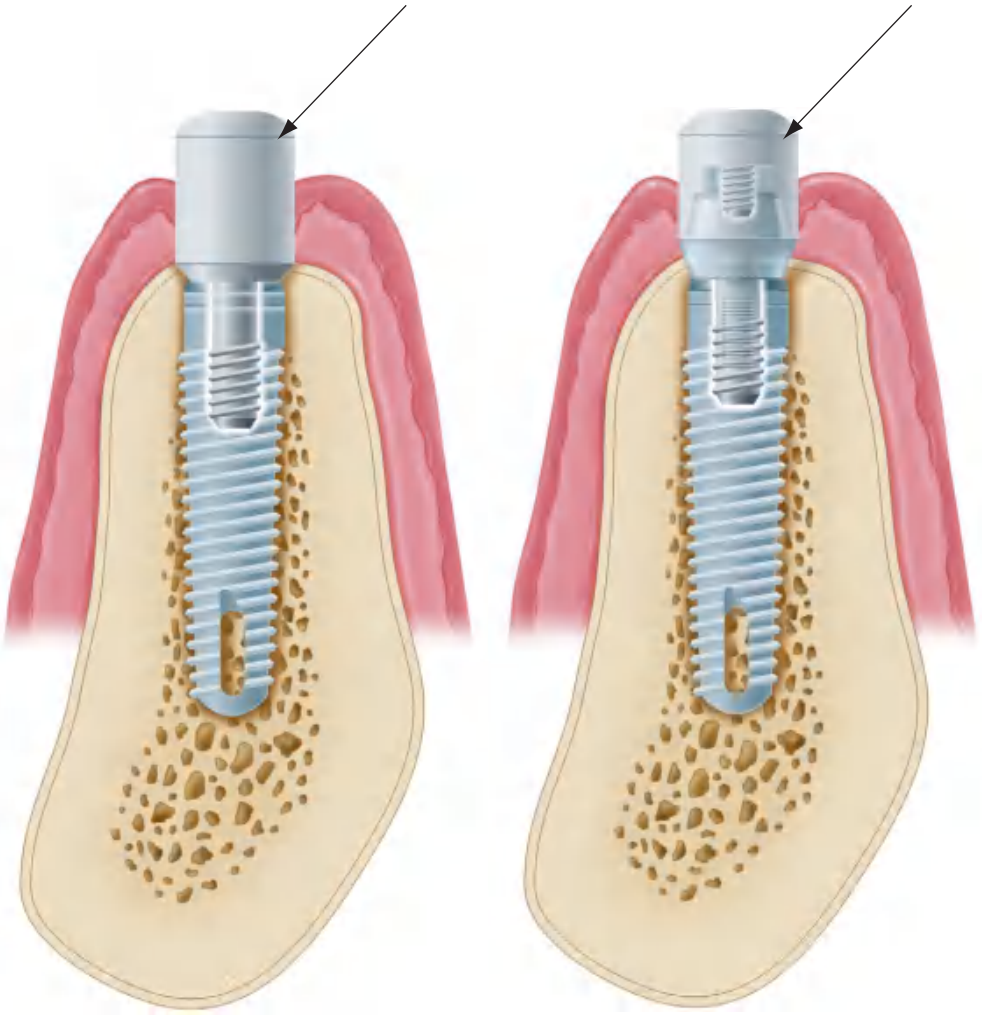


Fig. 13-24
Components that allow for soft tissue healing after second-stage surgery. **A,** This interim abutment screws into the implant. **B,** The healing cap screws into the abutment.

tion. Abutments take many forms (Fig. 13-25). Their walls are usually smooth, polished, and straight-sided titanium or titanium alloy. Their lengths range from 1 to 10 mm. In nonesthetic areas, 1 to 2 mm of titanium should be allowed to penetrate the soft tissue to maximize the patient's ability to clean the prosthesis (Fig. 13-26). In esthetic areas, an abutment can be selected to allow porcelain to be carried subgingivally for optimum esthetics (Fig. 13-27).

In implant systems that incorporate an antirotational feature, the abutment must have two components that move independently of each other: One engages the antirotational feature, and the other secures the abutment within the fixture (Fig. 13-28). With angled abutments, a similar technique is used to correct divergently placed implants (Figs. 13-29 and 13-30). Some systems have included tapered or wide-base abutments, which allow teeth with larger cross-sectional diameters to be restored with more physiologic contours. The nonsegmented implant crown (UCLA) bypasses the abutment portion by means of a sleeve waxed directly to the implant. Using nonsegmented implant crowns may be necessary when soft tissue thickness is less than 2 mm. All-ceramic components onto which all-ceramic crowns can be cemented are gaining popularity for the anterior part of the mouth. The ceramic components are usually made of sintered alumina, zirconia or a combination of the two.

The choice of abutment size depends on the vertical distance between the fixture base and opposing dentition, the existing sulcular depth, and the esthetic requirements in the area being restored. For acceptable appearance, fixtures in the posterior

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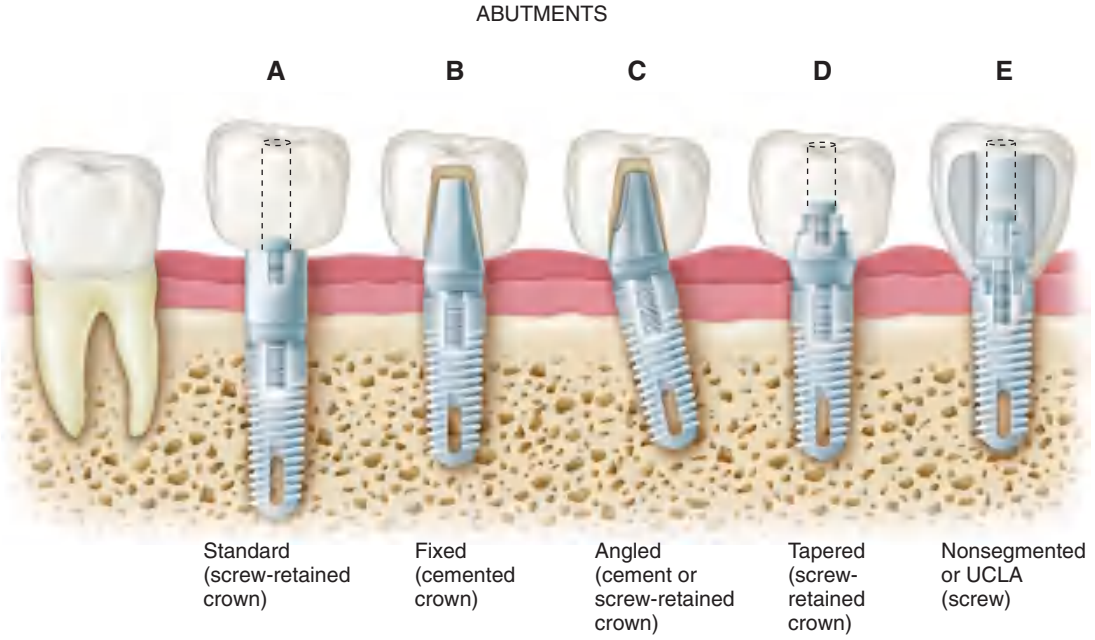


Fig. 13-25

Types of abutments *(left to right)*. **A,** Standard. Length can be selected to make the margin subgingival or supragingival. **B,** Fixed. This abutment is much like a conventional post and core. It is screwed into the implants, has a prepared finish line, and receives a cemented restoration. **C,** Angled. This type is available when implant angles must be corrected for esthetic or biomechanical reasons. **D,** Tapered. This type can be used to make the transition to restoration more gradual in larger teeth. **E,** Nonsegmented, or direct. This type is used in areas of limited interarch distance or areas where an esthetic outcome is important. The restoration can be built directly on the implant, so there is no intervening abutment. This direct restoration technique has been called the *UCLA abutment*. *(Modified from Peterson et al: Contemporary Oral Surgery, 3rd ed. St. Louis, Mosby, 1998.)*



Fig. 13-26

A, Interim abutments projecting through the soft tissue. **B,** Implant restorations supported by standard abutments that allow easy access for oral hygiene.

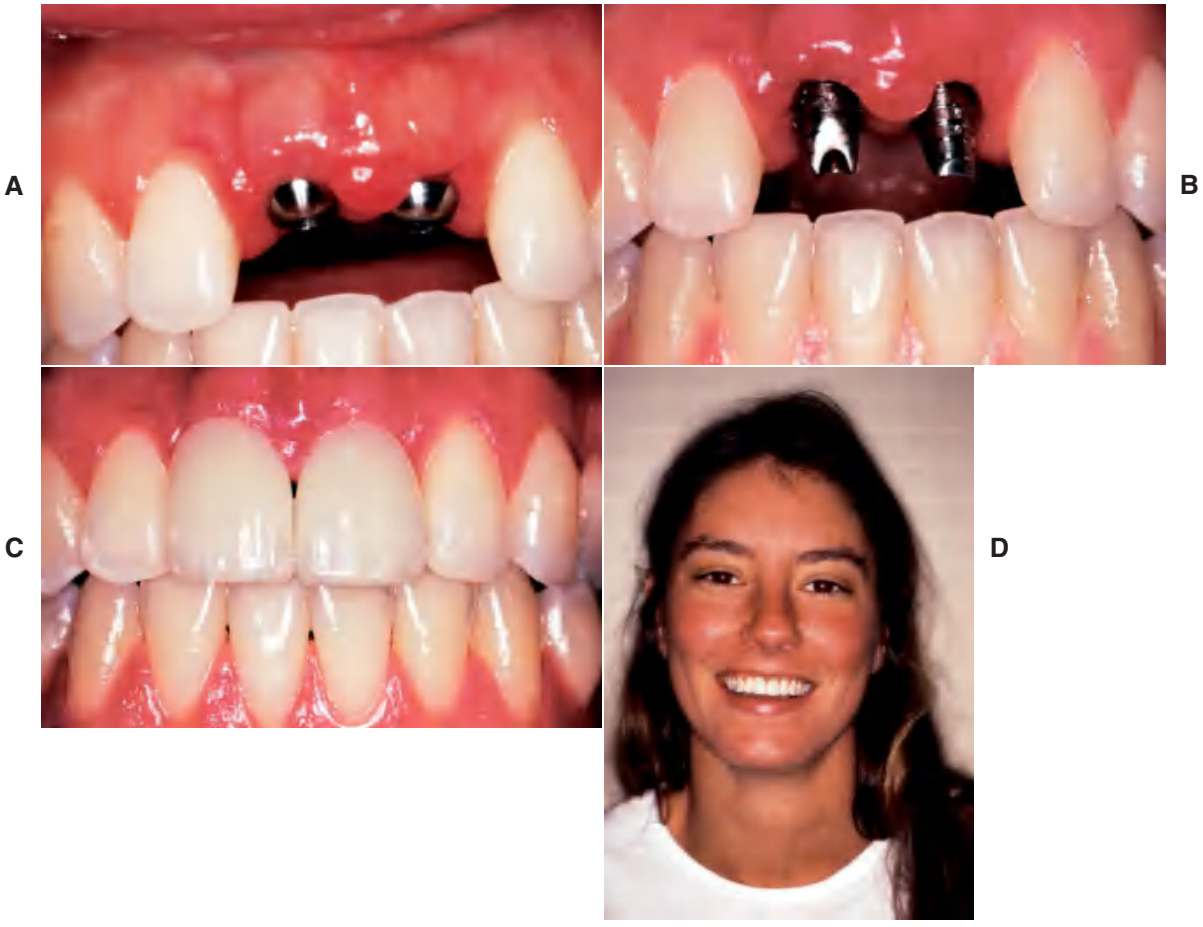


Fig. 13-27
A, Interim abutments projecting through the tissue for implant restoration of maxillary central incisors. **B,** Fixed abutments selected with margins 1 to 2 mm subgingival. **C,** Completed, cemented restorations. **D,** Overall esthetic result.

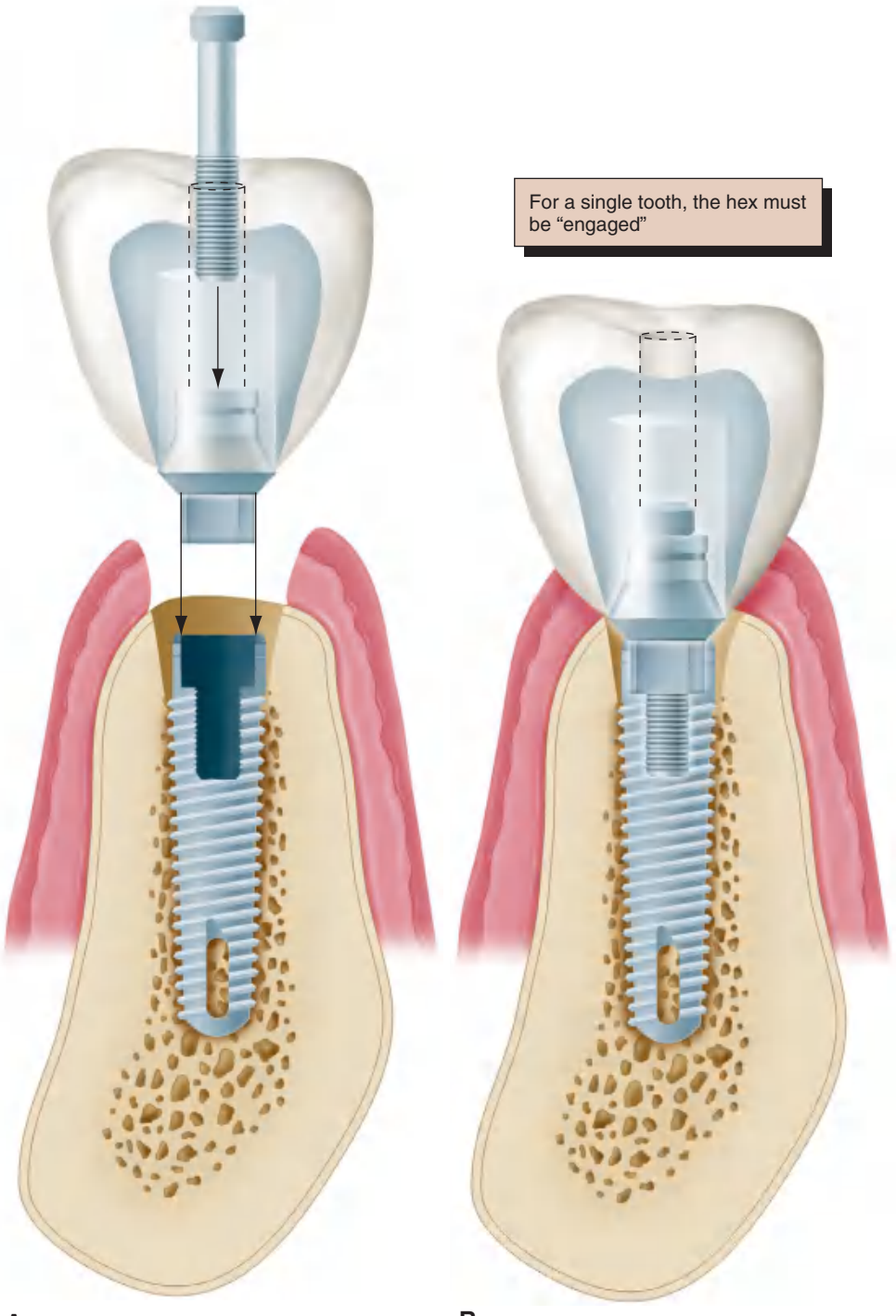


Fig. 13-28

A to D, When an antirotational feature is to be engaged by the abutment, one component of the abutment (the sleeve) must fit the hexagon, whereas the other (the screw) independently tightens the components together.

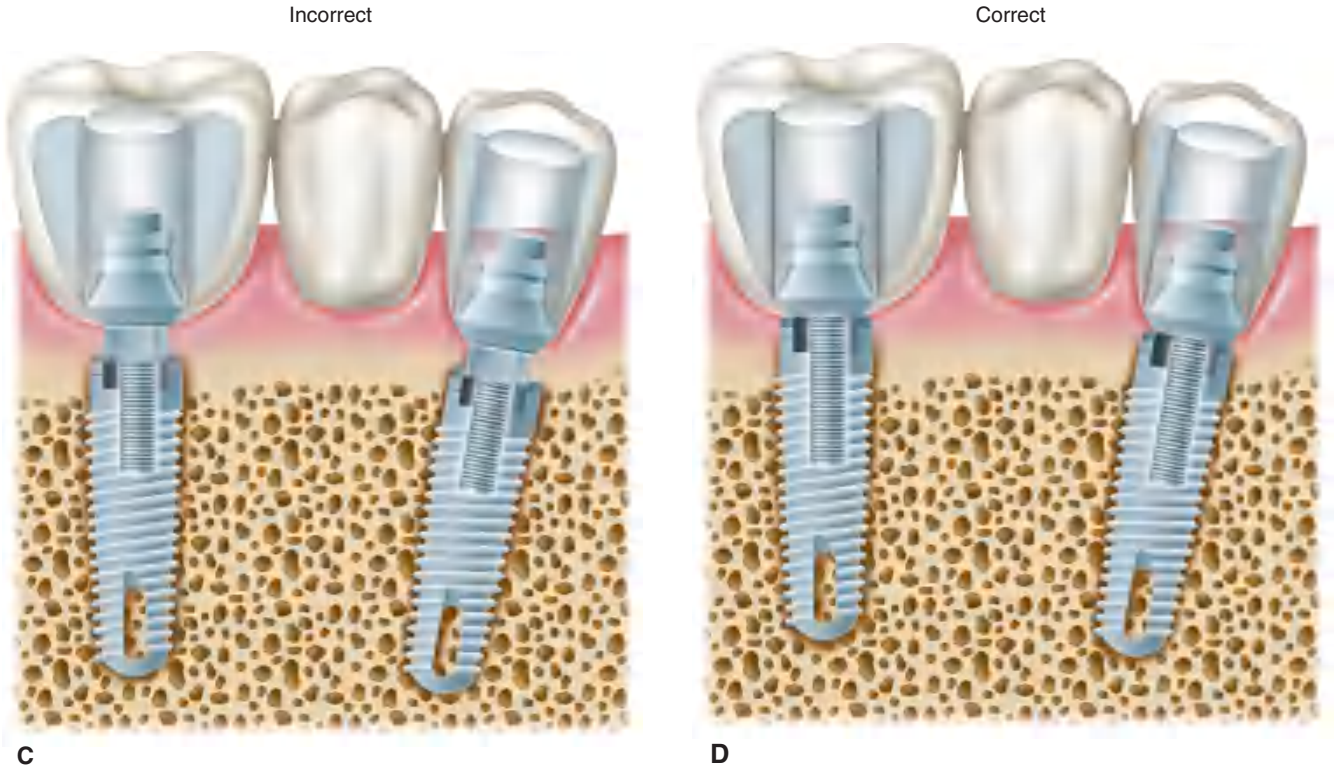


Fig. 13-28, cont'd

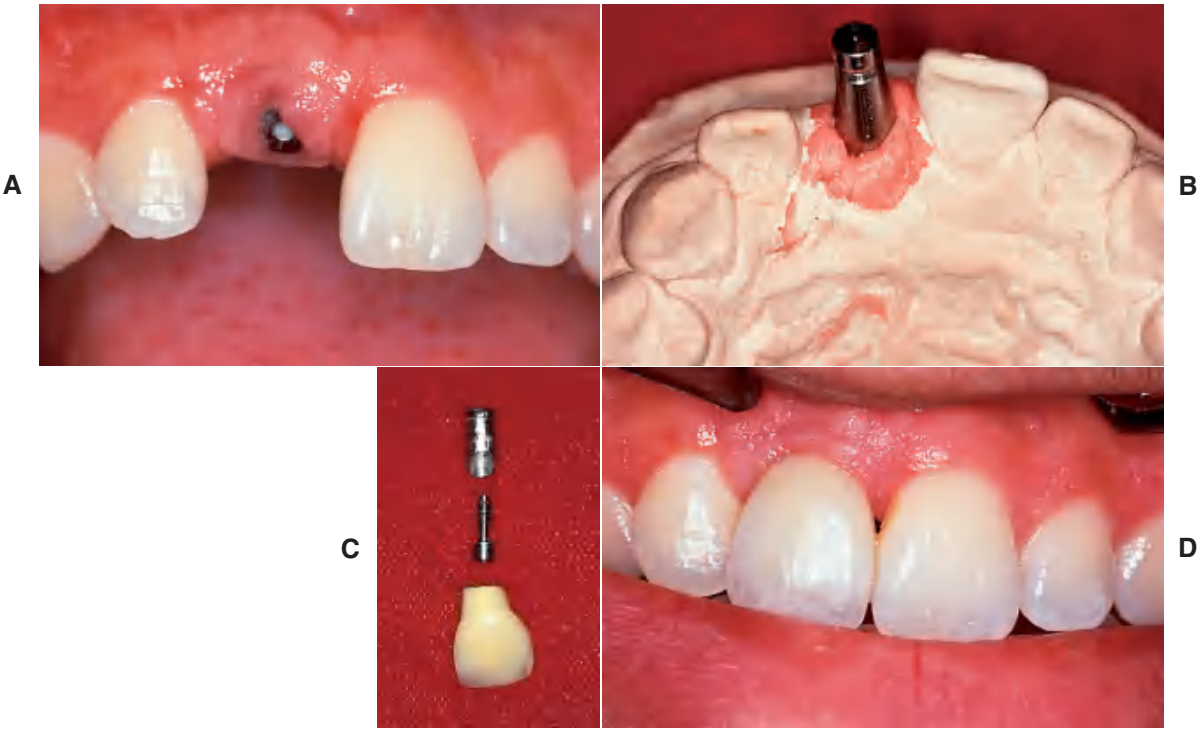


Fig. 13-29

A and **B,** This implant in the maxillary central incisor position is angled too far facially to restore with a straight abutment. **C,** An abutment angled 15 degrees with subgingival margins is chosen to rectify the situation. **D,** The completed crown cemented onto the angled abutment. An interim luting agent can be used to maintain retrievability, although choosing a suitable material that retains the restoration adequately but can still be removed is not always easy.

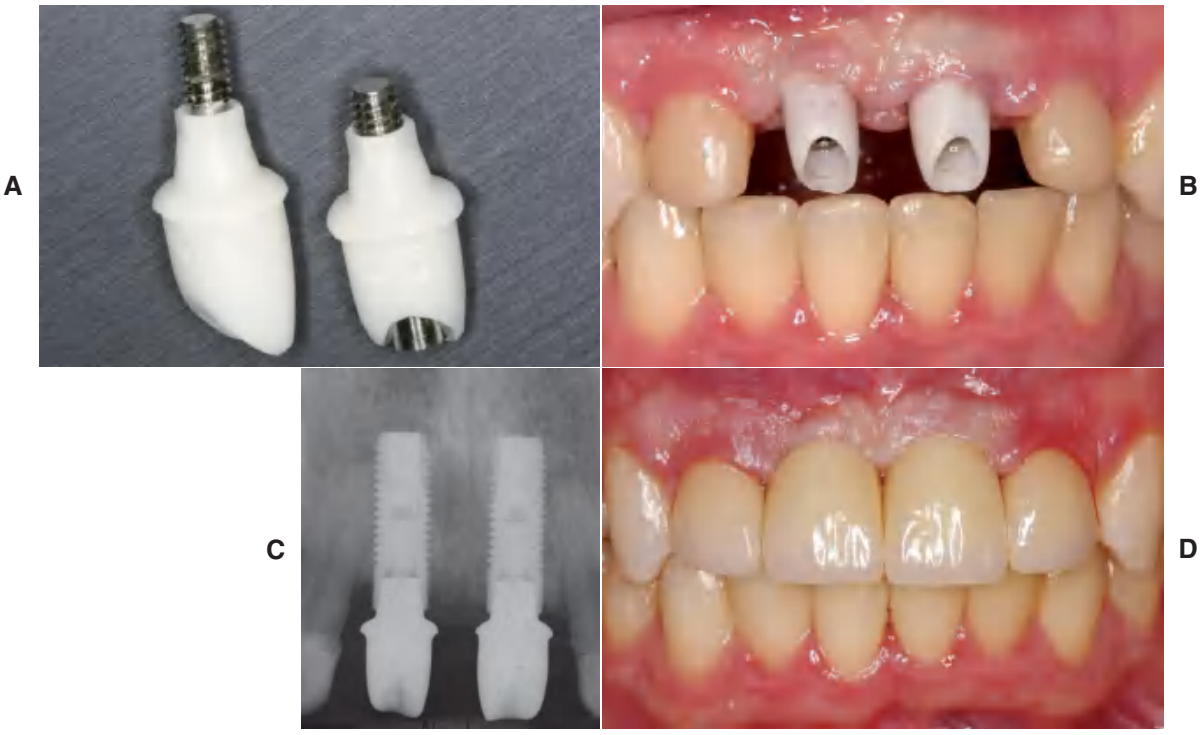


Fig. 13-30
A to D, Zirconia abutments with all-ceramic restorations used to replace missing maxillary central incisors. *(Courtesy of Dr. D. Gozalo.)*

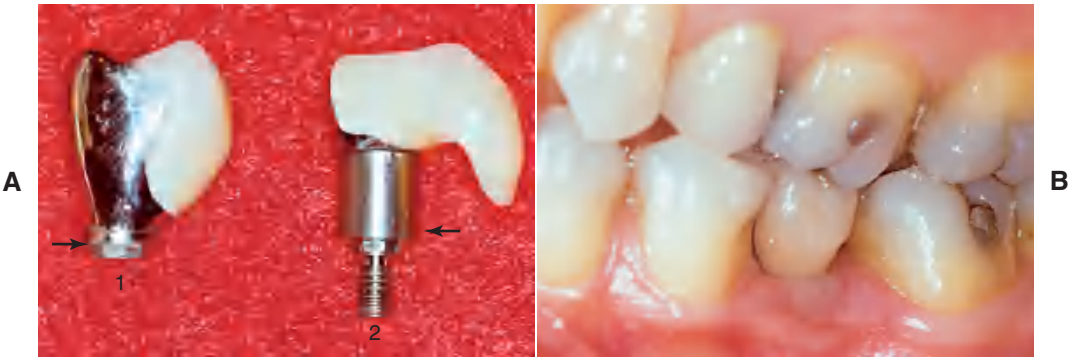


Fig. 13-31
A, Two crowns fabricated for the same lingually tipped mandibular implant. The *arrows* denote the connection to the implant body for both units. Crown 2 is fabricated on a 4-mm abutment. Crown 1 is connected directly to the implant body, allowing the creation of more physiologic contours. **B,** One-year follow-up of crown 1. The soft tissue response is excellent despite a poorly placed implant.

maxilla or mandible may require margin termination at or below the gingival crest. An anterior maxillary crown may require 2 to 3 mm of subgingival porcelain at the facial gingival margin to create the proper emergence profile and appearance. Framework fit should be checked on multiple unit restorations if abutment margins are no more than 1 mm subgingivally. Periodontal probing of the sulcus after the healing cap is removed reveals the space available for subgingival extension and can be performed at the time of abutment placement or after a period of tissue healing around an interim restoration. When these measurements have been made, the correct abutment is attached to the implant. The abutment length can have a dramatic effect on restoration contours (Fig. 13-31).

Impression copings

Impression copings facilitate transfer of the intraoral location of the implant or abutment to a similar position on the laboratory cast. They may screw into the implant or onto the abutment and are customarily subdivided into fixture types or abutment types (Fig. 13-32).

Both of these can be further subdivided into transfer (indirect) and pickup (direct) types. With the transfer impression coping in place, an impression is made intraorally, after radiographs are taken to confirm complete engagement. Heavier body impression materials (e.g., polyvinyl siloxane and polyether) are usually recommended, although any conventional impression material can be used. When the impression is removed from the mouth, the impression coping remains in place on the implant abutment or on the fixture. It is then removed from the mouth and joined to the **implant analog** before being transferred to the impression in the proper orientation. If the clinician anticipates that the implant angulation will have to be corrected on the laboratory cast, a flat-sided impression coping that goes directly into the fixture or implant should be used (Fig. 13-33). The flat side of the post accurately orients the location of the implant and positions the threads and the antirotational feature. When an angled abutment is placed or screwed onto the implant, it must be oriented in the same position in which the prosthesis was fabricated in the laboratory. Completely symmetric impression copings

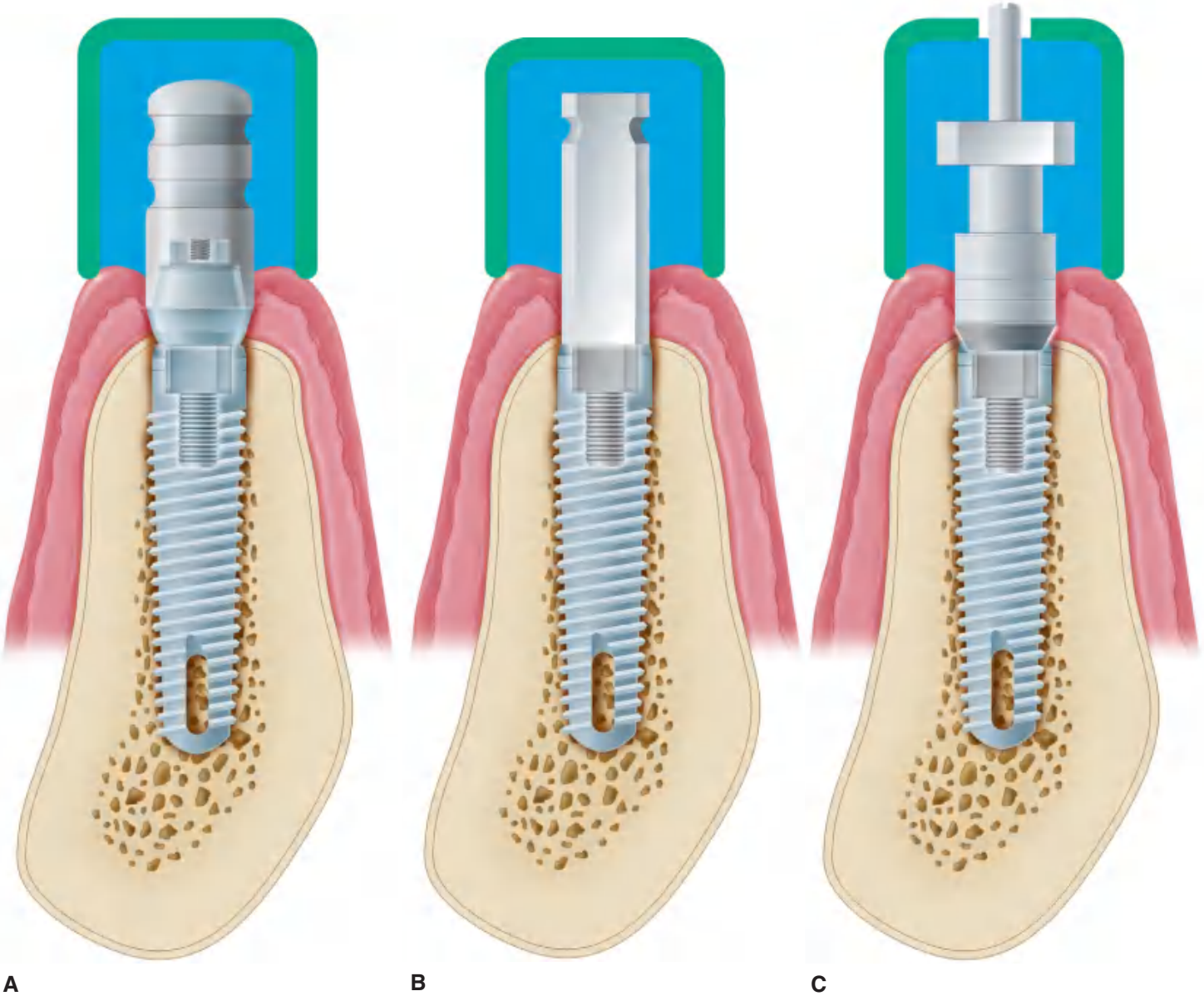


Fig. 13-32

Types of impression copings. **A,** A one-piece coping (screws onto abutment) is used if the abutment does not need to be changed on the laboratory cast. **B,** A two-piece coping (transfer/closed tray) is attached directly to the fixture if the abutment does need to be changed on the cast (it should have a flat side if angle correction is necessary). **C,** A two-piece coping (pickup/open tray), used to orient the antirotational feature or to make impressions of very divergent implants.



Fig. 13-33

A, A standard transfer impression coping is a sleeve that matches the implant diameter. A screw penetrates through its center. **B,** The screw can be placed through the impression coping sleeve and carried to the mouth with the standard hex driver (**C**). **D,** Impression coping seated into the implant. **E,** Radiograph confirming complete seating. **F,** Complete impression, clearly showing flat sides. **G,** Implant analog corresponding to the size of the implant. **H,** Impression coping removed from the mouth and attached to an implant analog. **I,** Impression coping/analog complex inserted into the impression with flat sides properly oriented. **J,** Polyether impression material injected around the complex before pouring. **K** and **L,** Impression coping orients the implant analog to the cast as the implant body is positioned in the mouth.

are contraindicated if angle correction may be necessary. If the clinician decides to transfer the orientation of an antirotational feature from the mouth to the laboratory model, the two-piece pickup (direct) impression technique should be used. This technique requires a two-piece impression coping with a removable guide pin that screws directly into the abutment or onto the fixture. A square coping with a long guide pin and usually an open-top tray are used. The impression coping is designed with square side walls to prevent rotation in the impression material. An open-top impression tray allows access to the guide pin for unscrewing after the material has set so that the copings can be picked up within the impression when removed from the mouth (Fig. 13-34). When implants are oriented at significantly divergent angles, the pickup technique is generally considered to be the more accurate of the two procedures. The transfer technique is more convenient and sometimes mandatory when space is limited and screwdriver access would be limited. Before an implant impression is taken, a radiograph should be made to ensure that the components are properly assembled. This requirement is

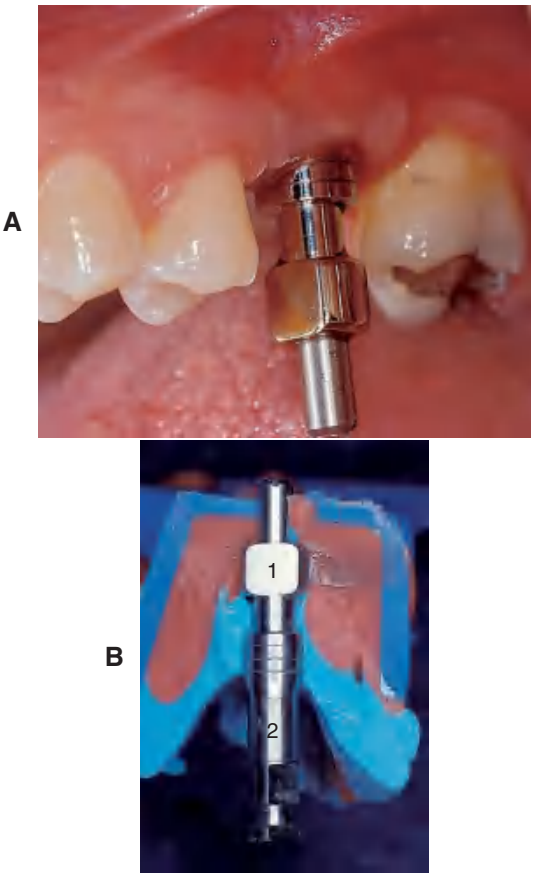


Fig. 13-34
A, Two-piece impression coping and screw seated intraorally. **B,** Cross-sectional view of the impression coping and screw *(1)* with the implant analog *(2)* attached. The impression coping remains within the impression material.

especially important when an antirotational feature is involved.

Implant analogs

Implant analogs are made to represent exactly the top of the implant fixture or the abutment in the laboratory cast. Therefore, they can be classified as fixture analogs and abutment analogs (Fig. 13-35). Both types screw directly into the impression coping after it has been removed from the mouth, and the joined components are returned to the impression before pouring. The final impression should be poured in either dental stone or die stone. The gingival tissues can be reproduced by injecting an elastomer (e.g., Permadyne*) to represent soft tissue around the implant analog before pouring. This facilitates removal of the impression coping from the stone cast and the placement of subsequent abutments without breaking the stone and losing the reference point of the soft tissue (Fig. 13-36).

*3M-ESPE North America, St. Paul, Minnesota.



Fig. 13-35
Implant analogs. These represent either implants or abutments. **A,** Analog that duplicates the top of the implant. **B,** Analog that duplicates the top of the abutment.

Abutment analogs are generally attached to an implant impression coping. Implant body impression copings are normally attached to implant body analogs. The advantage of using the implant body analog is that the abutments can be changed in the laboratory. Also, if a flat-sided impression coping has been used to orient the threads or the hexagon of the implant body analog properly, the decision to correct for less than optimal implant angulation can be deferred until the laboratory stage. If the clinician is confident that the appropriate abutment has been selected, using the abutment impression coping and abutment analog can simplify the procedure. If a supragingival abutment margin has been selected, a soft tissue cast is not necessary.

Waxing sleeves

Waxing sleeves are attached to the abutment by the relating screw on the laboratory model. They eventually become part of the prosthesis. In nonsegmented implant crowns, they are attached directly to the implant body analog in the cast.

Commonly referred to as *UCLA abutments,* they may be plastic patterns that are burned out and cast as part of the restoration framework, precious metal that is incorporated in the framework when it is cast to the precious alloy cylinder, or a combination of each. Use of a metal waxing sleeve ensures that two machined surfaces are always in contact. The cast surface of the plastic waxing sleeve may be retooled before it is returned to the fixture.

Waxing sleeves are available in several vertical dimensions. Tall ones can be shortened to conform to the requirements of the occlusal plane. Today, most waxing sleeves are a combination of gold alloy and plastic (Fig. 13-37). This combination allows the

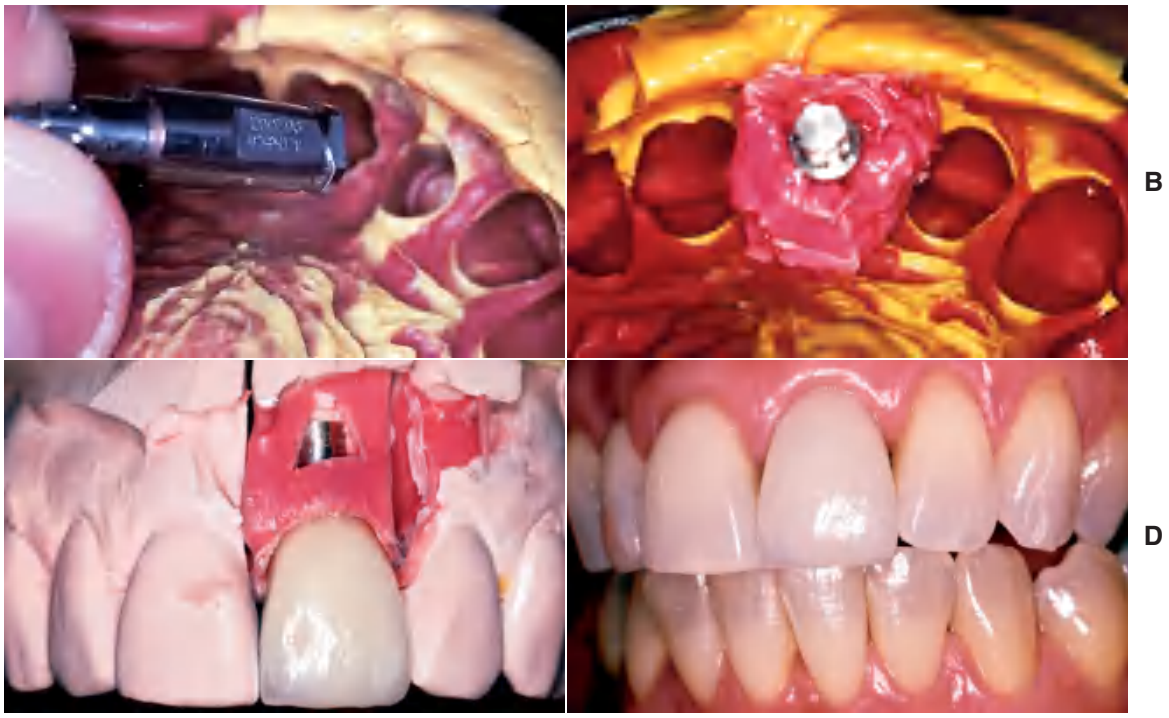


Fig. 13-36

A and **B,** Polyether impression material injected around an implant analog before the impression is poured. The gingival material should not cover any retention features of the analog. **C,** The impression material reproduces the patient's soft tissue contours adjacent to the implant. The impression coping may be removed and other components inserted without losing the associated anatomic landmarks. **D,** Completed restoration. *(Courtesy of Dr. C. Pechous.)*



Fig. 13-37

A, Waxing sleeves with gold alloy base and plastic extension. **B,** On the laboratory cast, the technician can wax to the plastic extension. The wax and plastic are burned out, and the new alloy is "cast to" the original alloy base.

machined fit of the alloy at the implant, with the cost advantage of plastic at the waxing surface.

Prosthesis-retaining screws

Prosthesis-retaining screws penetrate the fixed restoration and secure it to the abutment (Fig. 13-38). They are tightened with a screwdriver and attach nonsegmented crowns to the body of the implant. They generally are made of titanium, titanium alloy, or gold alloy and may be long (which allows them to penetrate the total length of the implant crown) or short (which requires countersinking them into the occlusal surface of the restoration). Screws that are countersunk must be covered by an initial layer of resilient material (e.g., gutta-percha, cotton, or silicone). A subsequent seal of composite resin is placed over the resilient plug (Fig. 13-39).

Implant Restorative Options

Distal-extension implant-supported restoration

Implant support offers major advantages in the treatment of partially edentulous patients in whom no

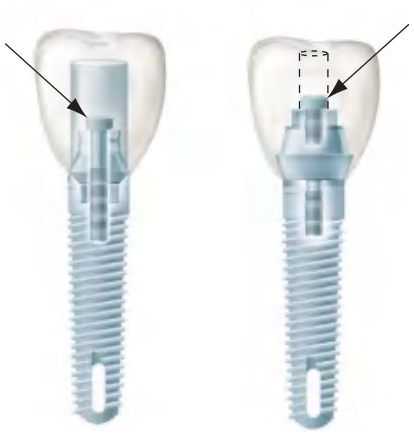


Fig. 13-38
Two types of prosthesis-retaining screws. **A,** Nonsegmented crown retained to implant. **B,** Crown retained on abutment.



Fig. 13-39
Prosthesis-retaining screws countersunk below the occlusal surface of the restoration.

terminal abutment is available. In this situation, the conventional dental treatment plan would include a partial removable dental prosthesis. However, with the implant alternative, patients can avoid the discomfort and inconvenience of a removable prosthesis.

There are two distal-extension restorative options. One option is to place an implant distal to the most posterior natural abutment and fabricate a fixed prosthesis connecting the implant with the natural tooth. However, there are problems associated with implants connected to natural teeth (see p. 422). The other option is to place two or more implants posterior to the most distal natural tooth and fabricate a completely implant-supported restoration (Fig. 13-40). If the crown/implant ratio is favorable, two implants to support a three-unit fixed dental prosthesis may be considered. If implants are short and crowns are long, one implant to replace each missing tooth is highly recommended. If doubt remains, more implants are used when heavier forces are expected (e.g., the posterior part of the mouth in patients with evidence of parafunctional activity). Fewer implants are used when lighter forces are expected (e.g., those opposing a complete denture or those supporting a prosthesis in the anterior part of the mouth).

Long edentulous span restoration

Similar options can be used to treat a long edentulous span. The clinician may choose to have multiple implants placed between the remaining natural teeth and to fabricate a fully implant-supported restoration. As an alternative, one or two implants can be placed in the long edentulous span and the final restoration connected to natural teeth. When it is necessary to connect implants and the natural teeth, protecting the teeth with telescopic copings is recommended. In this manner, prosthesis retrievability can be maintained. In addition, some long edentulous spans require the reconstruction of soft and hard tissue as well as teeth. In these instances, use of resin teeth processed to a metal substructure rather than a conventional metal-ceramic restoration is recommended. Soft tissue esthetics can be more easily and accurately mimicked with heat-processed resin and large defects (Fig. 13-41). This type of restoration is best described as a complete metal-resin fixed dental prosthesis. It has also been called a *hybrid prosthesis* because it combines the principles of conventional fixed and removable prosthodontics. For smaller defects, pink porcelain can be used to compensate for missing soft tissue (see Fig. 13-26*B*).

Single-tooth implant restoration

The use of single implants in restoring missing teeth is an attractive option for the patient and the dentist. However, it requires careful implant placement and precise control of all prosthetic components. Single-tooth restorations supported by implants may be indicated in the following situations:

1. An otherwise intact dentition.
2. A dentition with spaces that would be more difficult to treat with conventional fixed prosthodontics.
3. Distally missing teeth when cantilevers or partial removable dental prostheses are not indicated.
4. A prosthesis that needs to closely mimic the missing natural tooth.

The requirements for single-tooth implant crowns are as follows:

1. Esthetics.
2. Antirotation, to avoid prosthetic component loosening.
3. Simplicity, to minimize the amount of components used.
4. Accessibility, to maintain optimum oral health.



Fig. 13-40

A, Two implants placed distal to the mandibular premolar. **B** to **D,** The completed restoration is not connected to the crown on the natural tooth. *(Courtesy of Dr. R. B. Miller.)*



Fig. 13-41

A, Large mandibular defect created by a shotgun wound. **B,** Metal substructure of a metal-resin prosthesis tried onto three implants in this defect. **C,** Denture resin can more effectively recreate the soft tissue color and contours in the completed restoration than dental porcelain. **D,** Metal-resin restoration over the defect.

5. Variability, to allow the clinician to control the height, diameter, and angulation of the implant restoration.

Several systems have been developed to comply with these demands. Common indications include congenitally missing maxillary lateral incisors (Fig. 13-42) and teeth in which endodontic treatment was unsuccessful (Fig. 13-43). Screw loosening has most commonly been associated with the terminally positioned single molar implant crown (Fig. 13-44).

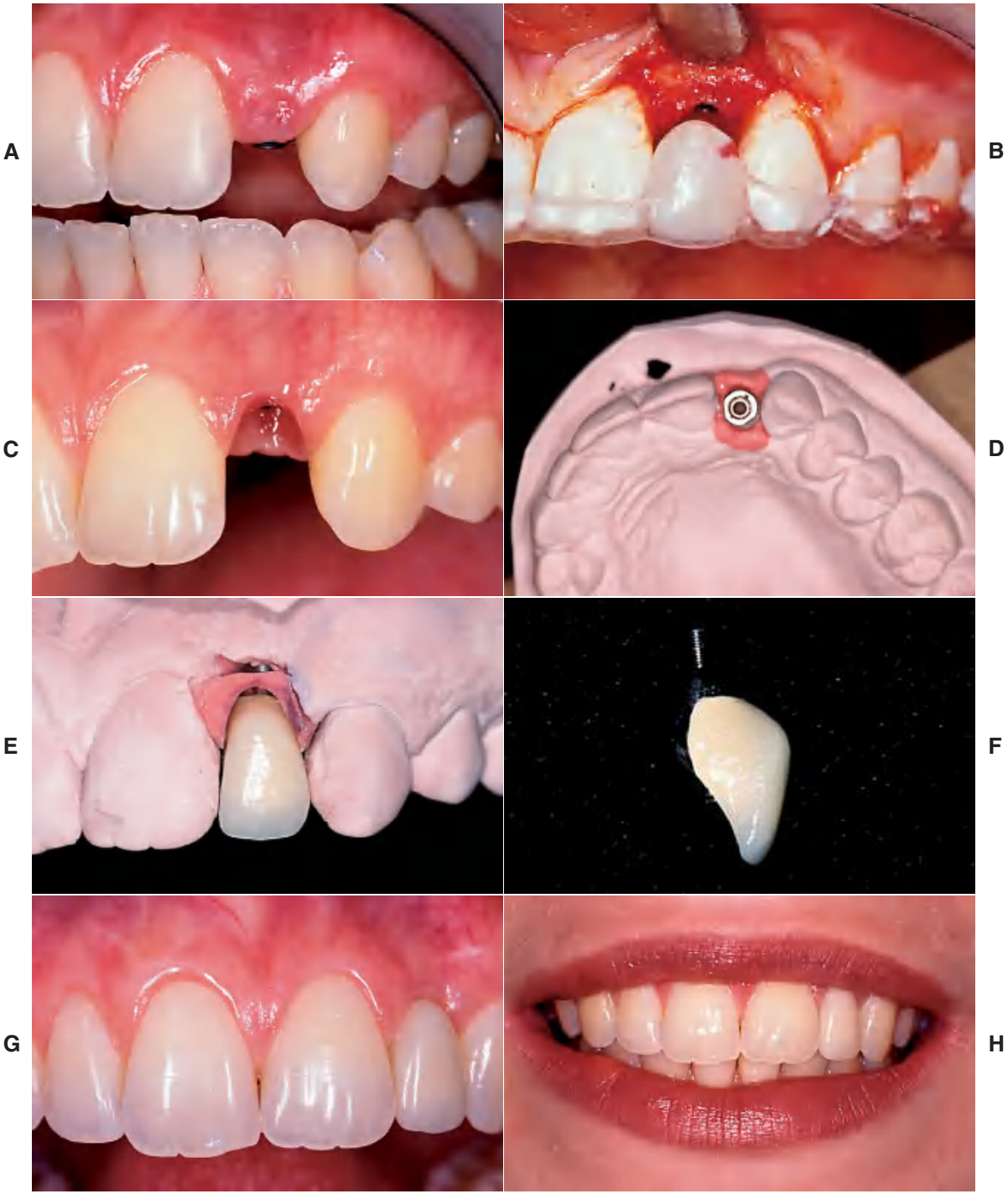


Fig. 13-42

A, Patient with congenitally missing maxillary lateral incisor. **B,** Placement of dental implant through the use of a surgical template. **C,** Final soft tissue contours. **D,** Impression post projecting from definitive cast. **E** and **F,** Final restoration. **G** and **H,** Single tooth implant crown replacing the maxillary lateral incisor.

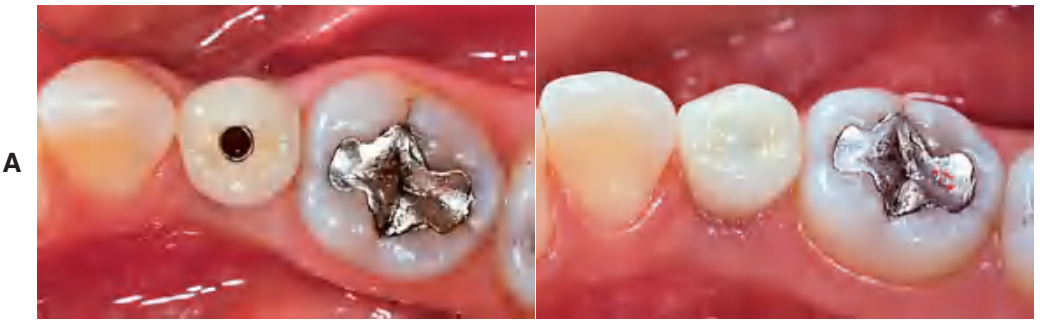


Fig. 13-43
A, Occlusal view of a single tooth implant crown replacing a fractured mandibular premolar. **B,** Implant crown with screw access restored.



Fig. 13-44
Screw loosening is most commonly associated with single-tooth molar implant crowns.

Matching the soft tissue contours of adjacent natural teeth remains the most difficult challenge for completing the anterior single-tooth restoration. These contours can be reliably created with interim restorations. One technique, which combines soft tissue contouring and interim placement, is shown in Figure 13-45. When the tissue has matured around the interim restoration, a final impression can be made to complete the definitive restoration (Fig. 13-46). Impressions can also be made at the time of stage I surgery so that an interim restoration can be delivered at stage II to facilitate more ideal soft tissue contours (Fig. 13-47). The best soft tissue esthetics is still generally achieved when interdental papillae are present before the surgery. If soft tissue contours are deficient before surgery, the patient should expect some compromise in the final soft tissue result.

Fixed restoration in the completely edentulous arch

For completely edentulous patients who require nonremovable restorations, there are two implant options: a complete metal-resin fixed dental prosthesis and a metal-ceramic fixed dental prosthesis (Figs. 13-48 to 13-50).

The complete metal-resin fixed dental prosthesis is a cast alloy framework with processed denture resin and teeth. It is typically supported by a minimum of five implants in the mandible and six in the maxilla. One major determining factor for selecting this option is the amount of bone and soft tissue that has been lost. For patients who have had moderate bone loss, the prosthesis restores both bone and soft tissue contours.

The metal-ceramic prosthesis also requires a minimum of five implants in the mandible and six in the maxilla. It can be made esthetically pleasing only if bone loss is minimal and is best suited for patients who have recently (within 5 years) lost their natural teeth. For patients with severe bone loss, there is probably only one option: a removable restoration (Fig. 13-51).

The main advantage of a fixed restoration, whether it is metal-resin or metal-ceramic, is that it is attached to the implants at all times. Therefore, patients experience the psychologic benefit of having a restoration that closely resembles their original natural teeth. In addition, movement within the system is minimized, and the components tend to wear out less quickly. Because the prosthesis is screw retained, the dentist can remove it, allowing access for cleaning and repairs. A potential disadvantage is that the implants must be precisely placed, especially in the maxillary anterior esthetic zone. Implants placed in embrasure spaces can lead to disastrous esthetic results and can impede access for hygiene. With a metal-resin prosthesis, the clinician must decide between leaving enough space for hygiene access and minimizing space for optimum esthetics. Some patients may be concerned by the amount of metal shown in a metal-resin prosthesis. However, from a conversational distance, a properly made prosthesis is hardly noticeable. Esthetic and phonetic problems in the maxillary arch can often be avoided by not placing implants near the midline and restoring the incisor teeth with pontics. This approach to implant placement improves the restorative outcome considerably (Fig. 13-52).

Text continues on page 420



Fig. 13-45

Soft tissue contouring with interim restoration. **A,** This patient has lost the left maxillary central incisor, which will be replaced with an implant-supported prosthesis. **B,** Soft tissue healing 2 weeks after second-stage surgery and placement of an impression coping. Note that the interdental papilla has been preserved. **C,** Soft tissue cast prepared with a laboratory bur to create the ideal soft tissue architecture. **D,** A waxing sleeve attached to the implant analog retains the interim restoration. **E,** An anatomic-contour wax pattern can be used to fabricate the interim restoration. **F,** Duplicate cast of the anatomic-contour wax pattern. **G,** An acrylic template is adapted to the duplicate cast and returned to the definitive cast. A waxing post is placed in the interim restoration to create a screw access hole. **H,** An interim implant-supported restoration is fabricated by one of the techniques described in Chapter 15. **I,** The soft tissue is contoured to accept the interim restoration. A diamond curettage bur can be used when sufficient attached tissue is present. **J,** Soft tissue contouring improves esthetics, minimizes pocket depths, and allows more physiologic restoration contours. **K,** The interim restoration. Soft tissue is allowed to heal for 4 to 6 weeks before the definitive impression is made. **L,** Definitive implant-supported restoration.

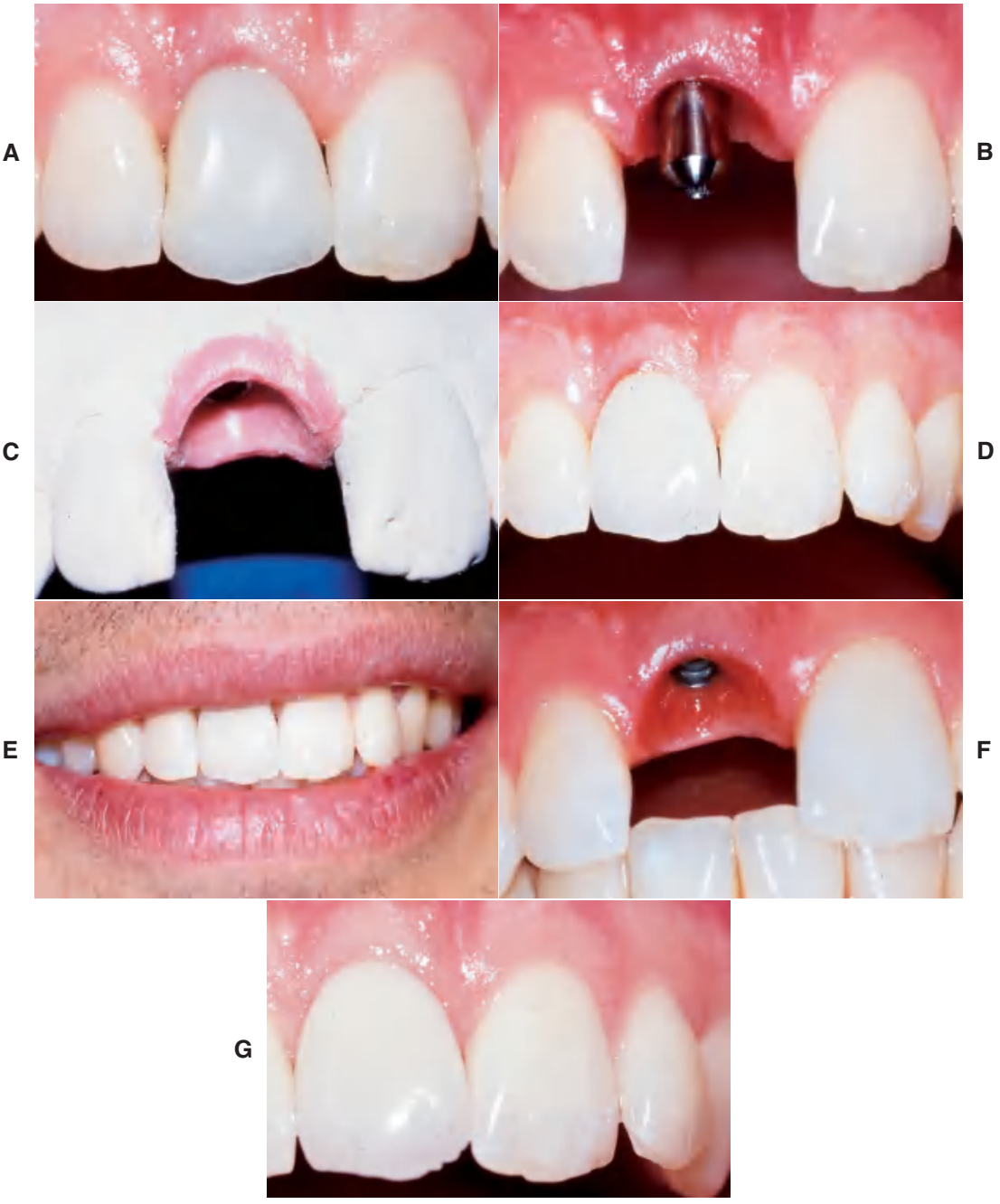


Fig. 13-46

A, Soft tissue around a maxillary implant provisional restoration after 6 weeks of healing. **B,** New soft tissue contours compared to the healing abutment previously in place. **C,** Final impression made and a definitive cast fabricated. The new soft tissue contours are reproduced. **D,** Implant crown placed on the maxillary right central incisor. **E,** Preservation of the interdental papilla is important for patients with medium to high smile lines. **F** and **G,** One- and five-year follow-ups showing that the patient has maintained healthy soft tissue contours. *(Courtesy of Dr. J.A. Holloway.)*

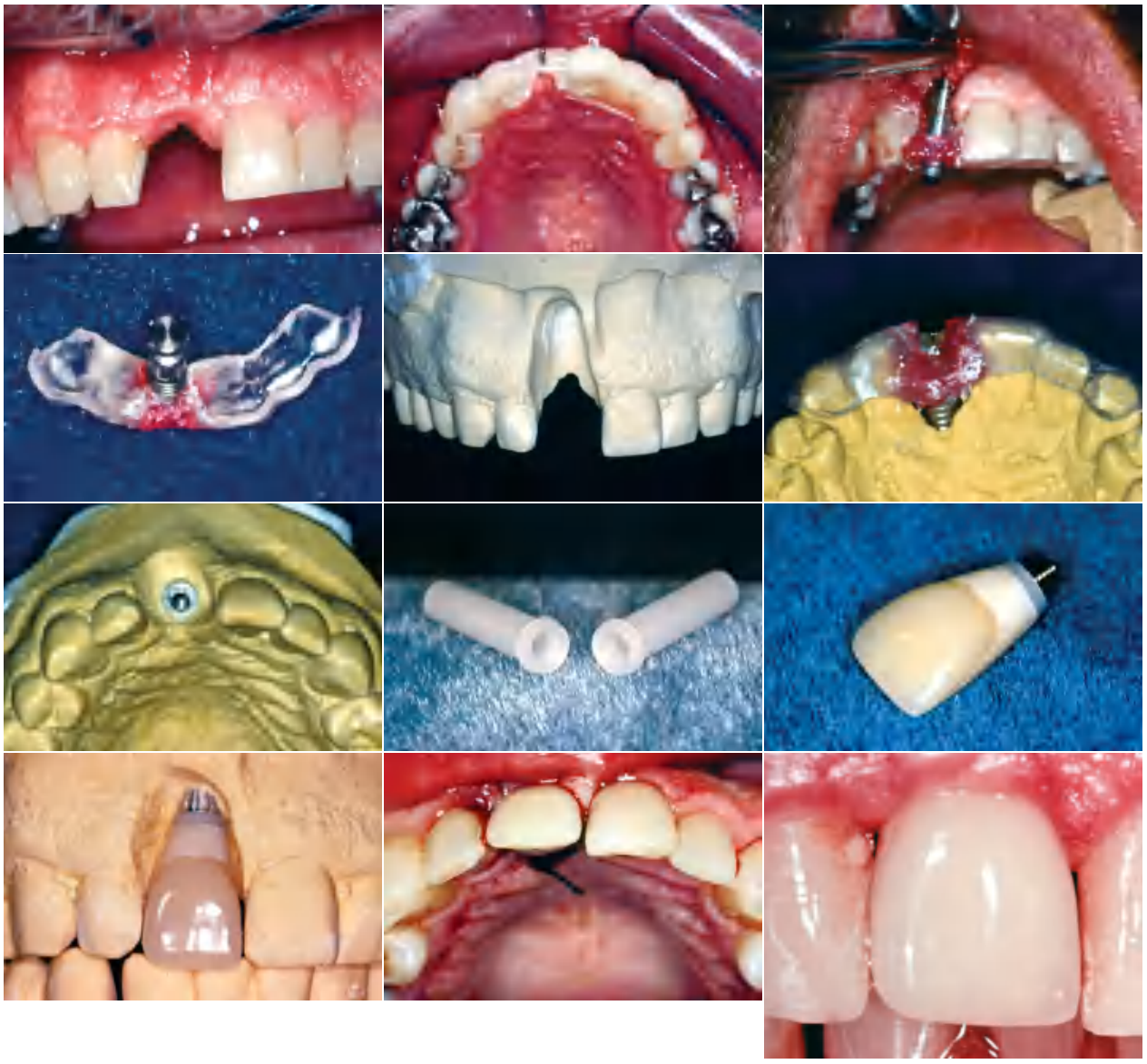


Fig. 13-47

Stage II interim restoration technique. **A,** View of missing maxillary right central incisor. **B,** Surgical template in position. **C,** Once the screw-shaped implant is in place, the fixture mount is luted to the surgical template with resin before it is unscrewed from the mouth. **D,** Analog attached to the fixture mount. **E,** Diagnostic stone cast prepared to position analog. **F,** Template placed back on diagnostic cast. **G,** Dental stone is flowed around the analog. The position of the analog is identical to the position of the implant in the mouth. **H** to **L,** A plastic sleeve is used for the fabrication of an interim restoration that can be delivered at stage II surgery.



Fig. 13-48
A to **D**, A metal-ceramic implant restoration may be indicated if adequate bone and soft tissue contours are available.

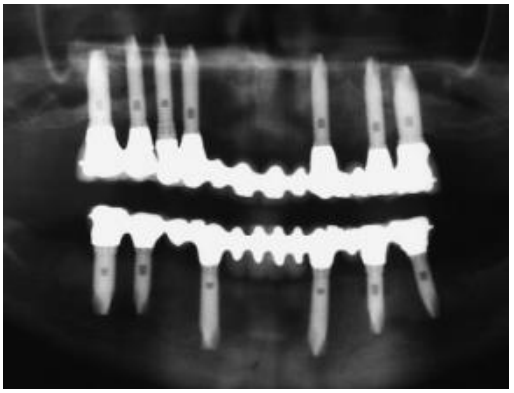


Fig. 13-49
Radiograph showing fixed restorations supported by seven implants in the maxilla and six in the mandible. Radiograph of patient in Fig. 13-48.



Fig. 13-50
Metal-resin restorations are the treatment of choice for edentulous patients with moderate bone resorption.

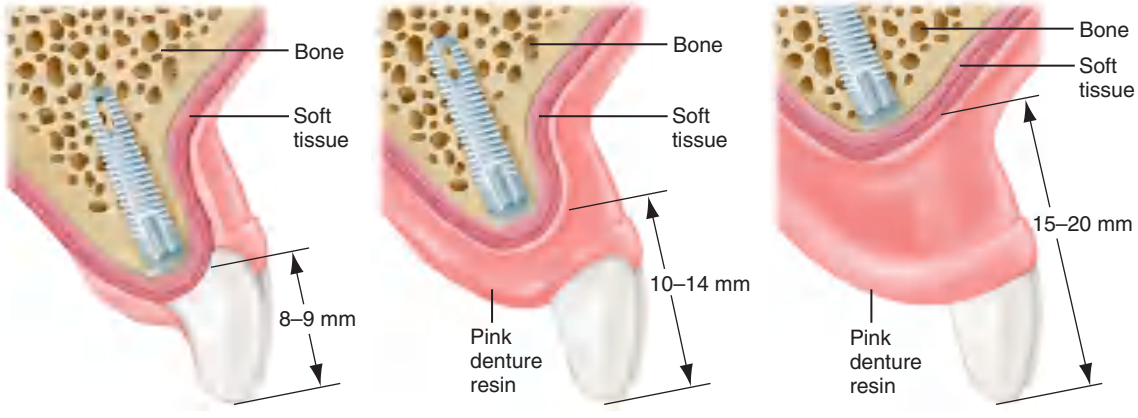


Fig. 13-51
The amount of bone resorption dictates the treatment options for an edentulous patient. **A,** Minimal resorption may allow metal-ceramic restorations. **B,** Moderate resorption may necessitate resin-to-metal restorations. **C,** Severe resorption necessitates only implant-supported overdentures for optimum esthetic results.

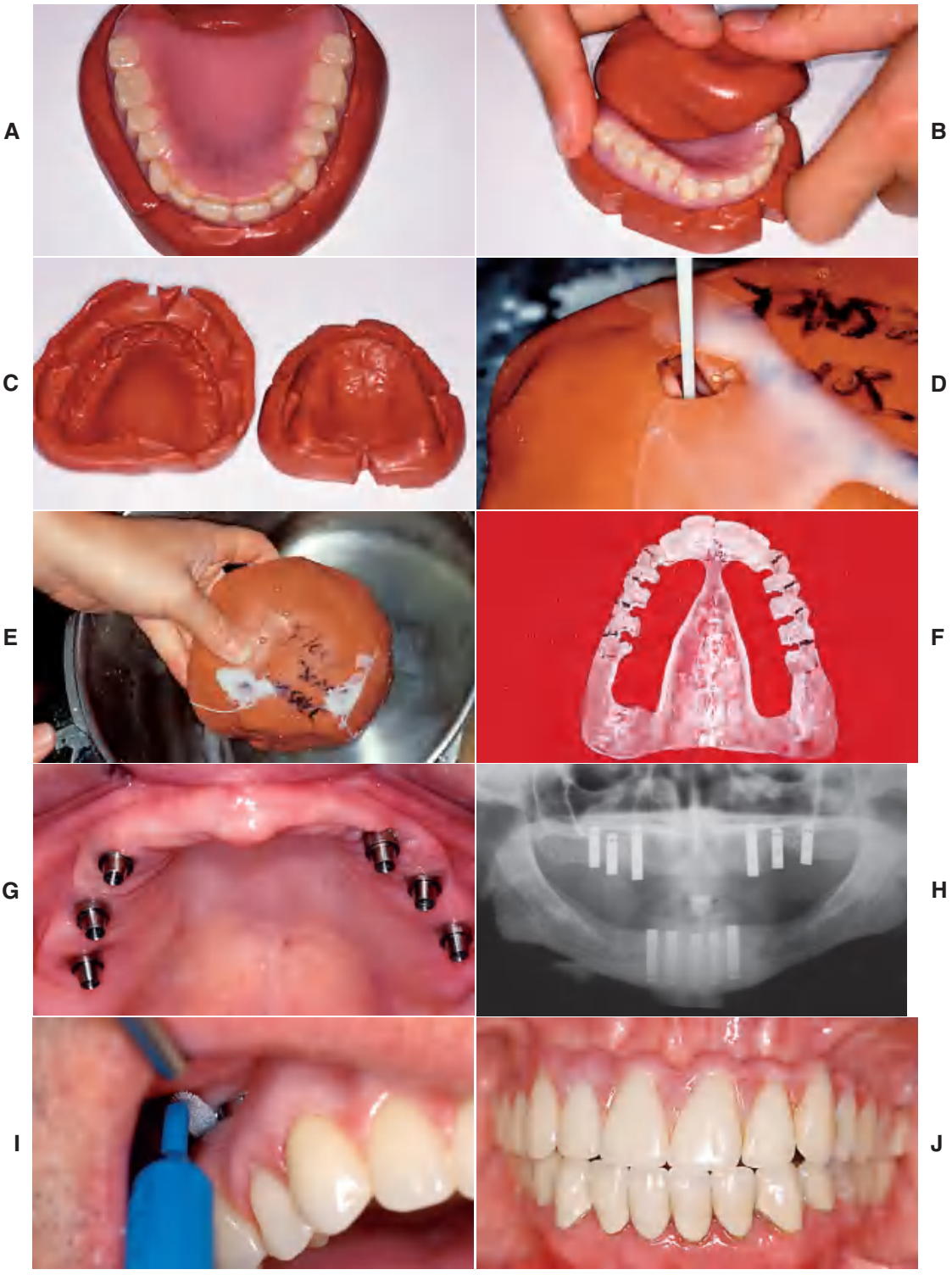


Fig. 13-52

Posterior implant placement for a maxillary complete arch prosthesis. A surgical template can be fabricated for an edentulous patient by duplicating the existing denture in clear resin. **A** to **C,** Putty impression material is used to form a mold of the fitting and polished surfaces of the denture, which is reassembled to form the mold. **D,** Clear autopolymerizing resin is poured into the mold and placed in a pressure pot (**E**). **F,** The lingual aspect of the template is removed, leaving the most facial 2 mm of resin intact. The surgeon will have access to the bone, but it will be confined to the arch form. **G,** The ideal positions for maxillary implants are the canine, second premolar, and second molar areas. **H,** Cross-arch implant parallelism is also important. **I,** Access for hygiene must be allowed around implant abutments. If implants are located posterior to the canine, access for hygiene can be created without compromising esthetics or phonetics. **J,** Reasonable esthetics and phonetics can be accomplished with a metal-resin restoration if modified ridge-lap pontics are used in the maxillary central and lateral incisor positions.

Cement-Retained versus Screw-Retained Implant Crowns

Cemented implant crowns can be luted to a screw-retained abutment. Zinc phosphate, glass ionomer, and composite resin cements have all been suggested for this purpose. However, retrievability of the implant restoration is ordinarily not considered when a permanent cement is used. The interim cements have been recommended because they allow restoration retrieval. However, unpredictability of the interim luting agents can lead to a difficult retrieval or premature displacement.[13]

Simplicity and, in some systems, economy are the major advantages of cement-retained restorations. In addition, cementing allows minor angle corrections to compensate for discrepancies between the implant inclination and the facial crown contour (Fig. 13-53). Resistance to rotation is particularly crucial with cemented prosthetics, and the abutment should then incorporate an antirotational feature. Very small teeth are most easily replaced with cement-retained implant crowns.

One misconception about cement-retained crowns is that they are simpler and have fewer screw-loosening episodes. They actually may require more chair time and have the same propensity to loosen as does a directly screw-retained restoration. They are, however, more esthetically pleasing and less expensive.

The screw-retained implant crown is fastened either to the abutment or directly to the implant. The main advantage of this restoration is its retrievability. Retrievability allows for crown removal, which can facilitate soft tissue evaluation, calculus débridement, and any other necessary modifications. In addition, future treatment considerations can be made more easily and are less costly if the implant restoration is retrievable. However, in screw-retained restorations, the access hole must be through the occlusal table of posterior teeth or the lingual surface of anterior teeth. Forces can then be directed in the long axis of the implant, and an optimum esthetic outcome is more easily achieved. This requirement dictates an ideal surgical location, which is not always possible because of anatomic limitations. A possible disadvantage of a screw-retained implant restoration is that the screw may loosen during function. Many techniques for retaining screw connection have been reported.[14] The direct mechanical interlock or antirotational feature appears to be the most effective.

If the screw is sufficiently tightened into the implant crown to seat it, a clamping load or preload is developed between the implant and the crown (Fig. 13-54). If this clamping force is greater than the forces trying to separate the joint between implant and crown, the screw will not loosen. A restoration screw should be tightened with sufficient force to

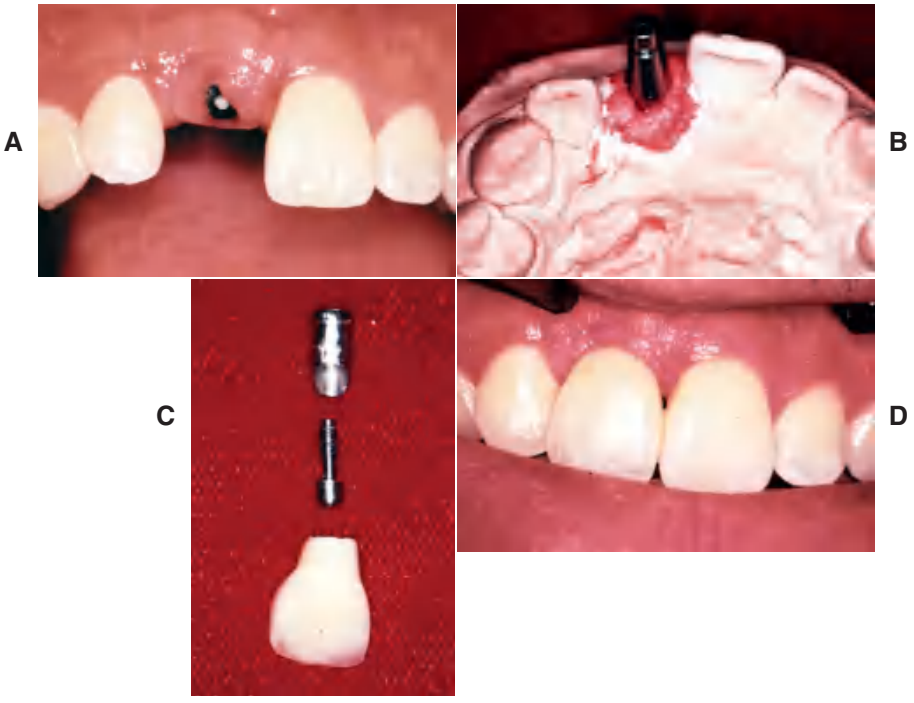


Fig. 13-53

A, Implant in position to replace the maxillary right central incisor. **B,** A laboratory cast demonstrates facial angulation of the implant. **C,** An angled abutment allows esthetic restoration (**D**). A cement retained restoration would be necessary to avoid a hole through the facial surface.

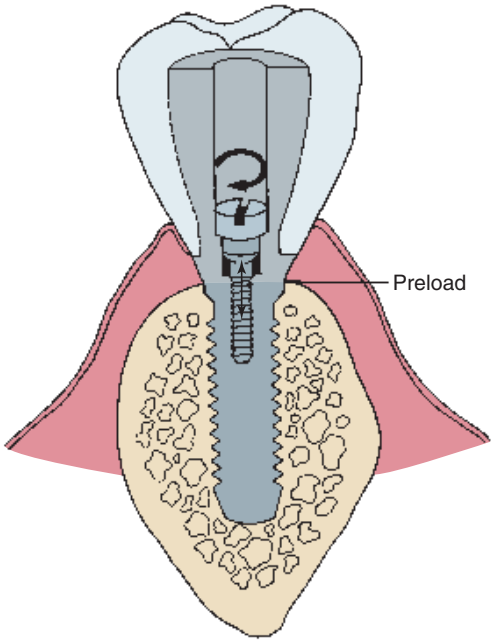


Fig. 13-54
Torque on the screw develops a preload (clamping force) between the implant and the crown.

Screw loosening can be a problem with implant prostheses.

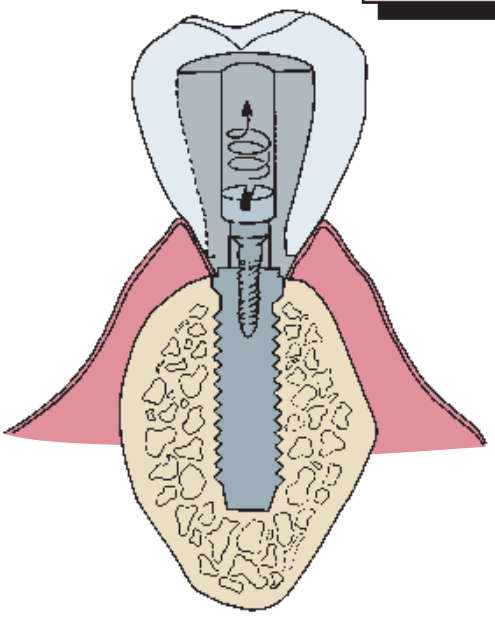


Fig. 13-55
The screw will loosen only if the joint-separating force is greater than the clamping force.

seat the crown, but not so much as to affect the bone-implant interface. Torque wrenches are available to achieve this. In addition, lateral forces (which tend to separate the joint) should be eliminated or reduced (Fig. 13-55 and BOX 13-4.)

BIOMECHANICAL FACTORS AFFECTING LONG-TERM IMPLANT SUCCESS

Occlusion

Bone resorption around dental implants can be caused by premature loading or repeated overloading. Vertical or angular bone loss is usually characteristic of bone resorption caused by occlusal trauma (BOX 13-5). When pressure from traumatic occlusion is concentrated, bone resorption occurs by osteoclastic activity. In the natural dentition, bone remodeling typically occurs once the severe stress concentration is reduced or eliminated. However, in the osseous integrated implant system, after bone resorbs, it usually does not re-form. Because dental implants most effectively resist forces directed primarily in their long axis, lateral forces on implants should be minimized.

Lateral forces in the posterior part of the mouth are greater and more destructive than lateral forces in the anterior part of the mouth. When they cannot be completely eliminated from the implant prosthesis, efforts should be made to distribute them equally over as many teeth as possible.

Implant restorations should be designed to minimize damaging forces at the implant-bone interface, with particular attention to the occlusion.[15] Flatter

Box 13-4 Loose Restoration Retaining Screws

Check for:
1. Excessive occlusal contacts not in the long axis of the implant body
2. Excessive cantilever contacts
3. Excessive lateral contacts
4. Excessive interproximal contacts
5. Inadequately tightened screws

Box 13-5 Occlusion on Implant-Supported Dental Prostheses

1. Direct forces in long axis of the implant body.
2. Minimize lateral forces on the implant.
3. Place lateral forces when necessary as far anterior in the arch as possible.
4. When it is impossible to minimize or move lateral forces anteriorly, distribute them over as many teeth and implants as possible.

A carefully designed occlusion is critical to implant success.

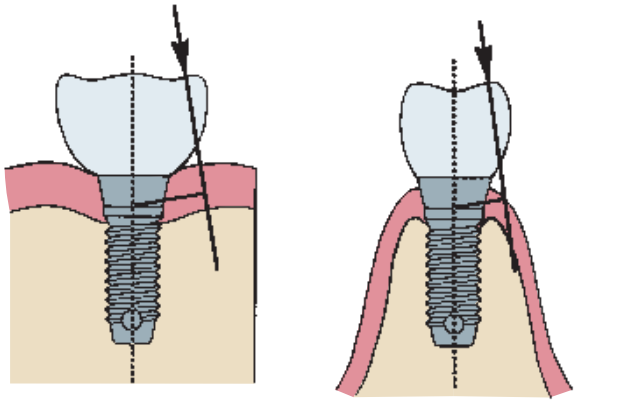


Fig. 13-56
Sharper cusp inclines and wider occlusal tables increase the resultant force on implant components.

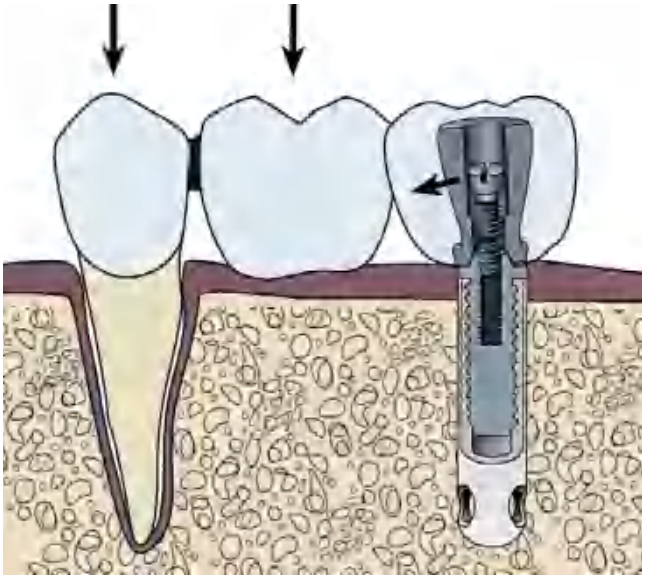


Fig. 13-57
When a single implant is attached to a natural tooth, biting forces on the natural tooth and pontic cause stress to be concentrated at the superior portion of the implant.

inclines can be developed on implant-supported cusps, creating more vertical resultant forces and a shorter moment arm (Fig. 13-56). Whenever possible, a cusp-fossa relationship should be established in maximum intercuspation with no eccentric occlusal contacts (see Chapter 18). The maxillary single-tooth restoration is vulnerable to screw loosening as a result of occlusal contacts, which usually produce an inclined resultant force with increased torque on the retaining screw. Optimum implant orientation effectively reduces these forces.

In general, the location and inclination of force should be seriously considered in the restorative phase of implant treatment. Divergent implant placement increases the moment arm through which force is transmitted to the bone-implant interface; this could exceed the threshold for bone resorption. Interchangeable components to alter implant angles have been produced by implant body manufacturers. However, it has been shown[16] that increasing abutment angles also produces increased stresses at the bone-implant interface. Angled abutments may solve immediate esthetic or contour problems while masking potential long-term consequences created by an implant placement that is poorly planned or dictated by the patient's anatomy.

Inadequate implant distribution may also lead to excessive cantilevers or forces that could potentiate overloading of implant bodies. Whenever possible, dental implants should be joined so that forces may be more equally distributed over multiple implants. Ideally, one implant for every tooth to be restored should be placed. This number is particularly important when shorter implants are placed in bone of poorer quality. When implants longer than 13 mm can be placed in dense bone, two for every three teeth being replaced are acceptable. Complete arch restorations should not be considered on fewer than six implants in the maxilla and five in the mandible. Implant cantilevers should be kept as short as possible. However, cantilevering considerable distances off five well-integrated fixtures in the anterior mandible is possible. Quite often, cantilevering to the first molar is possible. Equations based on the distribution and length of fixtures have been proposed.[17]

Connecting Implants to Natural Teeth

It has been suggested[18] that connecting a single osseous integrated implant to one natural tooth with a fixed dental prosthesis can create excessive forces because of the relative immobility of the osseous integrated implant in comparison with the functional mobility of a natural tooth. During function, the tooth moves within the limits of its periodontal ligament, which can create stress at the neck of the implant up to two times the implied load on the prosthesis (Fig. 13-57). Potential problems with this type of restoration include (1) breakdown of the osseous integration, (2) cement failure on the natural abutment, (3) screw or abutment loosening, and (4) failure of the implant prosthetic component. This situation is encountered clinically when the most pos-

terior abutment is lost in the dental arch and a fixed prosthesis is needed to connect a single implant to the natural tooth. If possible, a totally implant-supported fixed dental prosthesis with two or more implants should be provided. However, anatomic limitations of the maxillary sinus or the mandibular canal often limit restorative efforts directed at a single fixture site.

When connecting an implant to a natural tooth is necessary, multiple implant or natural tooth abutments should be used. A semiprecision attachment (keyway) in the prosthesis between the implant and the natural tooth may solve potential problems[18] (Fig. 13-58). However, under most circumstances, when a load is applied to the pontic, the additional movement at the attachment actually increases the cantilever effect on the implant abutment. In practice, the only advantage of a semiprecision attachment may be that it allows a screw-retained implant abutment crown to be removed for periodic evaluation.

When circumstances dictate use of a natural tooth abutment, a telescopic coping should be considered.



Fig. 13-58
A semiprecision attachment may compensate for vertical displacement forces in the tooth and an implant-supported fixed prosthesis. It does not compensate for forces in the buccolingual direction. *(Courtesy of Dr. G. Seal.)*

This is permanently cemented to the natural tooth and can prevent decay if loosening occurs. Interim cement is used to attach the prosthesis to the coping. If it leaches out of the implant crown, the natural tooth is still protected (Fig. 13-59).

Implant and Framework Fit

Pathogenic forces can be placed on an implant if the framework does not fit passively. When all the prosthesis-retaining screws are tightened, gaps between the abutment and a poorly fitting framework close, giving the appearance of an acceptable fit. However, significant compressive forces are placed on the interfacial bone, which can lead to implant failure. The fit of all implant frameworks should be checked with only one screw in place. No visible amounts of space or any amounts of movement with finger pressure should be discernible on any of the other implant abutments (Fig. 13-60). If a nonpassively fitting framework is identified, it should be sectioned and soldered and then reassessed for passive fit. A relation record should also be made.

CAD/CAM Abutments and Frameworks

Recent technology has made it possible to design virtual abutments and frameworks with nearly unlimited design options. By scanning the dental cast of the interim abutment (Fig. 13-61), some manufacturers can fabricate final ceramic or titanium abutments of any shape or angle with computer-assisted design/computer-assisted machining (CAD/CAM) technology. Interimplant titanium frameworks fabricated with this technology have been reported to fit more accurately and passively than those fabricated with standard casting technology.

A



B

Fig. 13-59
A, Maxillary abutments positioned to support a fixed prosthesis. **B,** Metal evaluation of maxillary rehabilitation with implant-supported abutments and telescopic copings.

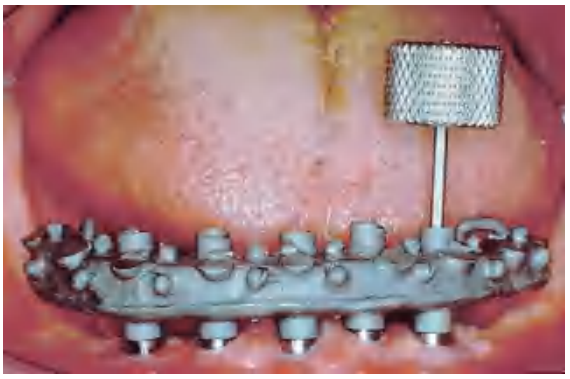


Fig. 13-60
Metal framework fit should be evaluated with only a single retaining screw tightened in place. Any detectable incomplete seating requires framework correction.



Fig. 13-61
A, Virtual implant-supported abutments designed on the computer screen. **B,** Titanium abutments fabricated through the use of computer-assisted design/computer-assisted machining (CAD/CAM) technology.

MAINTENANCE

The goal of implant maintenance is to eradicate microbial populations affecting the prosthesis. Although dental implants may be more resistant than natural teeth to the effects of bacterial plaque, this has yet to be definitively proved. Until more research is available, proper and timely home care measures for prolonging the lifetime of an implant are most effective. The clinician must ensure that the patient receives thorough instruction in maintenance techniques, including an initial session with the clinician. This should be reinforced by a training session with the dental hygienist during a recall visit. Recall visits should be scheduled at least every 3 months during the first year. The patient's oral hygiene should be evaluated and documented at a recall visit; reinstruction should be provided when necessary. Sulcular debridement must be performed with plastic or wooden scalers, because conventional instruments scratch the titanium. Implant abutments may be polished by rubber cups with a low-abrasive polishing paste or tin oxide.

At each recall appointment, implant mobility should be evaluated; any bleeding after probing should be examined. Framework fit and occlusion also must be checked. Attention to both biologic and biomechanical factors is important for the long-term success of dental implants.

COMPLICATIONS

Bone Loss

The primary complication with dental implant therapy is bone loss around the implant (Fig. 13-62). Any loss exceeding 0.2 mm per year is cause for concern. Multiple factors are associated with implant bone loss:

1. Inappropriate size and shape of the implant.
2. Inadequate number of implants or implant positioning.
3. Poor quality or inadequate amount of available bone.

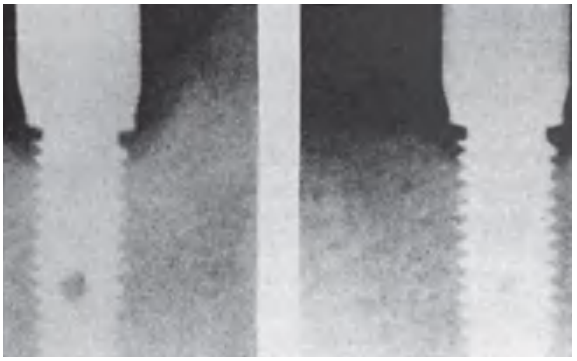


Fig. 13-62
To monitor implant bone loss, radiographs should be evaluated once a year. **A,** Post placement. **B,** One year follow-up.

4. Initial instability of the implant.
5. Compromised healing phase.
6. Inadequate fit of the prosthesis.
7. Improper design of the prosthesis (e.g., excessive cantilever, poor access for hygiene).
8. Excessive occlusal forces.
9. Deficient fit of abutment components (e.g., gaps that allow bacterial colonization).
10. Inadequate oral hygiene.
11. Systemic influence (e.g., tobacco use, diabetes).

The restorative dentist should pay particular attention to the fit of the prosthesis, the access for hygiene, and the presence of excessive occlusal forces. If bone loss reaches 25% to 30%, revision surgery should be considered.

Prosthetic Failure

Additional implant prosthetic complications include fracture of the implant components or of the prosthesis. Fracture of implant components is usually attributed to fatigue from biomechanical overload (Fig. 13-63). Failure of the implant prosthesis is usually traceable to less than ideal laboratory procedures or prosthesis design (Figs. 13-64 and 13-65).



Fig. 13-63
A and **B**, Fractured abutment and retaining screws on a metal-resin implant-supported prosthesis.

SUMMARY

Implant-supported prostheses, involving cylindrical osseous integrated fixtures placed by a two-stage surgical technique, should be considered in the treatment of any partially edentulous patient. They are a reliable solution to many situations that are difficult to treat by conventional measures: the patient who cannot wear removable appliances, the patient with a long edentulous span or other circumstance (e.g., short roots) that diminishes the prognosis for a fixed dental prosthesis, and the patient with a single missing tooth but sound adjacent teeth.

Success with **implant prosthodontics** requires the same attention to detail and careful planning as conventional fixed prosthodontics. Often a team approach is recommended, in which a surgeon places the implant and a restorative dentist designs the prosthesis. The crucial stage is optimum placement of the implant or implants. The surgeon's main concern is that it be well within the available bone and away from vital structures (e.g., the inferior



Fig. 13-64
Porcelain fracture on an implant prosthesis with inadequate metal support.



Fig. 13-65
Cantilever fracture on a metal-resin prosthesis. The prosthesis can be retrieved easily for a laser-welded repair.

STUDY QUESTIONS

1. Discuss the history and scientific basis for osseous integration.
2. Discuss the indications and contraindications for implant-supported fixed dental prostheses.
3. For planning treatment with the replacement of a congenitally missing lateral incisor by an implant restoration, describe the necessary minimum bone dimensions vertically, horizontally, and between roots. Also describe the guidelines used to position the implant in the appropriate anteroposterior and superoinferior location.
4. Describe the technique used to replicate the intraoral location of an implant on the laboratory cast.
5. List and describe the various types of abutments used for implant restorations. When is each type recommended? Why?
6. Describe some common problems with implant restorations and recommend methods to manage them.

dental canal). The restorative dentist's main concern is that the positioning and angulation of each fixture allow optimum occlusion, esthetics, and tissue health, as well as minimum stresses at the implant-bone interface. Information obtained from a clinical examination, radiographs, and a diagnostic waxing on articulated casts is crucial for planning. Surgery is guided by a template made from the diagnostic waxing.

Depending on the implant site, a two-stage surgical technique requires 3 to 6 months for bone to heal against the implant. In a second surgery, the implant is uncovered and implant abutments are screwed into place. Subsequently, a screw-retained prosthesis is fabricated to restore function and appearance.

Several implant systems are available, each with a variety of components for restorative management (e.g., an antirotational feature incorporated in an implant for single tooth replacement).

Problems unique to implant prosthodontics include screw loosening and bone loss from premature loading or repeated overloading. Occlusal considerations, prosthesis fit, plaque control, and follow-up care are all primary concerns to the professionals who deal with implants and conventionally supported prostheses.

GLOSSARY*

abutment analog *n* (2005): a replica of the superior portion of a dental implant. Usually used to provide an exact form of the dental implant abutment within the dental laboratory during fabrication of a prothesis supported in part or whole by the dental implant

abutment clamp \a-bŭt′ment klămp\ (1998): any device used for positioning a dental implant abutment upon the dental implant body

abutment driver *n* (2005): any hand instrument usually specifically made to assist in insertion and securing of a dental implant abutment to the superior portion of a dental implant

abutment healing cap *n* (2005): any temporary cover used to provide a seal over the superior portion of a dental implant; most such covers are metallic and are intended for interim usage following exposure of the dental implants superior surface

abutment post *n* (2005): that component of a dental implant abutment which extends into the internal structure of a dental implant and is used to provide retention and/or stability to the dental implant abutment

abutment screw *n* (1998): that component which secures the dental implant abutment to the dental implant body. See also ATTACHMENT SCREW

al·ve·o·lar \ăl-vē′a-ler\ *adj* (1799): that part of the jaws where the teeth arise

alveolar augmentation \ăl-vē′a-ler ôg′mĕn-tā′shun\: any surgical procedure employed to alter the contour of the residual alveolar ridge

an·a·log \ăn′a-lôg, -lŏg\ *n* (1826): **1:** in dentistry, something that is analogous in part or whole to something else; i.e., a replica of a portion of an implant abutment made of brass, aluminum, steel, or plastic **2:** an organ similar in function to an organ of another animal or plant but with different structure and origin—spelled also *analogue*

angulated abutment \ăng′gya-lāt′ĭd a-bŭt′ment\ (1998): any endosteal dental implant abutment which alters the long axis angulation between the dental implant and the angulated dental implant abutment—***syn*** ANGLED ABUTMENT

anti-rotation \ăn′tē-rō-tā′shun\ (1998): a structural feature of some endosteal dental implant components

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that prevents relative rotation of fastened parts. This feature may exist between a dental implant body and the dental implant abutment, and/or the dental implant abutment and dental implant abutment element(s)

attachment screw (1998): any component used to secure a fixed dental prosthesis to the dental implant abutment. See also ABUTMENT SCREW

aug·men·ta·tion \ôg′měn-tā′shun\ *n* (14c): to increase in size beyond the existing size. In alveolar ridge augmentation, bone grafts or alloplastic materials are used to increase the size of an atrophic alveolar ridge

basal bone \bā′sak bōn\: the osseous tissue of the mandible and maxillae exclusive of the alveolar process

basket endosteal dental implant \băs′kĭt ĕn′da-stēl′ dĕn′tl ĭm-plănt\: a perforated, cylindric, endosteal dental implant, the implant body of which is designed in the form of single, double, and/or triple contiguous cylinder(s)

can·cel·lous bone \kăn-sĕl′us, kăn′se-lus bōn\ (1836): the reticular, spongy or lattice-like portion of the bone; the spongy bone tissue located in the medulla of the bone; this bone is composed of a variable trabecular network containing interstitial tissue that may be hematopoietic

CAT: *acronym* for *Computerized Axial Tomography*

cephalometric radiograph \sĕf′a-lo-mĕt′rĭk rā′dē-ō-grăf′\: a standardized radiograph of the skull

clamping force: the compressive force which a fastener exerts on a bolted joint. The stability of a bolted joint depends upon the maintenance of the clamping force

computerized tomography \kom-pyōō′ta-rīzd tō-mŏg′ra-fē\: (CT) the technique by which multidirectional x-ray transmission data through a body is mathematically reconstructed by a computer to form an electrical cross-sectional representation of a patient's anatomy. CT is used as an acronym to designate any technical field associated with these techniques

cortical bone \kôr′tĭ-kal\: the peripheral layer of compact osseous tissue

dental implant \dĕn′tl ĭm-plănt\: 1. a prosthetic device made of alloplastic material(s) implanted into the oral tissues beneath the mucosal or/and periosteal layer, and on/or within the bone to provide retention and support for a fixed or removable dental prosthesis; a substance that is placed into or/and upon the jaw bone to support a fixed or removable dental prosthesis 2. the portion of an implant that provides support for the dental implant abutment(s) through adaptation upon (eposteal), within (endosteal), or through (transosteal) the bone—*usage:* although dental implants may be classified by their silhouette or geometrical form (i.e., fin, screw, cylinder, blade, basket, root form, etc.) generally dental implants are classified based on their anchorage component as it relates to the bone that provides support and stability. Thus, there are three basic types of dental implants: *eposteal* dental implants, *endosteal* dental implants, and *transosteal* dental implants. Some dental implants possess both eposteal and endosteal components (by design or subsequent anchorage change); the decision as to what anchorage system provides the most support at initial placement determines which category is used to best describe the dental implant; the dental implant(s) provide bony support via the dental implant attachment while the dental implant abutment(s) connect the dental implant to the dental prosthesis—see also DENTAL IMPLANT ABUTMENT, ENDOSTEAL DENTAL IMPLANT, EPOSTEAL DENTAL IMPLANT, TRANSOSTEAL DENTAL IMPLANT—*comp* MUCOSAL INSERT

dental implant abutment \ĭm′plănt′ a-bŭt′ment\: the portion of a dental implant that serves to support and/or retain any fixed or removable dental prosthesis—*usage:* frequently dental implant abutments, especially those used with endosteal dental implants, are changed to alter abutment design or use before a definitive dental prosthesis is fabricated. Such a preliminary abutment is termed an *interim (dental implant) abutment*. The abutment chosen to support the definitive prosthesis is termed a *definitive (dental implant) abutment*. Dental implant abutments frequently are described by their form (i.e., cylindrical, barrel), material (i.e., ceramic, titanium, zirconia ceramic), or special design factors (i.e., internal hex lock, external hex lock, spline)

dental implant attachment \ĭm′plănt′ a-tăch′ment\: 1. the biochemical/mechanical interconnection between the dental implant and the tissues to which it is attached 2. *slang* expression for the means of retention of the dental implant abutment to the dental implant

dental implant analog: a replica of the entire dental implant, not intended for human implantation

dental implant loading: the process of placing axial or tangential force on a dental implant usually associated with the intentional exposure of the dental implant either at the time of initial surgical placement of the dental implant or subsequent surgical exposure. Such forces may come from any of a variety of sources including intentional or/and unintentional occlusal loading, unintentional forces from the tongue or other oral tissues, food bolus, as well as alveolar/osseous deformation. Generally application of intentional occlusal forces may be termed *immediate loading, progressive loading,* or *delayed loading*—see AXIAL LOADING

dental implant system \ĭm′plănt sĭs′tem\ (1993): dental implant components that are designed to mate together.

An implant system can represent a specific concept, inventor, or patent. It consists of the necessary parts and instruments to complete the implant placement and abutment components

emergence angle \ĭ-mûr′jens ăng′gel\ (1993): the angle of the dental implants' transitional contour as determined by the relation of the surface of the abutment to the long axis of the implant body

endosteal dental implant \ĕn-dŏs′tē-l dĕn′tl ĭm-plănt′\: a device placed into the alveolar and/or basal bone of the mandible or maxilla and transecting only one cortical plate. The endosteal dental implant is composed of an anchorage component, termed the *endosteal dental implant,* which, ideally, is within the bone, and a retentive component, termed the *endosteal dental implant abutment.* The dental implant abutment connects to the dental implant (by means of screws, thread/screw interfacing, compression/luting agent etc. that can be termed *elements*), passes through the oral mucosa, and serves to support and/or retain the prosthesis (fixed dental prosthesis, removable dental prosthesis, maxillofacial prosthesis). The dental implant abutment may be for *interim* or *definitive* application–*usage:* interim abutment, definitive abutment. Descriptions of the dental implant or/and the dental implant abutment that use silhouette or geometric forms, such as cylinder, conical, pre-angled, angled, blade, basket, or endodontic, may be used as adjectives to enhance understanding of the geometry of any endosteal dental implant. Also, descriptive adjectives may be used to delineate the materials from which they are made, ie. a *ceramic* dental implant abutment. *Interim* or *definitive dental implant abutments* may be composed of one or more individual component parts, each of which is termed an *element.* The dental implant abutment element(s) usually is (are) described by means of their geometric form, function or means of adaptation, i.e., screw, coping, cylinder, lug, friction fitting, press-fit. Hence multiple adjectives may be used to describe both the endosteal dental implant and abutment.–see also BASKET E.D.I., BLADE E.D.I., DENTAL IMPLANT, ENDODONTIC E.D.I., EPOSTEAL D.I., SCREW E.D.I., TRANSOSTEAL D.I.

epithelial cuff \ĕp′a-thē′lē-al kŭf\: a term used to describe the relationship between the mucosal and the dental implant. The use of this term implies a close adherence, but not necessarily a biochemical attachment, between the implant and mucosa

first stage dental implant surgery \fûrst dĕn′tal ĭm-plănt sûr′ja-rē\: the initial surgical procedure in dental implant placement. For eposteal dental implants, this refers to the reflection of the oral mucosa, the impression made of the surgically exposed bone and usually an interocclusal record made to fabricate the implant body followed by surgical closure. For an endosteal implant, this refers to the reflection of the oral mucosa and investing tissues, preparation of the implantation site (i.e., removal of alveolar bone and, occasionally, tapping), placement of the dental implant body, and surgical closure of the overlying investing soft tissues–*comp* SECOND STAGE DENTAL IMPLANT SURGERY

[2]fix·ture \fĭks′chur\ *substand* (1982): an endosteal dental implant–see ENDOSTEAL DENTAL IMPLANT, DENTAL IMPLANT

fixture cover \fĭks′chur kŭv′er\ *substand* (1982): the component placed over a dental implant during the healing phase to prevent tissue from proliferating into the internal portion of the implant body–see COVER SCREW

healing screw \hē′lĭng skrōō\: the component of an endosteal dental implant system used to seal, usually on an interim basis, the dental implant body during the healing phase after surgical placement. The purpose of the healing screw is to maintain patency of the internal threaded section for subsequent attachment of the abutment during the second stage surgery

hybrid prosthesis \hī′brĭd prŏs-thē′sĭs\: *slang* for a nonspecific term applied to any prosthesis that does not follow conventional design. Frequently it is used to describe a dental prosthesis that is composed of different materials, types of denture teeth (porcelain, plastic, composite), variable acrylic denture resins, differing metals or design etc. It may refer to a fixed dental prostheses, removable dental prostheses, or maxillofacial prostheses.

[2]im·plant \ĭm-plănt′\ *n* (1809): any object or material, such as an alloplastic substance or other tissue, which is partially or completely inserted or grafted into the body for therapeutic, diagnostic, prosthetic, or experimental purposes–see DENTAL IMPLANT

implant prosthodontics \ĭm′plănt′ prŏs′tha-dŏn′tĭks\: the phase of prosthodontics concerning the replacement of missing teeth and/or associated structures by restorations that are attached to dental implants

implant substructure \ĭm′plănt′ sŭb′strŭk′chur\ *slang*: the metal *framework* of a eposteal dental implant that is embedded beneath the soft tissues, in contact with the bone, and stabilized by means of endosteal screws. The periosteal tissues retain the framework to the bone. The framework supports the prosthesis, frequently by means of dental implant abutments and other superstructure components

implant surgery \ĭm′plănt′ sûr′ja-rē\ (1993): the phase of implant dentistry concerning the selection, planning, and placement of the implant body and abutment

im·plan·tol·o·gy \ĭm′plăn-tŏl′a-gē\ *obs*: a term historically conceived as the study or science of placing and restoring dental implants—see IMPLANT DENTISTRY, IMPLANT SURGERY, IMPLANT PROSTHODONTICS

impression coping \ĭm-prĕsh′an kō′pĭng\ (1998): **1.** that component of a dental implant system used to provide a spatial relationship of an endosteal dental implant to the alveolar ridge and adjacent dentition or other structures. Impression copings can be retained in the impression or may require a transfer (termed an *impression transfer prodecure*) from intraoral usage to the impression after attaching the analog or replicas **2.** any device that registers the position of the dental implant or dental implant abutment relative to adjacent structures; most such devices are indexed to assure reproducible three dimensional location

mandibular nerve \măn-dĭb′ya-lar nûrv\: the third division of the trigeminal nerve that leaves the skull through the foremen ovale and provides motor innervation to the muscles of mastication, to the tensor veli palatini m., the tensor tympani m., the anterior belly of the digastric m., and the mylohyoid m. It also provides the general sensory innervation to the mandibular teeth and gingivae, the floor of the mouth, the epithelium of the anterior two thirds of the tongue, and the skin of the lower portion of the face

maxillary sinus \măk′sa-lĕr′ē sī′nas\: the anatomic space located superior to the posterior maxillary alveolus

os·se·ous \ŏs′ē-as\ *adj* (1707): bony

osseous integration \ŏs′ē-as ĭn′tĭ-grā′shun\ (1993): **1:** the apparent direct attachment or connection of osseous tissue to an inert, alloplastic material without intervening connective tissue **2:** the process and resultant apparent direct connection of an exogenous material's surface and the host bone tissues, without intervening fibrous connective tissue present **3:** the interface between alloplastic materials and bone

peri-implantitis \pĕr′ĭ-ĭm-plăn-tī′tĭs\ *substand*: in periodontics, a term used to describe inflammation around a dental implant, usually the dental implant abutment; *editorial note*: suggested terminology includes *gingivitis, acute gingivitis, chronic gingivitis* since the dental implant abutment does not exhibit inflammation

progressive loading \pra-grĕs′ĭv lō′dĭng\ (1998): the gradual increase in the application of force on a dental implant whether intentionally done with a prosthesis or unintentionally via forces placed by adjacent anatomic structures or parafunctional loading

root fracture \rōōt frăk′chur\: a microscopic or macroscopic cleavage of the root in any direction

rouge \rōōzh\ *n* (1753): a compound composed of ferric oxide and binders used for imparting a high luster to a polished surface, glass, metal, or gems

screw endosteal dental implant \skrōō ĭn-dŏs-tē-al dĕn′tl ĭm-plănt′\: **1:** any dental implant whose configuration resembles a screw **2:** any screw-shaped dental implant; it may be hollow or solid, and usually consists of the dental implant abutment and the dental implant

second stage dental implant surgery \sĕk′and stăj dĕn′tl ĭm-plănt sûr′ja-rē\: **1:** for eposteal dental implant surgery, the term refers to the procedure involving placement of the eposteal framework fabricated after the first stage implant surgery **2:** for endosteal dental implant surgery, after surgical reflection, the occlusal aspect of the dental implant is exposed, the cover screw is removed, and either the interim or definitive dental implant abutment is placed. After this, the investing tissues are (when needed) sutured

su·per·struc·ture \sōō′par-strŭk′chur\ *n*: the superior part of a multiple layer prosthesis that includes the replacement teeth and associated structures

surgical splint \sûr′jĭ-kal splĭnt\: any supplementary prosthesis designed to utilize existing teeth and/or alveolar processes as points of anchorage to assist in stabilization and immobilization of broken bones during healing. It is used to re-establish, as much as possible, normal occlusal relationships, during the process of immobilization. Frequently, existing prostheses (i.e. a patient's complete dentures) can be modified to serve as a surgical splint. Frequently surgical splints have arch bars added to facilitate intermaxillary fixation. Rubber elastics may be used to assist in this process. Circummandibular eyelet hooks can be utilized for enhanced stabilization with wiring to adjacent bone—***syn*** CAST METAL SPLINT, FENESTRATED SPLINT, GUNNING SPLINT, KINGSLEY SPLINT, LABIOLINGUAL SPLINT, MODIFIED GUNNING SPLINT

surgical template \sûr′jĭ-kal tĕm′plĭt\: **1:** a thin, transparent form duplicating the tissue surface of a dental prosthesis and used as a guide for surgically shaping the alveolar process **2:** a guide used to assist in proper surgical placement and angulation of dental implants **3:** a guide used to assist in establishing the desired occlusion during orthognathic surgery

transfer coping \trăns-fûr′, trăns′fur kō′pĭng\: a metallic, acrylic resin, or other covering or cap used to position a die in an impression

transosteal dental implant \trăns′ŏs-tē-al dĕn′tl ĭm-plănt′\: **1:** a dental implant that penetrates both cortical plates and passes through the full thickness of the alveolar bone **2:** a dental implant composed of a metal

plate with retentive pins to hold it against the inferior border of the mandible that supports transosteal pins that penetrate through the full thickness of the mandible and pass into the mouth in the parasymphyseal region—called also *staple bone implant, mandibular staple implant, transmandibular implant*

REFERENCES

1. NIH Consensus Development Conference: Statement on dental implants. J Dent Educ 52:824, 1988.
2. Adell R, et al: A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 10:387, 1981.
3. Kent J, et al: Biointegrated hydroxlapatite-coated dental implants: 5-year clinical observations. J Am Dent Assoc 121:138, 1990.
4. Lazzara RJ, et al: A prospective multicenter study evaluating loading of osseotite implants two months after placement: one-year results. J Esthet Dent 10:280, 1998.
5. Buser D, et al: Removal torque values of titanium implants in the maxillofacial of miniature pigs. Int J Oral Maxillofac Implant 13:611, 1998.
6. Smithloff M, Fritz ME: Use of blade implants in a selected population of partially edentulous patients. J Periodontol 53:413, 1982.
7. Kapur KK: VA cooperative dental implant study: comparisons between fixed partial dentures supported by blade-vent implants and removable partial dentures. II. Comparisons of success rates and periodontal health between two treatment modalities. J Prosthet Dent 62:685, 1989.
8. Smith D, Zarb GA: Criteria for success for osseointegrated endosseous implants. J Prosthet Dent 62:567, 1989.
9. Tarnow D, et al: Vertical distance from the crest of bone to the height of the interproximal papilla between adjacent implants. J Periodontol 74:1785, 2003.
10. Elian N, et al: Realities and limitations in the management of the interdental papilla between implants: three case reports. Pract Proced Aesthet Dent 15:737, 2003.
11. McGlumphy EA, Larsen PE: Contemporary implant dentistry. In Peterson LJ, et al, eds: Contemporary Oral and Maxillofacial Surgery, 4th ed, pp 305. St. Louis, Mosby, 2003.
12. Hobo S, et al, eds: Osseointegration and Occlusal Rehabilitation. Tokyo, Quintessence Publishing, 1990.
13. Chiche GI, Pinault A: Considerations for fabrication of implant-supported posterior restorations. Int J Prosthod 4:37, 1991.
14. Hurson S: Laboratory techniques to prevent screw loosening on dental implants. J Dent Technol 13(3):30, 1996.
15. Weinberg LA: The biomechanics of force distribution in implant-supported prostheses. Int J Oral Maxillofac Implants 8:19, 1993.
16. Clelland N, Gilat A: The effect of abutment angulation on the stress transfer for an implant. J Prosthod 1:24, 1992.
17. Takayama H: Biomechanical considerations on osseointegrated implants. In Hobo S, et al, eds: Osseointegrated and Occlusal Rehabilitation, pp 265. Tokyo, Quintessence Publishing, 1990.
18. Sullivan D: Prosthetic considerations for the utilization of osseointegrated fixtures in the partially edentulous arch. Int J Oral Maxillofac Implant 1:39, 1986.

14



TISSUE MANAGEMENT AND IMPRESSION MAKING

KEY TERMS

accelerator
addition silicone
condensation silicone
dimensional stability
elastomer
hydrocolloid
impression
impression material
impression technique
impression tray
ischemia
monomer
polyether
polysulfide
reversible hydrocolloid
tissue displacement

Because it is neither possible nor desirable to make patterns for fixed prostheses directly in the mouth, an **impression,** or negative likeness of the teeth and surrounding structures, is necessary to obtain a cast. This cast is then used to make a restoration in the laboratory. To obtain the cast, an elastic **impression material** is mixed and loaded in a tray that is inserted into the patient's mouth. When the material has set, it remains elastic; the impression is then poured into the "negative" impression, and a positive likeness or definitive cast is obtained.

An acceptable impression must be an exact record of all aspects of the prepared tooth. This means it must include sufficient unprepared tooth structure immediately adjacent to the margins for the dentist and laboratory technician to identify the contour of the tooth and all prepared surfaces. The contour of the unprepared tooth structure cervical to the preparation margin is crucial information that must be available when the restoration is fabricated in the dental laboratory. If the impression does not reproduce this critical area where tooth and future restoration meet, fabricating the restoration with proper contours is not possible (barring some lucky guesswork).

All teeth in the arch and the soft tissues immediately surrounding the tooth preparation must also be reproduced in the impression. They allow the cast to be accurately articulated and contribute to proper contouring of the planned restoration. Particular attention is given to reproducing the lingual surfaces of anterior teeth because they influence anterior guidance, which determines the occlusal structure of the posterior teeth (see Chapter 4). The impression must be free of air bubbles, tears, thin spots, and other imperfections that might produce inaccuracies.

The patient's mouth is a challenging environment in which to make an accurate impression. Moisture

control is probably one of the most important aspects of successful impression making. Except for the **polyethers,** all elastomeric impression materials are hydrophobic[1] (i.e., they do not tolerate or displace moisture). Any moisture results in voids. Consequently, saliva flow into the area must be reduced and diverted to obtain the necessary dry field of operation. Any bleeding must also be controlled in order to obtain a successful impression.

When the preparation margins extend subgingivally, the adjacent gingival tissues must be displaced laterally to allow access and to provide space for adequate impression material thickness. This may require enlarging the gingival sulcus through mechanical, chemical, or surgical means and must be done without jeopardizing periodontal health. Improper manipulation of impression material and poor **tissue displacement** technique can lead to permanent soft tissue damage.

PREREQUISITES

Tissue Health

After the teeth are prepared and an interim restoration has been made (see Chapter 15), the health of the surrounding soft tissues must be reevaluated. Careful preparation results in minimal tissue damage; however, if a subgingival margin is needed, some tissue trauma in the sulcular area may be unavoidable. The effects of this trauma can be transient as long as the patient receives a properly made interim restoration and maintains adequate oral hygiene. However, if the interim restoration is poorly contoured, is not polished, or has defective margins, plaque retention will lead to a localized inflammatory response. The combination of such tissue trauma in the presence of preexisting periodontal disease can produce disastrous results. Periodontal disease must be treated and resolved before fixed prostheses are placed.

On occasion, a defective restoration contributes to greater plaque accumulation[2] and an inflammatory sulcular response (Fig. 14-1). If this is the case, a properly adapted and well-contoured polished interim restoration must be fabricated and cemented on the prepared teeth; the focus must shift from the teeth to the soft tissues, which must be returned to a state of optimum health before impression making is even considered.

Saliva Control

Depending on the location of the preparations in the dental arch, several techniques can be used to create



Fig. 14-1
Compromised embrasure form (**A**) and excessive contours (**B**) have contributed to the inflammatory response and recession of the gingival tissue.

the necessary dry field of operation (Fig. 14-2). In areas where only supragingival margins are present, moisture control with a rubber dam is probably the most effective method. In most instances, however, a rubber dam cannot be used, and absorbent cotton rolls must be placed at the source of the saliva; an evacuator must be placed where the saliva pools. In the maxillary arch, placing a single cotton roll in the vestibule immediately buccal to the preparation and a saliva evacuator in the opposing lingual sulcus is usually sufficient. When work is being done on a maxillary second or third molar, multiple cotton rolls must sometimes be placed immediately buccal to the preparation and slightly anterior to block off the parotid duct, which opens just anterior to the maxillary first molar. If a maxillary roll does not stay in position but slips down, it can be retained with a finger or the mouth mirror. When a mandibular impression is made, placement of additional cotton rolls to block off the sublingual and submandibular salivary ducts is usually necessary. Rolls on the buccal and lingual sides of the prepared teeth help with soft tissue retraction: the cotton on the buccal side displaces the cheek laterally, and the cotton on the lingual side displaces the tongue medially. One or two cotton rolls placed vertically between the hor-

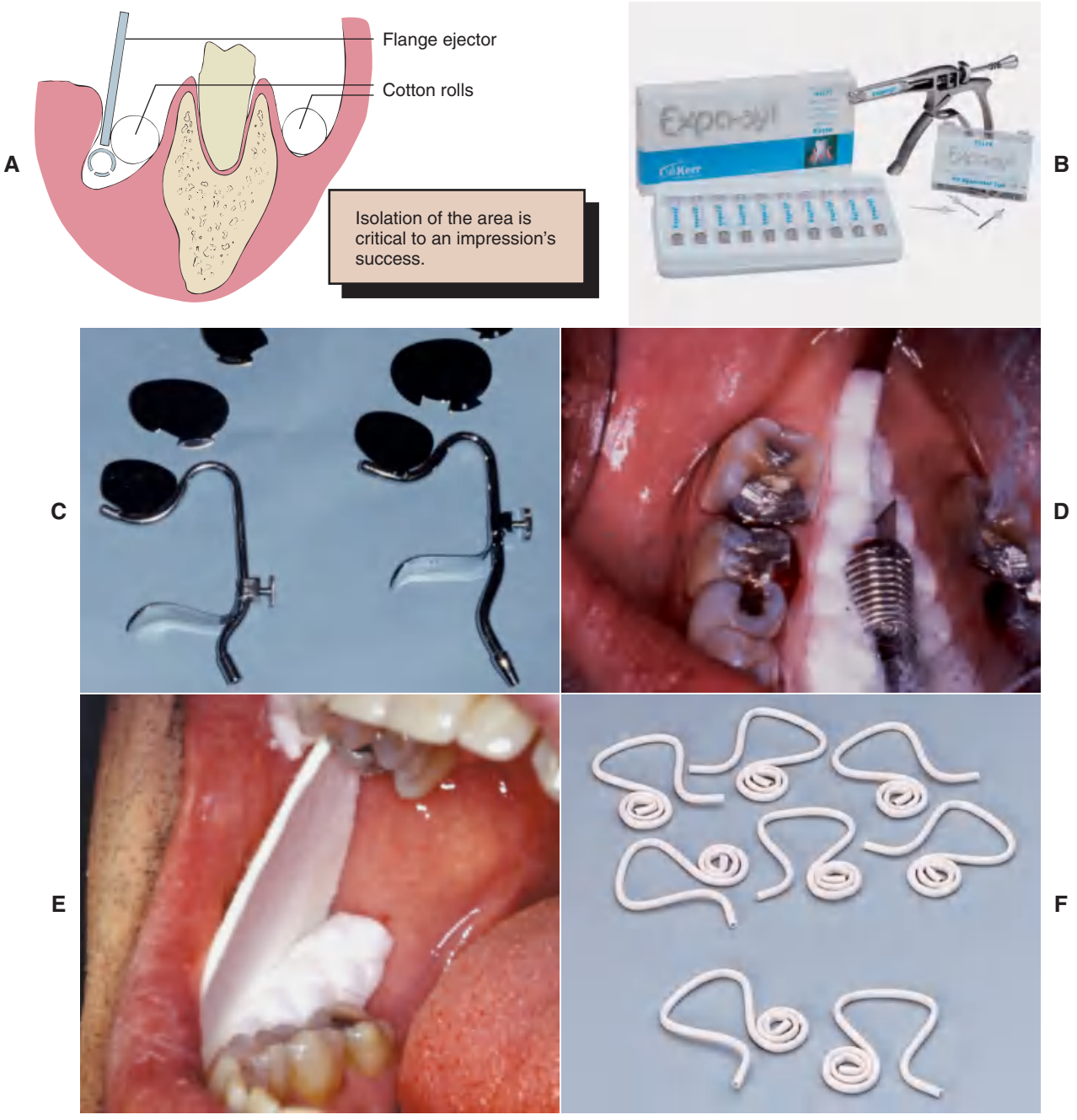


Fig. 14-2

Saliva control for impression making. A, When correctly placed, maxillary cotton rolls block salivary flow from the parotid gland. The evacuator removes saliva from the floor of the mouth, keeping the prepared tooth dry while the flange displaces the tongue medially. B, Expa-syl is a paste used for gingival retraction that opens the sulcus, physically displacing the tissue and leaving the field dry, ready for impression taking or cementation. C, Svedopter (*left*) and Speejector (*right*) saliva evacuators. D, Placement of the Svedopter with cotton rolls. E, An absorbent card. F, The disposable Hygoformic aspirator system. *(**B,** Courtesy of Kerr Dentistry, Orange, California; **F,** courtesy of Sullivan–Schein Dental, West Allis, Wisconsin.)*

izontally placed cotton rolls in the buccal vestibules help maintain the latter in position.

An alternative to multiple cotton rolls is placement of one long roll "horseshoe fashion" in the maxillary and mandibular mucobuccal folds. However, when part of the cotton is saturated, the entire roll must be replaced. The use of moisture-absorbing cards (see Fig. 14-2*E*) is another method for controlling saliva flow. These cards are pressed-paper wafers that may be covered with a reflective

foil on one side. The paper side is placed against the dried buccal tissue and adheres to it. In addition, two cotton rolls should be placed in the maxillary and mandibular vestibules to control saliva and displace the cheek laterally.

The tongue can cause problems when work is being done in the mandibular arch. Saliva evacuators may help eliminate excess flow, but most of these are easily displaced by a "probing" tongue. If lingually placed cotton rolls continually become dislodged or, in conjunction with a conventional saliva evacuator, fail to control moisture adequately, a flange-type evacuator (e.g., the Svedopter* or the Speejector†) should be considered (see Fig. 14-2*C*). To avoid the risk of soft tissue trauma, this device must be placed carefully. A cotton roll between the blade and the mylohyoid ridge of the alveolar process minimizes intraoral patient discomfort. Simultaneously, if properly positioned, the cotton roll provides a "stop" that prevents the flange from being displaced farther buccally and thereby allows excellent lingual access to mandibular posterior teeth. Care must be taken not to tighten the chin clamp excessively, because considerable discomfort can result from pressure to the floor of the mouth. A disposable saliva ejector designed to displace the tongue may also be effective (see Fig. 14-2*F*).

In addition to the pain control normally needed during tissue displacement, local anesthesia may help considerably with saliva control during impression making. Nerve impulses from the periodontal ligament form part of the mechanism that regulates saliva flow; when these are blocked by the anesthetic, saliva production is considerably reduced.

When saliva control is especially difficult, a medication with antisialagogic action may be considered (Table 14-1). Dry mouth is a side effect of certain anticholinergics[3,4] (drugs that inhibit parasympathetic innervation and thereby reduce secretions, including saliva). This group of drugs includes atropine, dicyclomine, and propantheline. Anticholinergics should be prescribed with caution in older adults and should not be used in any patient with heart disease. They are also contraindicated in individuals with glaucoma, because they can cause permanent blindness. The incidence of undiagnosed glaucoma in the general population is high, and some physicians recommend that all patients be evaluated ophthalmologically before anticholinergics are used.

Clonidine,[5] an antihypertensive drug, has successfully reduced salivary output. It is considered safer than anticholinergics and has no specified contraindications. However, it should be used cautiously in patients who take hypertension medication. In a clinical trial,[6] 0.2 mg of clonidine reduced salivary flow as effectively as 50 mg of methantheline.

*E. C. Moore Company, Dearborn, Michigan.
†Pulpdental Corporation of American, Brookline, Massachusetts.



Fig. 14-3
Cord has been placed intrasulcularly as close to the level of the prepared margin as possible to displace tissue laterally.

Table **14-1** **MEDICATIONS WITH ANTISIALAGOGIC EFFECT***

Brand name	Active ingredient	Dosage
Pro-Banthine	Propantheline bromide	7.5-15 mg
Robinul (Robinul Forte)	Glycopyrrolate	1-2 mg
Sal-Tropine	Atropine sulfate	0.4 mg
Antipas, Bentyl	Dicyclomine HCl	10-20 mg

*Given 30-60 minutes before drying effect is required. (Individual dosage should be adjusted in keeping with most recent guidelines.)

Displacement of Gingival Tissues

Tissue displacement is commonly needed to obtain adequate access to the prepared tooth to expose all necessary surfaces, both prepared and not prepared. This can be achieved by mechanical, chemical, or surgical means.

Mechanical displacement is most effectively achieved by placement of a cord (Fig. 14-3) (generally impregnated with a chemical agent). Alternatively, paste systems can be used, often in conjunction with directed pressure. Chemicals such as aluminum sulfate or epinephrine cause localized



Fig. 14-4
Hemostatic agents.

soft tissue shrinkage. Surgical tissue removal can be accomplished through curettage, excision with a scalpel, or electrosurgery.

Displacement cord

Some enlargement of the gingival sulcus can be obtained by placing a nonimpregnated cord and leaving it in place for a sufficient length of time. The cord is pushed into the sulcus and mechanically stretches the circumferential periodontal fibers. Placement is often easier if a braided cord (e.g., GingiBraid)* or a knitted cord (e.g., Ultrapak†) is used. However, larger sizes of braided cord should be avoided because they have a tendency to "double up" and can become too thick for atraumatic intrasulcular placement. In areas where very narrow sulci preclude placement of the smaller sizes of twisted or braided cord, wool-like cords that can be flattened are preferable for initial displacement of tissue.

Better sulcus enlargement can be achieved with a chemically impregnated cord or by dipping the cord in an astringent (e.g., Hemodent‡). These materials (Fig. 14-4) contain aluminum or iron salts and cause a transient **ischemia,** shrinking the gingival tissue. Cords with metal filament reinforcement have been developed to help maintain their intrasulcular position.

Even so, the sulcus closes quickly (less than 30 seconds) after the cord is removed; therefore, the impression must be taken immediately.[7] In addition, medicaments help control seepage of gingival fluid. Aluminum chloride ($AlCl_3$) and ferric sulfate [$Fe_2(SO_4)_3$] are suitable because they cause minimal tissue damage. As an alternative, a sympathomimetic amine-containing eye wash§ or nasal decongestant¶ has been shown to be effective.[8]

Many of the chemicals used for their astringent effect are stable only at narrow ranges of low pH levels. Table 14-2 shows the mean pH of some commonly used materials. The low pH levels have raised concern about the effect of acidic solutions on tooth structure and, perhaps of more importance, on the smear layer.[9,10] Figure 14-5 represents scanning electron micrographs of dentin after various durations of exposure to a commonly used ferric sulfate solution. Contact between the astringent and the prepared tooth surfaces must be minimized if the smear layer is to be maintained. A nonacidic hemostatic agent can be used as an alternative.

Several displacement cords preimpregnated with epinephrine are available commercially. Epinephrine should be used with caution, because it may cause tachycardia,[11] particularly if it is placed on lacerated tissue. Dosage control is also a potential problem. In one study,[12] clinicians were unable to detect any advantages of using gingival retraction cords that were impregnated with epinephrine.

A 1999 survey determined that 54% of prosthodontists prefer use of buffered $AlCl_3$ to soak displacement cord, whereas more than 35% routinely use ferric sulfate or aluminum.[13] The same researchers reported use of a double-cord technique in almost half of the clinical situations. With this technique, a thin cord is placed without overlap at the bottom of the gingival crevice. A second cord is placed on top to achieve lateral tissue displacement. The latter is removed immediately before impression making, whereas the initial cord is left in place to help minimize seepage.

Step-by-step procedure

1. Isolate the prepared teeth with cotton rolls, place saliva evacuators as required, and dry the field with air.
2. Cut a length of cord sufficient to encircle the tooth (Fig. 14-6*A* and *B*). Do not excessively desiccate the tooth, because this may lead to postoperative sensitivity.
3. Dip the cord in astringent solution and squeeze out the excess with a gauze square. An impregnated cord can be placed dry but should be moistened in situ to prevent the thin sulcular epithelium from sticking to it and tearing when it is removed.

*Van R Dental Products, Inc., Los Angeles, California.
†Ultradent Products, Inc., Salt Lake City, Utah.
‡ESPE-Premier, Norristown, Pennsylvania.
§Tetrahydrozoline HCl (Visine), 0.05%.
¶Oxymetazoline (Afrin), 0.05%.

Table **14-2 ACIDITY OF COMMONLY USED HEMOSTATIC AGENTS**

Agent	Manufacturer	Active ingredient	Vehicle	Mean pH
Astringedent	Ultradent	15.5% $Fe_2(SO_4)_3$	Aqueous	0.7
Gingi-Aid	Gingi-Pak	Buffered 25% $AlCl_3$	Aqueous	1.9
Styptin	Van R	20% $AlCl_3$	Glycol	1.3
Hemodent	Premier	21.3% $AlCl_3$-6-hydrate	Glycol (aqueous)	1.2
Hemogin-L	Van R	$AlCl_3$	Aqueous	0.9
Orostat 8%	Gingi-Pak	8% Racemic epinephrine HCl	Aqueous	2.0
ViscoStat	Ultradent	20% $Fe_2(SO_4)_3$	Aqueous	1.6
Aluminum chloride 25%	USP	25% $AlCl_3$	Aqueous	1.1
Stasis	Gingi-Pak	Basic $Fe_2(SO_4)_3$	Aqueous	0.8
For comparison: Ketac Conditioner	3M-ESPE	25% Polyacrylic acid	Aqueous	1.7

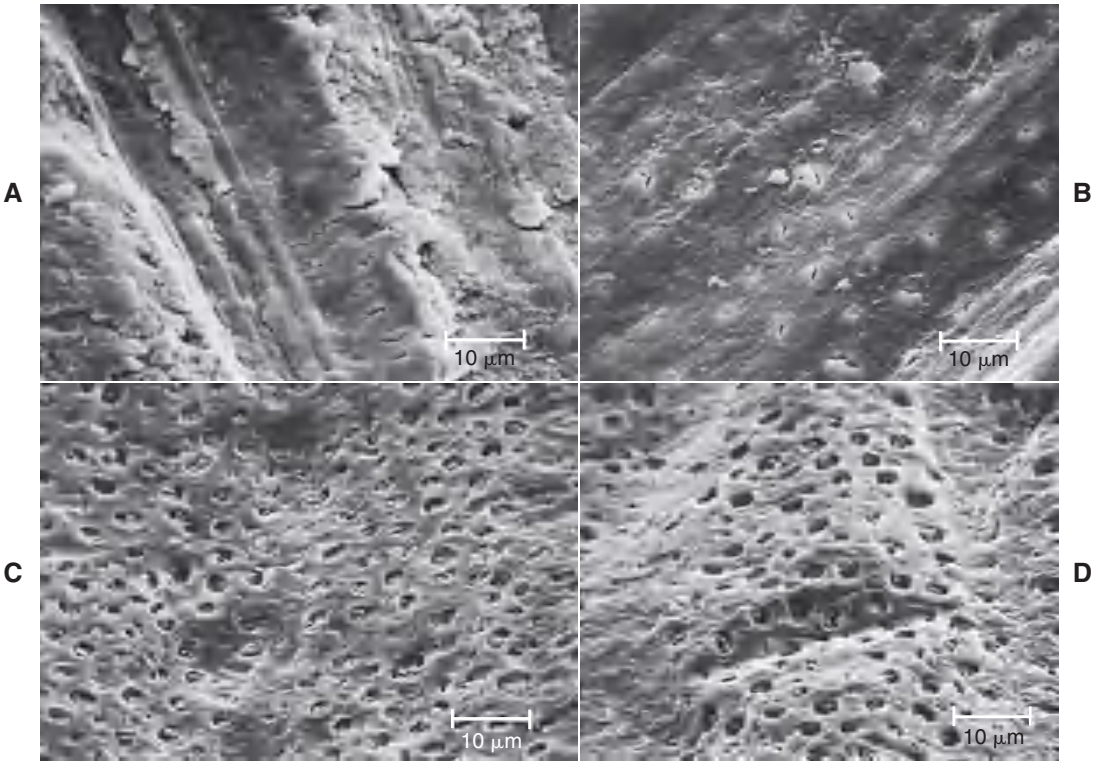


Fig. 14-5

Disturbance of the dentinal smear layer after contact with hemostatic agents. **A,** Dentin surface prepared with a high-speed, fine-grit diamond. **B,** After exposure to 15.5% $Fe_2(SO_4)_3$ solution for 30 seconds. The smear layer is largely removed, but many dentinal tubules are still occluded. **C,** After 2 minutes of exposure. Now the smear layer is totally removed, although the peritubular dentin appears to be largely intact. **D,** After 5 minutes of exposure. Now the dentin is etched, and peritubular dentin has been largely removed. *(From Land MF, et al: Disturbance of the dentinal smear layer by acidic hemostatic agents. J Prosthet Dent 72:4, 1994.)*



Fig. 14-6

A, Cutting a section of cord of adequate length to surround the tooth. **B,** Various examples of retraction cord. **C,** Most cord-packing instruments have a slightly rounded tip with serrations to hold the cord while it is positioned intrasulcularly. **D,** Initial proximal cord placement. **E,** An additional cord-packing instrument prevents the cord from dislodging.

4. If a nonbraided cord is used, twist it tightly for easier placement.
5. Loop the cord around the tooth, and gently push it into the sulcus with a suitable instrument (Fig. 14-6*C*).

It is best to start in the interproximal area (Fig. 14-6*D*), because the cord can be placed more easily there than facially or lingually. The instrument should be angled toward the tooth so the cord is pushed directly into the sulcus. It should also be angled slightly toward any cord already packed; otherwise, that might be displaced. A second instrument (Fig. 14-6*E*) may aid placement.

Tissue must be displaced gently but with sufficient firmness to place the cord just apical to the margin. Overpacking should be avoided because it could cause tearing of the gingival attachment, which leads to irreversible recession. Repeated use of displacement cord in the sulcus also should be avoided, because this can cause gingival recession.

Evaluation

Difficulty with tissue displacement is often the result of gingival inflammation. The inflamed and swollen tissue bleeds easily, preventing access by the impression material.

Initial assessment of cord placement can be a useful indicator of the amount of displacement accomplished. When looking at the tooth preparation from the occlusal aspect, the clinician should be able to see the preparation margin circumferentially and the uninterrupted cord, with no soft tissue folded over it, in contact with the tooth. If there is any doubt, assessing displacement by removing the cord is a good idea. The entire preparation margin should be clearly visible and remain directly accessible for about a minute.

Typically, if the result is acceptable, a second cord is quickly inserted to maintain the displacement while the impression material is mixed. If the sulcus enlargement is not favorable, the tissue health should be reassessed, particularly if adequate displacement cannot be obtained by repeating the previous steps.

Sometimes use of the double-cord technique is helpful. The first (thin) cord is trimmed and placed so that its ends do not overlap. The second (larger) cord is then saturated with astringent, placed in the normal manner, and removed after several minutes. The thin first cord remains during impression making. In order to be successful, this technique requires that about 1 mm of intact tooth structure remains between the top of the initial cord and the preparation margin. When using this technique, the clinician should be careful not to exert excessive pressure on the tissues, which can damage the epithelial attachment.

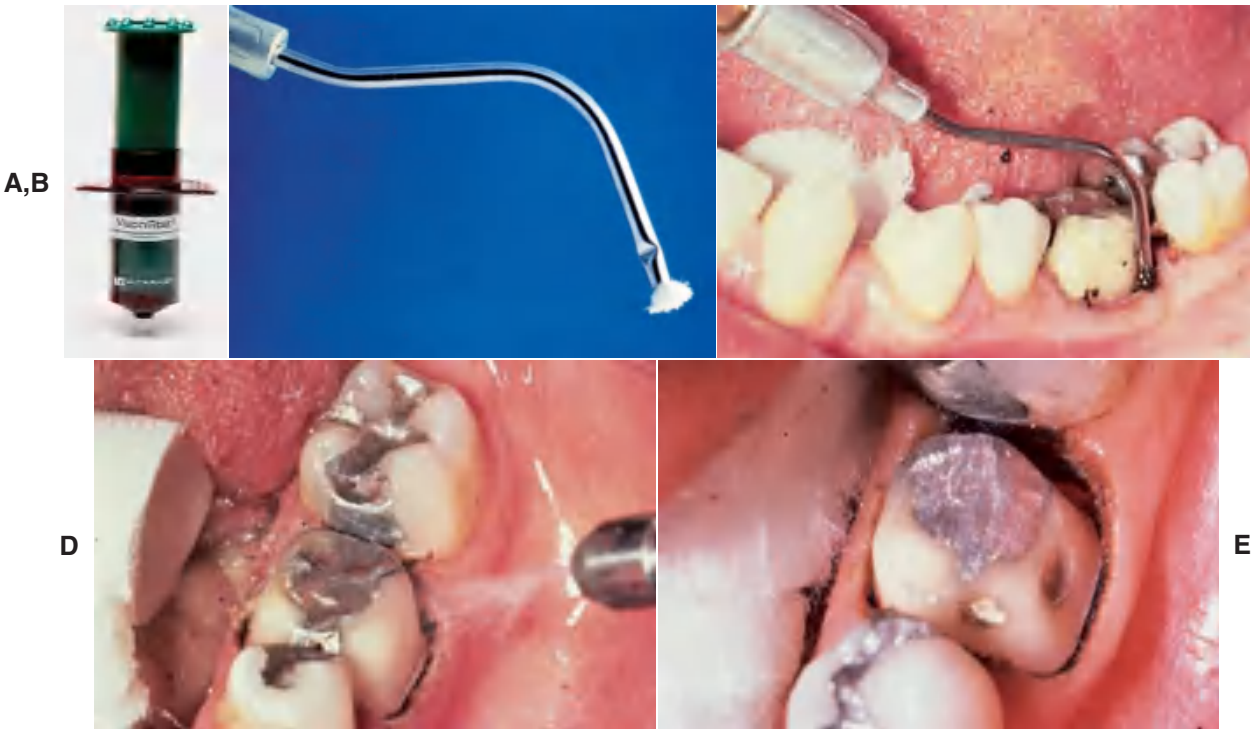


Fig. 14-7
Hemorrhage control with ferric sulfate with an infusor syringe. **A** and **B,** Ferric sulfate coagulative hemostatic gel and tip of infusor syringe. **C,** Ferric sulfate is released as the tip is moved back and forth in contact with the bleeding area. **D,** The area is cleaned with water spray. **E,** Once bleeding is controlled, cord is placed in the conventional manner before impression making. (**A** and **E,** Courtesy Ultradent Products Inc., Salt Lake City, Utah.)

On many occasions, it is better to delay impression making and concentrate on how to improve tissue health (e.g., by reassessing the quality of the interim restoration and reinforcing oral hygiene instructions) rather than to attempt impression making under adverse conditions. Minor hemorrhaging can sometimes be controlled with an astringent* or by infiltrating a local anesthetic directly into the adjacent gingival papillae.

Hemorrhage control with an infusor syringe

1. Fill the syringe with ferric sulfate solution (Fig. 14-7*A*) and attach the infusor tip (Fig. 14-7*B*). This hollow metal tip contains a cotton filament to help control flow of the medicament.
2. Rub the tip back and forth for approximately 30 seconds over the hemorrhaging area while slowly replenishing the solution by continuous injection (Fig. 14-7*C*).
3. Irrigate the area with an air-water syringe (Fig. 14-7*D*) and gently dry the tissues with air. Inspect to determine the degree to which bleeding has diminished (Fig. 14-7*E*). Repeat several times if necessary, and place a displacement cord.
4. Before cord removal, slightly moisten the cord with water to minimize the risk of dislodgment of blood clots and renewed hemorrhage. Gently dry the tissues, and proceed with impression making.

Displacement paste

Some dentists advocate displacement paste† (Fig. 14-8) as an alternative to cord.[14] The product consists of an aluminum chloride-containing paste that is injected into the dried sulcus with a special delivery gun. Advantages of the system include good hemostasis with less discomfort than traditional cord. However, less tissue displacement is achieved than with cord, which may make die trimming more problematic. Improved displacement may be achieved if the paste is directed into the sulcus by applying pressure with a hollow cotton roll.‡

Electrosurgery

An electrosurgery unit[15–18] (Fig. 14-9*A*) may be used for minor tissue removal before impression making.

*ViscoStat or Astringedent (15.5% ferric sulfate) used with the Dento-Infusor tips according to the recommendations of Ultradent Products, Inc., has been effective.

†Expa-syl, Kerr Dentistry, Orange, California.
‡Comprecap, Roeko, Coltène/Whaledent, Cuyahoga Falls, Ohio.



Fig. 14-8

A, Expa-syl is an aluminum chloride-containing paste used for gingival displacement. The material is dispensed from a syringe directly into the sulcus. **B,** Fractured ceramic crown had defective margins, which led to significant tissue inflammation and hemorrhage. **C,** Crown removed. **D** to **F,** Paste is directed into the gingival tissues around the prepared margin. **G,** After 1 to 2 minutes, the paste is removed with copious amounts of water. **H,** Prepared tooth before injecting impression material (**I**). (***A,*** *Courtesy of Kerr Dentistry, Orange, California;* ***B*** *to* ***I,*** *Courtesy of Dr. Tony Soileau.)*

In one technique,[19] the inner epithelial lining of the gingival sulcus is removed, thus improving access for a subgingival crown margin (see Fig. 14-9*B* to *F*) and effectively controlling postsurgical hemorrhage[20] (provided that the tissues are not inflamed). Unfortunately, there is the potential for gingival tissue recession after treatment.[21]

An electrosurgery unit works by passage of a high-frequency current (1 to 4 million Hz*) through the tissue from a large electrode to a small one. At the small electrode, the current induces rapid localized polarity changes that cause cell breakdown ("cutting"). For restorative procedures, an unmodulated alternating current is recommended, because it minimizes damage to deeper tissues.[16]

The following facts should be considered before electrosurgery is attempted:

1. It is contraindicated on or near patients with any electronic medical device (e.g., a cardiac pacemaker, transcutaneous electrical nerve stimulation [TENS] unit, insulin pump)[22] or patients with delayed healing as a result of debilitating disease or radiation therapy.
2. It is not suitable on thin attached gingivae (e.g., the labial tissue of maxillary canines).
3. It should not be used with metal instruments, because contact could cause electric shock. (Plastic mirrors and evacuation tubes are avaizable.)
4. Profound soft tissue anesthesia is mandatory.
5. A thin wire electrode is best for sulcular enlargement. Gingival contouring is usually performed with a loop electrode.
6. The instrument should be set to unmodulated alternating current mode.
7. The electrode should be passed rapidly through the tissue with a single light stroke and kept moving at all times.

*One hertz = 1 cycle/second.

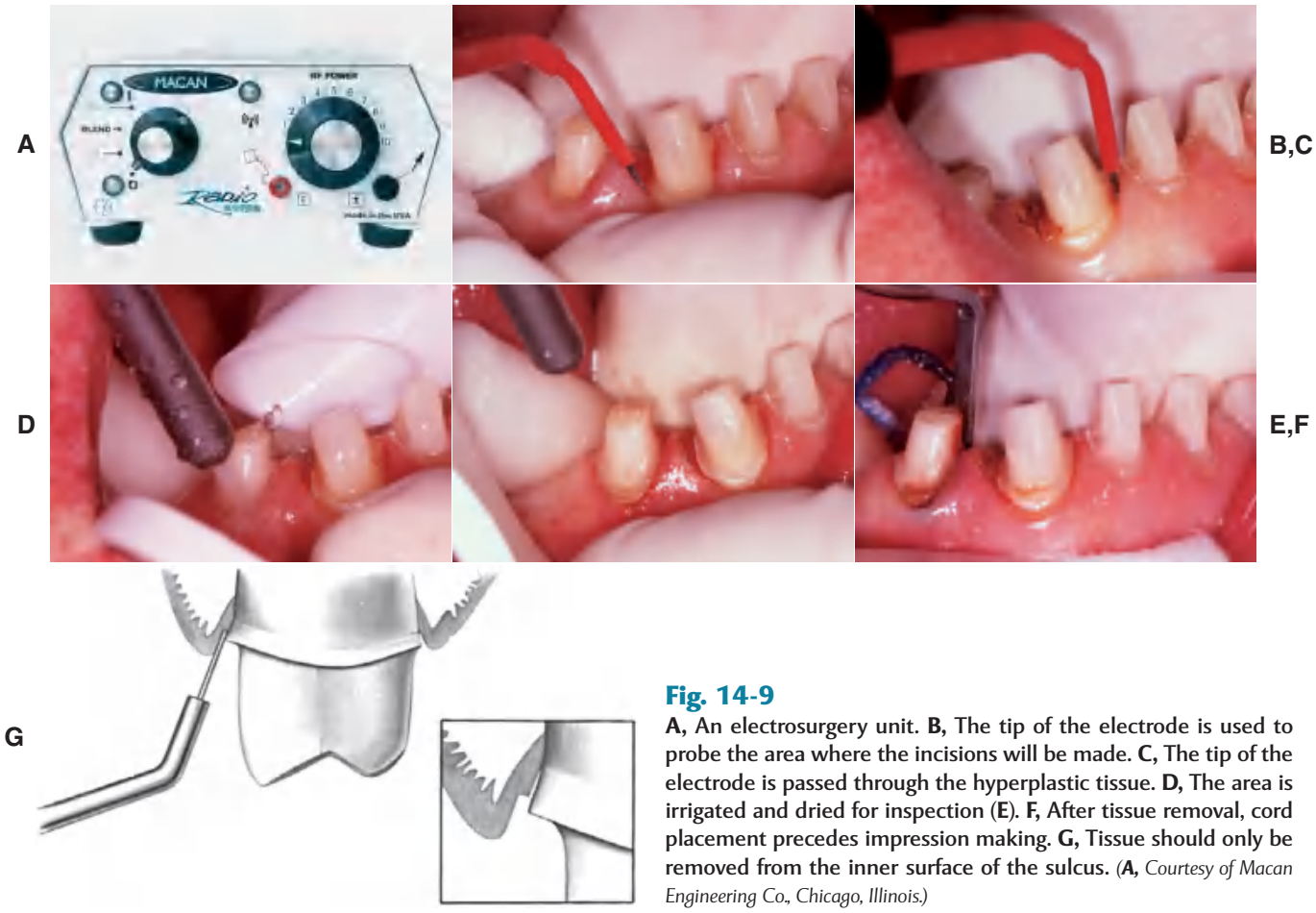


Fig. 14-9
A, An electrosurgery unit. **B,** The tip of the electrode is used to probe the area where the incisions will be made. **C,** The tip of the electrode is passed through the hyperplastic tissue. **D,** The area is irrigated and dried for inspection (**E**). **F,** After tissue removal, cord placement precedes impression making. **G,** Tissue should only be removed from the inner surface of the sulcus. (***A,*** *Courtesy of Macan Engineering Co., Chicago, Illinois.*)

8. If the tip drags, the instrument is at too low a setting, and the current should be increased.
9. If sparking is visible in the tissue, the instrument is at too high a setting, and the current should be decreased.
10. A cutting stroke should not be repeated within 5 seconds.
11. The electrode must remain free of tissue fragments.
12. The electrode must not touch any metallic restoration. Contact lasting just 0.4 second has been shown to lead to irreversible pulpal damage in dogs.[23]
13. The sulcus should be irrigated with hydrogen peroxide before the displacement cord is placed.

Soft tissue laser

Soft tissue lasers (Fig. 14-10) have been advocated as a means of removing a controlled amount of tissue before impression making.[24] They are also useful for tissue contouring procedures.

MATERIALS SCIENCE

James L. Sandrik

Elastic Impression Materials

There is an extensive variety of materials for making a precision negative mold of soft and hard tissues. In order of their historical development, they are the following:

1. **Reversible hydrocolloid.**
2. **Polysulfide** polymer.
3. Condensation silicone.
4. Polyether.
5. Addition silicone.

Irreversible **hydrocolloid** is not sufficiently accurate for cast restorations. Each material has advantages and disadvantages, and none is entirely free of shortcomings. However, they all share one important characteristic: when handled correctly, they can produce casts of sufficient accuracy[25] and surface detail[26] for the fabrication of clinically acceptable fixed prostheses.



Fig. 14-10
A, Erbium, chromium:yttrium-scandium-gallium-garnet (Waterlase YSGG) pulsed laser. **B,** Trough made with the laser before impression making. **C,** Impression. (**A,** *Courtesy of Biolase Technology, Inc.;* **B** *and* **C,** *courtesy of Dr. A. Scott.*)

Nevertheless, there are reasons for selecting one material over another: If it becomes necessary to store the impression before a cast is made, the polyethers and addition silicones are preferable because they exhibit sufficient long-term **dimensional stability;** the other materials, particularly the reversible hydrocolloids, must be poured immediately. If the impression is to be poured in epoxy or electroplated (see Chapter 17), reversible hydrocolloid should not be selected because it is compatible only with die stone.

The advantages and disadvantages of the elastic impression materials are summarized in Table 14-3.

Reversible hydrocolloid

Reversible hydrocolloid (also called *agar hydrocolloid* or simply *hydrocolloid*) (Fig. 14-11) was originally derived as a natural product of kelp. However, the material currently available is considerably different.

If poured immediately, reversible hydrocolloid produces casts of excellent dimensional accuracy and acceptable surface detail. At elevated temperatures, it changes from a gel to a sol. This change is reversible; that is, as the material cools, the viscous fluid sol is converted to an elastic gel. Agar changes from gel to sol at 99°C (210°F) but remains a sol as low as 50°C



Fig. 14-11
Reversible hydrocolloid impression material. **A,** Tray and wash material. **B,** Syringe material. *(Courtesy of Dux Dental, Oxnard, California.)*

Table **14-3 AVAILABLE ELASTIC IMPRESSION MATERIALS**

	Advantages	Disadvantages	Recommended uses	Precautions
Irreversible hydrocolloid	Rapid set Straightforward technique Low cost	Poor accuracy and surface detail	Diagnostic casts Not suitable for definitive casts	Pour immediately
Reversible hydrocolloid	Hydrophilic Long working time Low material cost No custom tray required	Low tear resistance Low stability Equipment needed	Multiple preparations Problems with moisture	Pour immediately Use only with stone
Polysulfide polymer	High tear strength Easier to pour than other elastomers	Messy Unpleasant odor Long setting time Stability only fair	Most impressions	Pour within 1 hr; allow 10 min to set
Condensation silicone	Pleasant to use Short setting time	Hydrophobic Poor wetting Low stability	Most impressions	Pour immediately Care to avoid bubbles when pouring
Addition silicone	Dimensional stability Pleasant to use Short setting time Automix available	Hydrophobic Poor wetting Some materials release H_2 Hydrophilic formulations imbibe moisture	Most impressions	Delay pour of some materials Care to avoid bubbles when pouring
Polyether	Dimensional stability Accuracy Short setting time Automix available	Set material very stiff Imbibition Short working time	Most impressions	Care not to break teeth when separating cast

(122°F), forming a gel only slightly above body temperature. These unique characteristics are very favorable for its use as an impression material.

Reversible hydrocolloid is supplied in a range of viscosities. In general, a heavy-bodied tray material is used with a less viscous syringe material. The required temperature changes are effected with a special conditioning unit (see Fig. 14-31) and water-cooled **impression trays**.

Reversible hydrocolloid's lack of dimensional stability results primarily from the ease with which water can be released from or absorbed by the material (syneresis and imbibition). The accuracy of a reversible hydrocolloid impression is improved if the material has as much bulk as possible (low surface area/volume ratio). This contrasts with the elastomeric impression materials, whose accuracy is improved by minimizing bulk (e.g., polysulfide and condensation silicone), because stresses produced during removal are reduced.[27] Therefore, an additional advantage of reversible hydrocolloid is that a custom impression tray is not required.

Polysulfide polymer

The polysulfides (Fig. 14-12), commonly (although erroneously) known as *rubber bases*,* were introduced in the early to middle 1950s. They were received enthusiastically by dentists because they had better dimensional stability and tear strength than did hydrocolloid. Nevertheless, they should be poured as

*All elastomeric materials, not just polysulfides, can be called *rubber base.*



Fig. 14-12
Polysulfide polymer. *(Courtesy of GC America Inc., Alsip, Illinois.)*



Fig. 14-13
Condensation silicone. *(Courtesy of Coltène AG, Altstätten, Switzerland.)*

soon as possible after impression making; delays of more than an hour result in clinically significant dimensional change.[22]

There is a slight contraction of polysulfide during polymerization, but the effects can be minimized with a custom impression tray to reduce the bulk of the material.[28] In general, a double-mix technique is used with a heavy-bodied tray material and a less viscous syringe material. These polymerize simultaneously, forming a chemical bond of adequate strength.[29]

The high tear resistance[30,31] and enhanced elastic properties of polysulfide facilitate impression making in sulcular areas and pinholes, and it has improved dimensional stability over hydrocolloid (inferior to polyether and addition silicone). Although it is the least expensive **elastomer,** it is not well liked by patients because of its unpleasant sulfide odor and long setting time in the mouth (about 10 minutes). Furthermore, high humidity and temperature dramatically reduce its working time,[32] which may be so short that polymerization begins before it is inserted in the mouth, which results in severe distortion. Although air conditioning is common in dental operatories, temperatures near 25°C (77°F) with humidity exceeding 60% can create problems.

Most polysulfide materials are polymerized with the aid of lead peroxides, which explains this material's typical brown color. The unpolymerized product is sticky and should be handled carefully, because it stains clothing permanently. Alternatives to lead are available; copper hydroxide is the most common. $Cu(OH)_2$-polymerized polysulfide is light green and shares many of the characteristics of the PbO_2-polymerized material (except for a reduced setting time).

Condensation silicone

Some of polysulfide's disadvantages have been overcome by condensation silicone (Fig. 14-13), which is essentially odorless and can be pigmented to virtually any shade. Unfortunately, its dimensional stability is less than that of polysulfide but greater than that of reversible hydrocolloid. An advantage of this silicone is its relatively short setting time in the mouth (about 6 to 8 minutes). As a result, patients tend to prefer condensation silicone over polysulfide. In addition, condensation silicone is also less affected by high operating room temperatures and humidity.[27]

Silicone's main disadvantage is its poor wetting characteristics, which stems from its being extremely hydrophobic (for this reason, it is used in commercial sprays that protect automobile electrical systems from moisture). In this context, the prepared teeth and gingival sulci must be completely free of moisture so that a defect-free impression is possible. Pouring without trapping air bubbles is also more difficult than with other impression materials, and a surfactant may be needed. Silicone impression material is available in a variety of viscosities. One technique involves a heavily filled putty material that is used to customize a stock impression tray in the mouth, generally with a polyethylene spacer. The spacer allows room for a thin wash of light-bodied material, which makes the impression. The technique requires considerable care in seating, however, to prevent strain in the set putty. If this happens, the impression rebounds when removed from the mouth, which results in dies that are too small.[33] Care is also needed to avoid contaminating the putty surface with saliva, which prevents the wash impression from adhering properly.[34]

Silicone and polysulfide have a dimensional instability that results from their mode of polymerization. Both are condensation polymers, which, as a byproduct of their polymerization reactions, give off alcohol and water, respectively. As a result, evaporation from the set material causes dimensional contraction in both.

Polyether

Polyether impression material (Fig. 14-14), developed in Germany in the mid-1960s, has a polymerization mechanism unlike those of the other elastomers. No volatile byproduct is formed, which results in excellent dimensional stability. In addition, its polymerization shrinkage[35] is unusually low in comparison with most room temperature–cured polymer systems. However, its thermal expansion[36] is greater than that of polysulfide.

With the high dimensional stability of polyether, accurate casts can be produced when the material is poured more than a day after the impression has been made. This is especially useful when pouring the impression immediately is impossible or inconvenient. Another advantage of polyether is its short setting time in the mouth (about 5 minutes, which is less than half the time required for polysulfide). For these reasons, polyether is used by many practitioners.

However, polyether has certain disadvantages. The stiffness of the set material is one such disadvantage, which causes problems when a stone cast is separated from the impression. Thin and single teeth, in particular, are liable to break unless the practitioner uses great care. Polyether is stable only if stored dry, because it absorbs moisture and undergoes significant dimensional change. Polyether's relatively short working time may limit the number of prepared teeth that can be reliably captured in a single impression. Isolated cases of allergic hypersensitivity[37] to polyether elastomer have been reported (manifested as sudden onset of burning, itching, and general oral discomfort). Therefore, the allergic patient's record should carry a warning against polyether's future use, and an alternative elastomer should be chosen. Improvements in these materials have reportedly reduced this problem.

Addition silicone

Addition silicone (Fig. 14-15) was introduced as a dental impression material in the 1970s. Also known as *poly(vinyl siloxane)* (*polysiloxane* is the generic chemical expression for silicone resins), it is similar in many respects to condensation silicone except that it has much greater dimensional stability[38] (equivalent to polyether polymer), and its working time is more affected by temperature.[26] The set material is less rigid than polyether but stiffer than polysulfide. As with the other materials previously described, adverse soft-tissue responses have been reported.[39] One disadvantage of some of these materials is that setting inhibition can occur with selected latex gloves.[40] Dithiocarbamates, which are used in glove manufacturing as either vulcanizing agents or **accelerators,** have been implicated as causative agents.[41] Glove exposure to alcohol has been shown to exacerbate setting inhibition for selected impression material–latex glove combinations.[42] The problem is most apparent if a hand-mixed putty is used, but problems can occur if the tissues are touched with gloved hands immediately before impression placement. It has also been shown that sulfide and sulfide-chloride can be transferred from latex gloves to retraction cord,[43] which enables the transfer of these known inhibiting agents to sulcular tissues (Fig. 14-16). When addition silicones



Fig. 14-14
Polyether impression material. *(Courtesy of 3M ESPE, St. Paul, Minnesota.)*



Fig. 14-15
Addition silicone. *(Courtesy of GC America Inc, Alsip, Illinois.)*

are used, gloves that do not interfere with setting should be selected.[44]

Like condensation silicone, addition silicones are hydrophobic. Some formulations contain surfactants, which give them hydrophilic properties,[45] imparting wettability similar to that of the polyethers.[46] However, these products also expand like polyether when in contact with moisture.[47] Addition silicone is generally used as a two-viscosity system, although monophase formulations are also available. It is easier to trap bubbles when the monophase formulation is used.[48]

Manufacturer recommendations should be followed when a cast is being poured, and pouring should be delayed with some of the earlier products. If this is not done, a generalized porosity of the cast surface caused by gas from the impression material will develop. Newer products contain "scavengers" that prevent the escape of gas at the polymer-cast interface. Addition silicone that contains scavenger material can be poured immediately.

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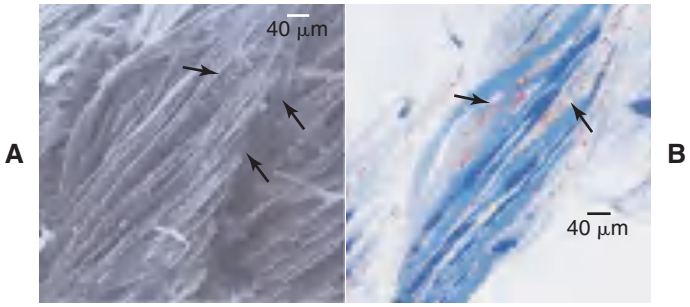


Fig. 14-16

A, Scanning electron microscope finding of gingival retraction cord contaminated by latex glove contact. *Arrows* indicate particles on surfaces and within fibers of gingival retraction cord. **B,** Electron probe microanalysis of gingival retraction cord contaminated by latex glove contact. Red color indicates sulfur element (***arrows***). *(From Kimoto K, et al: Indirect latex glove contamination and its inhibitory effect on vinyl polysiloxane polymerization. J Prosthet Dent 93:433, 2005.)*

IMPRESSION TRAYS

The choice of impression material influences tray selection. Reversible hydrocolloids require special water-cooled trays, whereas irreversible hydrocolloid and many elastomeric impressions for uncomplicated fixed prosthodontic procedures are made with prefabricated impression trays. To reduce associated distortion invariably associated with the use of such trays, they must have adequate rigidity, and tray design should provide for control of impression material thickness. Retention is provided by perforations, rim locks, and/or adhesives (Fig. 14-17). Custom trays are fabricated for each patient individually, through the use of diagnostic casts (see Chapter 2), and offer a number of advantages over prefabricated stock trays.

Adhesives should be applied sufficiently in advance to allow thorough drying, although they may remain slightly tacky to touch. Because evaporation of its volatile solvent is time dependent, it is preferable to apply the adhesive in a thin layer. Spray-on adhesives have been shown to result in significantly less retention of polyvinylsiloxane impression materials to both autopolymerizing and



Fig. 14-17

A, This prefabricated segmented tray relies on internal modification to ensure material thickness. **B,** This system allows the dentist to match tray size to patient arch width. (***B,*** *Courtesy of Clan Dental Products, Maarheeze, The Netherlands.)*

photopolymerizing tray materials than do paint-on adhesives.[49]

CUSTOM TRAY FABRICATION

A custom tray improves the accuracy[50] of an elastomeric impression by limiting the volume of the material, thus reducing two sources of error: stresses during removal and thermal contraction. Although reducing the bulk of an elastomeric impression material increases its accuracy, the opposite is true for reversible hydrocolloid impressions. In hydrocolloid impressions, dimensional change is caused by water loss (or gain) from the surface of the impression. A bulky hydrocolloid impression has a lower surface area/volume ratio and is therefore less subject to dimensional change.

Custom trays can be made from autopolymerizing acrylic resin (Fig. 14-18), thermoplastic resin, or photopolymerized resins. Thermoplastic materials can be softened in a water bath and adapted either manually or with a vacuum former with a heating element (Figs. 14-19 and 14-20). The accuracy of impressions made with a thermoplastic tray material or light-polymerized materials is comparable with that of impressions made with an autopolymerized resin.[51,52] Light-polymerized materials are convenient because a storage period is not needed for the completion of polymerization[53] (Fig. 14-21). In addition, the resin is less susceptible to distortion in mois-



Fig. 14-18

Custom tray fabrication. **A,** Armamentarium. **B,** Outlining the border of the tray on the diagnostic cast. **C,** The tray should extend 3 to 5 mm from the gingival margin and about 3 mm beyond the most distal tooth. **D,** Softened baseplate wax is adapted to form a spacer. Two thicknesses typically provide the recommended 2 to 3 mm of space. **E,** Spacer is trimmed to the pencil line. **F,** Wax is removed to form the tray stops. **G,** The impression is covered with tinfoil. **H,** The foil is adapted to the stops.



Fig. 14-18, cont'd

I, Custom tray resin. **J,** Wooden slab and roller are used. **K,** The resin is gently adapted to the cast, and the excess is trimmed. **L** and **M,** Resin is moistened with monomer to attach the handle. **N,** When the resin has cured, the periphery is shaped with an acrylic-trimming bur. **O,** Trimmed custom tray. (***I,*** *Courtesy of Harry J. Bosworth Company, Skokie, Illinois.*)

ture, and the impression is thus suitable for the electroformed die technique (see Chapter 17). With the appropriate adhesive, it produces a better bond to the impression material.[54]

With any system, tray rigidity is important, because even slight flexing of the tray leads to a distorted impression. This is particularly frustrating because the errors are usually undetectable until the practitioner attempts to seat the restoration. For this reason, thin, disposable plastic trays are unacceptable.[55] Resin thicknesses of 2 to 3 mm are needed for adequate rigidity. Clearance between the tray and the teeth should also be 2 to 3 mm; however, greater clearance is necessary for the more rigid polyether materials.

Armamentarium (see Fig. 14-18*A*)

- Baseplate wax
- 0.025-mm (0.001-inch) tinfoil
- Scalpel
- Scissors
- Waxing instrument

Step-by-Step Procedure: Autopolymerizing Resin

1. Using a pencil, mark the border of the tray on the diagnostic cast (see Fig. 14-18*B*) approximately 5 mm apically to the crest of the free



Fig. 14-19
Thermoplastic custom tray material. **A** and **B,** The material is softened in hot water. **C** and **D,** The material has been adapted to the spaced cast.



Fig. 14-20
Vacuum-formed custom tray material. **A,** The thermoplastic sheets are much thicker and more rigid than those used for making interim restorations (see Chapter 15), but the same equipment is used (**B**).

gingiva (less for the more rigid impression materials). Allow for muscle and frenum attachments (see Fig. 14-18*C*). Maxillary trays do not always necessitate covering the entire palate, although this may be desirable if a removable appliance is planned after completion of the fixed prostheses. Under no circumstances should the posterior border extend farther than the demarcation between hard and soft palates.

2. Adapt a wax or other suitable spacer to the diagnostic cast (see Fig. 14-18*D*). Two layers of baseplate wax result in a combined thickness of

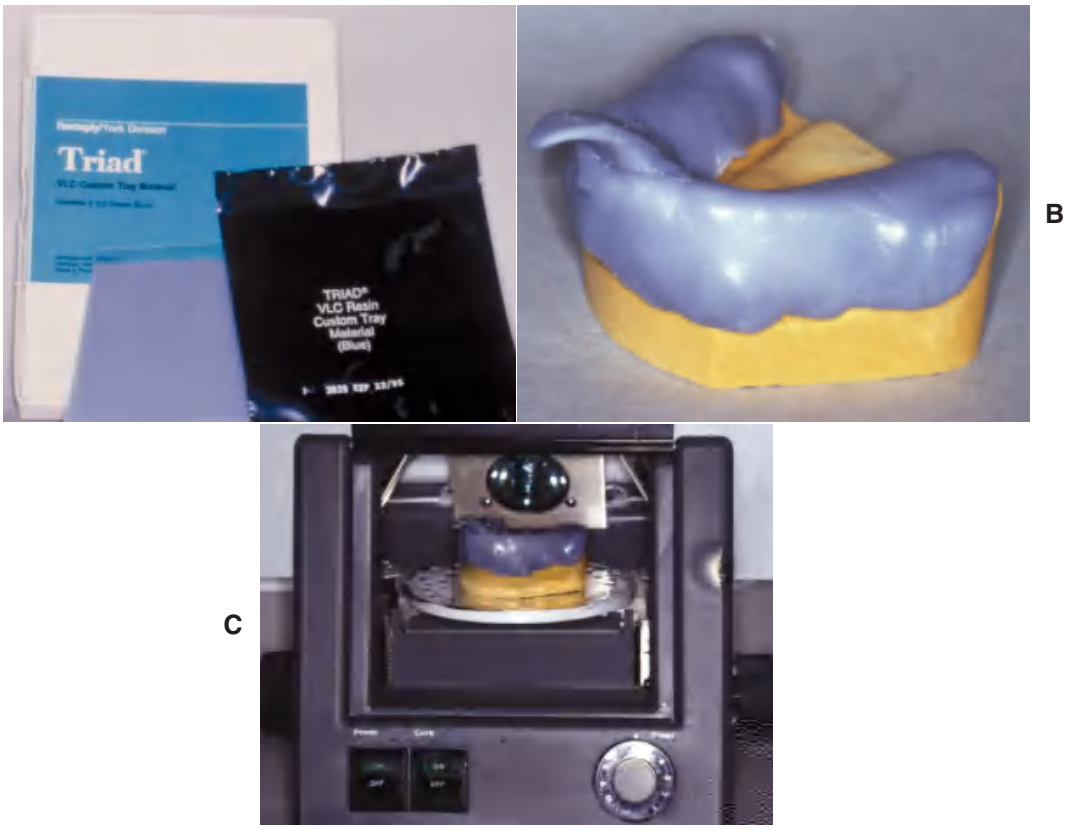


Fig. 14-21
Visible light-polymerized custom tray material. **A** and **B,** The material is removed from the packet and adapted to the spaced cast. **C,** The assembly is placed on the turntable of a special curing unit and exposed to intense light.

approximately 2.5 mm (the sheets should be measured with a thickness gauge, because wax thicknesses vary).

3. Soften the wax by carefully heating it over a Bunsen burner or in hot water. Overheating may melt it and produce an undesirable thin spot. Only light pressure should be applied.
4. After the second sheet of wax has been applied, trim it back (see Fig. 14-18*E*) until the pencil line is just visible. An alternative technique involves repeated dipping of the cast in molten wax. The cast is thoroughly wetted and then dipped three or four times to obtain a sufficient and uniform wax thickness (about 2 or 3 mm). This creates the space needed for the impression material. Three stops are needed in the tray to maintain even space for the impression material in the oral cavity. These are placed on nonfunctional cusps of teeth that are not to be prepared (buccal cusps of the maxillary, lingual cusps of the mandibular) (see Fig. 14-18*F*). If all teeth are involved, a larger soft tissue stop (Fig. 14-22) can be placed on the crest of the alveolar ridge or in the center of the hard palate.



Fig. 14-22
If necessary, a tray stop can be placed on the hard palate.

Stops are made (Fig. 14-23) by removing wax at an angle of 45 degrees to the occlusal surfaces of three teeth that have a tripodal arrangement in the arch. This lends stability to the tray, and the 45-degree slope helps center the tray during insertion.

5. Apply a layer of tin foil over the wax (which may melt from the polymerization heat of the mate-

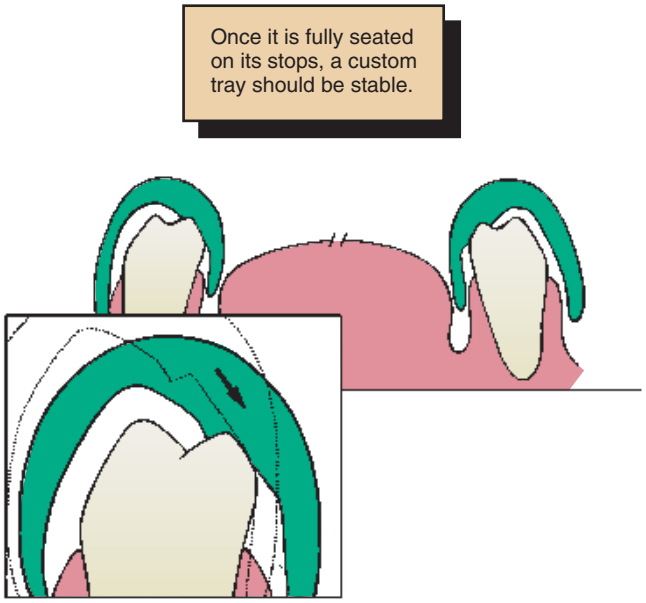


Fig. 14-23
Drawing of a cross-section through a mandibular custom tray. Stops have been placed on the nonfunctional cusps so that distortion does not interfere with the intercuspal relationship. The 45-degree slope helps to center the tray during seating *(arrow)*. Space exists for the impression material.

rial) to prevent it from contaminating the inside of the tray (see Fig. 14-18*G* and *H*).

6. Mix autopolymerizing acrylic resin (see Fig. 14-18*I*) according to the manufacturer's recommendations. The use of vinyl gloves is recommended to prevent the development of sensitivity to the **monomer.**
7. After the resin is mixed, set it aside until it is doughy (with the consistency of putty). A template or a wooden slab and roller (see Fig. 14-18*J*) may help obtain a consistent thickness, although with practice the resin can be thinned out accurately by hand. Care must be taken not to stretch the material when manipulating it; thin areas in the resin may lead to a flexible tray and produce distortions.
8. Gently adapt the resin to the cast (see Fig. 14-18*K*). A handle made from the excess resin can be attached at this time. If working time is unavailable, it can also be attached later with a separate second mix of acrylic resin (see Fig. 14-18*L* and *M*). Buccal ridges, which are helpful with impression removal, can also be added (Fig. 14-24).
9. After the material has polymerized, remove it from the cast and trim it with an acrylic-trimming bur (see Fig. 14-18*N*) where the indentation made by the wax ledge is visible. All rough edges should be rounded to prevent soft tissue trauma.
10. If necessary, fill defects in the stops with additional resin, wetting the set tray material with monomer to ensure a good bond. To prevent the material from lifting up, some pressure should be maintained during this phase.



Fig. 14-24
Buccal ridges can be provided to facilitate removal of the impression. *(Courtesy of Dr. H. Lin.)*

Step-by-Step Procedure: Photopolymerized Resin

Follow steps 1–5 as for the autopolymerizing technique.

6. Remove photopolymerized tray material sheets from their light-proof packaging, and adapt them to the relieved cast (Fig. 14-25*A*). Adapt small pieces in the areas of the stops first, to make sure they get filled completely (Fig. 14-25*B*). Two sheets are needed to make each tray and should be cut as shown in Figure 14-25*C*. Carefully adapt the large piece of material to the cast, being careful not to extend the material beyond the scribed borders (Fig. 14-25*D*). Use a scalpel blade to trim the excess material away from the cast. It may help to roll the edge of material back onto itself at the borders, so that it is not too thin in these areas for trimming. Adapt the material with fingers (gloves) until the pieces blend together and no seams are visible (Fig. 14-25*E*). Do not press hard, or the material will be deformed and thinned. This weakens the tray.
7. Shape and attach a handle by molding excess material. Blend into the tray material (Fig. 14-25*F*). A paper clip can be used to support the handle material by adapting the material around it.
8. Position the cast in the curing unit for approximately 2 minutes (Fig. 14-25*G*). Remove from the curing unit, separate the tray from the cast,

and remove the softened wax spacer and the aluminum barrier (Fig. 14-25*H*). Paint the tray with the air-barrier coating provided by the manufacturer (Fig. 14-25*I*).

9. Return the cast to the curing unit and cure in accordance with the time recommended by the manufacturer. Remove the tray and scrub it clean under running water.
10. Clean the tray, and trim as for the autopolymerizing resin tray (Fig. 14-25*J*). Add additional resin as needed.

Evaluation

The completed custom tray (Fig. 14-18*O*) needs to be rigid, with a consistent thickness of 2 to 3 mm. It should extend about 3 to 5 mm cervical to the gingival margins and should be shaped to allow muscle attachments. It should be stable on the cast with stops that can maintain an impression thickness of 2 or 3 mm. The tray must be smooth, with no sharp edges. Finally, the handle should be sturdy and shaped to fit between the patient's lips (Fig. 14-26).

To avoid distortion from continued polymerization of the resin,[56] the tray should be made at least 9 hours before its use. When a tray is needed more urgently, it can be placed in boiling water for 5 minutes and allowed to cool to room temperature. A light-polymerized tray can also be made (see Fig. 14-25).

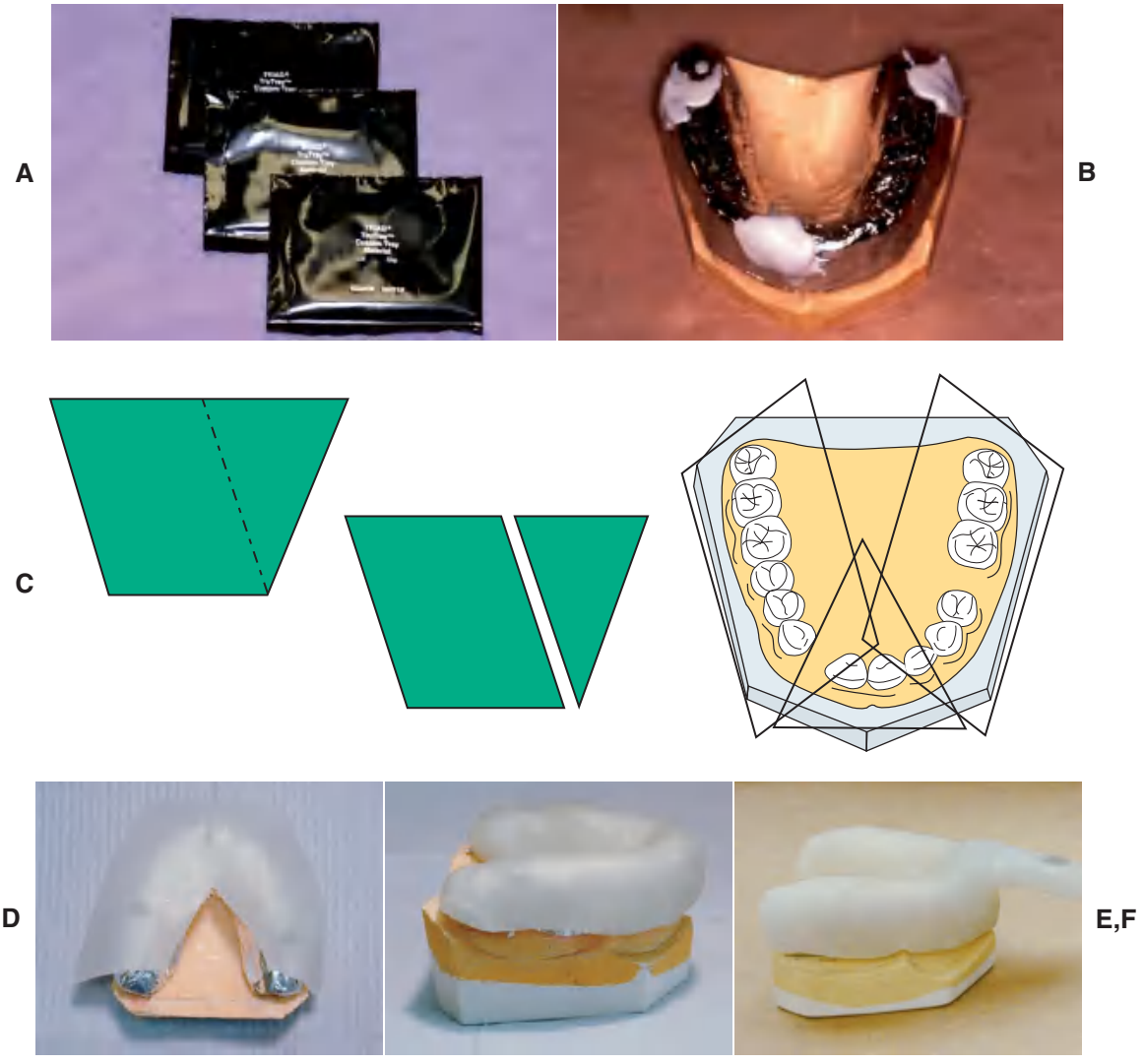
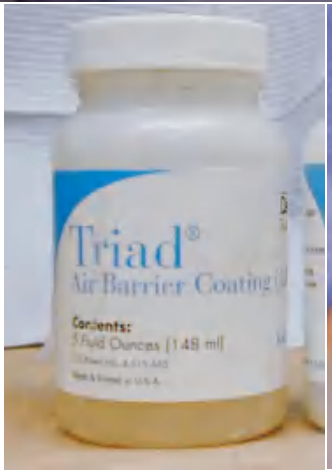


Fig. 14-25
Custom tray fabrication with photopolymerized resin. **A,** Material is supplied in light-proof packaging. **B,** Small pieces of resin are applied in the areas of the stops first, to make sure they get filled completely. **C,** Sheets should be cut as shown. **D,** Material is adapted to the cast, the large piece of material first. **E,** The material is adapted until the pieces blend together and no seams are visible. **F,** A handle is formed by molding excess material.


G


H



I


J

Fig. 14-25, cont'd
G, The resin is cured for approximately 2 minutes. **H,** The softened wax spacer and aluminum barrier are removed. **I,** An air-barrier coating is used to prevent a sticky oxygen-inhibited layer. **J,** Trimming the tray. *(**A** to **J,** Courtesy Dr. R. Seghi.)*



Fig. 14-26
A custom tray should be smooth and well finished. This will enhance patient acceptance.

IMPRESSION MAKING

Elastomeric Materials

When elastomeric impressions are made, an assistant is essential, unless the AutoMix technique is used.

Step-by-step procedure

Heavy body–light body combination

1. Evaluate the custom tray in the patient's mouth to verify its fit. Correct the tray as needed.
2. Apply tray adhesive to extend a few millimeters onto the external surface of the tray (Fig. 14-27*A*).
3. Isolate the abutment teeth and place gingival displacement cord in the sulcus.
4. On separate pads (one for the tray and one for the syringe material), disperse equal amounts of base and accelerator (Fig. 14-27*B* and *C*).

When mixing polysulfide polymers, pick up the brown catalyst first (Fig. 14-27*D*) rather than the

white base material, because the base sticks to the spatula and makes it virtually impossible to incorporate all the catalyst.

5. Blend the two pastes thoroughly (Fig. 14-27*E*). Initially, the spatula is kept somewhat vertical during mixing; this position is changed gradually to be more horizontal as the two pastes become better incorporated. At this time, the spatula is wiped on a clean paper towel. Mixing continues for another 10 seconds to ensure that the material is homogeneous.
6. Load the syringe. This can be done by holding the barrel vertically, pushing it through the mix, and then angling and sliding it sideways over the mixing pad. The syringe can also be loaded from the other end (Fig. 14-27*F*) by picking up the mixing sheet, forming a funnel, and expressing the material into the breech of the syringe.

Concurrently with steps 5 through 9, have the assistant mix the heavy-bodied material in a similar manner as the light-bodied material (Fig. 14-27*G* to *I*) and load the tray.

7. Remove the displacement cord and gently dry the preparation with compressed air.
8. Place the tip of the syringe nozzle so that it touches the margin and inject the material

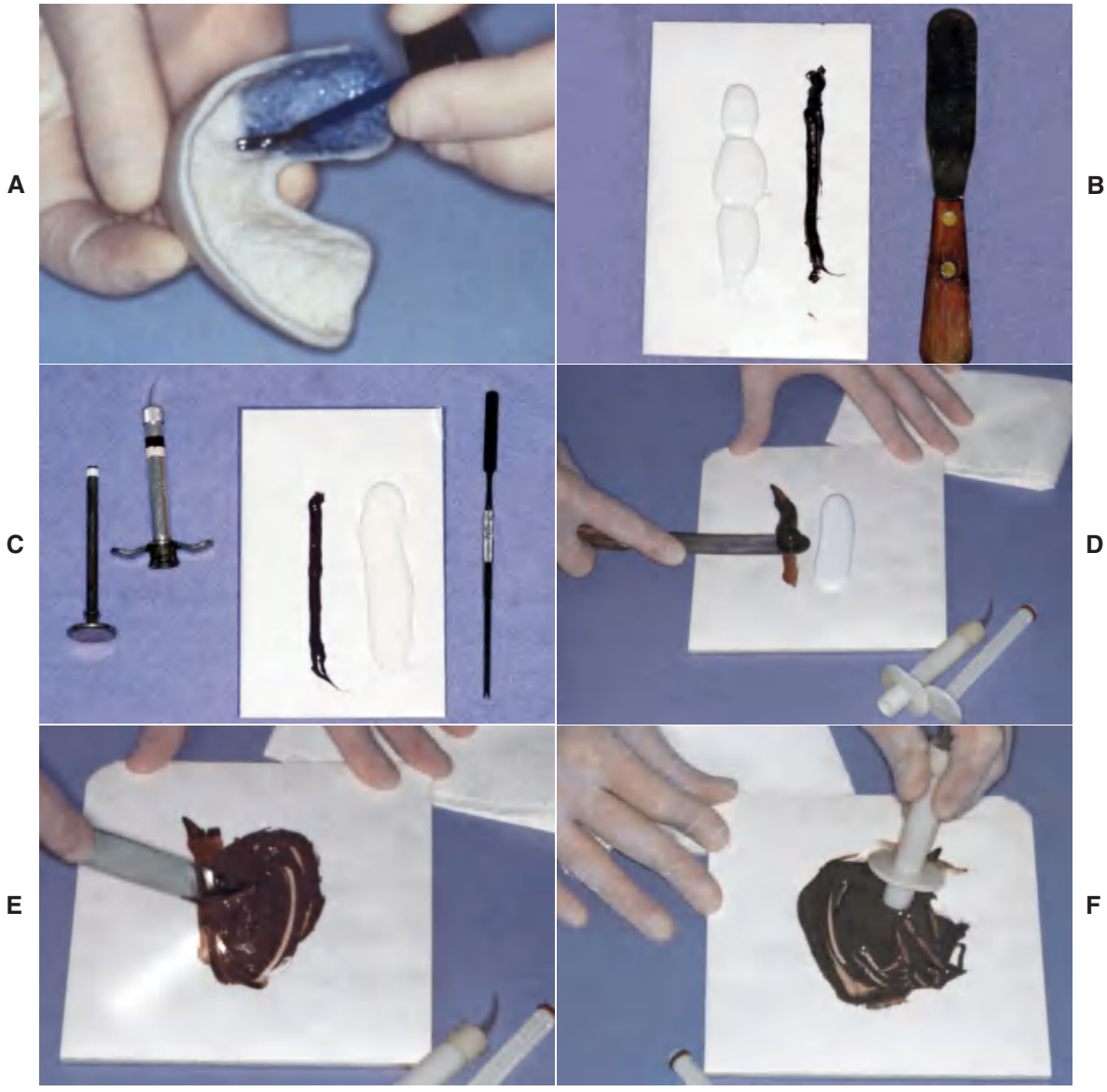


Fig. 14-27

Elastomeric impression-making (polysulfide polymer). **A,** Adhesive applied to the tray. Sufficient time is allowed for drying. **B,** Heavy-bodied tray material. **C,** Light-bodied syringe material. **D,** The brown catalyst is picked up first. **E,** The light-bodied (white) material is thoroughly spatulated. **F,** Impression syringe being loaded.

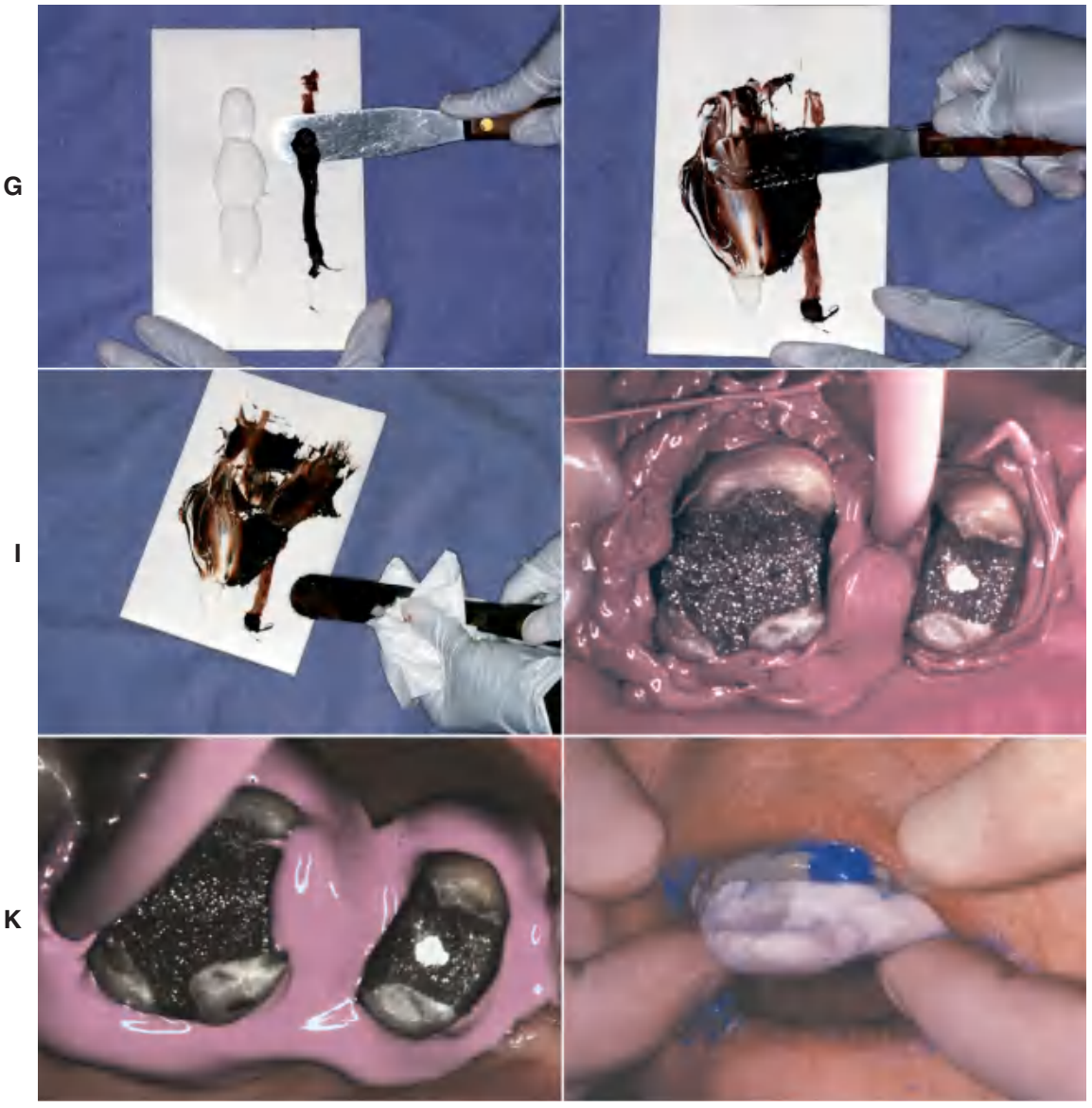


Fig. 14-27, cont'd

G and **H,** Meanwhile, an assistant mixes the heavy-bodied material. **I,** The spatula is wiped to prevent unmixed material from being incorporated into the impression. **J** and **K,** Displacement cord is removed, and the impression material is applied by syringe into the sulcus, around the prepared teeth, and into the grooves of the occlusal surfaces. The material is air-blown into a thin layer at this time. **L,** The impression tray is filled with heavy-bodied material and seated.

slowly (Fig. 14-27*J*). The tip should be inserted into the most distal embrasure first. This prevents the material from flowing down over the preparation and trapping air bubbles. The tip is moved so that it follows the material rather than traveling ahead of it. When all the margins and axial surfaces have been covered, the material is air-blown into a thin layer. This improves the accuracy of the impression because the light-bodied material has greater polymerization shrinkage than does the tray material.

9. Express additional material to any edentulous spaces, lingual concavities of the anterior teeth (which are important for guidance), and occlusal surfaces of the posterior teeth (which are important for obtaining an accurate articulation) (Fig. 14-27*K*).
10. Seat the tray (Fig. 14-27*L*). It must remain immobile while the material undergoes polymerization (6 to 12 minutes, depending on the material). Otherwise, strains form in the elastomer, which can cause distortion of the impression when it is removed. The manufacturer's recommendations for maximum working time and minimum setting time should be followed. It is difficult to judge clinically when elastomers start to develop

elasticity.[57] Any delay in seating the tray results in a distorted impression. It is tempting to remove the impression too soon, because the patient may find it uncomfortable. However, premature impression removal is a common cause of impression distortions.

Single-mix technique

The same steps are performed for the single-mix technique as for the heavy body–light body technique; however, as the name indicates, only one mix is used to load the syringe and fill the tray. Most single-mix materials tend to produce a slightly higher viscosity mix with a slightly shorter working time.

AutoMix technique

Most manufacturers offer impression material in prepackaged cartridges with a disposable mixing tip attached (Fig. 14-28). The cartridge is inserted in a caulking gun-like device, and the base and catalyst are extruded into the mixing tip, in which mixing occurs as they progress to the end of the tube. The homogeneously incorporated material can be directly placed on the prepared tooth and impression tray. One of this system's advantages is the elimination of hand mixing on pads; the elimination of this variable has been shown to produce fewer voids in the impression.[58] Following the manufacturer's



Fig. 14-28

A, AutoMix addition silicone impression materials are available in a range of viscosities. **B,** The barrels should be bled to ensure that any partially set material is removed and that the flow is even from each component. To prevent cross-contamination of the catalyst and base, a mixing tip should remain attached to the cartridge after each use. **C,** The light-bodied material can be dispensed into an impression syringe or directly onto the prepared tooth with a special tip (**D**). The heavy-bodied material is dispensed into the adhesive-coated tray (**E**).



Fig. 14-29
Machine mixing system. A, Pentamix machine. B, Polyether impression material. C, Loading an impression tray. *(Courtesy of 3M ESPE, St. Paul, Minnesota.)*

directions and bleeding the cartridge before inserting the tip are crucial to ensure that possible residue of partially polymerized material is removed from the cartridge openings, which might prevent equal amounts of base and catalyst from being dispensed. AutoMix material is not available for the polysulfide polymers because these materials are too sticky for proper mixing with existing cartridge tips.

Machine mixing technique

An alternative method for improving impression mixing is to use a machine mixer* (Fig. 14-29). This system is convenient and produces void-free impressions.

Evaluation

The impression must be inspected for accuracy when it is removed (Fig. 14-30). (Magnification is helpful.) If bubbles or voids appear in the margin, the impression must be discarded. An intact, uninterrupted cuff of impression material should be present beyond every margin. Streaks of base or catalyst material indicate improper mixing and may render an impression useless. If the impression passes all these tests, it can then be disinfected (see p. 460) and poured to obtain a die and definitive cast (see Chapter 17).

*3M ESPE, St. Paul, Minnesota.

Reversible Hydrocolloid

Reversible hydrocolloid impression material requires a special conditioning unit (Fig. 14-31), which is made up of three thermostatically controlled water baths:

1. A liquefaction bath (100°C [212°F]) for the heavy-bodied tray material and the light-bodied syringe material.
2. A storage bath (about 65°C [150°F]) for maintaining liquefied materials until needed.



Fig. 14-30
Impression evaluation. **A,** Low magnification of elastomeric impression. On the left an adequate cuff is formed by material extending beyond the preparation margin. On the right side (*arrow*) the impression does not extend adequately. **B,** This impression reproduces an adequate amount of the unprepared tooth structure cervical to the preparation margin.



Fig. 14-31
Hydrocolloid conditioning equipment consists of three thermostatically controlled water baths: boiling, storage, and tempering. *(Courtesy of Dux Dental, Oxnard, California.)*

3. A tempering bath (about 40°C [105°F]) for reducing the temperature of the heavy-bodied tray material enough to avoid tissue damage.

Step-by-step procedure

1. Select the correct size of water-cooled impression tray. For maximum accuracy, use as large a size as can be comfortably accommodated by the patient.
2. Place prefabricated stops across the posterior of the tray to prevent overseating and to provide additional retention.
3. For adequate access, displace the gingival tissues as previously described.
4. Fill the impression tray with heavy-bodied material from the storage bath. Add wash material to the surface of the hydrocolloid tray material in the area of the preparation and one adjacent tooth. (Figs 14-32*A* and *B*). Submerge the tray in a tempering bath (Fig. 14-32*C*).
5. Carefully remove the cord from the sulcus and flood the sulcus with warm water (Fig. 14-32*D*).
6. Remove the impression tray from the tempering bath and seat the tray in the patient's mouth. After seating, initiate and maintain the flow of room-temperature water through the tray (Fig. 14-32*E*).
7. Hold the tray firmly in the patient's mouth while the impression material is gelling.
8. Remove the tray with a rapid motion, wash it with room-temperature water, disinfect it (see Table 14-3), and evaluate it for accuracy. Potassium sulfate can be used as a dipping solution for improved stone characteristics.
9. After the impression is judged to be acceptable, pour immediately in type IV or V stone. If delay is inevitable, the impression can be immersed in a special oil-based solution.*

Evaluation

A reversible hydrocolloid impression is evaluated in the same manner as polysulfide polymer (Fig. 14-32*F*). However, the translucency of the material may make small imperfections difficult to detect. If doubt exists, it may be expedient to make a new impression, because this does not require additional tissue displacement and can be easily accomplished.

*Extend-A-Pour, Dux Dental, Oxnard, California.

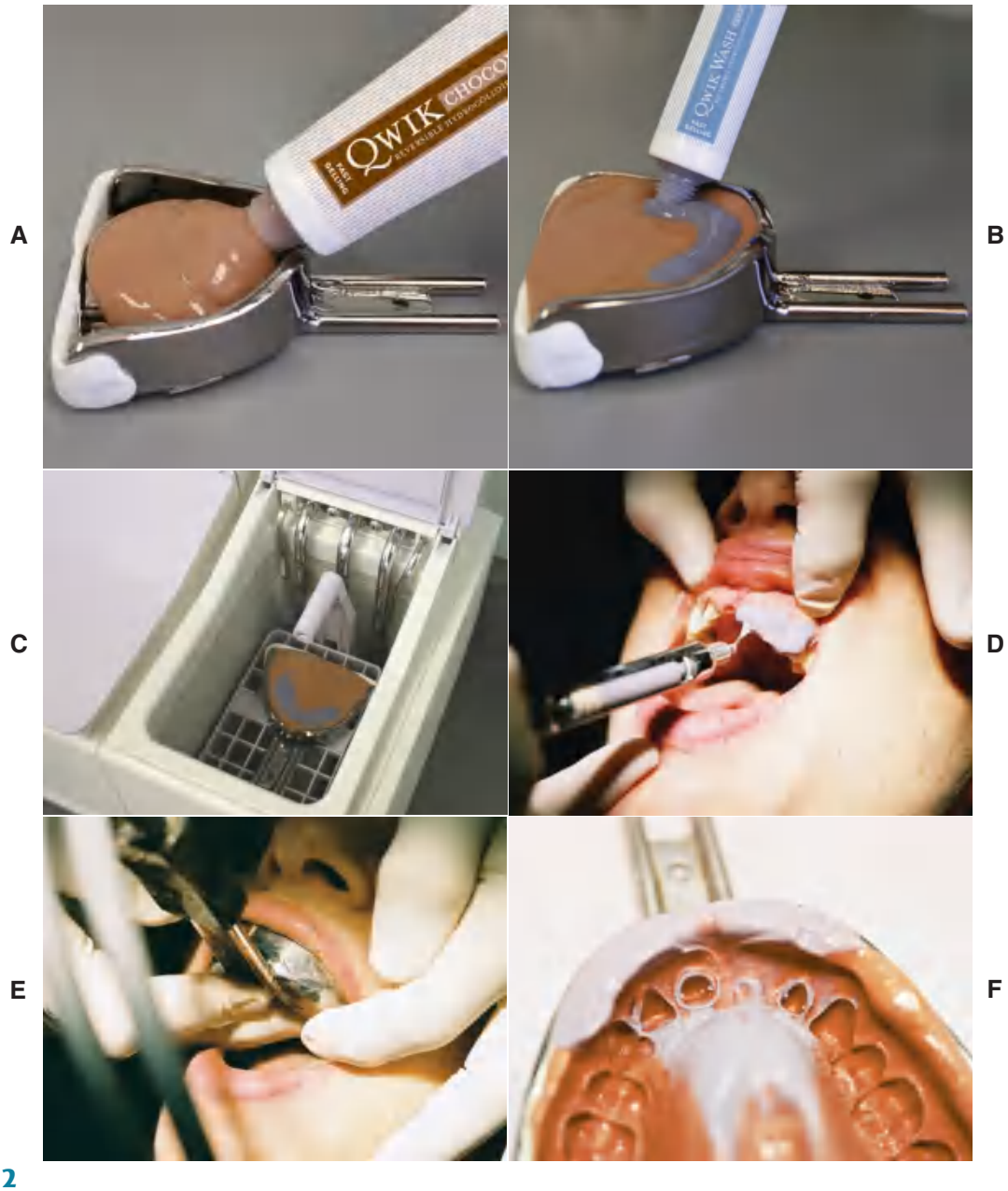


Fig. 14-32

Hydrocolloid impression technique. **A,** The water-cooled impression tray is loaded with heavy-bodied material. **B,** The wash hydrocolloid is squeezed onto the tray material in the area of the preparations. **C,** The filled tray is placed in a tempering bath for the recommended 3 minutes. The entire arch is flooded with water or a surfactant. **D,** Alternatively, some dentists prefer a syringe technique. **E,** Water-cooling tubes are connected and then the tray is seated. **F,** The completed impression. Light-bodied material should have been displaced by the tray material. *(Courtesy of Dux Dental, Oxnard, California.)*

Closed-Mouth Impression Technique

The closed-mouth impression technique, also called the dual-arch or triple tray technique, is popular for making impressions for single units and less expensive restorations made to conform to the existing occlusion.[59,60] The impression is made at maximum intercuspation with a high-viscosity polyether or polyvinylsiloxane impression material supported by a thin mesh in a frame. The impression includes the prepared tooth, the adjacent teeth, and the opposing teeth and records their maximum intercuspation relationship (hence the name "triple tray"). Because the impression is made at the occlusal vertical dimension, the technique facilitates making a highly accurate impression[61] and occlusal record. However, the laboratory stages must be performed very carefully and, as no eccentric relationships are recorded, these need to be evaluated and adjusted at restoration delivery.

Step-by-step procedure (Fig. 14-33)

1. Select and evaluate a closed-mouth tray. Make sure the patient can close easily into maximal intercuspation without interference with the tray.
2. Apply adhesive to tray walls. Load both sides of the closed-mouth tray with a high-viscosity elastomeric impression material.
3. Concurrently, remove cord and, using a syringe, apply impression material onto critical areas.

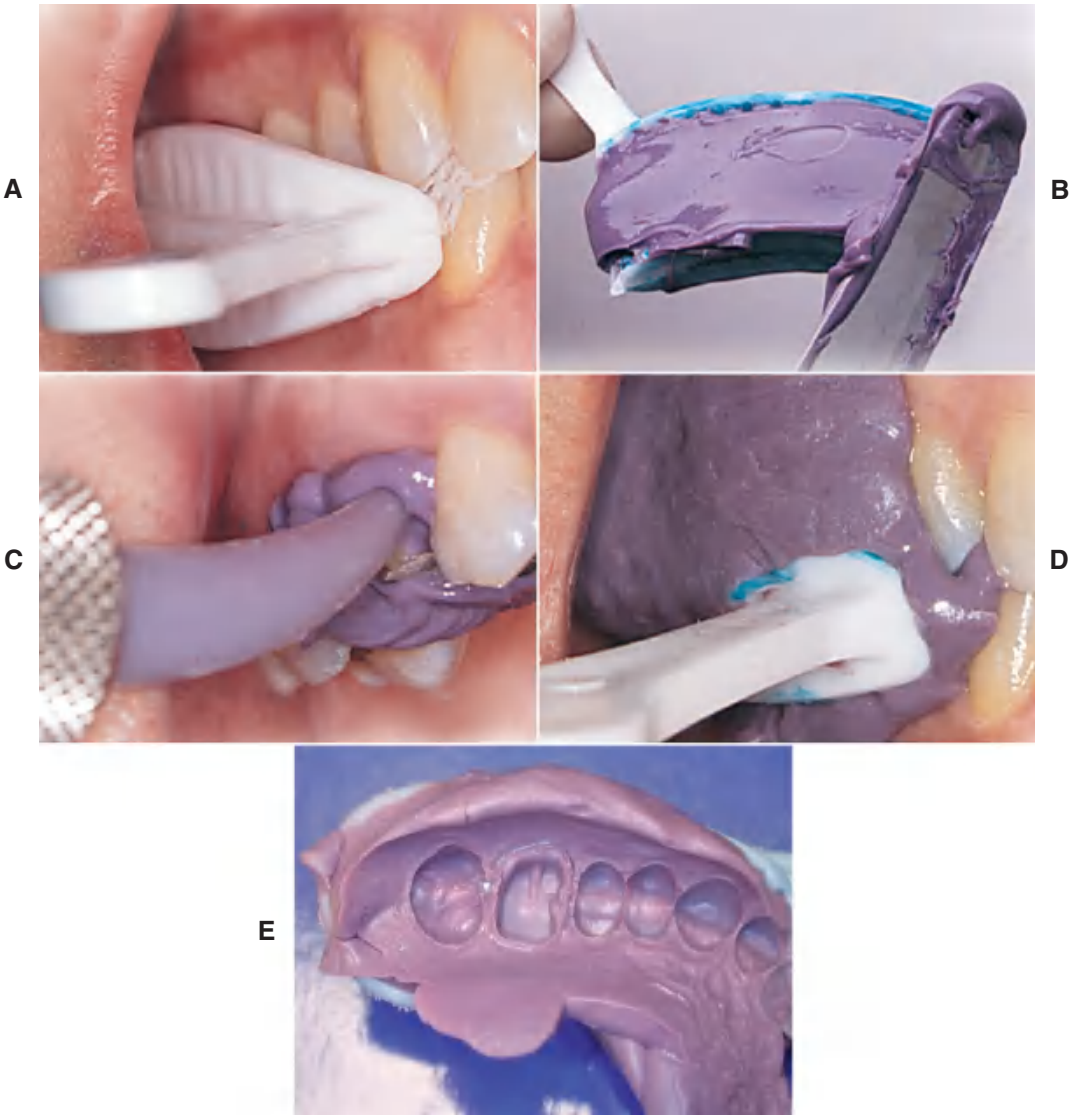


Fig. 14-33

Closed-mouth impression technique. **A,** The tray is selected and evaluated. **B,** Loaded tray. **C,** Impression material delivered by syringe. **D,** Patient closes into maximum intercuspation. **E,** Completed impression. (***A*** *to* ***D,*** *Courtesy of Premier Dental Products Co., Plymouth Meeting, Pennsylvania.)*

4. Place the loaded closed-mouth tray into position and have the patient close properly. Check the contralateral side to verify maximum intercuspation.
5. Remove the polymerized impression, helping the patient open the mouth by applying pressure to the set material or tray border on the nonprepared side.

Evaluation

The impression is evaluated for accuracy and detail (see Fig. 14-33*E*). Ensure that the patient has not closed into the sides or distal bar of the tray.

Special Considerations

Certain modifications of the basic **impression technique** are sometimes needed, particularly for making impressions with additional retention features such as pinholes and post space.

Pin-retained restorations

Elastomeric impression materials are strong enough to reproduce a pinhole without tearing. However, to avoid bubbles, they must be introduced carefully into the pinhole with a lentulo or cement tube (Fig. 14-34). With reversible hydrocolloid, a special nylon bristle must be used for the impression.

Step-by-step procedure

1. Apply a separating medium (e.g., die lubricant) to the pinholes, and isolate and displace the tissue in the conventional manner.
2. After mixing the light-bodied impression material, set aside a small amount for placement into the pinholes.

Cement tube

3. Fill the tube and squeeze a small amount of material into each pinhole. Make sure that no air is trapped in the base of the pinhole (insert an explorer into the material, remove, and repeat the application).

Lentulo

4. Be sure that the slow-speed handpiece is rotating clockwise before picking up a small quantity of impression material with the lentulo.
5. Deliver the material in a spiraling manner into the pinholes, rotating the instrument slowly while moving the lentulo along the side of the pinhole.
6. Increase the speed of the lentulo while backing it out (to prevent the material from being pulled out).

Prefabricated plastic pin

7. When making a reversible hydrocolloid impression of a pin-retained restoration, use plastic bristles to register the pinholes. The bristles can be modified as necessary with a sharp scalpel to eliminate any inaccuracy relating to fit. Their lengths should be adjusted so that they do not contact the impression tray. (A bristle should extend 2 mm above the opening of the pinhole.)
8. Apply a separating medium to the pinhole before placing the bristle and completing the impression.

Post and cores

Elastomeric materials can be successfully used to make impressions of the post space when endodontically treated teeth are being restored. The procedure involves reinforcing the impression with a plastic pin or suitable wire (e.g., orthodontic wire), as described in Chapter 12.

Disinfection

When they are removed from the patient's mouth, it must be assumed that all impression materials have been in contact with body fluids. They should be disinfected according to the recommended procedures for the material being used. After being removed



Fig. 14-34
Elastomeric impression for pin-retained restorations. **A,** A lentulo fills each pinhole; then material is delivered by syringe around the prepared teeth in the normal way, and the tray is seated. **B,** The completed impression.

from the patient's mouth, the impression is immediately rinsed with tap water and dried with an air syringe. Suitable chemicals should be used, such as glutaraldehyde solutions or iodophor sprays. Table 14-4 shows the most commonly recommended techniques for the materials discussed in this section. Some are perfectly acceptable for one material but unsuitable for others. Because of its tendency to distort and absorb moisture, polyether or "hydrophilic" addition silicone impression materials should be sprayed and stored in a plastic bag rather than submerged and soaked in a glutaraldehyde solution. Disinfection is an essential step for preventing cross-infection and exposure of laboratory personnel. If it is performed properly, disinfection does not affect the accuracy or surface reproduction of the elastomer.[62,63]

Evaluation

After disinfection, the completed impression (Fig. 14-35) is inspected carefully before the definitive cast is made. An elastomeric impression should be dried before it is evaluated. The following points are then considered:

1. Has the material been properly mixed? An impression that contains visible streaks of base or catalyst material should be rejected.
2. Is there an area where the custom tray shows through? This must be identified and its potential effect on the quality of the impression assessed. A common error is rotation and the resulting inaccurate seating of the tray. This can result in the tray's contacting several teeth and an uneven thickness of impression material. Normally this occurs only at the tray stops, but when it touches a critical area, the impression must be discarded and a new one made. However, if a thin spot is not near the prepared teeth, it can sometimes be allowed to remain.
3. Are there any voids, folds, or creases? These should have been avoided by careful technique; however, the impression may still be acceptable when a small defect is present in a noncritical area (e.g., away from the margin of a prepared tooth). Careful judgment must be exercised.
4. Is there an even, uninterrupted extension of impression material beyond the margins of the prepared teeth? This is essential if restorations with well-fitting margins and correct contours are to be made.
5. Has the impression material separated from the tray? This is a common cause of distorted impressions and results from improper application and/or inadequate drying of the adhesive.

Table **14-4 RECOMMENDED DISINFECTION METHOD BY IMPRESSION MATERIAL**

Disinfection	Irreversible* hydrocolloid	Reversible* hydrocolloid	Polysulfide	Silicones	Polyether†
Glutaraldehyde 2% (10-minute soak time)	Not recommended	Not recommended	Yes	Yes	No
Iodophors (1 : 213 dilution)	Yes	Yes	Yes	Yes	No
Chlorine compounds (1 : 10 dilution of commercial bleach)	Yes	Yes	Yes	Yes	Yes
Complex phenolics	Not recommended	Limited data	Yes	Yes	No
Phenolic glutaraldehydes	Not recommended	Yes	Yes	Yes	No

Modified from Merchant VA: Update on disinfection of impressions, prostheses, and casts. ADA 1991 guidelines, *J Calif Dent Assoc* 20:10, 31, 1992.

*Immersion time should be minimized. Dip in glutaraldehyde, rinse in sterile water, dip again, and delay pouring for 10 minutes while maintaining a humid environment. Alternatively, spray with sodium hypochlorite, rinse, and respray with a similar 10-minute delay before pouring.

†Imbibition distortion results from prolonged immersion. For 1 : 10 hypochlorite or chlorine dioxide: spray, rinse, repeat, spray again, and delay pouring for approximately 10 minutes.



Fig. 14-35
The completed impression. **A** and **B,** Careful technique ensures a complete cuff of impression material beyond the margin and greatly facilitates trimming of the die and contouring of the wax pattern.

STUDY QUESTIONS

1. Discuss the prerequisites to successful and predictable impression making with elastomeric impression materials.
2. Discuss three ways to ensure access to prepared tooth structure for impression making. What are the respective indications and contraindications?
3. Name three classes of impression materials for fixed prosthodontics, and discuss their advantages and disadvantages. Illustrate their indicated use with three clinical scenarios.
4. Describe 10 issues to consider before electrosurgery is implemented.
5. What are the requirements for a successful custom impression tray?
6. Disinfection techniques vary among materials. Select three classes of impression material and illustrate how the respective disinfection techniques change for each.

SUMMARY

An impression or negative likeness of the teeth and surrounding structures is used to obtain a cast, on which the planned restoration is fabricated. A good impression is an exact negative replica of each prepared tooth and must include all of the prepared surfaces and an adequate amount of unprepared tooth structure adjacent to the margin.

Healthy soft tissues and the control of saliva flow are essential for a successful impression. However, caution must be exercised to prevent injury to the gingiva. Cotton rolls, cards, and saliva evacuators are needed for adequate moisture control. Use of a local anesthetic to minimize discomfort and to reduce saliva flow during the impression procedure is recommended.

Mechanical, chemical, and surgical methods for enlargement of the gingival sulcus can be used to obtain access to subgingival margins of prepared teeth. However, a narrow cord impregnated with a mild astringent (e.g., $AlCl_3$) is recommended. To protect the smear layer, excessive contact between hemostatic agents and cut tooth structure should be avoided.

A custom acrylic resin tray should be used when making an impression with any of the elastomeric materials. All impression materials should be rinsed, dried, and disinfected when removed from the mouth. Impressions made with polysulfide polymer should be poured within 1 hour. Impressions made with polyether or addition silicone have high dimensional stability and can be stored considerably longer before pouring. When making pin-retained restorations, a cement tube, lentulo, or nylon bristle is needed for an accurate impression of the pinholes or post spaces. In this technique and others, a good impression is crucial for an accurately fitting restoration.

GLOSSARY*

ac·cel·er·a·tor \ăk-sĕl′a-rā′ter\ *n* (1611)**: 1:** a substance that speeds a chemical reaction **2:** in physiology, a nerve, muscle, or substance that quickens movement or response

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agar \ā′gar′, ä′gar′\ *n* (1889): a complex sulfated polymer of galactose units, extracted from *Gelidium cartilagineum, Gracilaria confervoides,* and related red algae. It is a mucilaginous substance that melts at approximately 100° C and solidifies into a gel at approximately 40° C. It is not digested by most bacteria and is used as a gel in dental impression materials and a solid culture media for microorganisms.

an·es·the·sia \ăn′ĭs-thē′zha\ *n* (ca. 1721): loss of feeling or sensation; also spelled *anaesthesia*

au·to·poly·mer \ô′tō-pŏl′a-mer\ *n*: a material that polymerizes by chemical reaction without external heat as a result of the addition of an activator and a catalyst—**au·to·poly·mer·i·za·tion** \ô′tō-pŏl′a-mĕr-zā′shun\ *vb*

cat·a·lyst \kăt′l-ĭst\ *n* (1902): a substance that accelerates a chemical reaction without affecting the properties of the materials involved

cau·tery \kô′te-rē\ *n, pl* **-ter·ies** (15c): the application of a caustic substance, hot instrument, electric current, or other agent used to burn, scar, or destroy tissue

colloid \kŏl′oid\: a material in which is suspended a constituent in a finely divided state that is invisible to the eye but capable of scattering light

custom tray \kŭs′tum trā\: an individualized impression tray made from a cast recovered from a preliminary impression. It is used in making a final impression

dimensional stability \dĭ-mĕn′shun-l sta-bĭl′ĭ-tē\: the ability of a material to retain its size and form

e·las·to·mer \ĭ-lăs′ta-mer\ *n* (ca. 1934): a polymer whose glass transition temperature is below its service temperature (usually room temperature). These materials are characterized by low stiffness and extremely large elastic strains—**e·las·to·mer·ic** *adj*

final impression \fī′nal ĭm-prĕsh′on\: the impression that represents the completion of the registration of the surface or object

functionally generated path \fŭngk′sha-na-lē jĕn′a-rāt′ĭd păth\: a registration of the paths of movement of the occlusal surfaces of teeth or occlusion rims of one dental arch in plastic or other media attached to the teeth or occlusal rims of the opposing arch

gingival displacement \jĭn′ja-val dĭs-plās′ment\: the deflection of the marginal gingiva away from a tooth

hydrocolloid \hī′dra-kŏl′oid\ *n* (1916): a colloid system in which water is the dispersion medium; those materials described as a colloid sol with water that are used in dentistry as elastic impression materials—see IRREVERSIBLE H., REVERSIBLE H.

hyperplastic tissue \hī′per-plăs′tik tĭsh′ōō\: excessive tissue proliferation, usually as a response to chronic irritation

hy·per·tro·phy \hī-pûr′tra-fē\ *n* (1834): an enlargement or overgrowth of an organ or tissue beyond that considered normal as a result of an increase in the size of its constituent cells and in the absence of tumor formation

im·pres·sion \ĭm-prĕsh′an\ *n* (14c): a negative likeness or copy in reverse of the surface of an object; an imprint of the teeth and adjacent structures for use in dentistry—see ALTERED CAST PARTIAL DENTURE I., DENTAL I., DIRECT BONE I., AREA, I. MATERIAL I., TRAY I., MASTER I., PARTIAL DENTURE I., PRELIMINARY I., SECTIONAL I., TUBE I.

impression material \ĭm-prĕsh′an mă-tîr′ē-al\: any substance or combination of substances used for making an impression or negative reproduction

impression technique \ĭm-prĕsh′an tĕk′nēk\ *obs*: a method and manner used in making a negative likeness (GPT-4)

impression tray \ĭm-orĕsh′an trā\: **1:** a receptacle into which suitable impression material is placed to make a negative likeness **2:** a device that is used to carry, confine, and control impression material while making an impression

is·chem·ia \ĭ-skē′mē-a\ *n* (ca. 1860): local and temporary deficiency of blood, chiefly resulting from the contraction of a blood vessel

master impression \măs′tar ĭm-prĕsh′an\: the negative likeness made for the purpose of fabricating a prosthesis

mon·o·mer \mŏn′a-mar\ *n* (1914): a chemical compound that can undergo polymerization; any molecule that can be bound to a similar molecule to form a polymer

ne·cro·sis \na-krō′sĭs, nĕ-\ *n, pl* **ne·cro·ses** \sēz\ (1665): localized death of living tissue

poly·eth·er \pŏl′ē-ē′thar\ *adj*: an elastomeric impression material of ethylene oxide and tetra-hydrofluro copolymers that polymerizes under the influence of an aromatic ester

poly·sul·fide \pŏl′ē-sŭl′fīd\ *n* (1849): an elastomeric impression material of polysulfide polymer (mercaptan) that cross-links under the influence of oxidizing agents such as lead peroxide

poly(vinyl siloxane) \pŏl′ē-vī′nal sī-lŏks′ān\ *n*: an addition reaction silicone elastomeric impression material of silicone polymers having terminal vinyl groups that cross-link with silanes on activation by a platinum or palladium salt catalyst.

reversible hydrocolloid \rĭ-vûr′sa-bal hī′dra-kŏl′oid′\: colloidal gels in which the gelation is brought about by cooling and can be returned to the sol condition when the temperature is sufficiently increased

spat·u·la \spăch′a-la\ *n* (1525)**:** a flat-bladed instrument used for mixing or spreading materials

surface tension \sûr′fas tĕn′shun**:** a property of liquids in which the exposed surface tends to contract to the smallest possible area, as in the spherical formation of drops. This is a phenomenon attributed to the attractive forces, or cohesion, between the molecules of the liquid.

tissue displaceability \tĭsh′ōō dĭs-plās′a-bĭl′ĭ-tē**: 1:** the quality of oral tissues that permits them to be placed in other than a relaxed position **2:** the degree to which tissues permit displacement

tissue displacement \tĭsh′ōō dĭs-plās′mant**:** the change in the form or position of tissues as a result of pressure. Frequently used to describe gingival tissue placement prior to impression making.

tissue reaction \tĭsh′ōō rē-ăk′shun**:** the response of tissues to an altered condition

vinyl polysiloxane \vī′năl pa-lē′sĭ-lŏk′sān\ *n***:** an addition reaction silicone elastomeric impression material of silicone polymers having terminal vinyl groups that cross-link with silanes on activation by a platinum or palladium salt catalyst. Called also *vinyl(polysiloxane)*

REFERENCES

1. McCormick JT, et al: Wettability of elastomeric impression materials: effect of selected surfactants. Int J Prosthod 2:413, 1989.
2. Kissov HK, Chalashkanova MI: The impression as a means for analysis of clinical mistakes in fixed prosthodontics. Folia Med (Plovdiv) 43(1–2):84, 2001.
3. Council on Dental Therapeutics, American Dental Association: Accepted Dental Therapeutics, 38th ed, p. 247. Chicago, American Dental Association, 1979.
4. Sherman CR, Sherman BR: Atropine sulfate: a current review of a useful agent for controlling salivation during dental procedures. Gen Dent 47:56, 1999.
5. Findlay D, Lawrence JR: An alternative method of assessing changes in salivary flow: comparison of the effects of clonidine and tiamenidine (HOE 440). Eur J Clin Pharmacol 14:231, 1978.
6. Wilson EL, et al: Effects of methantheline bromide and clonidine hydrochloride on salivary secretion. J Prosthet Dent 52:663, 1984.
7. Laufer BZ, et al: The closure of the gingival crevice following gingival retraction for impression making. J Oral Rehabil 24:629, 1997.
8. Bowles WH, et al: Evaluation of new gingival retraction agents. J Dent Res 70:1447, 1991.
9. Land MF, et al: Disturbance of the dentinal smear layer by acidic hemostatic agents. J Prosthet Dent 72:4, 1994.
10. Land MF, et al: Smear layer instability caused by hemostatic agents. J Prosthet Dent 76:477, 1996.
11. Pelzner RB, et al: Human blood pressure and pulse rate response to racemic epinephrine retraction cord. J Prosthet Dent 39:287, 1978.
12. Jokstad A: Clinical trial of gingival retraction cords. J Prosthet Dent 81:258, 1999.
13. Hansen PA, et al: Current methods of finish-line exposure by practicing prosthodontists. J Prosthodont 8:163, 1999.
14. Cranham JC: Predictable impressioning. Dent Equip Mater p. 46, May/June 2003.
15. Harris HS: Electrosurgery in Dental Practice. Philadelphia, JB Lippincott, 1976.
16. Gnanasekhar JD, al-Duwairi YS: Electrosurgery in dentistry. Quintessence Int 29:649, 1998.
17. Louca C, Davies B: Electrosurgery in restorative dentistry. I. Theory. Dent Update 19:319, 1992.
18. Louca C, Davies B: Electrosurgery in restorative dentistry. II. Clinical applications. Dent Update 19:364, 1992.
19. Podshadley AG, Lundeen HC: Electrosurgical procedures in crown and bridge restorations. J Am Dent Assoc 77:1321, 1968.
20. Maness WL, et al: Histologic evaluation of electrosurgery with varying frequency and waveform. J Prosthet Dent 40:304, 1978.
21. DeVitre R, et al: Biometric comparison of bur and electrosurgical retraction methods. J Prosthet Dent 53:179, 1985.
22. Walter C: Dental treatment of patients with cardiac pacemaker implants. Quintessence Int 8:57, 1975.
23. Krejci RF, et al: Effects of electrosurgery on dog pulps under cervical metallic restorations. Oral Surg 54:575, 1982.
24. Parker S: The use of lasers in fixed prosthodontics. Dent Clin North Am 48:971, 2004.
25. Tjan AH, et al: Clinically oriented evaluation of the accuracy of commonly used impression materials. J Prosthet Dent 56:4, 1986.
26. Setz J, et al: Profilometric studies on the surface reproduction of dental impression materials. Dtsch Zahnarztl Z 44:587, 1989.
27. Luebke RJ, et al: The effect of delayed and second pours on elastomeric impression material accuracy. J Prosthet Dent 41:517, 1979.
28. Eames WB, et al: Elastomeric impression materials: effect of bulk on accuracy. J Prosthet Dent 41:304, 1979.
29. Cullen DR, Sandrik JL: Tensile strength of elastomeric impression materials, adhesive and cohesive bonding. J Prosthet Dent 62:142, 1989.

30. Herfort TW, et al: Tear strength of elastomeric impression materials. J Prosthet Dent 39:59, 1978.
31. Hondrum SO: Tear and energy properties of three impression materials. Int J Prosthodont 7:517, 1994.
32. Harcourt JK: A review of modern impression materials. Aust Dent J 23:178, 1978.
33. Fusayama T, et al: Accuracy of the laminated single impression technique with silicone materials. J Prosthet Dent 32:270, 1974.
34. Tjan AH: Effect of contaminants on the adhesion of light-bodied silicones to putty silicones in putty-wash impression technique. J Prosthet Dent 59:562, 1988.
35. Henry PJ, Harnist DJR: Dimensional stability and accuracy of rubber impression materials. Aust Dent J 19:162, 1974.
36. Mansfield MA, Wilson HJ: Elastomeric impression materials: a method of measuring dimensional stability. Br Dent J 139:267, 1975.
37. Nally FF, Storrs J: Hypersensitivity to a dental impression material: a case report. Br Dent J 134:244, 1973.
38. Lacy AM, et al: Time-dependent accuracy of elastomer impression materials. II. Polyether, polysulfides, and polyvinylsiloxane. J Prosthet Dent 45:329, 1981.
39. Sivers JE, Johnson GK: Adverse soft tissue response to impression procedures: report of a case. J Am Dent Assoc 116:58, 1988.
40. Peregrina A, et al: Effect of two types of latex gloves and surfactants on polymerization inhibition of three polyvinylsiloxane impression materials. J Prosthet Dent 90:289, 2003.
41. Tseng KC, et al: Effect of dithiocarbamate on polymerization of polyvinylsiloxane impression materials [Abstract 1645]. Presented at American Association of Dental Research/International Association of Dental Research Annual Session, Baltimore, March 9–12, 2005.
42. Peregrina A, et al: Effect of two types of latex gloves and surfactants on polymerization inhibition of three polyvinylsiloxane impression materials. J Prosthet Dent 90:289, 2003.
43. Kimoto K, et al: Indirect latex glove contamination and its inhibitory effect on vinyl polysiloxane polymerization. J Prosthet Dent 93:433, 2005.
44. Matis BA, et al: The effect of the use of dental gloves on mixing vinyl polysiloxane putties. J Prosthodont 6:189, 1997.
45. Boening KW, et al: Clinical significance of surface activation of silicone impression materials. J Dent 26:447, 1998.
46. Pratten DH, Craig RG: Wettability of a hydrophilic addition silicone impression material. J Prosthet Dent 61:197, 1989.
47. Oda Y, et al: Evaluation of dimensional stability of elastomeric impression materials during disinfection. Bull Tokyo Dent Coll 36:1, 1995.
48. Millar BJ, et al: In vitro study of the number of surface defects in monophase and two-phase addition silicone impressions. J Prosthet Dent 80:32, 1998.
49. Peregrina A, et al: The effect of different adhesives on vinyl polysiloxane bond strength to two tray materials. J Prosthet Dent 94:209, 2005.
50. Millstein P, et al: Determining the accuracy of stock and custom tray impression/casts. J Oral Rehabil 25:645, 1998.
51. Gordon GE, et al: The effect of tray selection on the accuracy of elastomeric impression materials. J Prosthet Dent 63:12, 1990.
52. Martinez LJ, von Fraunhofer JA: The effects of custom tray material on the accuracy of master casts. J Prosthodont 7:106, 1998.
53. Wirz J, et al: Light-polymerized materials for custom impression trays. Int J Prosthod 3:64, 1990.
54. Bindra B, Heath JR: Adhesion of elastomeric impression materials to trays. J Oral Rehabil 24:63, 1997.
55. Burton JF, et al: The effects of disposable and custom-made impression trays on the accuracy of impressions. J Dent 17:121, 1989.
56. Pagniano RP, et al: Linear dimensional change of acrylic resins used in the fabrication of custom trays. J Prosthet Dent 47:279, 1982.
57. McCabe JF, Carrick TE: Rheological properties of elastomers during setting. J Dent Res 68:1218, 1989.
58. Chong YH, et al: The effect of mixing method on void formation in elastomeric impression materials. Int J Prosthod 2:323, 1989.
59. Wilson EG, Werrin SR: Double arch impressions for simplified restorative dentistry. J Prosthet Dent 49: 198, 1983.
60. Donovan TE, Chee WWL: A review of contemporary impression materials and techniques. Dent Clin North Am 48:445, 2004.
61. Ceyhan JA, et al: The effect of tray selection, viscosity of impression material, and sequence of pour on the accuracy of dies made from dual-arch impressions. J Prosthet Dent 90:143, 2003
62. Drennon DG, et al: The accuracy and efficacy of disinfection by spray atomization on elastomeric impressions. J Prosthet Dent 62:468, 1989.
63. Drennon DG, Johnson GH: The effect of immersion disinfection of elastomeric impressions on the surface detail reproduction of improved gypsum casts. J Prosthet Dent 63:233, 1990.

15

INTERIM FIXED RESTORATIONS



Anthony G. Gegauff and Julie A. Holloway

KEY TERMS

acrylic resin
autopolymerizing resin
exotherm
external surface form (ESF)
interim luting agent
poly(methylmethacrylate)
poly(R′ methacrylate)
tissue surface form (TSF)

Interim crowns or partial fixed dental prostheses (FDPs) are essential in prosthodontic therapy. The word *interim* means established for the time being, pending a permanent arrangement. Even though a definitive restoration may be placed as quickly as 2 weeks after tooth preparation, the interim fixed restoration must satisfy important needs of the patient and dentist. Unfortunately, *temporary* usually connotes laxity, and this may imply that requirements pertaining to the more permanent condition are ignored. If this connotation becomes a philosophy governing the interim phase of treatment, the clinical efficiency and treatment quality will be needlessly reduced. Experience has repeatedly shown that time and efforts expended in fulfilling the requisites of interim fixed restorations are well spent.

Because of unforeseen events (e.g., laboratory delays or patient unavailability), an interim fixed restoration may have to function for an extended period. On the other hand, a delay in placing the definitive restoration may be deliberate (e.g., because the etiologic factors of a temporomandibular disorder or periodontal disease must be corrected). Whatever the intended length of time of treatment, an interim restoration must be adequate to maintain patient health. Thus, it should not be casually fabricated on the basis of an expected short term of use.

Interim procedures also must be efficiently performed, because they are done while the patient is in the operatory and during the same appointment that the teeth are prepared. Costly chairside time must not be wasted, but the dentist must produce an acceptable restoration. Failure to do so results in the eventual loss of more time than was initially thought saved. For example, an inadequate restoration may lead to unnecessary repairs or to the need to treat gingival inflammation and remake the impression. Such problems can be avoided if the dentist thoroughly understands what is required of the interim restoration and makes the effort to meet these requirements.

REQUIREMENTS

An optimum interim fixed restoration must satisfy many interrelated factors, which can be classified as biologic, mechanical, and esthetic (Fig. 15-1).

Biologic Requirements

Pulpal protection

An interim fixed restoration must seal and insulate the prepared tooth surface from the oral environ-

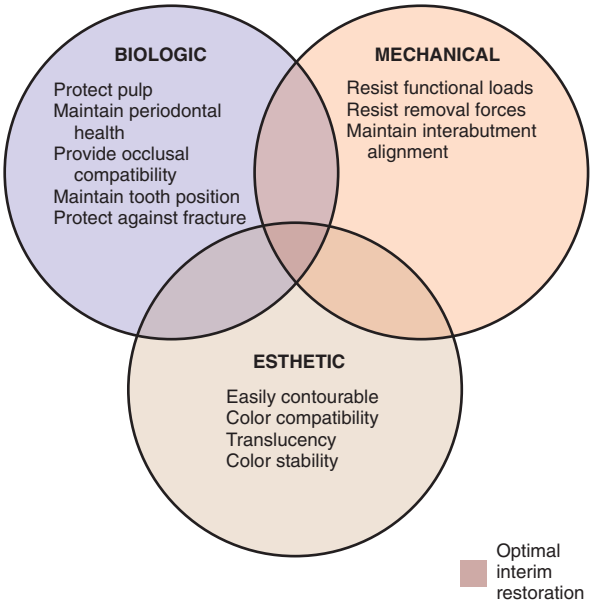


Fig. 15-1
Factors to be considered in making an interim restoration. The *central area* represents the optimum, in which biologic, mechanical, and esthetic requirements are adequately met.

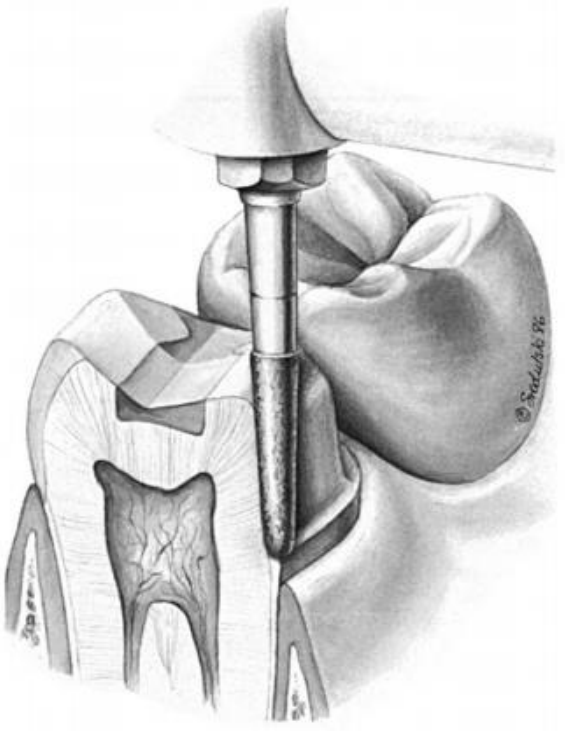


Fig. 15-2
Pulp trauma and exposure of the dentinal tubules from tooth preparation.

ment to prevent sensitivity and further irritation to the pulp. A certain degree of pulp trauma is inevitable during tooth preparation because of the sectioning of dentinal tubules (Fig. 15-2). In health, each tubule contains the cytoplasmic process of a cell body (the odontoblast), whose nucleus is in the pulp cavity. Unless the environment around the exposed dentin is carefully controlled, adverse pulp effects can be expected.[1] In addition, the pulp health of a tooth requiring a cast restoration is likely to be compromised before and after preparation (Table 15-1). In severe situations, leakage can cause irreversible pulpitis, with the consequent need for root canal treatment.[2]

Table **15-1 FACTORS CONTRIBUTING TO PULP DEATH**

Past	Present (during fixed prosthodontic therapy)
Caries	Preparation trauma
Operative dentistry	Microbial exposure
Bruxism	Desiccation
Periodontal surgery	Chemical exposure
Prosthodontic therapy	Thermal exposure

Periodontal health

To facilitate plaque removal, an interim fixed restoration must have good marginal fit, proper contour, and a smooth surface. This is particularly important when the crown margin is placed apical to the free gingival margin.[3] If the interim fixed restoration is inadequate and plaque control is impaired, gingival health deteriorates.[4]

The maintenance of good gingival health is always desirable, but it has special practical significance when fixed prosthodontics is undertaken. Inflamed or hemorrhagic gingival tissues make subsequent procedures (e.g., impression making and cementation) very difficult. The longer the interim fixed restoration must serve, the more significant any deficiencies in its fit and contour become (Fig. 15-3). When gingival tissue is impinged upon, ischemia is likely to develop. This can be detected initially as tissue blanching. If it is not corrected, a localized inflammation or necrosis develops.

Occlusal compatibility and tooth position

The interim fixed restoration should establish or maintain proper contacts with adjacent and opposing teeth (Fig. 15-4). Inadequate contacts allow supraeruption and horizontal movement. Supraeruption is detected at the evaluation appointment, when the definitive restoration makes premature contact. It is possible to correct this in the operatory, but the effort is time consuming and often leads to

Rough margins around interim restorations will jeopardize subsequent procedures.

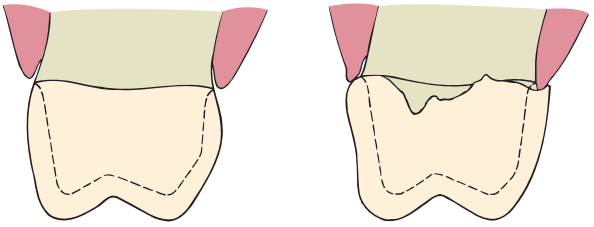


Fig. 15-3
An interim restoration should have good marginal fit, proper contour, and a smooth surface finish. **A,** The properly contoured interim restoration. Smoothly continuous with the external surface of the tooth. **B,** Overcontouring. Irregular transition from the restoration to the root surface and inadequate marginal adaptation. These contribute to plaque accumulation and an unhealthy periodontium.

If an interim restoration does not ensure positional stability, tooth movement can occur, and additional treatment will be necessary.

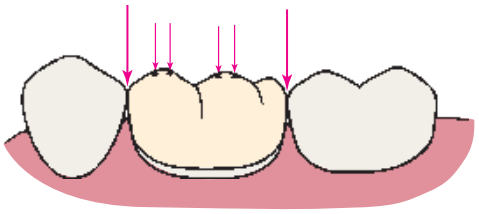


Fig. 15-4
Proper occlusal and proximal contacts promote patient comfort and maintain tooth position.

a restoration with poor occlusal form and function. Horizontal movement results in excessive or deficient proximal contacts. The former require tedious chairside adjustment; the latter involve a laboratory procedure to add metal or ceramic to the deficient site. In spite of these efforts, proximal crown contours are distorted. This, along with a resulting root proximity (Fig. 15-5), impairs oral hygiene measures.

Prevention of enamel fracture

The interim fixed restoration should protect teeth weakened by crown preparation (Fig. 15-6). This is

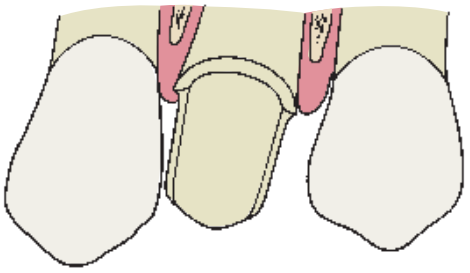


Fig. 15-5
A missing proximal contact allows tooth migration. The resulting root proximity may necessitate surgical or orthodontic correction to allow impression making.

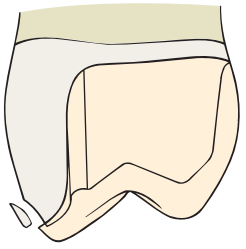


Fig. 15-6
The interim restoration must protect the tooth. Fracture of a tooth after the impression phase delays treatment and jeopardizes restorability.

particularly true with partial coverage designs in which the margin of the preparation is close to the occlusal surface of the tooth and could be damaged during chewing. Even a small chip of enamel makes the definitive restoration unsatisfactory and necessitates a time-consuming remake.

Mechanical Requirements

Function

The greatest stresses in an interim fixed restoration are likely to occur during chewing. Unless the patient avoids contacting the prosthesis when eating, internal stresses are similar to those occurring in the definitive restoration. The strength of polymethyl methacrylate resin is about one-twentieth that of metal-ceramic alloys,[5] which makes fracture of the interim fixed restoration much more likely. Fracture is not usually a problem with a complete crown as long as the tooth has been adequately reduced. More frequently, breakage occurs with partial-coverage restorations and partial FDPs. Partial-coverage restorations are inherently weaker because they do not completely encircle the tooth.

A partial FDP must function as a beam in which substantial occlusal forces are transmitted to the abutments. This creates high stresses in the connectors,[6] which are often the site of failure. To reduce

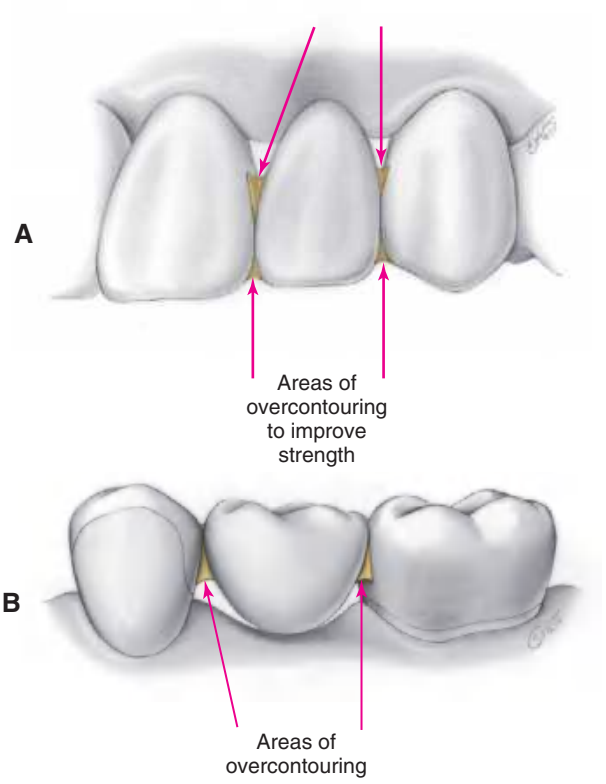


Fig. 15-7
The connectors of an interim fixed dental prosthesis are often purposely overcontoured. **A,** In the anterior region, the degree of overcontouring is substantially limited by esthetic requirements. **B,** In the posterior region, esthetics is less restrictive, but overcontouring still must not jeopardize the maintenance of periodontal health.

the risk of failure, connector size must be increased in the interim restoration in comparison with the definitive restoration (Fig. 15-7). Greater strength is achieved by reducing the depth and sharpness of the embrasures. This increases the cross-sectional area of the connector while reducing the stress concentration associated with sharp internal line angles. The biologic and sometimes the esthetic requirements place limits on just how much larger connectors can be made. To avoid jeopardizing periodontal health, they should not be overcontoured near the gingiva (Fig. 15-8). Good access for plaque control must have high priority.

In some instances, cast metal or heat-processed resin interim restorations can spare the practitioner and the patient inconvenience, lost time, and the expense of remaking a restoration (Box 15-1).

Displacement

If irritation to the pulp and tooth movement are to be avoided, a displaced interim restoration must be recemented promptly. An additional office visit is

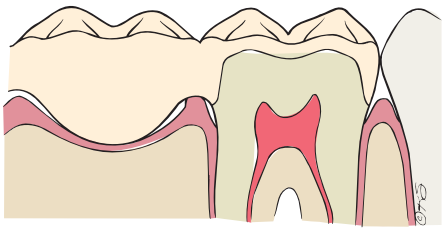


Fig. 15-8
In this mesiodistal section, an overcontoured connector impinges on the gingiva. Pressure ischemia and poor access for plaque removal promote gingivitis.

BOX 15-1 Indications for Cast Metal Interim Restorations

- A long-span posterior partial fixed dental prosthesis
- Prolonged treatment time
- Patient's inability to avoid excessive forces on the prosthesis
- Above-average masticatory muscle strength
- History of frequent breakage

usually required, which results in considerable inconvenience for both patient and dentist. Displacement is best prevented through proper tooth preparation and an interim restoration with a closely adapted internal surface. Excessive space between the restoration and the tooth places greater demands on the luting agent, which has lower strength than regular cement and thus cannot tolerate the added force. For this and for biologic reasons, unlined preformed crowns should be avoided.

Removal for reuse

Interim restorations often need to be reused and so should not be damaged when removed from the teeth. In most instances, if the cement is sufficiently weak and the interim restoration has been well fabricated, it does not break upon removal.

Esthetic Requirements

The appearance of an interim fixed restoration is particularly important for incisors, canines, and sometimes premolars. Although it may not be possible to duplicate exactly the appearance of an unrestored natural tooth, the tooth contour, color, translucency, and texture are essential attributes. When necessary, esthetic enhancement procedures are available to create personalized details; however, because these are not routinely called for, they are addressed on page 500, after the discussion of cementation and repair.

How well a material matches the color of adjacent teeth initially is easily recognized as an essential requirement of prosthodontics. However, some resins discolor with time intraorally,[7] and thus color stability (along with the propensity for stain accumulation) governs the selection of materials when a long period of service is anticipated.

The interim restoration is often used as a guide to achieve optimum esthetics in the definitive restoration. In complete denture prosthodontics, it is customary to have a wax evaluation so that the patient can respond to the dentist's esthetic interpretation before the denture is processed. Many dentists consider this essential because of the frequency of patients' requests for changes and the ease with which such changes can be made. When fixed prosthodontics is performed in the anterior oral cavity, it greatly influences appearance, and the patient should be given an opportunity to voice an opinion. Beauty and personal appearance are highly subjective and difficult to communicate verbally, and a facsimile prosthesis can play a vital role in the patient's consideration of esthetics and the effect that the prosthesis has on his or her self-image. Obtaining the opinions of others whose judgment is valued is also important. An accurate interim restoration is a practical way of obtaining specific feedback for the design of a definitive restoration. Word descriptions alone are often too vague and frequently cause overcorrections, which are difficult to reverse in the definitive restoration. The interim restoration is shaped and modified until its appearance is mutually acceptable to dentist and patient. When this is achieved, an impression is made of the interim restoration (Fig. 15-9) and a cast is poured. This cast accompanies the fixed prosthodontic definitive cast to the laboratory, where the contours are duplicated. This process is more efficient when it begins with diagnostic waxing procedures. Involving the patient in decision making results in greater patient satisfaction.

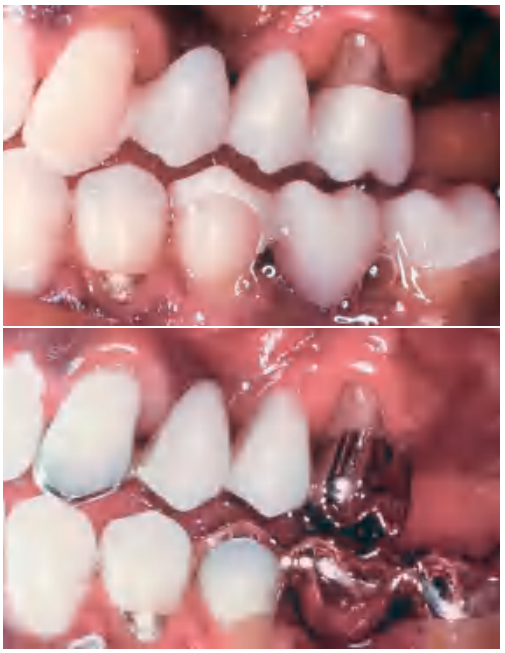


Fig. 15-9
A, This interim fixed dental prosthesis established anterior guidance and pontic form before work on the definitive restoration was begun. (Note the facial cavosurface margin of the mandibular second premolar covered by the interim restoration to protect it from damage.) **B,** The definitive restoration closely matches its predecessor in form and function.

MATERIALS AND PROCEDURES

Many procedures involving a wide variety of materials are available to make satisfactory interim restorations (Fig. 15-10). As new materials are introduced, associated techniques are reported, and thus there is even more variety. It is a helpful principle that all the procedures have in common the formation of a mold cavity into which a plastic material is poured or packed. Furthermore, the mold cavity is created by two correlated parts: one forming the external contour of the crown or FDP, the other forming the prepared tooth surfaces and (when present) the edentulous ridge contact area. The terms *external surface form* (ESF) and *tissue surface form* (TSF) are suggested for these mold parts. This terminology is used in the ensuing discussions.

External Surface Form

There are two general categories of ESFs: custom and preformed.

Custom

A custom ESF is a negative reproduction of either the patient's teeth before preparation or a modified diagnostic cast. It may be obtained directly with any impression material. Impressions made in a quadrant tray with irreversible hydrocolloid or silicone are convenient. The higher cost of addition silicone may be offset by its ability to be retained for possible reuse at any future appointment. Accurate reseating of the ESF is easier and the mold cavity produces better results if thin areas of impression material (as may be found interproximally or around the gingival margin) are trimmed away (Fig. 15-11). The moldable putty materials are popular because they can be used without a tray and are easily trimmed to minimum size with a sharp knife. Also, their flexi-



Fig. 15-10
Although there are many variations, molds used in making interim restorations consist of an external surface form (ESF) and a tissue surface form (TSF). Direct techniques entail use of the patient's mouth directly as the TSF. **A,** Indirect technique: ESF, an alginate impression; TSF, a quick-set plaster cast. **B,** Direct technique: ESF, a baseplate wax impression; TSF, the patient. **C,** Direct technique: ESF, a vacuum-formed acetate sheet; TSF, the patient. **D,** Direct technique: ESF, a polycarbonate preformed shell; TSF, the patient. **E,** Indirect-direct technique: ESF, a custom preformed three-unit fixed dental prosthesis shell (maxillary right central incisor to canine) made indirectly; TSF, the patient. **F,** Indirect technique: ESF, a silicone putty impression; TSF, a quick-set plaster cast of the preparations.



Fig. 15-11
Shortening proximal projections of the impression material facilitates complete reseating of the ESF. Note that excess impression material palatally and facially has been trimmed away with a sharp knife for this reason. The anterior sextant tray shown was selected because it adequately captures the teeth adjacent to the proposed interim restoration.

bility facilitates subsequent removal of the polymerized resin (Fig. 15-12).

A custom ESF can be produced from thermoplastic sheets, which are heated and adapted to a stone cast with vacuum or air pressure while the material is still pliable (Fig. 15-13). This produces a transparent form with thin walls, which makes it advantageous in the direct technique because of its minimum interference with the occlusion. It is filled with resin, placed in the mouth, and fully seated as



Fig. 15-12

A, One of the flexible silicone putties suitable for making external surface forms. **B,** The putty form has been spread apart. Note the completed resin interim restoration in place, to demonstrate the degree of putty flexibility.



Fig. 15-13

A, Inexpensive system for producing external surface forms from thermoplastic sheets. **B,** After heating, the sheet is formed with reusable putty and finger pressure applied over a stone cast. **C,** More expensive system incorporating an electric heating element and a vacuum source. **D,** Trimmed polypropylene external surface form. Note the detail that can be captured with this material.

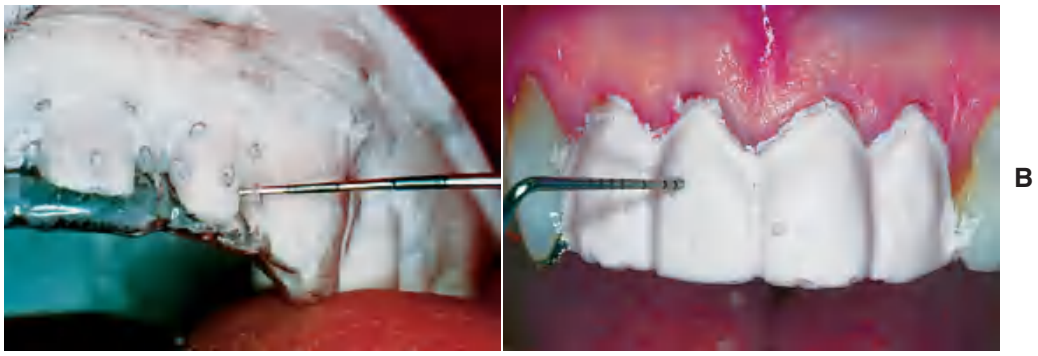


Fig. 15-14
A, The thinness and transparency of these external surface forms (ESFs) allow their use directly as tooth-reduction guides both in and out of the mouth. **B,** Tooth reduction may be assessed by using the ESF to mold alginate over the prepared tooth. When the alginate is set, the ESF is removed, and a periodontal probe is pushed through the alginate for measurements at desired locations. (***B,*** *Courtesy Dr. T. Roongruangphol.)*

the patient closes into maximum intercuspation. Little additional effort is required to adjust the occlusal contacts. The thinness of the material may also be a disadvantage in the direct technique, however. The material is a poor dissipater of the heat released during resin polymerization, and so care must be taken to remove it from the mouth before injury can occur. A thermoplastic ESF has other uses in fixed prosthodontic treatment, in both the clinical and the laboratory phase; for example, it can be helpful in evaluating the adequacy of tooth reduction[8,9] (Fig. 15-14).

Transparent sheets are available in cellulose acetate or polypropylene of various sizes and thicknesses; a 125 × 125 mm sheet of 0.5-mm (0.020-inch) thickness is recommended for making interim restorations. Polypropylene is preferred because it produces better surface detail and is more tear resistant. Better tear resistance makes initial removal from the forming cast less tedious and enables the ESF to be used more than once.

Although thermoplastic sheets have a number of advantages, a wide variety of other materials and methods can be used successfully. For example, some practitioners favor baseplate wax because it is convenient and economical (see Fig. 15-10*B*).

Preformed

Various preformed "crowns" are available commercially. On their own, they rarely satisfy the requirements of a interim restoration, but they can be thought of as ESFs rather than as finished restorations and thus must be lined with autopolymerizing resin. Most crown forms need some modification (internal relief, axial recontouring, occlusal adjustment) in addition to the lining procedure (Fig. 15-15). When extensive modification is required, a custom ESF is superior because it is less time consuming. Preformed crowns are generally limited to use as single restorations, because it is not feasible to use them as pontics for partial FDPs.

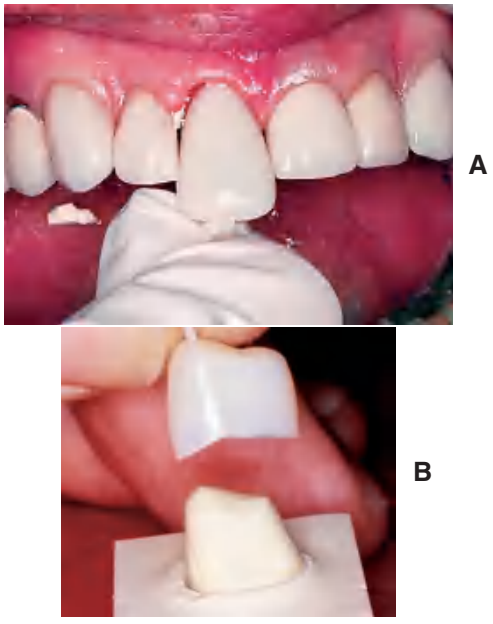


Fig. 15-15
A, The time necessary to modify this particular preformed crown outweighs the advantages it might provide. Were a custom external surface form available, it would be more efficient and more economical. **B,** The excessively tapered internal lingual wall of this preformed crown requires grinding in order to accommodate a properly prepared tooth. The stone cast in the lower portion of the illustration duplicates the internal surface of the preformed crown.

Materials from which preformed ESFs are made (Fig. 15-16) include polycarbonate, cellulose acetate, aluminum, tin-silver, and nickel-chromium. These are available in a variety of tooth types and sizes (Table 15-2).

Polycarbonate

Polycarbonate (Fig. 15-17) has the most natural appearance of all the preformed materials. When properly selected and modified, it rivals in appearance a well-executed porcelain restoration. Although available in only a single shade, this can be modified to a limited extent by the shade of the lining resin.



Fig. 15-16

A, Preformed anterior crown forms: polycarbonate (left) and cellulose acetate (right). **B,** Preformed posterior crown forms: aluminum shell (left), aluminum anatomic (center), and tin-silver anatomic (right).

Polycarbonate ESFs are supplied in incisor, canine, and premolar tooth types.

Cellulose acetate

Cellulose acetate is a thin (0.2- to 0.3-mm) transparent material available in all tooth types and a range of sizes (see Fig. 15-16*A*). Shades are entirely dependent on the autopolymerizing resin. The resin does not chemically or mechanically bond to the inside surface of the shell; therefore, after polymerization, the shell is peeled off and discarded to prevent staining at the interface. Removing the shell has the disadvantage of necessitating the addition of resin to reestablish proximal contacts.

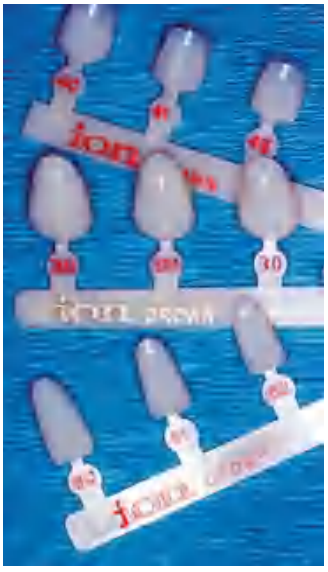


Fig. 15-17

Polycarbonate crowns. Available in maxillary and mandibular incisor, canine, and premolar shapes.

Table **15-2** **PREFORMED CROWNS**

	AREA OF USE					
	Incisor	**Canine**	**Premolar**	**Molar**	**Sizes in each mold**	**Approximate cost ($/unit)**
RESIN						
Cellulose acetate	X	X	X	X	6	1.00
Polycarbonate	X	X	X		7	0.64
METAL						
Aluminum			X	X	20	0.16
Aluminum (anatomic)			X	X	6	2.90
Tin-silver (anatomic)			X	X	7	5.00
Nickel-chromium (anatomic)	X*	X*	X	X	5	4.83

*Primary teeth.



Fig. 15-18
Aluminum anatomic crowns. Available in a variety of sizes and shapes. The manufacturer has produced two maxillary and four mandibular shapes for the left and right side of the mouth, each in six sizes.



Fig. 15-19
Nickel-chromium anatomic crowns. These are available in an array of sizes and shapes, including ones for the primary teeth, with straight and contoured axial surfaces.

Aluminum and tin-silver

Aluminum (Fig. 15-18) and tin-silver are suitable for posterior teeth. The most elaborate crown forms have anatomically shaped occlusal and axial surfaces. The most basic and least expensive forms are merely cylindrical shells resembling a tin can (see Fig. 15-16*B*).

The nonanatomic cylindrical shells are inexpensive but require modification to achieve acceptable occlusal and axial surfaces. It is more efficient to use crowns that have been preformed as individual maxillary and mandibular posterior teeth. Care must also be taken to avoid fracturing the delicate cavosurface margin of the tooth preparation when a metal crown form is fitted. This is a greater risk if adaptation is carried out directly by having the patient forcefully occlude on the crown shell. The edge of the shell can engage the margin and fracture it under biting pressure. An even greater risk occurs when the crown has a constricted cervical contour. Tin-silver crowns are deliberately so designed (see Fig. 15-16*B*). This highly ductile alloy allows the crown cervix to be stretched to fit the tooth closely. Direct stretching on the tooth is practical only where feather edge margins are used. For other margin designs, cervical enlargement should be performed indirectly on a swaging block, which should be supplied with the crown kit.

Nickel-chromium

Nickel-chromium shells (Fig. 15-19) are used primarily for children with extensively damaged primary teeth. In that application, they are not lined with resin but are trimmed, adapted with contouring pliers, and luted with a high-strength cement. They may be applied to secondary teeth but are more suitable for primary teeth, where longevity is less critical. Nickel-chromium alloy is very hard and thus can be used for longer-term interim restorations.

Tissue Surface Form

There are two primary categories of TSFs: indirect and direct. A third category, indirect-direct, is the sequential application of these.

Indirect procedure

An impression is made of the prepared teeth and ridge tissue and is poured in quick-setting gypsum or polyvinyl siloxane.[10] The interim restorations are fabricated outside the mouth. This technique has several advantages over the direct procedures:

1. There is no contact of free monomer with the prepared tooth or gingiva, which might cause tissue damage[11] and an allergic reaction or sensitization.[12-15] One group of investigators[16] reported a 20% incidence of allergic sensitivity in subjects previously exposed to a monomer patch test. The risk of sensitization in patients who are not allergic to monomer increases with the frequency of exposure. In allergic patients, an exposure to even small amounts of monomer usually causes painful ulceration and stomatitis (Fig. 15-20).
2. The procedure avoids subjecting a prepared tooth to the heat evolved from polymerizing resin. The exotherm charted in Figure 15-21 gives an indication of temperature increases with time for several materials under similar experimental conditions. Clinical simulation experiments[17,18] have shown peak temperature increases of approximately 10° Celsius in the pulp chambers of prepared teeth upon which direct interim restorations had been made. That amount of temperature elevation is capable of causing



Fig. 15-20
Labial (**A**) and gingival (**B**) ulcerations after brief polymethyl methacrylate monomer exposure.

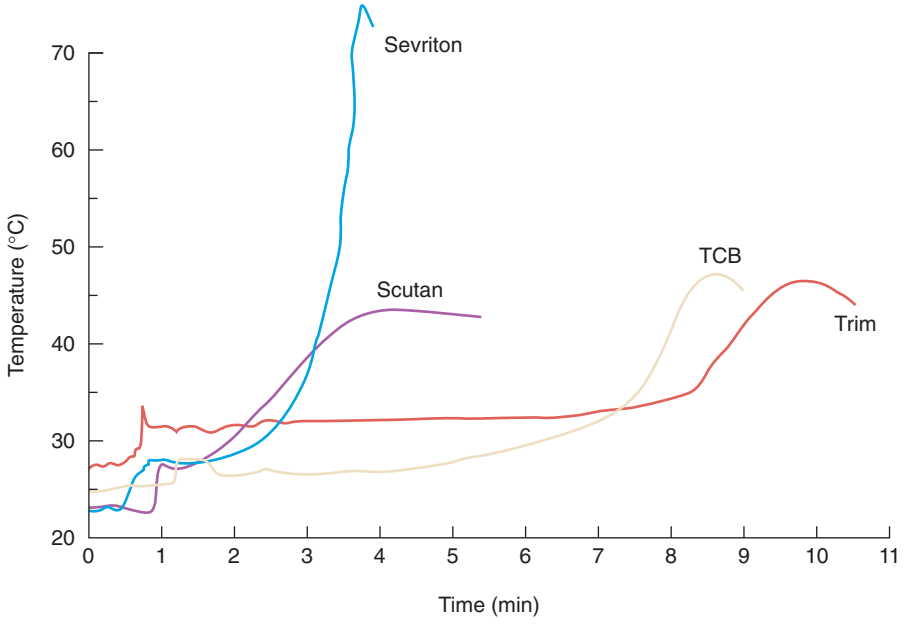


Fig. 15-21
Heat generated during resin polymerization. Under nonclinical experimental conditions, the temperature rises are severe. Sevriton (a polymethyl methacrylate resin) produced significantly higher temperatures than did the others represented. This is useful information for selecting resins to be used intraorally, although under clinical conditions the differences may be insignificant. *(Redrawn from Braden M, et al: A new temporary crown and bridge resin. Br Dent J 141:269, 1976.)*

irreversible damage to the pulp.[19] The simulation experiments also indicate that temperature rise depends directly on the type and volume of resin present. Therefore, a directly made restoration with a large pontic is more likely to cause injury than one for a single crown (especially if the tooth is prepared conservatively). These studies also demonstrate that the heat-conducting properties of the ESFs significantly influence the maximum temperature reached. However, of importance is that peak temperatures were not reached until 7 to 9 minutes had elapsed[18] (Fig. 15-22). For this and the practical reason that it must be drawn through the undercuts of adjacent proximal tooth surfaces, the resin should be removed at the rubbery stage of polymerization, which typically occurs 2 to 3 minutes after insertion in the mouth. In Figure 15-22, the temperature rise is negligible at 3 minutes, which suggests that thermal injury is easily avoidable.

3. The marginal fit of interim restorations that have been polymerized undisturbed on stone casts is significantly better than that of interim restorations that have been removed from the mouth

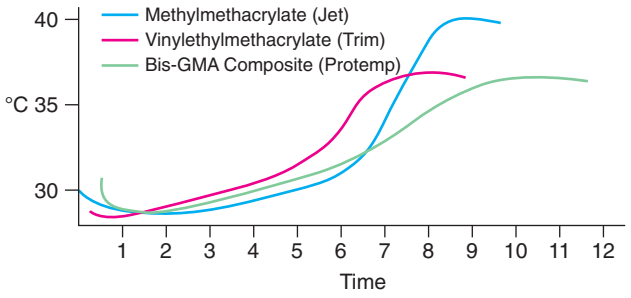


Fig. 15-22

These exotherms (time in minutes) are derived from a simulated clinical procedure for making a single crown with silicone putty as the ESF. A thermocouple probe in the pulp chamber of an extracted tooth was used to measure temperature changes. Initial readings reflect the cooling effect of room-temperature resin mixtures. For all three classes of resins tested, the temperatures did not exceed 35°C until more than 6 minutes had elapsed. *(Redrawn from Tjan AHL, et al: Temperature rise in the pulp chamber during fabrication of provisional crowns. J Prosthet Dent 62:622, 1989.)*

before becoming rigid.[20,21] The reasons for this are that (1) the stone restricts resin shrinkage during polymerization and (2) separating the resin from the tooth causes distortion. Directly made long-span or multi-abutment partial FDPs are likely to have unacceptable marginal discrepancies caused by shrinkage and distortion.

4. When a dimensionally stable elastomer impression is made to form the TSF,[10] it can be retained for possible reuse with the ESF. This allows replacement restorations to be made without having the patient present. For example, if a patient calls to report a lost interim partial FDP, a replacement can be made at the dentist's convenience before the patient arrives. This minimizes disruption of the office schedule and earns the appreciation of the patient. Whether using an elastomer TSF results in margins that fit as well as those obtained with a gypsum TSF is not known. The elastomer may not resist polymerization shrinkage as effectively as the gypsum.
5. The technique gives the patient a chance to rest, and it frees the dentist to perform other tasks, provided that an auxiliary is trained to carry out the laboratory procedures.

Direct procedure

The patient's prepared teeth and gingival tissues (in the case of a partial FDP) directly provide the TSF, and so the intermediate steps of the indirect technique are eliminated. This is convenient when assistant training and office laboratory facilities are inadequate for efficiently producing an indirect restoration. However, the direct technique has significant disadvantages: potential tissue trauma from the polymerizing resin and inherently poorer marginal fit. Therefore, the routine use of directly formed interim restorations is not recommended when indirect techniques are feasible.

Indirect-direct procedure

In this technique the indirect component produces a "custom-made preformed ESF" similar to a preformed polycarbonate crown. In most cases, the practitioner uses a custom ESF with an underprepared diagnostic cast as the TSF. The resulting mold forms a shell that, after tooth preparation, is lined with additional resin (the patient serving as the TSF). This last step is the direct component of the procedure. Another method of creating the shell eliminates the need for an indirect TSF. It is accomplished by painting monomer liquid into the ESF and carefully sprinkling or blowing resin powder on it. The thickness of the resin shell is difficult to control with this technique, however, and may result in the need for time-consuming corrective grinding.

The indirect-direct approach has these advantages:

1. Chairside time is reduced. Most of the procedures have been completed before the patient's visit.
2. Less heat is generated in the mouth. The volume of resin used during lining is comparatively small.
3. Contact between the resin monomer and soft tissues is minimized in comparison with the direct procedure. Because pontic ridge areas do not normally require lining, there is reduced risk of allergic reaction.

However, even with the diagnostic cast method, adjustments are frequently needed to seat the shell completely on the prepared tooth. This is the chief disadvantage of the indirect-direct procedure.

Materials for Interim Fixed Restorations

While in a fluid state, the interim restorative materials fill the cavity formed by the external and TSFs; they then solidify, producing a rigid restoration.

Ideal properties

The characteristics of an ideal interim material are as follows:

- Convenient handling: adequate working time, easy molding, rapid setting time
- Biocompatibility: nontoxic, nonallergenic, nonexothermic
- Dimensional stability during solidification
- Ease of contouring and polishing
- Adequate strength and abrasion resistance



Fig. 15-23
Currently available interim materials. **A,** A poly(methyl methacrylate) resin. **B,** A poly(R′ methacrylate) resin. **C,** Microfilled composite resins with AutoMix delivery system. **D,** Light-cured resins: a microfilled urethane-dimethacrylate (*left*) and a light-cured polyethyl methacrylate.

- Good appearance: translucent, color controllable, color stable
- Good acceptability to patient: nonirritating, odorless
- Ease of adding to or repairing
- Chemical compatibility with interim luting agents

Currently available materials

As yet, an ideal interim material has not been developed. A major problem still to be solved is dimensional change during solidification. These materials (Fig. 15-23) shrink and cause marginal discrepancy,[20-22] especially when the direct technique is used (Fig. 15-24). Also, the resins currently employed are exothermic and not entirely biocompatible.

The materials can be divided into four resin groups:

Poly(methyl methacrylate)
Poly(R′ methacrylate)*
Microfilled composite
Light-cured

The properties of these resins are compared in Table 15-3. The overall performances of the groups are similar, with no material being superior in all categories. Choosing a material should be based on optimally satisfying the requirements or conditions crucial for the success of the treatment. For example, materials with the least toxicity and least polymerization shrinkage should be chosen for a direct technique. Alternatively, when a long-span prosthesis is being fabricated, high strength is an important selection criterion.

*The *R′* represents an alkyl group larger than methyl (e.g., ethyl or isobutyl).

MATERIALS SCIENCE

William M. Johnston

The material used for fabrication of an interim restoration consists of pigments, monomers, filler, and an initiator, all combining to form an esthetic restorative substance. The pigments are incorporated by the manufacturer so that the set material appears as much like natural tooth structure as possible, with a variety of shades available. Although each of the other ingredients plays a role in the handling, setting, and final properties of the interim restoration, many important characteristics of the material are determined by the primary monomer. The ability of this monomer to convert to a polymer allows the material, after it has been formed as desired, to set into a

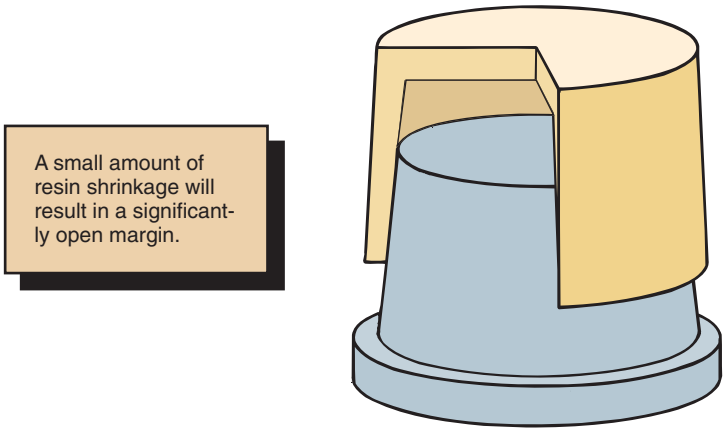


Fig. 15-24 With ideal axial wall convergence, a 2% reduction in crown diameter results in a comparatively high marginal discrepancy.

solid that is durable enough to withstand the oral environment for the necessary interim period.

Depending on the brand, the most commonly used monomers are methyl methacrylate, ethyl methacrylate, isobutyl methacrylate, bisphenol A diglycidylether methacrylate (bis-GMA), and urethane dimethacrylate. Each of these, or combinations thereof, may be converted to a polymer by free radical polymerization, although the conversion process is never perfectly complete.

Free Radical Polymerization

The polymerization process invokes chemical, mechanical, dimensional, and thermal changes that affect the successful use of these materials in dentistry. Because monomers may be unpleasant or even harmful biologically, the chemical conversion of monomer to a biologically inert polymer is desirable. Also, if the polymerization process is not properly initiated or if it is prematurely terminated, the resultant restoration may not have adequate mechanical properties and may fail easily or quickly. However, because the density of the polymer is inherently and often substantially greater than that of the monomer, a dimensional contraction occurs during polymerization. The polymerization reaction is exothermic, which causes the material to become hot before it loses its fluidity, and so an additional contraction occurs on cooling of the restoration. If a direct technique is being used, the heat of reaction can cause irreversible damage to nearby pulpal tissues, which may already have been thermally insulted during cavity preparation.

Initiation

Free radical polymerization begins with the formation of a free radical, a process called *activation*, and the subsequent combination of this free radical with a monomer. Free radicals are formed by the decomposition of a chemical (the initiator), with the method of decomposition dependent on the nature of the initiator. Possible initiators include benzoyl peroxide and camphoroquinone.

Benzoyl peroxide decomposes to free radicals at approximately 50°C or higher in a process called *thermal activation*. Because the heating of some monomers to temperatures near 100°C can cause them to vaporize, with subsequent formation of porosity in the resultant polymer, excessive temperatures should be avoided during the early stages of thermal activation. Thermal activation results in greater contraction on cooling than is obtained with other activation methods and therefore is usually avoided for interim restorations.

Benzoyl peroxide also decomposes to free radicals when catalyzed by a tertiary amine, and this process is called *chemical activation*. Chemical activation occurs when the activator, initiator, and monomer are mixed together, and so these materials are usually supplied separately, the monomer and activator in one container and the initiator and filler in another. Proper mixing is necessary to prevent voids. Because chemical activation requires intimate contact of the chemical activator with the initiator, this activation method is not as efficient as thermal activation. Inefficient activation of the initiator results in more residual monomer and less color stability of the restoration, inasmuch as unreacted benzoyl peroxide can cause color changes. However, because benzoyl peroxide is decomposed by both thermal and chemical activation, increased temperature can enhance its decomposition in a chemically cured system and does not increase contraction if the restoration initially undergoes chemical setting. Heating a recently set restoration in 100°C water promotes greater polymerization efficiency and removes any unconverted monomer, which might

Table **15-3 RANKED CHARACTERISTICS OF REPRESENTATIVE PROVISIONAL RESTORATION RESINS**

Material/characteristic	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Jet (PMMA)	2*	2†	3	1‡	1†	3†	1§	2	1	1	2¶	1	3	1
Duralay (PMMA)	1†	–	3	–	–	–	1	2	1	1	–	1	3	1
Trim (PR′MA)	2†	1†	2	3‡	–	3†	2†	3	1	1	3¶	1	2	1
Snap (PR′MA)	2†	2†	2	–	–	2†	2	3	1	1	–	1	2	1
Protemp Garant (bis-GMA composition)	1*	1	1	2	2	1	2†	3	2	2	1¶	2	1	2
Unifast LC (light-cured, PR′MA)	2*	2**	3	–	–	2††	2	1	3	1	–	2	3	2
Triad (light-cured, urethane DMA composition)	2§	3†	1	1	1†	1†	3†	1	3	3	–	3	1	3

Column heads: *A*, marginal adaptation (indirect); *B*, temperature release during reaction; *C*, toxicity/allergenicity; *D*, strength (fracture toughness); *E*, repair strength (% original); *F*, color stability (ultraviolet light); *G*, ease of trimming and contouring; *H*, working time; *I*, setting time; *J*, flowability for mold filling; *K*, contaminated by free eugenol; *L*, special equipment needed; *M*, odor; *N*, unit volume cost.
Numbers in table: *1*, Most desirable; *2*, Less desirable; *3*, Least desirable.
*Tjan AHL, et al: Marginal fidelity of crowns fabricated from six proprietary provisional materials. J Prosthet Dent 77:482, 1997.
†Wang RL, et al: A comparison of resins for fabricating provisional fixed restorations. Int J Prosthodont 2:173, 1989.
‡Gegauff AG, Pryor HG: Fracture toughness of provisional resins for fixed prosthodontics. J Prosthet Dent 58:23, 1987.
§Koumjian JH, Holmes JB: Marginal accuracy of provisional restorative materials. J Prosthet Dent 63:639, 1990.
¶Gegauff AG, Rosenstiel SF: Effect of provisional luting agents on provisional resin additions. Quintessence Int 18:841, 1987.
**Castelnuovo J, Tjan AH: Temperature rise in pulpal chamber during fabrication of provisional resinous crowns. J Prosthet Dent 78:441, 1997.
††Doray PG, et al: Accelerated aging affects color stability of provisional restorative materials. J Prosthodont 6:183, 1997.
Bis-GMA, bisphenol A diglycidylether methacrylate; DMA, dimethacrylate; PMMA, poly(methyl-methacrylate); PR′MA, poly(R′ methacrylate).

cause a sensitivity reaction in a patient susceptible to monomer irritation.

Camphoroquinone decomposes to free radicals in the presence of both an aliphatic amine and blue light energy, and this process is called *visible-light activation.* Light-activated materials have two advantages: (1) the ingredients can be mixed by the manufacturer with little porosity, and (2) working time is infinitely long because no setting occurs if the material is kept in a dark environment. The limitation of this method is the depth to which visible light can penetrate (less for darker materials). Whenever possible, the activation illumination should be directed toward the center of the restoration from all surfaces. Also, for darker materials, the exposure time should be longer.

Propagation

After its onset, the polymerization process continues by including more monomer molecules in the growing molecular chain. It is important that the material be allowed to set undisturbed because, during this phase, defects can easily result if the material is jostled. During propagation, (1) the setting material undergoes an increase in density, causing contraction, (2) the exothermic heat of reaction may cause a substantial increase in temperature, with subsequent increased contraction, and (3) other physical properties (e.g., rigidity, strength, and resistance to dissolution) increase.

Termination

Because of the randomness of position of the growing chains, it is possible that some of them might combine and thereby terminate the growth process. This type of termination cannot be avoided, although it is desirable to have termination only after polymerization of all the monomer has occurred. Termination may also result from the reaction with eugenol, hydroquinone, or oxygen; therefore, contact with these substances must be avoided or at least minimized when possible.

Properties Associated with the Monomer

The various monomers exhibit different initial and setting characteristics and result in polymers with significantly different properties (i.e., viscosity before setting, exothermic heat of reaction, dimensional change on setting, and strength). In general, the greater the size of the monomer molecule, the less is the exothermic heat of reaction on setting and the lower the physical strength of the set mass. Properties of available materials are presented in Table 15-3.

Filler

Although the primary properties of an interim restorative material are determined by the monomer or monomers involved, a decrease in the less desirable setting and mechanical properties is accomplished mainly through the filler. An increase in filler content reduces the relative amounts of exothermic heat and contraction while increasing the strength of the set material. However, too much filler can lead to insufficient handling characteristics before setting, and this impedes mixing and shaping, as well as introduces porosity in the set restoration. For light-activated systems, the amount of filler is determined by the manufacturer; for the other systems, it is desirable to incorporate as much filler as possible without interfering in the handling or manipulation characteristics of the material.

• • •

PROCEDURES

To minimize duplication, a basic clinical and a basic laboratory armamentarium are listed just once; they may be referred to as needed. As each procedure is discussed, only items necessary to augment the basic armamentarium are listed.

Clinical Armamentarium (Fig. 15-25)

- Gloves
- Face mask
- Protective eyewear
- Mouth mirror
- Explorer
- Periodontal probe
- Saliva evacuator
- Cotton rolls
- Gauze squares
- Gingival displacement cord
- Astringent solution
- Cotton-roll pliers
- Plastic filling instrument
- Cotton pellets
- Petrolatum
- Autopolymerizing resin
- Dropper
- Three dappen dishes
- Cement spatula
- Backhaus towel clamp forceps
- Soft lead pencil
- Straight slow-speed handpiece
- Carborundum disks with mandrels, straight handpiece
- Fine garnet paper disks (7/8-inch diameter) with mandrels, straight handpiece



A

B

Fig. 15-25
A and **B,** Basic clinical armamentarium.

- Tungsten carbide burs, straight handpiece
- High-speed handpiece with air-water supply
- Round bur (No. 4), friction-grip
- Tungsten carbide 12-fluted finishing bur, friction-grip (e.g., 7803)
- High-volume evacuation
- Articulating ribbon and holder
- Disposable brush
- Cup of warm water

Laboratory armamentarium (Fig. 15-26)

- Protective eyewear
- Face mask (for respiratory protection)
- Soft lead pencil
- Disposable brush
- Gypsum-resin separating medium
- Autopolymerizing resin
- Dropper
- Two dappen dishes
- Cement spatula
- Polypropylene syringe
- Rubber bands
- Pressure vessel
- Cast trimmer
- Straight slow-speed handpiece
- Carborundum disks with mandrels, straight handpiece
- Fine garnet paper disks (7/8-inch diameter) with mandrels, straight handpiece
- Tungsten carbide burs, straight handpiece
- Dental lathe
- Muslin wheels
- Robinson bristle brushes
- Felt wheels (1-inch diameter) with mandrels
- Fine pumice
- Resin-polishing compound
- Ultrasonic cleaner with detergent solution

Custom Indirect Interim Partial Fixed Dental Prostheses

The custom indirect procedure is probably the best overall technique for partial FDPs and should provide the most predictable results with the least risk to patient health.

Additions to clinical armamentarium

- Shade guide
- Irreversible hydrocolloid impression material
- Rubber bowl
- Impression tray
- Mixing spatula

Step-by-step procedure

1. After shade selection and tooth preparation, obtain an impression tray for an irreversible hydrocolloid impression. A sextant impression is adequate only if it extends one tooth beyond the abutments, and so the ESF will index accurately with the cast (TSF).
2. Displace the gingiva if necessary to expose the cavosurface margins (Fig. 15-27).
3. Make an irreversible hydrocolloid impression. Other clinical procedures (e.g., making the definitive impression) can take place while the assistant is pouring the cast.

Additions to laboratory armamentarium

- Accelerated-setting plaster
- Rubber bowl
- Spatula
- Vibrator
- ESF

Step-by-step procedure

The setting of plaster can be accelerated by shaking dry powder with the water before mixing (1 tsp of powder in 30 mL water[23]). Alternatively, a commercially available quick-setting plaster may be used.

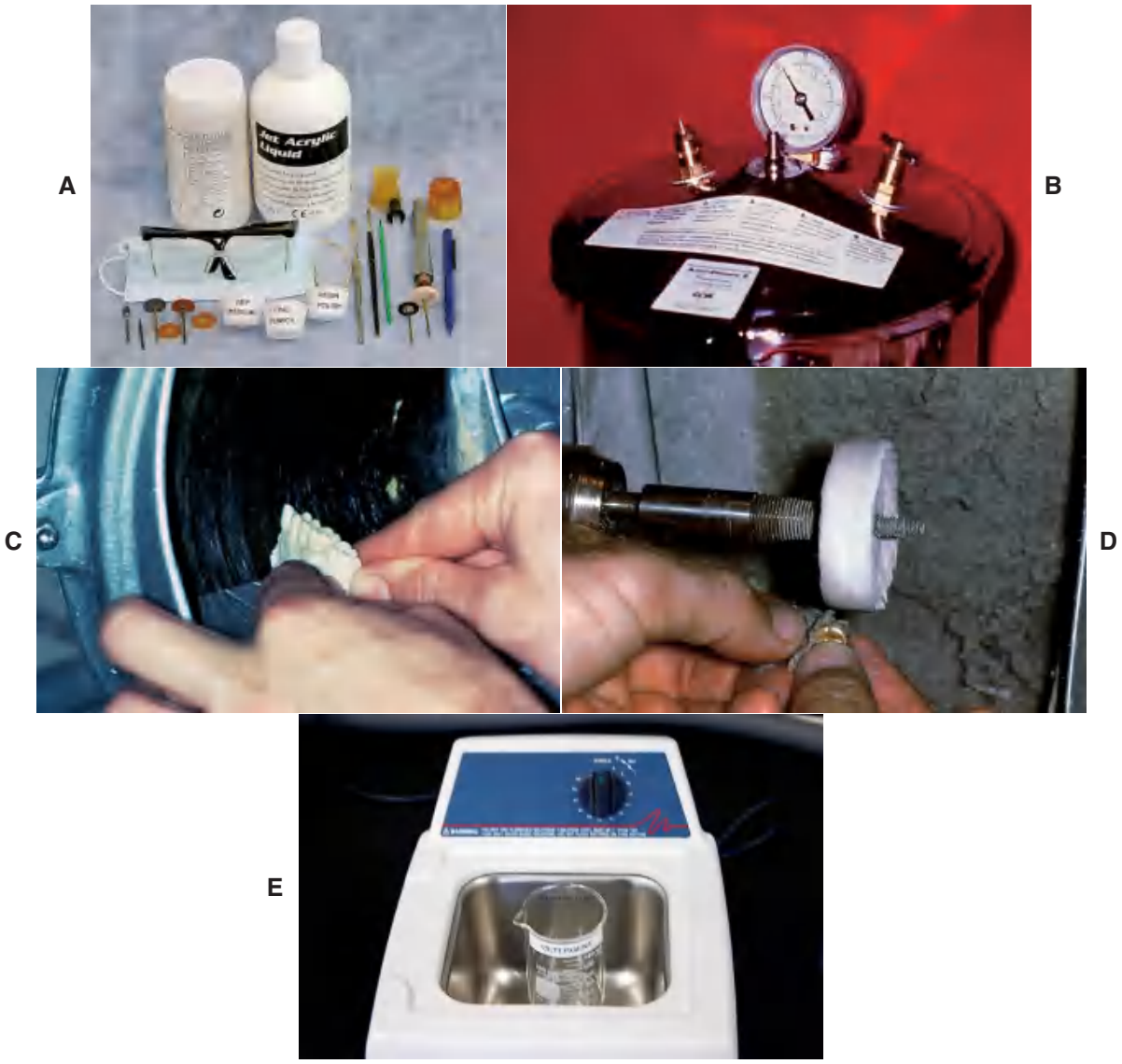


Fig. 15-26
Basic laboratory armamentarium. **A,** Assorted small items appearing on the accompanying list. **B,** Pressure-curing vessel. **C,** Cast trimmer. **D,** Dental lathe and dust collector. **E,** Ultrasonic cleaner and liquid detergent.

1. Pour the quick-setting stone or plaster into the irreversible hydrocolloid impression and allow it to set for 8 minutes.
2. Remove the cast and trim it to provide proper indexing with the ESF. The ESF is normally made from a diagnostic waxing of the proposed restoration. Check that the two forms fit together passively and completely.
3. Paint the cast uniformly with separating medium (Fig. 15-28). Avoid leaving unpainted "islands" on the cast, especially at the cavosurface margin areas. Drying can be accelerated by a gentle stream of air. Do not forcefully blow the medium from the surface of the cast. When the cast is thoroughly dry, it is optional to mark the cavosurface margins of the preparations with a soft lead pencil to serve as a guide for trimming later. This should not be done where the margins are highly visible.
4. Mix autopolymerizing resin (methyl methacrylate is a good choice) and load it into a polypropylene syringe. The orifice of the syringe tip should be about 2 or 3 mm in diameter.
5. Fill the ESF methodically with the syringe, starting at one end of the restoration space and working to the other. To avoid trapping air, keep the syringe tip in constant contact with the resin. The mold should not be overfilled; the resin should just reach the level of the gingiva (Fig. 15-29).



Fig. 15-27
Subgingival margins often require tissue displacement before an adequate impression can be made. Alginate in a disposable tray produces an economical and satisfactory impression. After treatment for infection control, the impression is poured in quick-set plaster to create the tissue surface form (TSF).



Fig. 15-29
A polymer syringe with a widened orifice (2 mm diameter) is useful for filling the external surface form (ESF). To avoid entrapping air, it is best to begin at one end and progress slowly to the other, keeping the syringe tip in contact with the expressed resin.

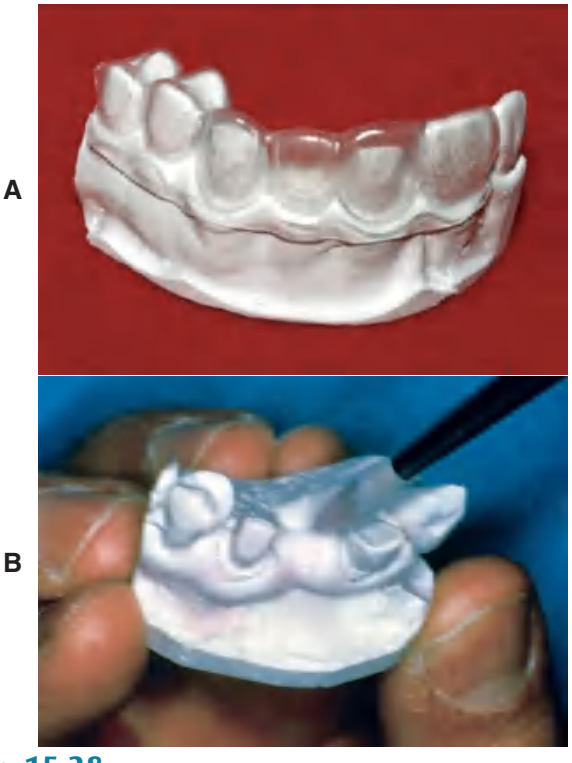


Fig. 15-28
A, After trimming, the indirect tissue surface form (TSF) is mated with the external surface form (ESF) to verify accurate passive indexing. **B,** With this accomplished, the forms are separated, and the TSF is completely coated with a resin-gypsum separating medium (brushed on).

6. Seat the TSF into the filled ESF (Fig. 15-30). They can be lightly held together by rubber bands. The assembly is then placed in warm water (40°C [100°F]) in a pressure vessel, after which air is applied at about 0.15 MPa (20 psi). Pressure curing reduces resin porosity.
7. Remove the assembly after 5 minutes.
8. Separate the ESF from the cured resin restoration, which usually remains in contact with the TSF (Fig. 15-31). The bulk of the stone can be removed on a cast trimmer and with a carborundum disk (Fig. 15-32). If the margins were marked with lead, dielike remnants of the TSF should be retained for use as a guide to correct trimming. However, the TSF often separates completely from the resin during handling. This is an advantage because it eliminates any further effort needed to remove the stone. Even if the margins were marked, it would probably be better to discard the stone and carefully mark the resin margins with a fine-pointed graphite pencil. This should not be postponed, because the margins are more difficult to identify accurately after trimming is begun.
9. Eliminate resin flash with an acrylic-trimming bur and a fine-grit garnet paper disk.
10. Contour the pontic areas according to proper pontic design (Fig. 15-33) (see Chapter 20.)
11. Finish the restoration with wet pumice. Do not neglect the gingival surface of the pontic. If this area is not otherwise accessible, a Robinson brush on a straight handpiece should be used.
12. Check for and remove any resin blebs or remnants of stone on the internal surfaces of the restoration.

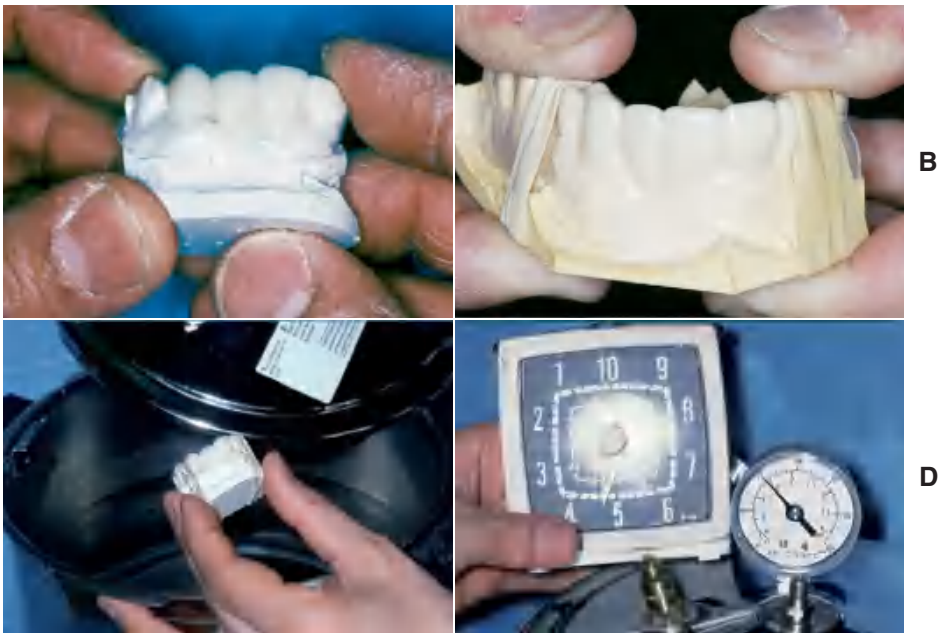


Fig. 15-30
A, The resin-filled external surface form placed on the tissue surface form. **B,** Rubber bands around the mold assembly and located over adjacent unprepared teeth. This avoids distorting the external surface form. **C,** The assembly being placed into a pressure vessel filled with warm water. **D,** The resin cures for 5 minutes under 0.15 MPa (20 psi) pressure.



Fig. 15-31
External surface form removed.

13. Clean the restoration, using appropriate infection control procedures in preparation for clinical try-in.

Evaluation

The interim partial FDP should be evaluated in the patient's mouth for proximal contacts, contour, surface defects, marginal fit, and occlusion. Deficient proximal contacts, imperfections in contour, or surface defects can be corrected by adding resin through the bead-brush technique (Fig. 15-34; see Fig. 15-70).

Unacceptable marginal fit can be corrected as for custom indirect-direct partial FDPs (p. 487, steps 3 to 9), provided that the patient has no history of allergy to monomer. If occlusal correction is needed, the restoration is marked with articulating ribbon and adjusted with a 12-fluted tungsten carbide finishing bur rotating at high speed with copious air-water spray to prevent the resin from melting (Fig. 15-35). Adequate intraoral evacuation and eye protection are essential.

14. After practicing appropriate infection control procedures, return to the laboratory for final wet pumice finishing and dry polishing with resin-polishing compound. If access to the gingival surfaces of the pontics is restricted, a 3/4-inch diameter felt wheel can be used for polishing.

Custom Indirect-Direct Interim Partial Fixed Dental Prostheses

The custom indirect-direct procedure may be a good compromise when laboratory support is not immediately available and chair time must be minimized.

Additions to laboratory armamentarium

(Fig. 15-36)

- Diagnostic TSF (duplicate of conservatively prepared diagnostic cast)
- ESF (vacuum-formed polypropylene sheet)
- Original diagnostically prepared cast mounted on an articulator
- Articulating ribbon



Fig. 15-32
Tissue surface form reduced to attain the final shape of the restoration. **A,** Bulk reduction on a cast trimmer. **B,** Sectioning and removal of pontic-contact areas with a carborundum disk. **C,** Linguogingival surface of the pontic shaped with a tapered bur. **D,** An abrasive disk (7/8-inch diameter, garnet) is excellent for creating proper embrasure form. It must be carefully oriented parallel to the desired contour so that overtrimming at the margins is avoided. **E,** The contoured restoration.



Fig. 15-33
The restoration before try-in.



Fig. 15-34
Proximal contact added by the bead-brush technique. When the resin reaches the doughy stage, the restoration is set on the prepared tooth to form the contact.



Fig. 15-35
Intraoral adjustment of occlusal contacts.



Fig. 15-36
Additions to the basic laboratory armamentarium for the indirect-direct procedure: the diagnostic tissue surface form (TSF) and the polypropylene external surface form (ESF).

Step-by-step procedure

1. Prepare the abutment teeth on articulator-mounted diagnostic casts (Fig. 15-37). The diagnostic preparation should be more conservative than the eventual tooth preparation and should have supragingival margins. These preparations are often helpful for treatment planning (see Chapter 2).
2. Make an irreversible hydrocolloid impression of the diagnostic preparations to duplicate them in stone (Fig. 15-38).

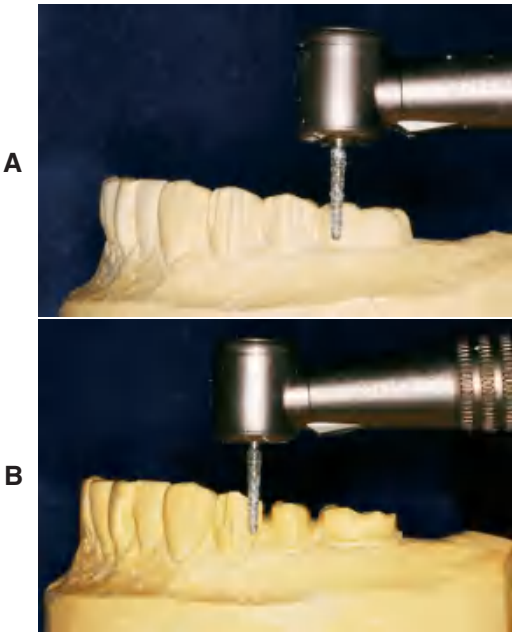


Fig. 15-37
Preparations involved in making the articulator-mounted diagnostic cast. **A,** Conservative depth-orientation grooves. **B,** Placement of supragingival cavosurface margins.



Fig. 15-38
The prepared cast is duplicated by means of an alginate impression. This creates the indirect tissue surface form. Quick-set plaster is used.

3. Coat the stone TSF with separating medium.
4. Perform a diagnostic waxing procedure on the articulated casts. This step also is often recommended in the treatment planning phase. The ESF is made from the diagnostically waxed cast. If a thermoplastic sheet is used, it should be molded over a stone duplicate of the cast rather than directly on the wax (which melts if contacted by the heated sheet) (Fig. 15-39).
5. Check that the external and TSFs fit together accurately (Fig. 15-40).
6. Using a syringe, apply the resin into the ESF and complete the interim restoration as described in the preceding section (see Figs. 15-29 to 15-33).
7. If the wax has been removed from the diagnostic cast (after duplication), seat the



Fig. 15-39
Creating a custom external surface form (ESF) from a diagnostic waxing. **A,** The diagnostically waxed articulated casts. Patterns should satisfy biologic, mechanical, and esthetic requirements. **B,** If a thermoplastic ESF is desired, the completed waxing must be duplicated in stone.



Fig. 15-40
Proper relationship between the external surface form (ESF) and the tissue surface form (TSF). If it is necessary to remove any cast artifacts to correct the relationship, this should be done before the separating medium is applied.

completed interim restoration (custom-preformed ESF) on it and refine the occlusion by using the articulator. If this cannot be done, more clinic time is required for adjustment.
8. Finish and clean the preformed ESF for try-in, which follows tooth preparation (Fig. 15-41).

Addition to clinical armamentarium

- Custom-preformed ESF

Step-by-step procedure

1. Prepare the patient's teeth in the usual manner.
2. Try in the preformed ESF (Fig. 15-42). If it is not compatible with the occlusion (does not seat completely) and the teeth have been reduced adequately, the internal surface of the ESF should be relieved until the occlusion is acceptable. If the teeth require more reduction, this should be done and the ESF then reevaluated and adjusted. The adjustment process can be tedious, particularly if the preliminary steps were not performed carefully enough. This is the chief disadvantage of the indirect-direct procedure. The remaining steps outline the (direct) procedure for lining, which is necessary to produce internal and marginal adaptation (Fig. 15-43). Because of their relatively low potential for tissue trauma, resins in the poly(R′



Fig. 15-41
The completed custom-preformed external surface form (ESF). This is the end product of the indirect component of the indirect-direct technique.



Fig. 15-42
The custom-preformed external surface form (ESF) fully seated over the prepared teeth. Note the marginal discrepancy on each abutment. The tip of the periodontal probe easily fits into the space, which will be filled by a direct lining procedure.



Fig. 15-43
Lining the custom-preformed external surface form (ESF). This is the direct component of the indirect-direct technique. **A,** Oral tissues are protected with petrolatum. **B,** Vent holes help to eliminate trapped air. **C,** Abutment retainers filled with lining resin. **D,** The restoration completely seated. (The amount of resin at the margins is controlled by covering or uncovering the vent holes.)

methacrylate) group are recommended for direct procedures.
3. Apply a uniform coat of petrolatum on the prepared abutment teeth, gingival tissues, and external surfaces of the ESF.
4. Make a vent hole with a round bur through the occlusal (or lingual) surface of each abutment retainer.
5. Fill the retainers with resin, and after it loses its surface sheen, seat the restoration. Placing fingertips over the vent holes in a manner similar to playing a flute can control the quantity of excess resin expressed around the margin. When a small amount of excess resin appears around the entire periphery of the margin, the fingertip is lifted, which allows trapped air and remaining excess resin to escape. Resin on the occlusal surface can be wiped away immediately, which eliminates the need to grind it off after it sets.
6. When the rubbery stage of polymerization is reached (about 2 minutes in the mouth), engage the facial and lingual surfaces of an abutment retainer with the Backhaus forceps, and rock the interim restoration buccolingually to loosen it. Move to the other retainer and rock it in a similar manner. When the partial FDP is loosened at both ends, remove it from the patient's mouth. The forceps tines make small indentations in the resin, but this is not usually a concern for posterior units. The defects can be smoothed later during the finishing procedures.
7. Place the interim restoration in warm water (37°C) to hasten polymerization.
8. After 3 to 5 minutes, mark the margins with a sharp pencil and eliminate the excess resin. The bulk of it can be removed with an acrylic resin-trimming bur or carborundum disk (Fig. 15-44). A fine-grit garnet paper disk completes axial shaping.

Accurate trimming to the margins can be simplified by holding the disk parallel to the desired final contour. A paper-thin extension remaining beyond the marked margin is an indication that the contour is correct and the cavosurface margin fully covered. Often this flash can be easily peeled away from the margin with the fingers (Fig. 15-45).

9. Confirm the marginal fit and occlusion, refinish and polish where necessary, and cement the restoration (Fig. 15-46).



Fig. 15-44
Removal of excess after the lining resin hardens. **A,** Margins marked with a sharp soft lead pencil. **B,** Gross resin excess is quickly removed. (Margins must be avoided.) **C,** The final axial contours, connectors, and marginal fit are perfected with an abrasive disk rotating toward the margin to prevent debris from obscuring the pencil line. Note the orientation of the disk, parallel to the desired final contour.

Custom Single-Unit Interim Restorations

Complete crowns

Single-unit complete crowns or splinted crowns may be made directly or indirectly in accordance with the basic procedures described for partial FPDs. Because pontics are not involved, creating an ESF is simpler. Diagnostic procedures are not required unless extensive coronal changes are planned. For example, extensive changes are usually required



Fig. 15-45
Flash at the margin of a restoration whose axial surface was contoured with proper disk orientation. *(Courtesy Dr. R.E. Kerby.)*



Fig. 15-46
Occlusal contacts of the completed restoration are checked and adjusted before polishing. Note that the units are splinted together for increased resistance to dislodgment during an anticipated lengthy treatment period. *(Courtesy Dr. R. Liu.)*

when the occlusal vertical dimension is increased. If diagnostic procedures are not needed, an alginate impression of the crown or crowns before tooth preparation should be adequate to serve directly as the ESF or indirectly when a cast has been poured in another impression material.

Onlays and partial veneer crowns

The technique for making onlay and partial veneer interim restorations is similar to that for making custom single crowns. However, the interim restorations are more easily distorted during handling because of the conservative tooth preparations that interrupt the continuity of the axial walls. Thus, the direct method mandates extra care in separating the resin from the tooth. Significantly better results can be expected with the indirect procedure.

Two other points merit mention. When the polymerized resin is trimmed to the margin, it is advisable to leave an excess of resin at the occlusal cavosurface margin (see Fig. 15-9). This helps prevent fracture of enamel, which is likely to result from the lesser strength of resin in comparison with metal. Second, if lining is needed, an occlusal vent hole is not necessary because the shape of these restorations provides an adequate escape way for trapped air and excess resin.

Inlays

Inlays present the problem of being small and difficult to handle, especially during trimming. Making interim restorations requires a number of modifications.

Additions to clinical armamentarium

- Tofflemire retainer/matrix band
- Wedges
- Amalgam condenser
- Spoon excavator
- Scalpel handle and blade (No. 15)

Step-by-step procedure

1. For a two- or three-surface inlay, apply the matrix band and wedges as in preparation for condensing a Class II amalgam restoration. The wedges should be placed with firm pressure so that when the band is removed, proximal contact is reestablished. The band must seal all aspects of the proximal cavosurface margins.
2. Using petrolatum on a small cotton pellet, lightly coat all sides of the cavity preparation and the matrix band.
3. Make a handle to remove the resin by placing one end of a 2- to 3-cm length of unwaxed dental floss in the preparation cavity.
4. Mix a small amount of poly-R′ methacrylate, and when it can be kneaded like bread dough, mold a small cone of it on the end of an amalgam condenser.
5. Lightly condense the resin into the cavity, being careful not to force it past the matrix into an undercut. Immediately remove as much occlusal excess as possible with a sharp spoon excavator.
6. Monitor the polymerization by light probing with a hand instrument. When the resin reaches the late rubbery stage, remove it by tugging the floss handle with cotton roll forceps along the path of withdrawal (Fig. 15-47).
7. Place the resin in a cup of warm water (37°C) for 5 minutes.
8. Mark the margins with a sharp pencil and trim away whatever flash may be present.
9. Return the cured resin to the cavity preparation and adjust the occlusion, using marking film and a slow-speed handpiece. (Take extreme care to avoid removing tooth structure.) Leave the



Fig. 15-47
A floss handle facilitates removal of an inlay resin interim restoration during late rubbery stage.

floss handle in place as long as it does not interfere with adjustments of the occlusion.
10. Remove the adjusted interim restoration with the floss handle and put it aside where it may be found easily after impression making for the definitive inlay.
11. Clean and dry the cavity preparation and place a thin coat of interim cement on the cavity walls. Immediately insert the interim restoration.
12. When the cement is set, remove the excess with an explorer and a spoon excavator. Carefully cut off the floss handle with the scalpel blade.

Laminate Veneers

Additions to clinical armamentarium

- Composite resin shade guide
- Light-cured composite resin
- Hand-held curing light
- Phosphoric acid etchant gel
- Autopolymerizing unfilled resin

Step-by-step procedure

1. Select the most appropriate resin shade or combination of shades before preparing the tooth.
2. When tooth preparation is complete, apply a thin coat of petrolatum to the prepared tooth surface.
3. Using a plastic instrument wetted with alcohol, form the preselected light-cured resin.

If the material is difficult to control, placement and curing may be accomplished in stages.

It is also possible to form the veneers indirectly by creating a TSF and an ESF, as was recommended for the partial FDP interim restoration. The indirect method may be more efficient if multiple veneers are being made.

4. Light-cure the resin and remove it from the tooth surface.
5. Thoroughly clean the petrolatum from the prepared tooth enamel, and apply the etchant gel to three 1-mm diameter areas to form an equilateral triangle, with two of the corners at the mesioincisal and distoincisal line angles and the third centered more cervically. Allow the etchant to remain for 20 seconds, rinse completely with water, and dry.
6. Mix the autopolymerizing unfilled resin and place a small amount on the three etched areas. Immediately place the veneer on the tooth and hold it in place until the resin is set.
7. At the patient's return visit, remove the veneers with a spoon excavator.

Mass-Produced ESF Interim Crowns

Under most circumstances, a custom ESF yields the best results in the shortest time. However, there are instances when a custom ESF is not readily available: for example, a first-visit emergency in which a crown is missing and must be replaced. If by coincidence a crown form closely matches the size and shape of the desired interim restoration, the mass-produced form is more convenient than initiating custom procedures (generating a diagnostic cast and waxing the missing crown contours). Such coincidences, however, are not routine and should not be relied upon. Whatever the situation, the dentist should think of mass-produced interim crowns as ESFs; they need to be lined with resin to meet the basic requirements of a interim restoration.

Polycarbonate Crown Forms

Polycarbonate crown forms are useful for making interim restorations on single anterior teeth and premolars.

Additions to clinical armamentarium

- Assorted polycarbonate crowns
- Boley gauge or dividers
- Green stone, straight handpiece

Step-by-step procedure

1. Measure the mesiodistal width of the crown space with dividers (some crown kits provide a selection guide), and select a shell that is of the same or slightly larger width (Fig. 15-48).
2. Mark the crown height (from the incisal edge) with a pencil (Fig. 15-49), and use this measurement as a guide to trimming the shell so that it matches the approximate curvature of the



Fig. 15-48
Crown selection. **A,** Measuring the mesiodistal width of the space with dividers. **B,** Appropriate crown size for the measured space.

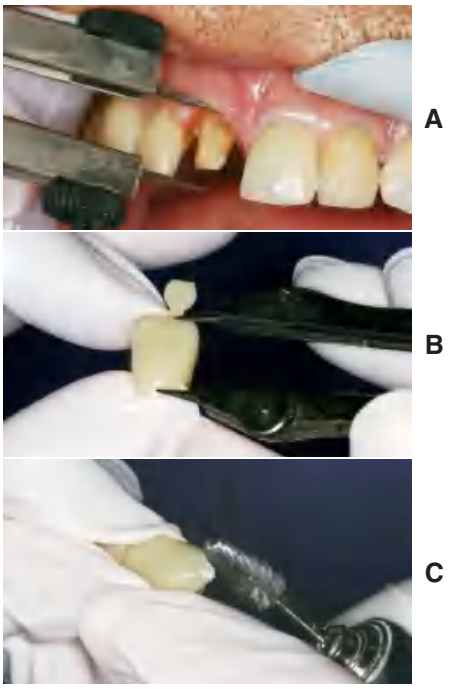


Fig. 15-49
Crown length adjustment. **A,** Incisocervical height required for the completed restoration. **B,** Measurement transferred to the crown. **C,** Cervical portion of the crown adjusted to duplicate the curvature of the cavosurface margin.

prepared cavosurface margin. For this trimming, it is recommended that a green stone or small-diameter carbide be used.

3. Try the shell on the prepared tooth (Fig. 15-50), being especially careful that the incisal edge and labial surface of the shell align properly with those of the adjacent teeth. The internal surface of the shell often needs reduction to achieve this match. For now, the occlusion should be ignored, inasmuch as it is usually better to adjust it after lining. When the shell can be properly positioned without forceful gingival contact, it is ready to be lined with resin.
4. Apply a uniformly thin coat of petrolatum to the prepared teeth and adjacent gingivae (Fig. 15-51). This prevents direct contact of the monomer with these tissues and the possibility of injury.
5. Mix the autopolymerizing resin and fill the shell (poly[R′ methacrylate] is recommended). When the surface just loses its gloss or the resin forms a peak without slumping, place the shell over

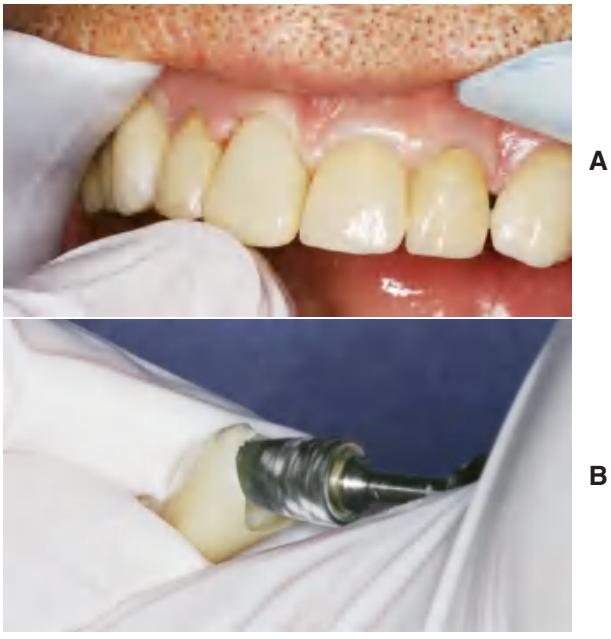


Fig. 15-50
A, Cervical portion of the crown trimmed until the length and axial inclination are correct. **B,** If necessary, internal surfaces are adjusted for proper orientation of the crown.

the tooth and align the incisal and labial surfaces with those of the adjacent teeth.

6. Immediately eliminate any marginal excess. If polymerization is too far advanced, the doughy resin will pull away from the margin and necessitate a repair later.

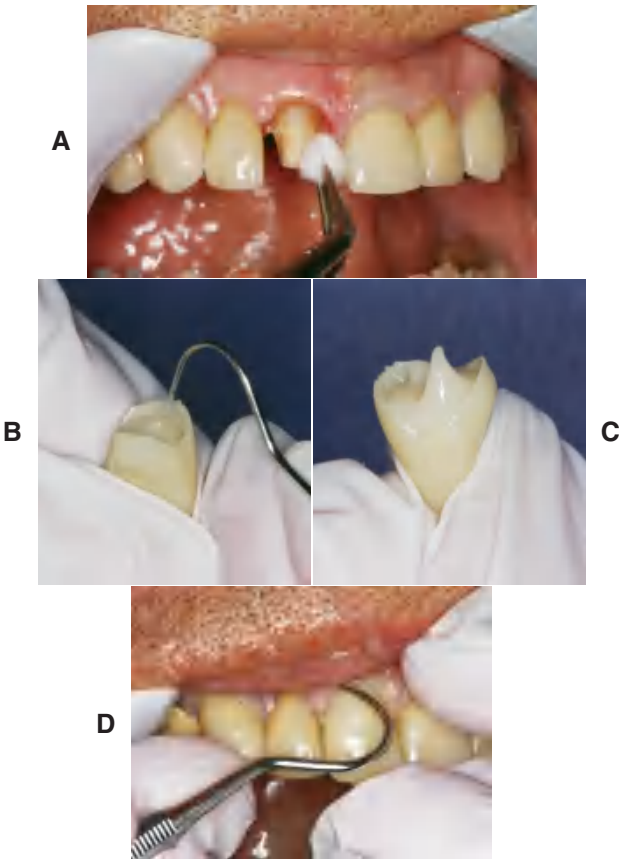


Fig. 15-51
Lining the adjusted shell. **A,** Protection with petrolatum. The shell is filled with resin (**B**) and is seated (**C**) when the resin does not slump after a peak is formed with the tip of an explorer. **D,** Excess resin is immediately removed after the crown has been positioned.

7. When the rubbery stage of polymerization is reached (after about 2 minutes), rock the crown faciolingually to loosen and remove it. The Backhaus forceps should be kept within easy reach in case there is difficulty separating the crown from the tooth. However, because it makes small indentations in the crown surface, the forceps should be used only when needed on anterior units.
8. Place the crown in warm water (37°C) (Fig. 15-52).
9. When the resin has fully set (after about 5 minutes), mark the margins with a sharp pencil. The axial surfaces can be shaped, and flash eliminated, with straight-handpiece carbide burs or abrasive disks.
10. Try on the newly lined crown, and adjust the lingual surface to the desired occlusion and contour (Fig. 15-53).
11. Polish and cement the restoration (Fig. 15-54).

Aluminum Crown Forms

Aluminum shells are useful for restoring single posterior teeth, where their unnatural appearance is not a disadvantage.

Additions to clinical armamentarium

(Fig. 15-55)

- Assorted aluminum crowns
- Dividers
- Crown-and-collar scissors
- Contouring pliers
- Cylindrical green stone, straight handpiece
- Coarse garnet paper disk (7/8-inch diameter)

Step-by-step procedure

1. Measure the mesiodistal width of the crown space, using dividers, and select an appropriate



Fig. 15-52
A, When the resin has reached the rubbery stage, the crown is removed and placed in warm water (37°C). Hot water must not be used, because it increases resin shrinkage. However, warm water is not recommended for polymethyl methacrylate resin, because excessive shrinkage makes the marginal fit unacceptable. **B,** After about 5 minutes in warm water, the resin should be rigid enough for marking the margins. **C,** Initial removal of the excess lining resin is accomplished with a coarse garnet disk.



Fig. 15-53
A, A considerable amount of lingual reduction may be called for. If it is only minor, it can be accomplished intraorally. **B,** To increase efficiency and ensure patient comfort, any bulk reduction should be accomplished extraorally. **C,** Finalized lingual contour that promotes gingival health and allows access for oral hygiene. Note the more natural contour of the left central incisor than that of the interim crown on the right central incisor.



Fig. 15-54
A, A rag wheel and pumice are used before polishing with compound. Note the parallel orientation of the wheel to the crown's axial surface at the point of contact (*arrow*). The crown should be positioned so that the wheel rotates from the surface toward the margin. **B,** An explorer and dental floss are used to carefully remove all excess luting agent. **C,** Overpolishing results in a deficient mesial contact (*arrow*). The bead-brush technique is recommended for correcting a small inadequacy.



Fig. 15-55
Additions to the basic clinical armamentarium for aluminum crown forms.

shell type with a width as close as possible to that measured. A slightly larger or smaller shell can be deformed with contouring pliers to attain the proper fit (Fig. 15-56).

2. Measure the occlusocervical height, and trim the shell with crown-and-collar scissors so that it extends about 1 mm apical to the cavosurface margin (Fig. 15-57). Sharp burrs left by the scissors can be smoothed or rounded with the green stone.
3. Place the trimmed shell over the prepared tooth, and apply seating pressure gradually while observing the gingiva. Trim the margins further at any location where the gingiva blanches. The shell margin should not engage the prepared tooth margin.
4. Repeat the evaluation, and trim as necessary.
5. Instruct the patient to close with moderate force. The soft aluminum should deform until normal intercuspation is reached (Fig. 15-58).
6. Apply petrolatum to the prepared tooth and adjacent gingival tissues; mix poly(R′ methacrylate) resin, and fill the shell.
7. When the resin surface becomes matte, place the shell over the tooth and guide it to a slightly supraclusal position (Fig. 15-59). Have the patient close.
8. To avoid pulling the resin away from the cavosurface margin, immediately remove the marginal excess.

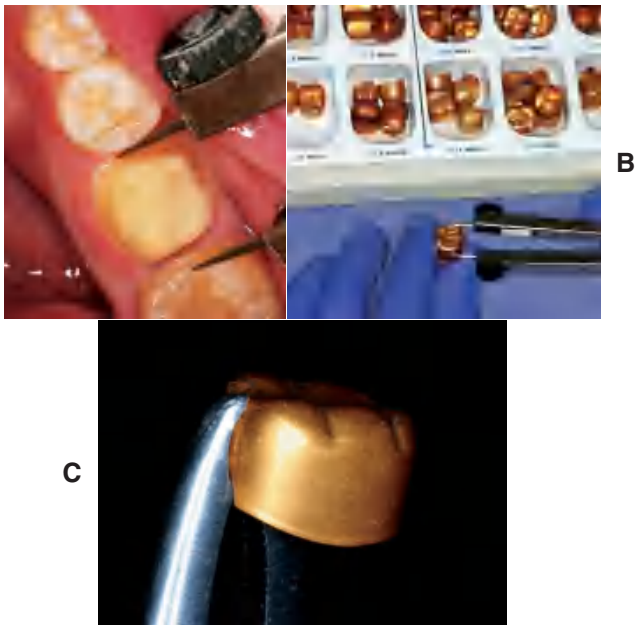


Fig. 15-56
Aluminum crown selection and modification. **A,** Mesiodistal dimension of the space. **B,** Appropriate crown size, nearest this measurement. **C,** Contouring pliers to make small size modifications. This is frequently unnecessary.

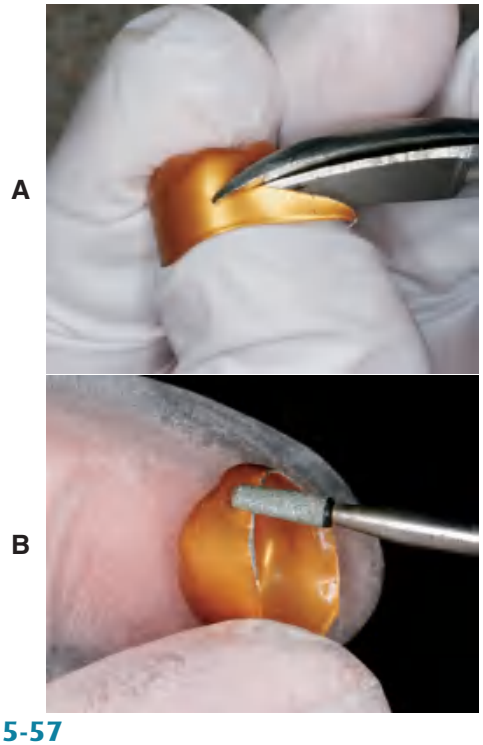


Fig. 15-57
A, Cervical portion of the crown trimmed to proper length. **B,** Smoothing the cut edge to prevent gingival injury.

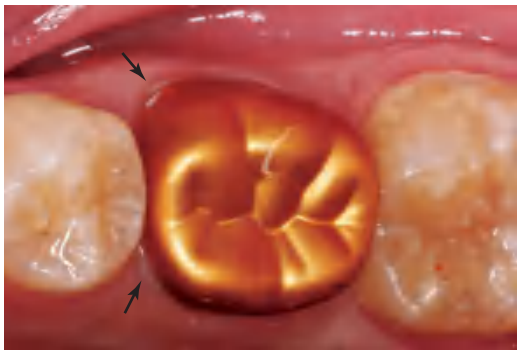


Fig. 15-58
The patient is instructed to bite on the shell after the length has been adjusted. Note the occlusal indentation and gingival blanching (*arrows*). Additional shortening should be done where the blanching occurs.

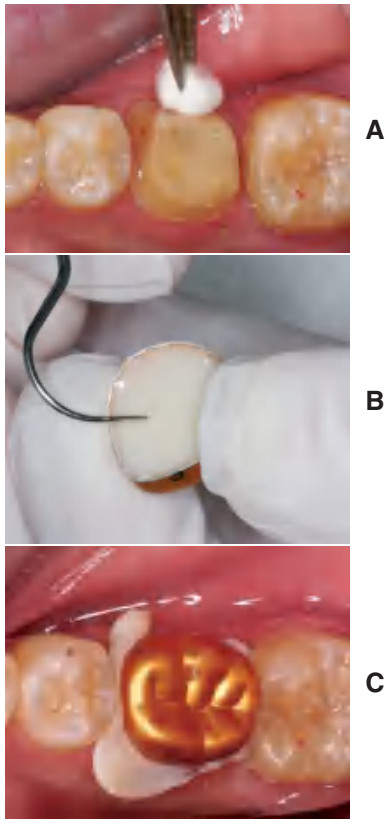


Fig. 15-59
A, Protection with petrolatum. **B,** The adjusted shell is filled with lining resin and seated to just short of its final position after the resin has lost its sheen. **C,** The final position is determined by the patient's closing into maximum intercuspation. Excess resin is immediately removed.

9. When the rubbery stage of polymerization is reached (after about 2 minutes in the mouth), engage the crown with the Backhaus forceps to just penetrate the aluminum shell (Fig. 15-60). Loosen and remove the crown by rocking it buccolingually or by using the thumb and index finger of the other hand to apply occlusally directed force under the tines. The small buccal and lingual holes created in the surface of the aluminum are not usually a problem and can be ignored until the patient returns, whereupon they may be used to remove the crown again.
10. Place the shell in a cup of warm water (37°C).
11. After about 5 minutes, mark the margins and trim away any excess. To establish periodontally healthy axial contours, the aluminum shell frequently is ground away in certain areas (Fig. 15-61).
12. Replace the crown and adjust the occlusion as deemed necessary. If either proximal surface lacks contact, resin can be added to correct the deficiency. Metal must be ground away in the contact area to provide a resin-to-resin bond (Fig. 15-62).
13. Polish, clean, and cement the restoration.

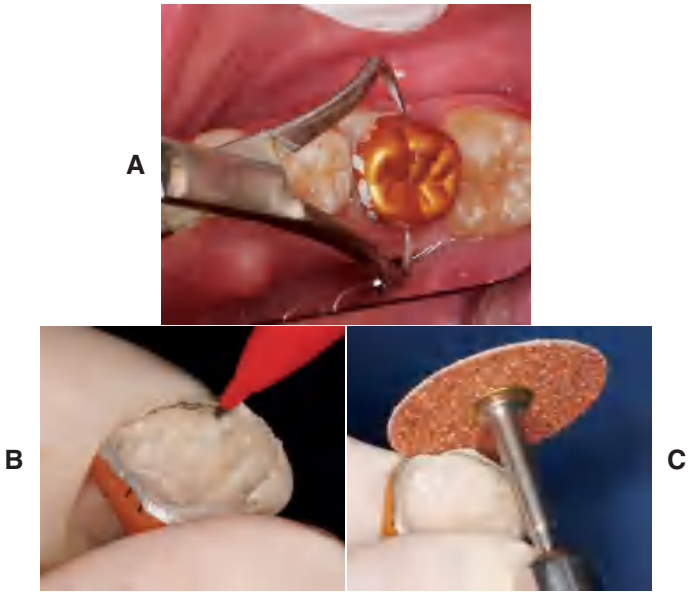


Fig. 15-60
A, Backhaus forceps provides definite purchase of the shell for controlled removal. **B,** After 5 minutes in warm water, the margin is marked with a pencil. **C,** A coarse garnet disk is recommended for initial contouring of the axial surfaces. This usually necessitates partially removing the aluminum. After the overcontoured aluminum has been ground away, a fine garnet disk is used to finalize the axial contours (including the marginal areas). Again, disk orientation is important to establishing a straight emergence profile and well-adapted margins.

Post and Core Interim Restorations

Intraradicular retention and support are often obtained from a cast metal post and core (see Chapter 12). A interim restoration is needed while the casting is being made.

Additions to clinical armamentarium

- Wire
- Wire cutting pliers
- Cylindrical green stone, straight handpiece
- Wire-bending pliers
- Paper points

Step-by-step procedure

1. Place a piece of wire (e.g., a straightened paper clip) in the post space. To avoid root fracture, it must extend passively to the end of the post space. A mounted stone can be used to taper the wire if binding occurs.
2. Mark the wire with a pencil at the mouth of the post space. Then, at a point slightly occlusal to this

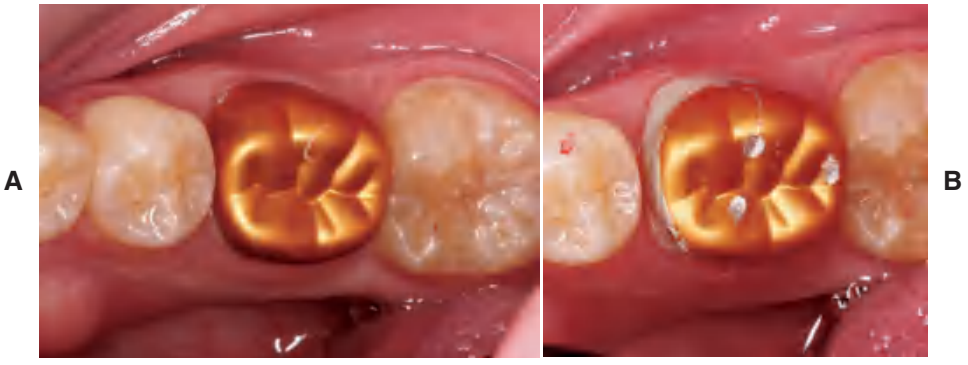


Fig. 15-61
A, Proper contouring of the axial walls exposes lining resin in the cervical area. Note the indentations in the shell from the Backhaus forceps. **B,** Final occlusal adjustment removes the anodized gold finish, but this is of no concern.



Fig. 15-62
Adding proximal contacts to aluminum crowns. **A,** Contacts absent in this lined crown (*arrows*). **B,** The metal in the contact area is ground away to expose the underlying resin. The bead-brush technique is then used for correcting the deficiency. **C,** Crown after resin addition to the mesial surface. Further contouring with a disk is recommended to improve the gingival embrasure form.



Fig. 15-63
Interim post preparation. **A,** Wire marked so that the bend is made at the correct level. When in position, the wire must not interfere with the external surface form. **B,** A 180-degree or greater bend in the wire to resist displacement in the lining resin.



Fig. 15-64
A, Wire in the post space just before placement of the filled external surface form (ESF). A gauze throat pack is recommended to protect the patient from aspirating or swallowing the wire. **B,** Filled ESF seated.

mark, use the pliers to make a 180-degree bend in the wire (Fig. 15-63).
3. Lubricate the tooth and surrounding soft tissues with petrolatum. Paper points are convenient for lubricating the post space.
4. Fill the ESF with interim resin (poly[R′ methacrylate] is recommended).
5. When the resin loses its surface gloss, place the wire in the post space and seat the ESF over it (Fig. 15-64).

Precautions must be taken to protect the patient from swallowing or aspirating the wire.
6. Remove the ESF while the resin is still rubbery (after about 2 to 2½ minutes). The stage of polymerization should be monitored. If the resin is allowed to become rigid and lock into the undercut surfaces within the post preparation, removing it and the wire will be time consuming and risk the restorability of the tooth. The interim usually remains in the ESF, which can be placed

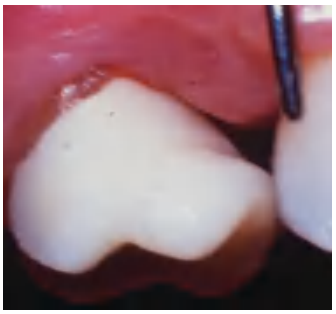


Fig. 15-65
The completed interim post and crown restoration. Note the unusual mesial contour (which is the result of a mesiobuccal root amputation).



Fig. 15-66
A noneugenol and a eugenol interim luting agent.

in warm water to hasten polymerization. The wire must not be disturbed while the resin is soft. If the interim remains on the tooth, it should be loosened and reseated several times and then removed before the resin has fully polymerized.

7. Mark the margins with a pencil, and trim and contour the restoration with disks or straight-handpiece carbide burs.
8. Evaluate the restoration in the mouth, and adjust as necessary.
9. Polish, clean, and cement the restoration (Fig. 15-65).

Cementation

The primary function of the interim luting agent is to provide a seal, preventing marginal leakage and hence pulp irritation. The luting agent should not be relied upon to resist occlusal forces, inasmuch as it is purposely formulated to have low strength. Unintentional displacement of an interim restoration is frequently caused by a nonretentive tooth preparation or excessive cement space rather than the choice of luting agent.

Ideal properties

Desirable characteristics of an interim luting agent are as follows:

- Seal against leakage of oral fluid
- Strength consistent with intentional removal
- Low solubility
- Blandness or obtundent quality
- Chemical compatibility with the interim polymer
- Convenience of dispensing and mixing
- Ease of eliminating excess
- Adequate working time and short setting time

Available materials

Of the currently available materials (Fig. 15-66), zinc oxide–eugenol (ZOE) cements appear to be the most satisfactory. Zinc phosphate, zinc polycarboxylate, and glass ionomer cements are not recommended because their comparatively high strength makes intentional removal difficult. Using high-strength cements frequently damages the restoration or even the tooth when removal is attempted and can make seating of the definitive restoration difficult. Weaker ZOE cements provide for easy removal, allowing the restoration to be reused when additional service is needed. ZOE also has an obtundent effect on the pulp in addition to its acceptable sealing properties.[24] Unfortunately, however, free eugenol acts as a plasticizer of methacrylate resins. It has been shown to reduce surface hardness[25] and presumably strength. New resin applied over polymerized resin previously in contact with free eugenol results in softening[26] of the added resin, making linings or repairs unsuccessful. The R′ methacrylates are severely affected by free eugenol. Methyl methacrylates are affected moderately, and the composites are only slightly softened. These adverse effects have stimulated the marketing of interim luting agents without eugenol, but in the studies cited, the mere presence of eugenol in a cement was not enough to cause adverse effects. It appears that unreacted or free eugenol must be present to cause problems. Therefore, when using products that contain eugenol, the dentist must be sure that the correct proportions are blended. Whether free eugenol is necessary to provide an obtundent effect on the pulp remains a question.

In situations in which the tooth preparation lacks retention, a span is great or long-term use is anticipated, or parafunction exists, it may be desirable to use a higher strength cement. A good compromise would be reinforced ZOE; another might be eugenol-free zinc oxide, which has slightly greater strength than cements containing eugenol.[27] Conversely,

sometimes minimum strength is desired, as with temporary placement of the definitive restoration. (Its removal may be needed to refire the porcelain.) Petrolatum can be mixed with equal parts of the interim cement base and catalyst to reduce the cement's strength by more than half. When the definitive cement planned is a resin luting agent, non-eugenol cements are recommended for the interim restoration because of the adverse effect of eugenol on bond strength.

Armamentarium (Fig. 15-67)

- Interim luting agent (A)
- Mixing pad (B)
- Cement spatula (C)
- Plastic filling instrument (D)
- Petrolatum (E)
- Mirror and explorer (F)
- Dental floss (G)
- Gauge (H)

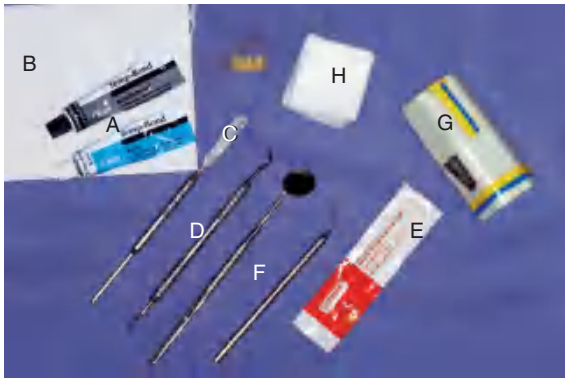


Fig. 15-67
Interim restoration luting armamentarium.

Step-by-step procedure

Most interim luting agents are supplied as a two-part system (Fig. 15-68).

1. To facilitate removal of excess cement, lubricate the polished external surfaces of the restoration with petrolatum (see Fig. 15-68*A*).
2. Mix the two pastes together rapidly, and apply a small quantity just occlusal to the cavosurface margin (see Fig. 15-68*B*). A marginal bead of cement forms the required seal against oral fluids. Filling the crown or abutment retainers should be avoided, because it prolongs cleanup and increases the risk of leaving debris in the sulcus.
3. Seat the restoration and allow the cement to set (see Fig. 15-68*C*).
4. Carefully remove excess with an explorer and dental floss (see Fig. 15-68*D* to *F*).

Cement remnants left in the sulcus have an irritating effect on the gingiva and may cause severe periodontal inflammation with possible bone loss. Therefore, the sulcus must be carefully checked and irrigated with the air-water syringe.



Fig. 15-68
Luting procedure. **A,** The external surface is lightly coated with petrolatum to aid removal of the set luting agent. **B,** Careful placement of the luting agent seals the margins and reduces the clean-up effort. **C,** The restoration is seated with firm finger pressure, or (for posterior restorations) the patient may bite on a cotton roll. **D** and **E,** An explorer is used to remove excess and to probe the sulcus gently for remnants. **F,** The proximal contact areas and sulcus are cleaned with dental floss (a knot will help remove excess cement), followed by copious irrigation with the air-water syringe.

Removal, Recementation, and Repair

Armamentarium

- Backhaus towel clamp or hemostatic forceps
- Spoon excavator
- Ultrasonic cleaner with cement-remover solution

The interim restoration is removed when the patient returns for placement of the definitive restoration or for continued preparation. Fracture of the prepared tooth or foundation must be avoided. Risk of this can be minimized if removal forces are directed parallel to the long axis of the preparation. The Backhaus or a hemostatic forceps is effective for obtaining sound purchase on a single unit (Fig. 15-69). A slight buccolingual rocking motion helps break the cement seal.

Damage can occur when an FDP is being removed. If one abutment retainer suddenly breaks loose, the other can be subjected to severe flexure stresses when the FDP acts as a lever arm. Care must be exercised to remove the prosthesis along the path of placement. Sometimes it is helpful to loop dental floss under the connector at each end of the FDP.

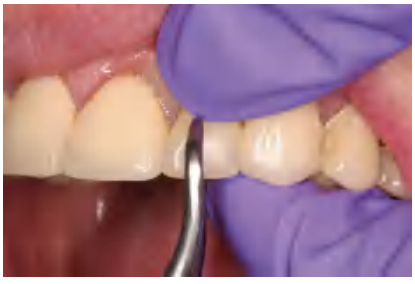


Fig. 15-69
Backhaus towel clamp forceps provide positive purchase on interim restorations. For maximum control, occlusal finger pressure is applied directly to the tines.

Step-by-step procedure

1. If the interim restoration is going to be recemented, clean out the bulk of cement with a spoon excavator.
2. Place the restoration in a cement-dissolving solution, and set this in the ultrasonic cleaner.
3. Line the restoration with a fresh mix of resin if necessary (e.g., if the tooth preparation has been modified). The internal surface is relieved slightly and painted with monomer to ensure good bonding of the new material.

A fractured or damaged interim restoration can be easily repaired with resin, added directly by using the bead-brush technique (Fig. 15-70).

Esthetic Enhancement

Contour, color, translucency, and texture are the key elements of coronal appearance. Contour and color are fundamental and more important than the other two elements. The indirect partial FDP procedure just described includes methods for controlling contour and color.

Contour

Diagnostic waxing provides the ultimate control of contour, and using a shade guide before tooth preparation gives the operator some control of color. If contour and color are well controlled, most interim restorations are very acceptable to excellent in appearance. Routinely achieving this requires attention to detail and skill. Although listed third, translucency can be a significant appearance element for patients with unabraded teeth.

Color

Whereas some resin manufacturers use only general color descriptors (light, medium, dark) for their products, most cross-reference their colors to

A



B,C

Fig. 15-70
Bead-brush technique for repairs. **A,** Monomer liquid is painted on the surface of the thoroughly cleaned restoration to which resin will be added. **B,** The brush is dipped in monomer and briefly touched to the powder, forming a small bead on the tip. **C,** The bead is touched to the repair site, and the brush handle is rolled to deposit it. Bead placement continues in this manner until the desired contour is achieved. To prevent excessive porosity, the unset resin should be painted lightly with monomer until hard.

popular shade guides for porcelain or denture teeth. However, even when cross-referenced, manufacturer and material differences make shade matching inaccurate. Better control of color is obtained by using a custom shade guide. This can be easily made by casting the resins into an elastomeric putty mold of an extracted incisor crown. Combining two or more existing hues in known proportions can create a wider selection of shades, or resin-coloring tints are an option.

Custom color effects that simulate intrinsic and extrinsic stains, cracks, or hypocalcification of adjacent teeth may be added to interim restorations with the help of paint-on stain kits (Fig. 15-71). These are best applied quickly, and overmanipulation should be avoided because it causes streaking and surface roughness. Under optimum conditions, the surface should have a glazed appearance similar to that of porcelain. Thickening of stains as a result of the evaporation of solvent is a common problem hampering manipulation. Another problem with the paint-on colorants is their poor resistance to abrasion. Loss of the pigments in high-abrasion areas produces an unattractive mottled effect.

Translucency

Coronal translucency is determined by the type and amount of enamel present. At the incisal edge of an unworn anterior tooth where there is no dentin in the light path, that region often takes on a blue or gray hue, which comes about from the dark oral cavity. This effect is most pronounced with enamel that scatters very little light as a result of the absence of pigments or opacifying mineralization (e.g., fluorosis). Although less obvious, the translucent appearance of enamel is observable over the entire incisal or occlusal third of the crown. Thus, when it is readily visible in adjacent teeth or when a more realistic appearance is desired, translucency can be simulated in the interim. The procedure requires two resins, one colored to match the body and one to match the enamel of the tooth. Some manufacturers produce enamel or incisal shades that may be used without modification. When these are not available or when variation is needed, clear resin powder may be mixed with a smaller fraction of the "body" powder to produce the desired translucency.

Two procedures can be followed to create a translucent effect. In the first, which is more difficult to control, the enamel color resin is carefully bead-brushed onto the occlusal or incisal surface of the ESF and tapered to end at the middle or cervical third. The tendency to flow where it is not wanted is controlled in part by the orientation of the ESF with regard to gravity and in part by manipulation with the brush tip. When the desired distribution of enamel color resin is achieved, a disposable syringe is loaded with body color resin and the ESF is immediately filled, to avoid disruption of the enamel color resin. The TSF is then positioned in the ESF, and normal procedures are followed (Fig. 15-72).

In the second procedure, the enamel color resin is allowed to polymerize on the ESF without adding body color resin or the TSF. The rigid enamel veneer is removed from the ESF and trimmed to occupy



Fig. 15-71
This interim stain kit contains violet, blue, yellow, orange, brown, white, and gray paint-on colorants to create custom effects and a clear material used to form a glazed translucent surface. The liquids are formulated to dry quickly, which requires that they be kept covered until immediately before use. A thinner and brush cleaner are provided.



Fig. 15-72
The layering of translucent resin and dentin-shaded resin allows a more realistic appearance of the premolar and canine interim restorations. They serve as removable dental prosthesis (RDP) abutments and are splinted together to help resist dislodgment.

only the space intended for enamel. It is important to check that the ESF and TSF can be mated without interference from the in-place veneer. With the veneer in place, monomer liquid is painted on it and the body color resin is added. The TSF is then inserted, and standard procedures are followed for the remainder of the restoration. The timing for this procedure is less crucial than for the first one described and may be better suited to practitioners with less experience. A disadvantage is that sometimes there is a more obvious demarcation between the enamel and the body resins.

Texture

With practice, texture effects require only a small amount of time, but in some cases they contribute significantly to the overall appearance of the interim restoration. These effects are most important for maxillary anterior teeth adjacent to teeth with well-defined lobes, imbrication lines, or developmental defects.

Developmental lobes are best simulated in wax during the final stage of the diagnostic waxing. To produce a natural effect, it is crucial to avoid making grooves that are straight or sharp edged or have uniform cross-sections. Rather, the simulation should have a gentle crescent shape, with softening of the edges and slight varying of the cross-section by burnishing with the largest diameter waxing wire. If a polypropylene sheet is used to form the ESF, these subtle details can be reproduced in the resin.

Placement of developmental defects is best accomplished in the resin just before pumice and rag wheel finishing. Depending on their size and definition, these features may be made with a sharp-edged inverted-cone green stone rotating parallel to the occlusal plane and touched briefly to the resin. Often the defects are most noticeable in the cervical third of the tooth, but an adjacent tooth is the best guide for determining their distribution.

Imbrication lines may be simulated with a coarse diamond rotary instrument rotating slowly and moved across the facial surface from proximal to proximal. This reduces the surface reflectance of the resin after it is finished and polished. However, as with all texture effects, overfinishing obliterates these lines. Care must be taken to monitor the finishing by rinsing pumice from the surface and drying it. A completely smooth and highly polished interim restoration may be excellent for plaque control but not esthetically compatible with the adjacent teeth. The debate as to which is more important can probably best be settled by consulting with the patient to determine his or her needs.

SUMMARY

Although interim restorations are usually intended for short-term use and then discarded, they can be made to provide pleasing esthetics, adequate support, and good protection for teeth while maintaining periodontal health. They may be fabricated in the dental office from any of several commercially available materials and by a number of practical methods. The success of fixed prosthodontics often depends on the care with which the interim restoration is designed and fabricated.

STUDY QUESTIONS

1. What are the ideal properties of an interim restorative material? What are the ideal properties of the optimal interim luting agent?
2. List at least five requirements of a successful interim restoration.
3. Explain why these factors are crucial to clinical success. What would occur if they were not appropriately performed or obtained?
4. Select three techniques for fabricating an interim restoration for a single tooth. Identify the factors involved when a certain technique is selected for an indication or tooth.
5. What are the currently available materials for fabrication of interim restorations? What are their respective material properties, advantages, and disadvantages?
6. Explain the basic chemistry involved in resin polymerization.
7. What factors should be considered when deciding between a direct, indirect, or indirect-direct fabrication technique for interim fixed dental prostheses?

GLOSSARY*

ac·cel·er·a·tor \ăk-sĕl′a-rā′ter\ *n* (1611)**: 1:** a substance that speeds a chemical reaction **2:** in physiology, a nerve, muscle, or substance that quickens movement or response

acrylic resin \a-krĭl′ĭk rĕz′ĭn**: 1:** pertaining to polymers of acrylic acid, methacrylic acid, or acrylonitrile; for example, acrylic fibers or acrylic resins **2:** any of a group of thermoplastic resins made by polymerizing esters of acrylic or methylmethacrylate acids

ac·ti·va·tor \ăk′tĭ-vā′ tôr\ *n***:** a removable orthodontic device intended to stimulate perioral muscles

au·to·poly·mer \ô′tō-pŏl′a-mer\ *n***:** a material that polymerizes by chemical reaction without external heat as a result of the addition of an activator and a catalyst–**au·to·poly·mer·i·za·tion** \ô′tō-pŏl′a-mĕr-zā′shun\ *vb*

autopolymerizing resin \ô′tō-pŏl-a-mĕr-ī′zing rĕz′ĭn**:** a resin whose polymerization is initiated by a chemical activator

bench set \bĕnch sĕt**:** a stage of resin processing that allows a chemical reaction to occur under the conditions present in the ambient environment; also used to describe the continuing polymerization of impression materials beyond the manufacture's stated set time

[1]fes·toon \fĕ-stōōn\ *n* (1630)**: 1:** any decorative chain or strip hanging between two points **2:** in dentistry, carvings in the base material of a denture that simulate the contours of the natural tissues that are being replaced by the denture

[2]fes·toon \fĕ-stōōn\ *vt* (1800)**:** to shape into festoons

hy·per·tro·phy \hī-pûr′tra-fē\ *n* (1834)**:** an enlargement or overgrowth of an organ or tissue beyond that considered normal as a result of an increase in the size of its constituent cells and in the absence of tumor formation

methyl methacrylate resin \mĕth′al mĕth-ăk′ra-lāt rĕz′ĭn**:** a transparent, thermoplastic acrylic resin that is used in dentistry by mixing liquid methyl methacrylate monomer with the polymer powder. The resultant mixture forms a pliable plastic termed a *dough*, which is packed into a mold prior to initiation of polymerization

ob·tun·dent \ŏb-tŭn′dant\ *n***:** an agent or remedy that lessens or relieves pain or sensibility

pho·to·ac·tive \fō′tō-ăk′tĭv\ *adj***:** reacting chemically to visible light or ultraviolet radiation–**pho·to·ac·ti·va·tion**

[1]pum·ice \pŭm′ĭs\ *n* (15th cent.)**: 1:** a type of volcanic glass used as an abrasive. It is prepared in various grits and used for finishing and polishing **2:** a polishing agent, in powdered form, used for natural teeth and fixed and removable restorations

res·in \rĕz′ĭn\ *n* (14c)**: 1:** any of various solid or semisolid amorphous natural organic substances that usually are transparent or translucent and brown to yellow; usually formed in plant secretions; are soluble in organic solvents but not water; are used chiefly in varnishes, inks, plastics, and medicine; and are found in many dental impression materials **2:** a broad term used to describe natural or synthetic substances that form plastic materials after polymerization. They are named according to their chemical composition, physical structure, and means for activation of polymerization–see AUTOPOLYMERIZING R., COPOLYMER R.

resin crown \rĕz′ĭn kroun**:** a resin restoration that restores a clinical crown without a metal substructure

[1]spat·u·late \spăch′a-lĭt\ *adj* (1760)**:** shaped like a spatula

[2]spat·u·late \spăch′a-lĭt\ *vt* **-ed/-ing/-s:** to work or treat with a spatula

ther·mo·plas·tic \thûr′ma-plăs′tĭk\ *adj* (1883)**:** a characteristic or property of a material that allows it to be softened by the application of heat and return to the hardened state on cooling–**ther·mo·plas·tic·i·ty** *n*

tin·foil \tĭn′foil′\ *n* (15c)**: 1:** paper thin metal sheeting usually of a tin-lead alloy or aluminum (a misnomer) **2:** a base-metal foil used as a separating material between the cast and denture base material during flasking and polymerizing

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REFERENCES

1. Seltzer S, Bender IB: The Dental Pulp; Biologic Considerations in Dental Procedures, ed 3, p 191. Philadelphia, Lippincott, 1984.
2. Seltzer S, Bender IB: The Dental Pulp; Biologic Considerations in Dental Procedures, ed 3, pp 267-272. Philadelphia, Lippincott, 1984.
3. Larato DC: The effect of crown margin extension on gingival inflammation. J South Calif Dent Assoc 37:476, 1969.
4. Waerhaug J: Tissue reactions around artificial crowns. J Periodontol 24:172, 1953.
5. Phillips RW: Skinner's Science of Dental Materials, 8th ed, pp 221, 376. Philadelphia, WB Saunders, 1982.
6. El-Ebrashi MK, et al: Experimental stress analysis of dental restorations. VII. Structural design and stress analysis of fixed partial dentures. J Prosthet Dent 23:177, 1970.

7. Koumjian JH, et al: Color stability of provisional materials in vivo. J Prosthet Dent 65:740, 1991.
8. Preston JD: A systematic approach to the control of esthetic form. J Prosthet Dent 35:393, 1976.
9. Moskowitz ME, et al: Using irreversible hydrocolloid to evaluate preparations and fabricate temporary immediate provisional restorations. J Prosthet Dent 51:330, 1984.
10. Roberts DB: Flexible casts used in making indirect interim restorations. J Prosthet Dent 68:372, 1992.
11. Hensten-Pettersen A, Helgeland K: Sensitivity of different human cell lines in the biologic evaluation of dental resin-based restorative materials. Scand J Dent Res 89:102, 1981.
12. Munksgaard EC: Toxicology versus allergy in restorative dentistry. Adv Dent Res 6:17, 1992.
13. Dahl BL: Tissue hypersensitivity to dental materials. J Oral Rehabil 5:117, 1978.
14. Weaver RE, Goebel WM: Reactions to acrylic resin dental prostheses. J Prosthet Dent 43:138, 1980.
15. Giunta J, Zablotsky N: Allergic stomatitis caused by self-polymerizing resin. Oral Surg 41:631, 1976.
16. Spealman CR, et al: Monomeric methyl methacrylate: studies on toxicity. Industrial Med 14:292, 1945.
17. Moulding MB, Teplitsky PE: Intrapulpal temperature during direct fabrication of provisional restorations. Int J Prosthodont 3:299, 1990.
18. Tjan AHL, et al: Temperature rise in the pulp chamber during fabrication of provisional crowns. J Prosthet Dent 62:622, 1989.
19. Zach L, Cohen G: Pulpal response to externally applied heat. Oral Surg 19:515, 1965.
20. Crispin BJ, et al: The marginal accuracy of treatment restorations: a comparative analysis. J Prosthet Dent 44:283, 1980.
21. Monday JJL, Blais D: Marginal adaptation of provisional acrylic resin crowns. J Prosthet Dent 54:194, 1985.
22. Robinson FB, Hovijitra S: Marginal fit of direct temporary crowns. J Prosthet Dent 47:390, 1982.
23. Von Fraunhofer JA, Spiers RR: Accelerated setting of dental stone. J Prosthet Dent 49:859, 1983.
24. Pashley EL, et al: The sealing properties of temporary filling materials. J Prosthet Dent 60:292, 1988.
25. Rosenstiel SF, Gegauff AG: Effect of provisional cementing agents on provisional resins. J Prosthet Dent 59:29, 1988.
26. Gegauff AG, Rosenstiel SF: Effect of provisional luting agents on provisional resin additions. Quintessence Int 18:841, 1987.
27. Olin PS, et al: Retentive strength of six temporary dental cements. Quintessence Int 21:197, 1990.

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16



COMMUNICATING WITH THE DENTAL LABORATORY

KEY TERMS

certified dental technician (CDT)
communication
dentist and technician responsibilities
infection control
margin design
quality control
work authorization

To make a high-quality fixed prosthesis, all members of the dental team must understand what they can reasonably expect from each other. A mutual knowledge of individual limitations is crucial. The dentist who does not understand and appreciate the challenges faced by the technician is at a serious disadvantage when prescribing and delegating laboratory procedures (Fig. 16-1). Crucial to the development of sound clinical judgment is a thorough understanding of technical procedures and their rationale, which are described in the chapters of this section.

DENTAL TECHNOLOGY TRAINING AND CERTIFICATION

The National Association of Dental Laboratories (NADL) is committed to upholding and advancing the commercial dental laboratory industry. This organization emphasizes the following information[1]:

In 46 states, there are no laws to set minimum qualifications for performance of dental technology or the operation of a dental laboratory. However, several states are moving forward with legislative proposals on "mandated technician certification." The American Dental Association (ADA) Council on Dental Practice voted in 2005 at the NADL's request to remove some policy language that was an obstacle to laboratory regulation/technician licensure through certification at the state level.[2] Technicians and laboratories that become certified do so as evidence of their commitment to maintaining professional standards in dental technology. There are approximately 52,000 individual dental laboratory technicians in the United States. Because technicians are not required to be registered or licensed in most states, tracking has to come from various government and private sources.

In 2002, 25 programs in dental laboratory technology were approved (accredited) by the Commission on Dental Accreditation in conjunction with the ADA.

The National Board for Certification, an independent board established by the NADL, offers voluntary certification in dental laboratory technol-



Fig. 16-1
A, This six-unit anterior metal-ceramic framework did not seat. After sectioning between the incisors, the adaptation of the individual components was satisfactory. Note the (correct) narrow width of the soldering gap. **B,** The two segments indexed with autopolymerizing resin for subsequent soldering. **C,** The dentist sectioned this fixed dental prosthesis (FDP) incorrectly: the soldering gap is much too wide (*arrow*), and distortion during soldering will almost certainly result.

ogy. Certification can be obtained in five specialty areas: crowns and bridges, ceramics, partial dentures, complete dentures, and orthodontic appliances. Certification is required in the states of Kentucky, Texas, and South Carolina. The standards and requirements for certification do not vary across state lines. A **certified dental technician (CDT)** tested in New England must demonstrate the same competencies as a CDT tested on the Pacific coast.

To qualify for certification, technicians must have a 2-year dental technology degree or at least 5 years' experience in dental technology and must pass written and practical examinations. To maintain certification, they must document at least 12 hours of continuing education annually, including study of **infection control** (specific procedures designed to control the spread of disease agents). The requirements for a certified dental laboratory include having a Certified Dental Technician (CDT) present to supervise each department in the specialty, in which they and the laboratory are certified, to ensure that proper safety and production practices are followed. Certification must be renewed annually.*

Technicians who maintain their certification must take 12 hours of continuing education each year, including a required hour in OSHA compliant infection control procedures.

The first CDTs were tested in 1958. Today the National Board for Certification tests more than 1200 technicians annually. In 1978, the current standards for laboratory certification were adopted; today there are more than 400 certified dental laboratories.[2]

In 2004, the U.S. dental laboratory industry produced approximately $5 billion in sales. The number of dental laboratories in the United States is about 12,000.

MUTUAL RESPONSIBILITIES

Good communication is the key to the technical success of the dental team[3-5] This requires a close working relationship between the dentist and laboratory technician. Anticipating satisfactory results is unrealistic if the dentist does not have a reasonable amount of experience with, and a thorough understanding of, dental laboratory procedures. Active participation in the technical procedures by the dentist is paramount, and clinicians who take the time to develop an in-depth understanding of laboratory work make better clinical decisions because of their understanding of applicable technical and material science limitations. Only then can a dentist select the best compromise between technical restrictions, on the one hand, and biologic factors and esthetic needs, on the other. Similarly, if the technician does not appreciate and respect the clinical demands or the treatment rationale of the dentist, the results will be less than satisfactory (Fig. 16-2). The dentist can earn this respect by being prepared to meet personal responsibilities, by listening carefully to technical advice rendered, and by actively participating in the technical decision-making process.

Surveys[6-8] of fixed prosthodontic laboratories reveal that dentists delegate a significant proportion of their responsibilities. The technicians surveyed were often dissatisfied with the quality of work received; complaints included insufficient informa-

*Reproduced by permission of National Association of Dental Laboratories.



Fig. 16-2
It is often difficult for the technician to appreciate soft tissue contours and embrasure form. These substructures were not fabricated properly—the metal porcelain junction was placed too far facially (*arrows*). Unless corrected during clinical evaluation, metal would be visible and detract from the appearance of the prosthesis.

tion being included in the **work authorization,** the submission of deficient impressions, and inadequate occlusal records. Such surveys highlight significant problems in dentist-technician communication. In other studies and opinions concerning dentist-technician interaction, whether written by dentists or technicians, the authors emphasized that better patient care is achievable only by better patient care communication.[9]

The ADA has issued guidelines to improve the relationship between dentist and technicians.[10] They are reprinted here:

> Working relationships between dentists and dental laboratories: The current high standard of prosthetic dental care is directly related to, and remains dependent upon, mutual respect within the dental team for the abilities and contributions of each member. The following guidelines are designed to foster good relations between dental laboratories, dental laboratory technicians and the dental profession. Applicable laws shall take precedence if they are inconsistent with any of the following guidelines.

The Dentist

1. The dentist should provide written instructions to the laboratory or dental technician. The written instructions should detail the work which is to be performed, describe the materials which are to be used, and be written in a clear and understandable fashion. A duplicate copy of the written instructions should be retained for an appropriate time as may be required by law.
2. The dentist should provide the laboratory technician with accurate impressions, casts, occlusal registrations and/or mounted casts. Materials submitted should be identified.
3. The dentist should identify, as appropriate, the crown margins, post palatal seal, denture borders, any areas to be relieved, and design of the removable partial dentures on all cases.
4. The dentist should furnish instruction regarding preferred materials, coloration, [and] description of prosthetic tooth/teeth to be utilized for fixed or removable prostheses, which may include, but [is] not limited to, a written description, photograph, drawing, or shade button.
5. The dentist should provide verbal or written approval to proceed with a laboratory procedure, or make any appropriate change(s) to the written instructions as the dentist deems necessary, when notified by a laboratory/dental technician that a case may have a questionable area with respect to paragraphs 2-4.
6. The dentist should clean and disinfect all items according to current infection control standards prior to sending them to the laboratory technician. All prostheses and other materials that are forwarded to the laboratory/technician should be prepared for transport, utilizing an appropriate container and packaged adequately to prevent damage and maintain accuracy.
7. The dentist should return all casts, registration, and prostheses/appliances to the laboratory/technician if a prosthesis/appliance does not fit properly or if a shade selection is incorrect.

The Laboratory Technician

1. The laboratory technician should custom manufacture dental prostheses/appliances which follow the guidelines set forth in the written instructions provided by the dentist and should fit properly on the casts and mounting provided by the dentist. Original written instructions should be retained for a period of time as may be required by law. When a laboratory provides custom-printed written instruction forms to a dentist, the laboratory document should include the name of the laboratory and its address, provide ample space for the doctor's written instruction, areas to indicate the desired delivery date, the patient's name, a location for the doctor to provide his/her name and address, as well as to designate a site for the doctor to provide a signature. The form should also allow for other information which the laboratory may deem pertinent or which may be mandated by law.

2. The laboratory should return the case to the dentist to check the mounting if there is any question of its accuracy or of the bite registration furnished by the dentist.
3. The laboratory/technician should match the shade which was described in the original written instructions.
4. The laboratory/technician should notify the dentist within two (2) working days after receipt of the case, if there is a reason for not proceeding with the work. Any changes or additions to the written instructions must be agreed to by the dentist and must be initialed by authorized laboratory personnel. A record of any changes shall be sent to the dentist upon completion of the case.
5. After acceptance of the written instructions, the laboratory/technician should custom manufacture and return the prostheses/appliances in a timely manner in accordance with the customary manner and with consideration of the doctor's request. If written instructions are not accepted, the laboratory/technician should return the work in a timely manner and include a reason for the denial.
6. The laboratory should follow current infection control standards with respect to the personal protective equipment and disinfection of prostheses/appliances and materials. All materials should be checked for breakage and immediately reported if found.
7. The laboratory/technician should inform the dentist of the materials present in the case and may suggest methods on how to properly handle and adjust these materials.
8. The laboratory/technician should clean and disinfect all incoming items from the dentist's office; e.g., impressions, occlusal registrations, prostheses, etc., according to current infection control standards, placed in an appropriate container, packed properly to prevent damage, and transported.
9. The laboratory/technician should inform the dentist of any subcontracting laboratory/technician employed for preparation of the case. The laboratory/technician should furnish a written order to the dental laboratory which has been engaged to perform some or all of the services on the original written instructions.
10. The laboratory/technician should not bill the patient directly unless permitted by the applicable law. The laboratory should not discuss or divulge any business arrangements between the dentist and the laboratory with the patient.

RESPONSIBILITIES OF THE DENTIST

The dentist has the overall responsibility for the treatment rendered. Delegating many procedures to auxiliary personnel is possible if all the necessary information is provided to enable them to deliver high-quality service. However, errors such as insufficient tooth reduction, uncertainty about the location of tooth preparation margins, improper interocclusal records and articulations, and ambiguity in communicating the desired shades for esthetic restorations to the technician hamper this responsibility.

Infection Control

The U.S. Department of Health and Human Services[11] and the ADA[12] have issued guidelines about the disinfection and handling of impressions and other material transferred from the dental office to the dental laboratory. Applicable guidelines are detailed in Chapter 14. Strict adherence to infection control guidelines cannot be overemphasized, because the potential for infection of dental laboratory personnel exists. In a 1990 sample,[13] of all materials sent from dental offices to dental laboratories, 67% were contaminated. Results from a more recent questionnaire submitted to dental laboratories suggest that technicians believed in less than 60% of the cases that materials had been appropriately disinfected before being submitted to the laboratory.[8]

Tooth Preparation

An organized approach to tooth preparation has been discussed in Chapters 7 to 11, which provide the criteria for minimally necessary clearances for the various restorations.

Inadequate tooth reduction in the cervical third for a metal-ceramic restoration is a common error. Obviously, on long clinical crowns of vital teeth (e.g., after periodontal surgery), it is not always possible to reduce the desired 1.2 to 1.5 mm without pulp exposure. Nevertheless, it is generally impossible, even for an experienced ceramist, to achieve superior esthetic results if the tooth is underprepared.[14] Inexperienced technicians tend to resolve the problem by overcontouring (Fig. 16-3), but this usually leads to the initiation or recurrence of periodontal disease. Esthetic difficulties and treatment limitations such as these should be discussed with the patient during the treatment planning phase. Communication regarding any deviation from "ideal" criteria ahead of time is essential and can prevent misunderstanding, frustration, and ultimate failure.



Fig. 16-3

Unrealistic expectations. Restoration failure resulting from excessive axial contours. **A,** Recently placed metal-ceramic crowns have contributed to gingival inflammation. **B,** Insufficient shoulder width is seen when the crowns are removed. **C** and **D,** Excessive contours: Note the cervical bulge on the facial aspect of this restoration (**D**). **E,** A significant amount of axial wall is visible from a gingival view. **F** to **H,** The restorations are recontoured and polished. Compare the view in **G** with that in **D** and the view in **H** with that of **E. I,** Tissue health quickly improves when the recontoured restorations are temporarily recemented. After correction of the underreduced tooth preparations, replacement crowns were made for esthetic reasons.

Preparation Margins

Margins should be easily discernible and accessible on the casts submitted to the technician. The saying "If you can't see it, you can't wax it" describes the situation well. (The requirements for dies are listed in Chapter 17.)

The dentist should outline the margins on the dies[15] (Fig. 16-4). However, in practice, few dentists do this.[16] If the teeth are properly prepared and the impression is accurate, the margins should be obvious, which makes this step unnecessary. When doubt exists, the dentist's knowledge of the extent of the preparation should resolve any uncertainty.

Dentists must understand the importance of **margin design** and geometry. For instance, it is unrealistic to request a collarless restoration on a shoulder-bevel type of margin or an all-ceramic crown restoration on a tooth with a narrow chamfer finish line (Figs. 16-5 and 16-6).



Fig. 16-4
Marking the preparation margin with a colored pencil. The line must be clearly visible but of minimal thickness.



Fig. 16-5
The expectations of the dentist are not realistic. These preparations are unsuitable for the metal-ceramic restorations requested, because the gingival one-third was inadequately reduced.

Although an experienced technician will probably bring any unrealistic demands to the attention of the dentist, some well-meaning technicians may attempt to meet a request that is doomed to failure from the beginning. To quote one excellent dentist, "When you discover an error has occurred–STOP! Don't proceed. Return to the step where the error occurred and correct it. Attempting to blunder on without correcting it properly will only compound and complicate the error."

Articulation

Proper articulation of opposing casts is the responsibility of the dentist. Often it is advisable to schedule a separate appointment with the patient for verification of the articulation. This is particularly crucial as the complexity of treatment increases (Fig. 16-7). An apparently slight discrepancy may require a remake or hours of corrective grinding and a compromised result. With careful planning, verification of the articulation can be done efficiently and results in peace of mind. Appropriate trimming of interocclusal records should be done by the dentist. Only after trimming is it possible to verify the positional stability of the record on the cast (Fig. 16-8).

Work Authorization

In some jurisdictions, the written instructions may be referred to as a *work authorization,* whereas elsewhere it may be referred to as a *laboratory work order* or *prescription.* In addition to certain general information that is required by law, a work authorization form (Fig. 16-9) should include the following:

1. General description of the restoration to be made.
2. Material specification (e.g., ADA type IV gold).
3. Desired occlusal scheme.



Fig. 16-6
Three types of esthetic restorations. The restoration with the metal collar can be fabricated on a shoulder or shoulder-bevel margin; the porcelain labial margin metal-ceramic crown can be fabricated on a shoulder margin; and the all-ceramic crown requires a slightly rounded internal angle. The latter two require margins that are glasslike in smoothness.

Text continues on page 519



Fig. 16-7

A to **F,** In the presence of compromised periodontal support, optimal loading is crucial to enhance the prognosis. Accurate occlusion is essential to successful restoration of this periodontally compromised patient for whom multiple hemisections, root resections, and amputations have been performed. Extensive communication with the technician is necessary.

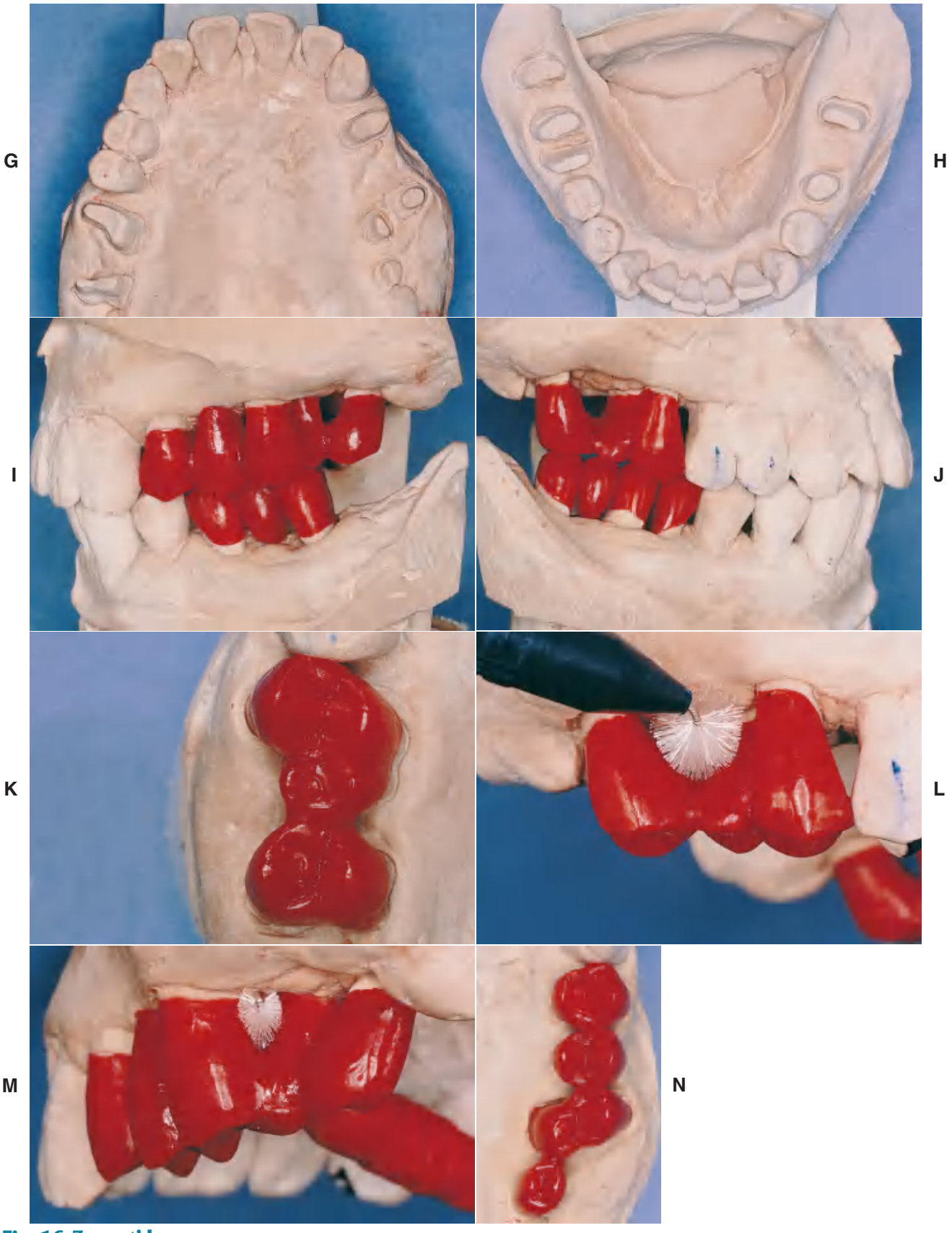


Fig. 16-7, cont'd

G to N, After verification of the articulation, the restorations are waxed to anatomic contour. Wax patterns are designed to combine occlusal function with maximum access for oral hygiene. Note the buccolingual reduction in width of the occlusal table (I) and the emergence profile on the maxillary molars (I and J).



Fig. 16-7, cont'd

O to R, In the bisque stage, the restorations are evaluated, and form is modified as required before indexing and post-soldering. S to X, Glazed and polished restorations on the definitive cast. Note that occlusal rests have already been incorporated in the fixed prostheses in the mandibular arch (T, U, and V) to anticipate possible failure (see Chapter 32).



Fig. 16-7, cont'd
Y to CC, Completed restorations in place.



Fig. 16-7, cont'd
DD to FF, Note that embrasure design allows proper cleaning.



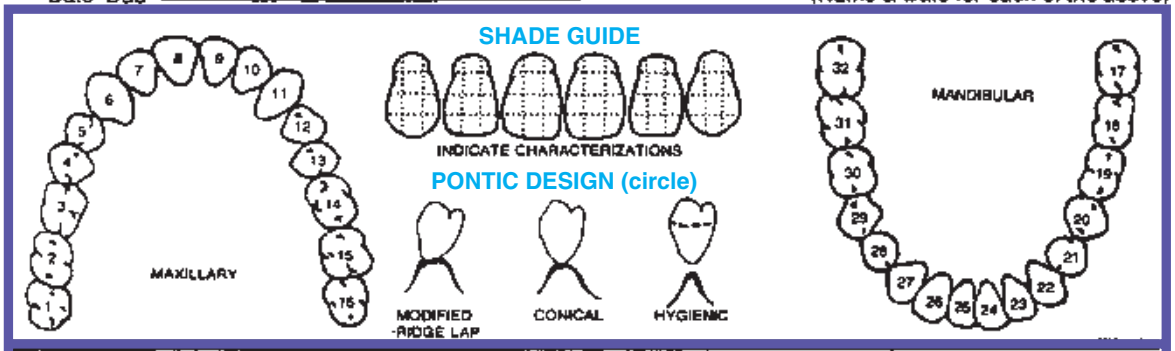
Fig. 16-8
It is important that interocclusal records are trimmed through the buccal cusp tips to enable easy verification that both casts are properly positioned in the record and stable.

SIU
SCHOOL OF DENTAL MEDICINE

DENTAL LABORATORY WORK AUTHORIZATION

School of Dental Medicine, 2800 College Avenue, Alton, IL 62002-4700

Student _____ Rec. by SDM Lab _____ Units Rec. _____
Patient _____ F. P. Sec. Head Begin _____
Patient # _____ Technician _____
Lab _____ F.P. Sec. Head Complete _____
Received by Student _____
Date Due _____ (Name & Date for each of the above)



Porcelain Shades										Articulator Number
				Shade		Margin		Contacts		Articulator Settings
Tooth #	Rest. Type	Metal	Guide	Incisal	Gingival	0.3 mm metal	Porc. Shoulder	Metal	Porcelain	R L
										Cond. Guid.
										Inc. Guid.
										ISS
										PSS

℞

Dental License No. _____ Signature _____ D.M.D. D.D.S.

Office Use Only

Wax		Bridge Units	
Cast			
Porc.		Crown Units	
Sold.			

Business Office Paid

EML 11/89 White–Lab. Credit Voucher / Yellow–Lab. Record Copy / Pink–File Copy 1810-23 rev. 4/99

Fig. 16-9
Work authorization form. Cond. Guid., condylar guidance angle; Inc. Guid., incisal guidance; ISS, immediate side shift; Porc., porcelain; PSS, progressive side shift; SDM, School of Dental Medicine.

4. Connector design for fixed dental prostheses.
5. Pontic design, including the material specification for tissue contact.
6. Substructure design for metal-ceramic restorations.
7. Information regarding the shade selection for esthetic restorations.
8. Proposed partial removable dental prosthesis design (if applicable).
9. Date of the next scheduled patient appointment and the stage of completion required by then.

The dentist must be familiar with the materials that the technician prefers to use for certain procedures. Specifying those materials can save both time and effort. The technician should also respect the selection when the dentist requests a specific material. Written instructions should be explicit.[17]

Communication improves if the technician and dentist discuss a particular choice rather than if the dentist issues a bald statement written on the work authorization form. It may be inconvenient for the technician to comply with a request, and so its importance should be discussed.

Occlusion

The work authorization form should designate the location of the occlusal contacts. It must be specified whether they are to be on metal or porcelain. In theory, the two most desirable occlusal schemes are cusp-fossa and cusp-marginal ridge. Assuming that these will be attained in every case is unrealistic, however, because they can be accomplished consistently only when the opposing teeth are reasonably close to ideal relative positions (Angle Class I; see Chapter 1). Compromises often must be made, especially when teeth are being restored to conform to an existing dentition. For example, when a mandibular molar is in a buccolingual edge-to-edge posterior relationship with its antagonist, a decision must be made whether to restore the tooth in a reverse articulation or whether the tooth preparation should be modified (additional reduction of the buccal functional cusp bevel) to accommodate a more conventional occlusal relationship. As an alternative, restoring the opposing tooth may need to be considered.

If the dentist has performed a diagnostic tooth preparation and waxing (see Chapter 2), it is possible to communicate the desired occlusal relationship or tooth form very specifically (Fig. 16-10). A wax record rim that has been adjusted intraorally can convey a general idea of the desired position of the occlusal plane (Fig. 16-11). Similarly, a custom anterior guide table made by the dentist from anterior provisional restorations that have proved comfortable for the patient is most helpful to the technician

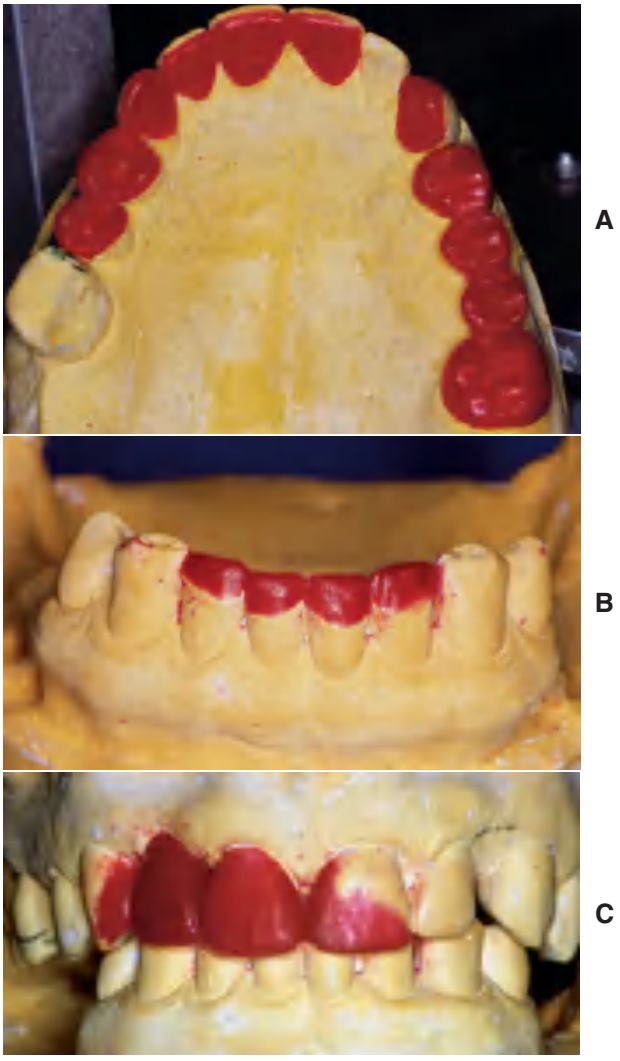


Fig. 16-10
Diagnostic waxing used to communicate desired occlusal form (**A**), the mandibular incisal edge position (**B**), and the shape of maxillary incisors (**C**). *(Courtesy of Dr. M. Chen.)*



Fig. 16-11
A wax record rim that has been adjusted intraorally with a Fox plane can provide helpful information to the technician. Note that the desired position of the midline has been marked.

in reproducing the same anterior guidance in the definitive fixed prostheses (Fig. 16-12). An impression of an interim crown poured in fast-setting dental stone is an excellent means of communicating the desired size and contours (Fig. 16-13). On occasion, when a single crown is to be made, an existing malocclusion may be accepted. This can limit the need for more extensive treatment, although it makes sense only if the opposing teeth will not need a restoration in the near future.

Connectors

The work authorization form should specify which connectors are to be cast, which are to be preceramic soldered, and which are to be postceramic soldered.



Fig. 16-12
A custom anterior guide table made from anterior provisional restorations that have proved comfortable for the patient: The guide table helps the technician replicate lingual contours in the fixed prostheses.



Fig. 16-13
A putty impression of the interim restorations has been poured. The resulting cast conveys desired tooth size and form and can be used as a starting point for contour waxing (see Chapter 19). *(Courtesy of Dr. M. Chen.)*

The sequence of the planned procedures should be indicated and discussed when necessary or when clarity can be enhanced. If nonrigid connectors are requested, the desired type of connector and path of placement should be specified.

Pontic and substructure design

Pontic design is discussed in Chapter 20. A simple checklist on the work authorization form should suffice if the dentist and technician have agreed on applicable expectations and requirements.[17,18]

The design of metal substructures for metal-ceramic restorations is somewhat controversial. Many technicians believe that it is not necessary to first create the contours of the completed restoration in wax and then cut back the veneering area. We disagree, and we present our reasoning in Chapter 19 (Fig. 16-14). The authorization should specify whether the anatomic contour wax patterns are to be returned for evaluation and possible modification. The more complex the restorative effort, the more crucial a careful evaluation becomes at this stage. Long-term success is the goal, and inadequate framework design is a relatively common cause of failure for which the dentist bears the responsibility (although the dentist often blames the ceramist).

Shade selection

With the prevalence of tooth-colored restorations, dentists and technicians have become acutely aware of the difficulty involved in communicating shade selection. A thorough understanding of the principles of color science (presented in Chapter 23) and of the use of internal and surface colorants (discussed in Chapters 24 and 30) is essential to both parties.

Many dentists and technicians have found a diagram of the tooth that allows specifications of multiple shades helpful (Fig. 16-15).[19] The diagram should be large enough to designate a cervical shade, an incisal shade, and any applicable individual characterization. Diagrams on most preprinted laboratory prescription forms do not provide adequate space (see Fig. 16-9), and so other space must be available. A separate entry regarding the value or brightness can be helpful. When selecting a shade, the dentist should use a guide that corresponds to the ceramic system used by the technician. On occasion, it may not be possible to obtain a match with a simple shade guide (e.g., the Vita Lumin vacuum system). In those cases, an alternative guide or a shade distribution chart (outlined in Chapter 23) should be used. The dentist must have excellent color perception skills and should be able to precisely transfer those onto a written prescription that includes a large, detailed diagram that allows the



Fig. 16-14
Anatomic contour waxing (**A**) and cutback (**B**) with the use of incisal (**A**) and facial (**B**) polyvinyl siloxane indexes. **C,** The same indexes are used during porcelain application. **D** and **E,** The desired form is accurately replicated (**D**), and this leads to predictable success when esthetics are paramount (**E**).

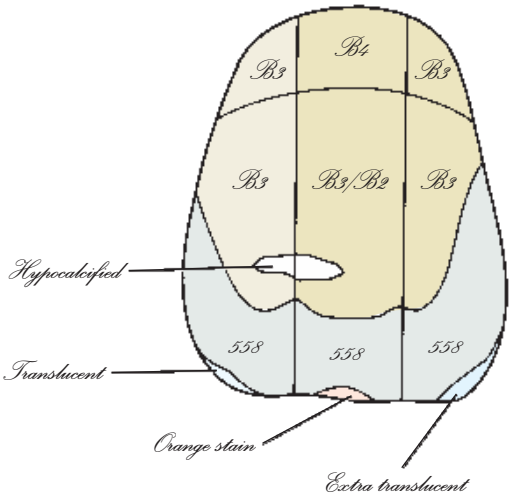


Fig. 16-15
A shade distribution chart must be adequate in size to permit inclusion of enough detail. Subtle differences observed in cervical shades are identified, as are surface details such as hypocalcification, incisal translucency, and stains.

ceramist to accurately reproduce the shade observed and described by the clinician. Close communication and cooperation are obviously necessary, and a trial porcelain firing may be needed.

A practical alternative to written color communication is the use of light-cured, resin-based staining kits to custom-stain a shade tab. The closest matching shade tab is selected and modified by stains mixed with liquid resin. Once the desired match has been obtained, the resin is light-cured, and the customized tab is sent to the dental laboratory. The ceramist then has an actual reference and can compare the work and make the required modifications, thus ensuring predictable success. A number of tooth shade–recording devices have been developed: colorimeters, spectrophotometers, and digital camera systems. (See also Chapter 23.) These techniques hold promise, although research on their reliability and reproducibility shows varying results with different shade guides. In general, color measurement reproducibility is better under controlled research laboratory setting than intraorally. Several of these systems provide a detailed color analysis in printed or electronic format (Fig. 16-16), which can be used to help communicate the specific shade or shades to the dental ceramist.

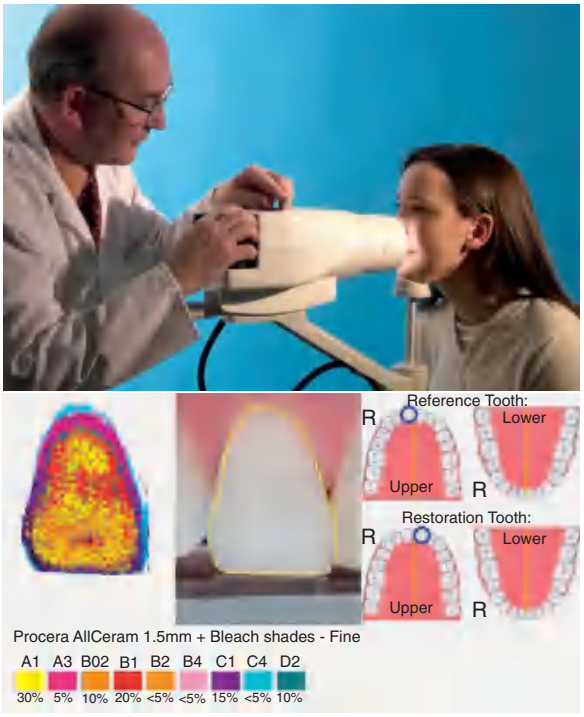


Fig. 16-16
Digital shade analysis. A, DCM Ikam digital camera with D-65 illumination. **B,** Example of analysis that is provided to assist the technician in development of the desired shade. *(Courtesy of Digital Colour Measurement Ltd., West Yorkshire, United Kingdom.)*

If esthetic requirements are extensive or difficult to communicate through the means just described, involving dental laboratory personnel in the shade selection process may be helpful. The ADA takes the position that when a dentist requests the assistance of a dental laboratory technician in the shade selection process, this does not constitute the practice of dentistry by the technician, provided the activity is undertaken in consultation with the dentist and that it complies with the dentist's written instructions. Specifically, the shade selection site, whether dental office or laboratory (where lawful), should be determined by the professional judgment of the dentist in the best interest of the patient and where communication between dentist, patient, and technician is enhanced.[10]

Additional information

Additional information often helps the technician considerably. Reference to diagnostic waxing can communicate specific information about desired tooth length and form or a desired occlusal arrangement. A custom anterior guide table (see Chapter 2) provides specific information to follow as anterior guidance is established in maxillary and/or mandibular anterior crowns. Casts of provisional restorations are invaluable to the technician when he or she is asked to fabricate fixed dental prostheses with a high esthetic requirement. They provide information about midlines, incisal edge position, and coronal form and are the most practical way of accurately conveying information to the laboratory (Fig. 16-17). The diagnostic waxing enables the dentist to explore all the treatment alternatives before choosing a course of therapy. A resin interim restoration can be fabricated and adjusted intraorally as necessary for optimum appearance and function. Standardized digital images can be especially helpful in conveying essential additional information.

APPROPRIATE CHECKS

In any new working relationship between a dentist and a technician, every laboratory step should be reviewed in detail for the initial patients. Only then can teamwork develop over time. As the dentist and technician become familiar with each other's preferences, several steps may then be combined.

The initial review may include the wax patterns for corrective shaping of occlusal and axial contours of retainers and pontics. When treating patients with fixed dental prostheses and metal-ceramic crowns, the dentist must decide whether the restorations should be completed through porcelain application in the laboratory or whether a preliminary metal



Fig. 16-17

A, Diagnostic casts, anterior guide table, and waxing provide additional information for the technician. **B** and **C,** Carefully adjusted interim restorations are an essential part of complex rehabilitation. The 19-year-old patient had generalized hypoplastic amelogenesis imperfecta, rough pattern (type I F). Her interim restorations were duplicated and replicated in the definitive prosthesis. *(B and C, Courtesy of Dr. A. Hernandez.)*

substructure evaluation appointment is needed. We recommend routine evaluations of the metal substructure for metal-ceramic restorations (Fig. 16-18). As an example, the technician may not have adequate information to evaluate how far the veneering area should be extended into the cervical embrasures, and this can be readily determined by the dentist during evaluation. When fixed dental prostheses are soldered, often it is best to index the component parts directly in the mouth rather than rely on the accuracy of the definitive cast (Fig. 16-19). An evaluation appointment can facilitate making small corrections of discrepancies that could later become significant errors. Similarly, it may be advantageous to plan an evaluation appointment for final contouring, texturing, and characterization of a metal-ceramic restoration in the bisque bake, before glazing. It takes time and effort to perform these clinical procedures (see Chapter 30), but patients will recognize and appreciate the improved results.

The use of checklists by both clinician and technician can be helpful.[18,20] For instance, before an impression leaves the dental office, the dentist and auxiliary personnel can use a standard protocol to confirm that finish lines are distinct; that no blood or saliva is present in impressions; that disinfection protocols were followed; that no voids, tears, defects, or areas where the tray was seated are present; and that contact has not occurred between occlusal sur-



Fig. 16-18

Unrealistic expectations by the dental technician. Inappropriate substructure design provides insufficient support for the porcelain veneer. This fixed dental prosthesis must be remade.

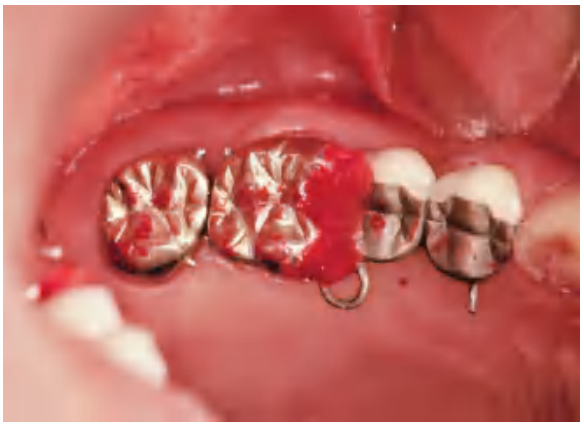


Fig. 16-19
Intraoral fabrication of an autopolymerizing resin soldering index that relates two components of a fixed dental prosthesis.



Fig. 16-20
Tripod marks provide accurate information to the technician about the planned path of placement of the partial removable dental prosthesis.

faces and the tray, creating thin spots that can lead to articulation errors. For casts, die trimming, the absence of undercuts, the retention form, the adequacy of reduction for facial porcelain and porcelain margins, and the occlusal clearance need to be confirmed.

Where retainers for partial removable dental prostheses are involved, the prescription and cast are checked to ensure availability of all pertinent information in relation to the path of insertion of the partial removable dental prosthesis, the guide planes, the rest seats, and the desired heights of contour (Fig. 16-20).

SUMMARY

The key to high-quality fixed prosthodontics lies in good communication between the dentist and the technician. All too often, each operates in a vacuum: The dentist forgets how a straightforward step such as rounding line angles can expedite the fabrication of a restoration, or the technician is unaware of the difficulties of a particular clinical phase (e.g., impression making or a remount procedure).

Through mutual respect and a coordinated effort, each can contribute to the delivery of patient care and at the same time keep failures to a minimum.

The most common problems seen by the dentist at evaluation are poor marginal adaptation, poor occlusion, poor axial contour (specifically, overcontouring of the cervical third of the tooth), and haphazard pontic and substructure design. The most common problems encountered by the technician are inadequate tooth reduction, "mystery margins," improper articulation, and vagueness in color communication.

The use of certain ancillary devices (e.g., diagnostic waxing and casts of provisional restorations) helps both dentist and technician deliver more effective treatment to the prosthodontic patient.

The student and practitioner involved in fixed prosthodontic treatment must acquire an in-depth understanding of the laboratory procedures described in the following chapters in this section. Often such understanding is most rapidly developed by personal involvement in the technical aspects of clinical dentistry. Over time, this leads to signifi-

STUDY QUESTIONS

1. Discuss the guidelines issued by the ADA in relation to working relationships between dentists and dental laboratories. What are specific responsibilities of the dentist? What are the responsibilities of the dental technician?
2. What is a CDT? What are requirements for certification?
3. Write a series of complete and comprehensive prescriptions for the various stages of laboratory fabrication of an anterior metal-ceramic fixed dental prosthesis from tooth #8 to tooth #11 (two pontics), to be fabricated in two segments and soldered after clinical evaluation and before porcelain application. List the various materials and models to be submitted with each prescription.
4. What is the purpose of submitting a custom anterior guide table to the dental laboratory? When would this be advisable?

cantly improved interaction with dental technicians, resulting in improved clinical decision making and more predictable and successful fixed prostheses.

GLOSSARY*

CDL: *acronym* for *Certified Dental Laboratory*

CDT: *acronym* for *Certified Dental Technician*

Certified Dental Laboratory: in the United States, a dental laboratory that has met established specific standards for personnel skills, laboratory facilities and infection control and is certified by The National Board for Certification of Dental Laboratories

Certified Dental Technician: in the United States, a dental technician who has met established specific standards and is certified by The National Board for Certification of Dental Laboratories

work authorization: a signed written order provided by the dentist to the dental laboratory detailing the work to be performed and specifying the materials to be used

REFERENCES

1. NADL [National Association of Dental Laboratories] Media Room. Available at: http://www.nadl.org/mediafacts.shtml (accessed August 11, 2005).
2. Bennett Napier CAE (Executive Director, National Association of Dental Laboratories): Personal communication July 18, 2005.
3. Small BW: Laboratory communication for esthetic success. Gen Dent 46:566, 1998.
4. Gleghorn T: Improving communication with the laboratory when fabricating porcelain veneers. J Am Dent Assoc 128:1571, 1997.
5. Warden D: The dentist-laboratory relationship: a system for success. J Am Coll Dent 69:12, 2002.
6. Aquilino SA, Taylor TD: Prosthodontic laboratory and curriculum survey. III. Fixed prosthodontic laboratory survey. J Prosthet Dent 52:879, 1984.
7. Leith R, et al: Communication between dentists and laboratory technicians. J Ir Dent Assoc 46:5, 2000.
8. Lynch CD, Allen PF: Quality of written prescriptions and master impressions for fixed and removable prosthodontics: a comparative study. Br Dent J 198:17, 2005.
9. Landesman HM: Prosthodontics. Clinical practice—professional affairs. Review of the literature. J Prosthet Dent 64:252, 1990.
10. American Dental Association: Current Policies, 1954-2003, pp 137-140. Chicago: American Dental Association.
11. U.S. Department of Health and Human Services, Public Health Service: Recommended infection control practices for dentistry. MMWR 35:237, 1986.
12. Infection control recommendations for the dental office and the dental laboratory. Council on Dental Materials, Instruments, and Equipment. Council on Dental Practice. Council on Dental Therapeutics. J Am Dent Assoc 116:241, 1988.
13. Powell GL, et al: The presence and identification of organisms transmitted to dental laboratories. J Prosthet Dent 64:235, 1990.
14. Jorgenson MW, Goodkind RJ: Spectrophotometric study of five porcelain shades relative to dimensions of color, porcelain thickness, and repeated firings. J Prosthet Dent 42:96, 1979.
15. Leeper SH: Dentist and laboratory: a "love-hate" relationship. Dent Clin North Am 23:87, 1979.
16. Olin PS, et al: Current prosthodontic practice: a dental laboratory survey. J Prosthet Dent 61:742, 1989.
17. Drago CJ: Clinical and laboratory parameters in fixed prosthodontic treatment. J Prosthet Dent 76:233, 1996.
18. Deyton G: Communications checksheet will ease relations with laboratories. Mo Dent J 74(5):32, 1994.
19. Pensler AV: Shade selection: problems and solutions. Compendium Contin Educ Dent 19:387, 1998.
20. Maxson BB: Quality assurance for the laboratory aspects of prosthodontic treatment. J Prosthodont 6:204, 1997.

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17

DEFINITIVE CASTS AND DIES



KEY TERMS

cyanoacrylate
definitive cast
dental stone
die trimming
dowel pin
electroplated die
electroplating
epoxy resin
gypsum
master cast
mounting
multiple-pour technique
split-cast mounting technique
stone die
vacuum mixing
working cast

Because direct fabrication of patterns for extracoronal restorations in the mouth is inconvenient, difficult, time consuming, and virtually impossible, practically all wax patterns are made in the laboratory with the indirect technique. This technique requires an accurate reproduction of the prepared tooth, the surrounding soft tissues, and the adjacent and opposing teeth. A cast-and-die system captures the necessary information so that it can be transferred to the laboratory.

The definitive cast (or **master** or **working cast**) is the replica of the prepared teeth, ridge areas, and other parts of the dental arch. The die is the positive reproduction of the prepared tooth and consists of a suitable hard substance of sufficient accuracy (usually an improved stone, resin, or metal) (Fig. 17-1).

The accuracy of a cast and die is a function of the completeness and accuracy of the impression. The cast cannot contain more information than the impression from which it was made.

This chapter describes the requirements of a cast-and-die system and correlates these with the available materials. The procedures are generally straightforward, but the steps must be followed carefully if the intended prosthesis is to be successful.

PREREQUISITES

The cast that will be used to make the fixed restoration must meet certain requirements. It must reproduce all details captured in the impression and should be free of defects. Depending on their location, however, minor imperfections may be acceptable (Fig. 17-2). The cast must meet certain requirements:

1. It must reproduce both prepared and unprepared tooth surfaces.
2. The unprepared teeth immediately adjacent to the preparation must be free of voids.
3. All surfaces of any teeth involved in anterior guidance and the occlusal surfaces of all unprepared teeth must allow for precise articulation of the opposing casts (Fig. 17-3).
4. All relevant soft tissues should be reproduced in the definitive cast, including all edentulous

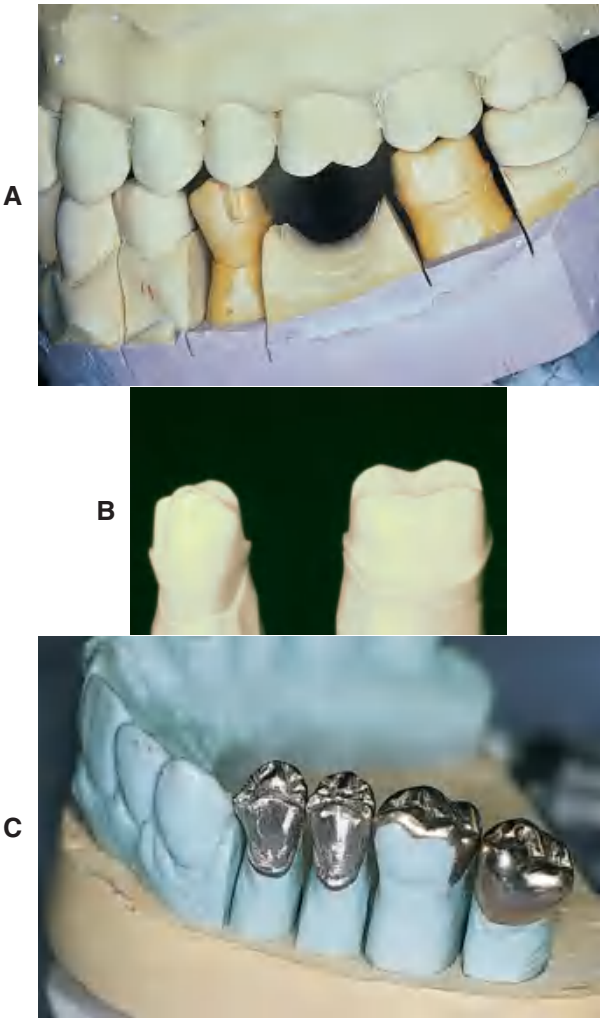


Fig. 17-1
Removable die system. A, Definitive cast. B, The individual dies. C, Epoxy die. *(C, Courtesy of Dr. J. H. Bailey.)*

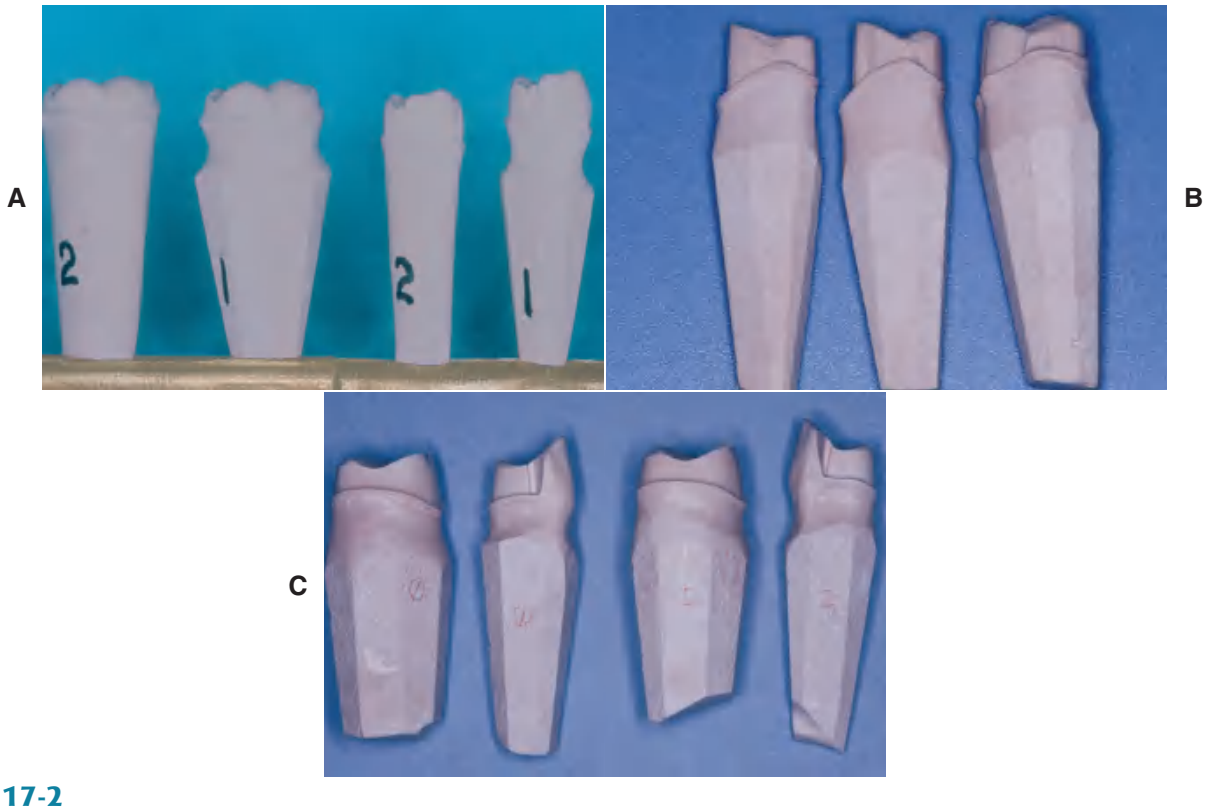


Fig. 17-2
A to C, Examples of individual dies.

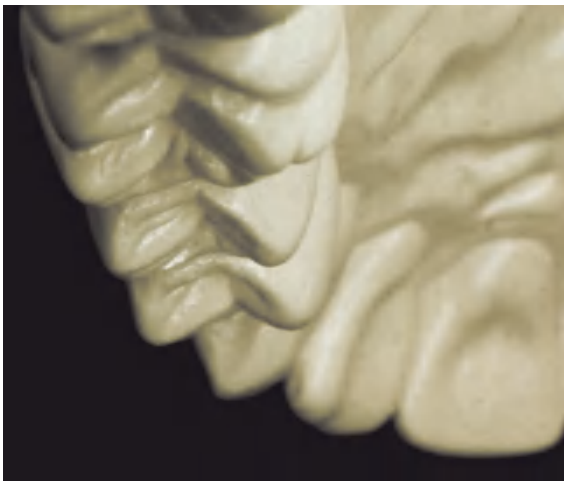


Fig. 17-3
Defect-free occlusal surfaces are essential to enable precise articulation.

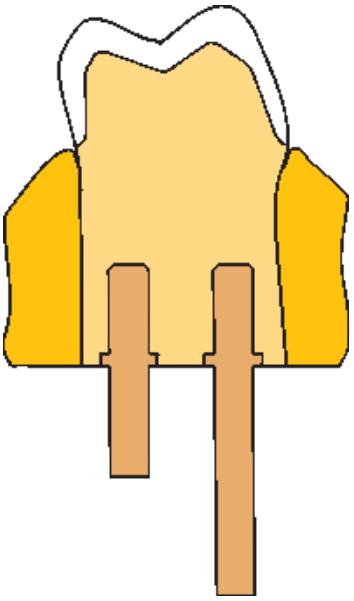


Fig. 17-4
To facilitate trimming, the impression should extend beyond the preparation margin. A properly trimmed die must have the same cervical contour as the tooth. (The gold areas indicate the parts of the die to be removed during trimming.)

spaces and residual ridge contours that will be involved in the fixed prosthesis.

The die for the fixed restoration also must meet certain requirements:

1. It must reproduce the prepared tooth exactly.
2. All surfaces must be accurately duplicated, and no bubbles or voids can be accepted.
3. The remaining unprepared tooth structure immediately cervical to the finish line should be easily discernible on the die, ideally with 0.5 to 1 mm visible (enough must be present to help the technician establish the correct cervical contour of the restoration) (Fig. 17-4).
4. Adequate access to the margin is imperative.

MATERIALS SCIENCE

James L. Sandrik

Gypsum

The two crucial characteristics of cast-and-die materials, dimensional accuracy and resistance to abrasion while the wax pattern is being formed, are adequately achieved with **gypsum**. This material is inexpensive, is easy to use, and produces consistent results. Manufactured in enormous quantities for industrial use, it can easily be modified for dental use.

Dental gypsum products are available in five forms (American Dental Association [ADA] types I to V), defined as impression plaster; model plaster; **dental stone;** high-strength dental stone; and high-strength, high-expansion stone. The gypsum components are identical chemically. The setting reaction results from the hydration of calcium sulfate hemihydrate:

$$CaSO_4 \cdot \tfrac{1}{2}H_2O + 1\tfrac{1}{2}H_2O \rightarrow CaSO_4 \cdot 2H_2O$$

The hemihydrate is manufactured by heating the dihydrate under controlled conditions to drive off some of the water of crystallization (a process called *calcination*). The differences between the various types of dental gypsum are attributable to calcination. The physical properties of die stone are improved over those of dental stone and plaster because less water is needed to obtain a sufficiently fluid mix.*

Hand mixing of gypsum products is easy, but results are better when the mixing is done mechanically in a vacuum. Porosity is reduced, with a concomitant increase in strength, after only 15 seconds of mechanical mixing. Newly poured casts should be left undisturbed for at least 30 minutes; superior

*Thus 100 g of plaster requires 45 to 50 ml of water, 100 g of dental stone requires 30 to 35 ml, and 100 g of die stone requires 20 to 25 ml, depending on the particular brand. Theoretically, the stoichiometric amount of water needed for the setting reaction is 18.6 ml. Only die stone has suitable physical properties for making cast restorations. However, its properties are totally dependent on accurate measurement of the water/powder ratio.

results are achieved at 1 hour, although these times may vary among brands.

Surface detail reproduction is acceptable with type IV and type V gypsum products. The materials are capable of reproducing a 20-μm-wide line as prescribed by ADA specification No. 19.[1] However, not all brands of die stone are compatible with all brands of impression material,[2,3] and if poor surface detail reproduction is experienced, an alternative product should be selected.

With some techniques (e.g., when a cast is prepared for duplication), it is necessary to soak the set gypsum in water. However, although it appears to be insoluble, the gypsum slowly dissolves, which ruins the surface detail of the cast. If soaking is required, it should be done in water saturated with plaster slurry and only long enough to achieve the desired degree of wetting.

Gypsum's greatest disadvantage is its relatively poor resistance to abrasion. Attempts to overcome this have included the use of so-called "gypsum hardeners." Although these materials (e.g., colloidal silica) have relatively little effect on the hardness of the stone, they improve abrasion resistance (some by as much as 100%).[4] Their use is accompanied by a slight increase in setting expansion, but such is probably not clinically significant. An alternative approach[5] is to impregnate the surface of the die with a low-viscosity resin such as **cyanoacrylate.** As mentioned earlier, abrasion resistance is the physical property most improved by this technique. Care is needed when the resin is selected and applied so that the resin film will have no significant thickness.[6] Experts continue their efforts to improve the properties of die stone. One approach is to apply additives used in industrial applications (e.g., concrete manufacture) to dental gypsum products.[7] Another is the use of a gum arabic, calcium hydroxide mixture.[8] Resin-strengthened gypsum products such as ResinRock,* with high strength and low expansion,[9] are also popular and are particularly suitable for casts for implant restorations (see Chapter 13).

Additional, even stronger die materials are also available. These include resin and **electroplated dies.**

Resin

Resins are used as a die material to overcome the low strength and abrasion resistance of die stone. Most available resin die materials are **epoxy resins,** but polyurethane is also used. Epoxy resin is well known as a household and industrial adhesive. It can be cured at room temperature without expensive or complicated equipment, and it yields a form that is reasonably stable dimensionally. Its abrasion resistance is many times greater than that of gypsum products. However, it is more expensive than gypsum, and it undergoes some shrinkage during polymerization.

Epoxy resins suitable for fabrication of precision dies are available, although there is a great deal of variability among brands.[10] The amount of shrinkage upon polymerization is quantitatively about equal to the expansion with gypsum. Polymerization shrinkage is less of a problem with newer formulations[11] and polyurethane resin.[12] When used with poly (vinyl siloxane), contemporary resin systems produce complete arch casts with similar dimensional accuracy to traditional die stone.[13] In general, detail reproduction is better[14]; however, prostheses fabricated on resin dies tend to fit more tightly than those made on gypsum.[15]

Certain impression materials (i.e., polysulfide and hydrocolloid) are not compatible with resin. However, good results are achieved with silicone and polyether.

Electroplated Dies

Besides resin, **electroplating** can be used to overcome the poor abrasion resistance of gypsum. This technique[16] has been in use for many years and involves the deposition of a coat of pure silver or copper on the impression. The areas to be plated are first coated with finely powdered silver or graphite to make them conduct electricity, and the impression is then placed in an electroplating bath. A layer of pure metal is deposited on the impression and is supported with type IV stone or resin.

Although electroplating has been in use for some time, several problems remain. Variable degrees of distortion commonly occur, and the technique must be performed slowly; otherwise, distortions in the metal subsequently stress the impression. The time necessary to produce a cohesive film of metal (typically 8 hours) is ample for the development of dimensional changes in the impression. However, when made properly, an electroplated die can be as accurate as a stone die,[17,18] although not all impression materials are suitable for plating. Because of their low surface energies, silicone impression materials are difficult to electroplate evenly. Some brands, however, are easier to plate than others.[19] Polyether impressions, because of their hydrophilic nature, imbibe water and become distorted; they therefore cannot be plated accurately. Polysulfide polymers

*Whip Mix, Louisville, Kentucky.

can be silver plated, but it is much more difficult to copper plate them. The main drawback of silver plating is the use of a cyanide solution, which requires special precautions because of its extreme toxicity.

Flexible Die Materials

Flexible die materials are similar to heavy-bodied silicone or polyether impression materials (see Chapter 14) and have been used to make interim restorations[20,21] or indirect composite resin inlays or onlays[22,23] chairside. The advantages of the flexible material over a stone die include more rapid setting and the ease of removal of the interim restoration or inlay. When choosing materials for flexible dies, the dentist must be sure to select a compatible combination of impression and die materials that provides good surface details. One study[24] revealed that the best detail reproduction was obtained when Impregum F die material* was combined with Extrude Light impression material.†

• • •

SELECTION CRITERIA

Choosing one cast-and-die system over another depends on several factors:

1. The material must allow a dimensionally accurate cast and should be strong and resistant to abrasion.
2. It should be easy to section and easy to trim with the routinely available equipment.
3. It should be compatible with the separating agent that will be used so that the wax pattern does not stick.
4. It should reproduce surface detail accurately.
5. It should be available in a color that contrasts with the wax used so that the preparation margin can be seen.
6. It should be easily wettable by the wax. In addition, it must be compatible with the impression material.
7. The type of restoration needs to be considered, because certain procedures (e.g., some all-ceramic crowns) require the strength of metal or epoxy resin and cannot be fabricated as readily on a weaker stone die.

The advantages and disadvantages of the available materials are summarized in Table 17-1.

*3M ESPE, St. Paul, Minnesota.
†Kerr Corporation, Orange, California.

Available Methods

Removable dies

In a removable die system (see Fig. 17-1), the die is an integral component of the **definitive cast** and can be lifted from the cast to facilitate access. Precise relocation of the die in the definitive cast is crucial to this system's success and is usually accomplished with brass pins or dowels (Fig. 17-5). When a single dowel is used, it should have at least one flat surface to provide resistance against rotation. Alternative methods (e.g., the popular Pindex* system [Fig. 17-6]), use multiple or interlocking dowels to ensure such resistance.

The cast is made in two pours of type IV or V stone† of contrasting colors: the first forms the teeth, and the second forms the base of the cast. The area to be removed is coated with a separating agent before the second layer is poured. In other areas, undercuts are provided to prevent unwanted separation. The location and orientation of the dowels are critical; if they are improperly placed, the dowels do not allow the die of the prepared teeth to be withdrawn from the cast (Fig. 17-7).

In normal situations, dowels are positioned in the stone before it is set. However, drilling the cast and cementing the pins into the set stone are also possible.[25]

The Pindex system is designed to facilitate this latter technique. All removable die systems depend on careful execution so that the die will separate cleanly and return to place accurately. In one study, investigators found similar accuracy with four removable die systems, although the Pindex system showed the least horizontal movement, and the brass **dowel pins** produced the least occlusogingival reseating discrepancy.[26]

Solid cast with individual die

The solid cast-and-individual die system, also referred to as the **multiple-pour technique,** has certain advantages over the removable die system; its primary advantage is its simplicity. It may also be slightly more accurate.[27] When the impression is judged to be satisfactory, it is poured in type IV or V stone in the area of the preparation or preparations only. When set, it is separated. A second pour is then made of the entire arch. (Sometimes the second pour is used for an additional set of individual dies

*Coltène/Whaledent, Inc., Cuyahoga Falls, Ohio.
†Type V stone, with greater expansion, requires less die spacing (see Chapter 18) to achieve the appropriate space for luting agent.

Table **17-1 DIE MATERIALS**

	Advantages	Disadvantages	Recommended use	Precautions
ADA type IV stone	Dimensional accuracy Straightforward technique Low cost Straightforward in-office procedure	Will be damaged if not handled carefully	Most situations	Accurate proportioning essential Vacuum mix recommended
ADA type V stone	Straightforward technique Low cost Straightforward in-office procedure Harder than type IV	Increased expansion	Most situations	Accurate proportioning essential Vacuum mix recommended
Epoxy resin	High strength Good abrasion resistance	Polymerization shrinkage Time-consuming, complex procedure	Complete ceramic crowns	Not compatible with polysulfide or hydrocolloid
Electroplating	High strength Good abrasion resistance	Time-consuming Special equipment needed	Complete ceramic crowns	Silver entails use of cyanide, which is toxic Incompatible with many impression materials

ADA, American Dental Association.



Fig. 17-5
Dowel pins.



Fig. 17-6
Removable dies made with the Pindex (Whaledent) dowel system (see Fig. 17-21). *(Courtesy of Coltène/Whaledent AG, Altstatten, Switzerland.)*

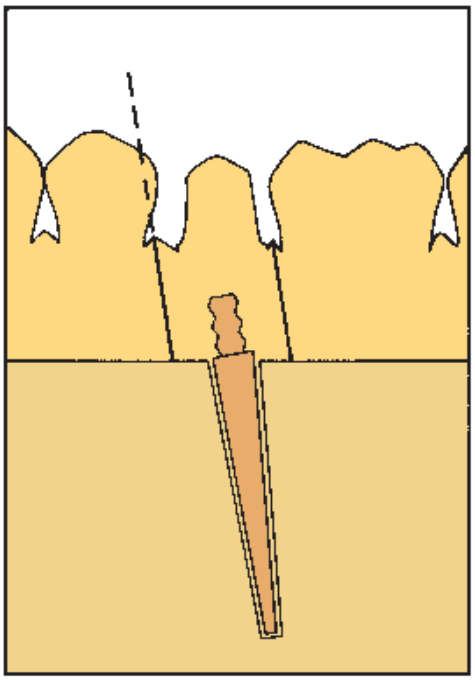


Fig. 17-7
Incorrect alignment of the dowel pin prevents removal of the die. The proximal surface of the adjacent tooth blocks die removal (*dotted line*).

for polishing, and the solid cast is obtained from a third pour.)

The first pour, which is the most accurate, is trimmed into a die with a handle of sufficient length (similar to a tooth root [Fig. 17-8]). The complete arch cast (second pour) is mounted on an articulator. The wax pattern is started on the initial pour (the die) and is then transferred to the articulated cast for refinement of axial contours and occlusal anatomy (see Chapter 18). When completed, this pattern is returned to the die so that the margins can be readapted immediately before investing.

An advantage of the solid cast–individual die system is that the definitive cast requires only minimum trimming. Because the gingival tissues around the prepared teeth are left intact, they can be used as a guide when contouring the restorations. Disadvantages of the solid cast technique include the following:

1. It may be difficult to transfer complex or fragile wax patterns from cast to die.
2. Seating the pattern on the definitive cast may be problematic because the second pour of many impression materials is slightly larger than the first; therefore, it may be necessary to relieve the stone slightly to seat the pattern before occlusal evaluation.
3. The technique can be used only with elastomeric impression materials (if reversible hydrocolloid is used, separate impressions are needed for definitive cast and die).



Fig. 17-8
A, An accurate impression is essential for successful fixed prostheses. **B,** The first and second pours have been sectioned into individual dies. The third pour will be the definitive cast. **C,** Small defects (*arrow*) can sometimes be overcome, but any voids make the laboratory phase much more difficult.

Alternative die systems

The Di-Lok* technique (Fig. 17-9) involves the use of a specially articulated tray for precise reassembly of a sectioned definitive cast. The impression is poured, and the cast is trimmed into a horseshoe configuration that fits in the special tray. The tray is filled with a second mix, and the cast is seated. When the stone has set, the tray is disassembled, saw cuts are made on each side of the preparation, and the resulting die is trimmed. The cast and die can be reassembled in the tray, which is then mounted on an articulator. A disadvantage of this system is that the overall size of the tray can make articulation and manipulation awkward and difficult.

*DentiFax/Di-Equi, Buffalo, New York.

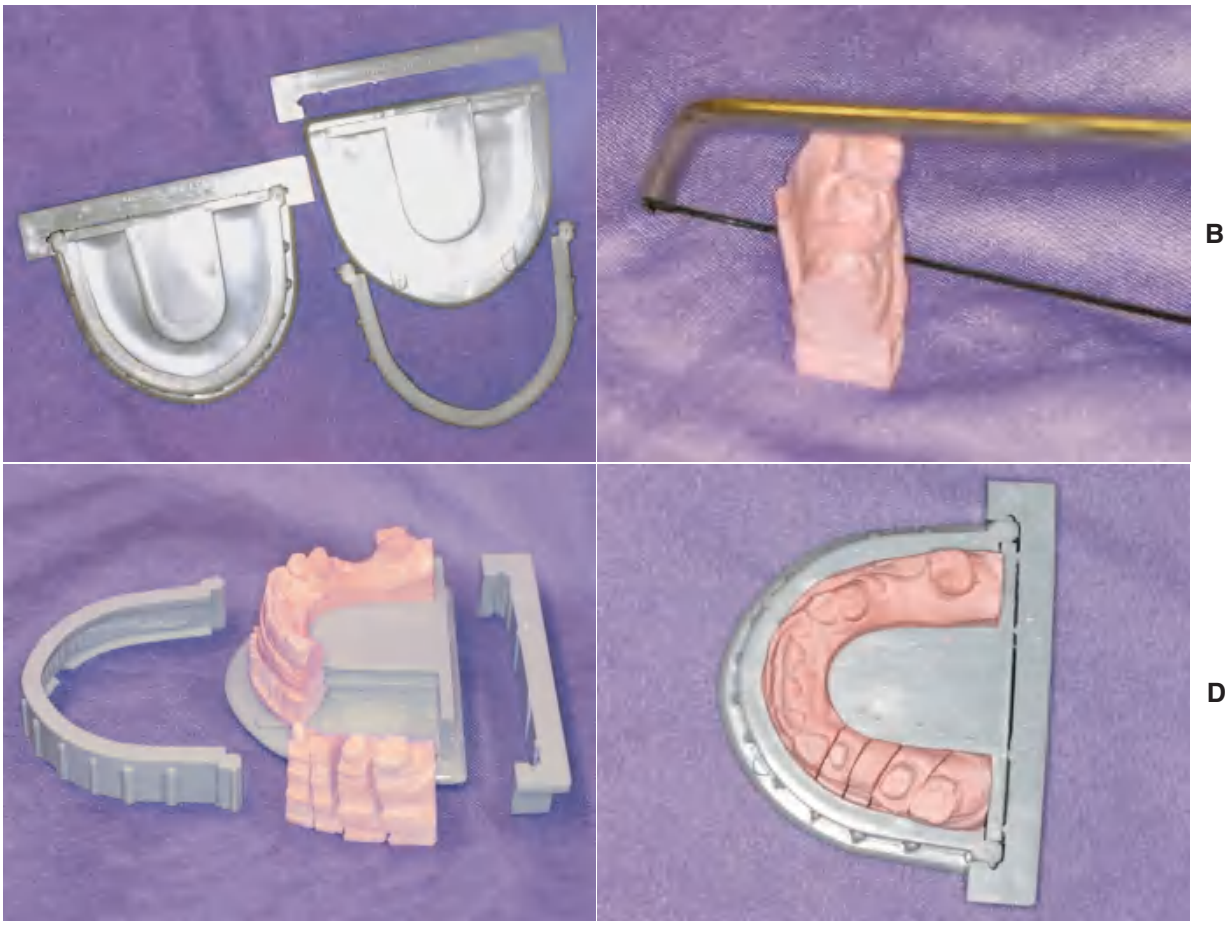


Fig. 17-9
The Di-Lok system. **A,** The system involves the use of specially segmented trays. With a single-pour technique, the impression is formed in the usual way, and the Di-Lok tray is filled. Then the tray is inserted into the impression while the stone is still wet. After the die stone has fully set, the locking and curved arms of the tray are removed. The cast can then be removed by tapping the anterior pad of the tray base. **B,** The dies are sectioned by sawing three-fourths through the stone and are separated by breaking the remaining stone base. **C,** Trimmed dies. **D,** Assembled cast ready for articulating. *(Courtesy of DentiFax/Di-Equi, Buffalo, New York.)*

The DVA Model System* (Fig. 17-10) and the Zeiser model system† (Fig. 17-11) use a precision drill and special baseplates that are aligned and drilled to provide die removal. These systems offer the advantage of allowing for the expansion of stone, which is relieved by the saw cuts.

Choice of Definitive Cast-and-Die System

The choice of a specific technique relies on operator preference and an assessment of each method's advantages and disadvantages. If they are used properly, all the available systems achieve clinically acceptable accuracy.[28] When establishing a new relationship with a dental technician, it is important to determine which cast-and-die systems are preferred and why the technician has chosen them. Close cooperation between the dentist and technician is a key factor in fixed prosthodontics.

The solid cast technique simplifies cast-and-die fabrication, but it makes the waxing and porcelain stages more difficult. However, there is no need for special equipment, and the soft tissues immediately adjacent to the preparation are not removed (which facilitates contouring the gingival areas of the restorations). The use of a solid definitive cast precludes errors caused by incomplete seating of a removable die. In practice, this means that the components of a fixed dental prosthesis (FDP) can be indexed from the cast for soldering; on the other hand, it also means that if an FDP is not accurately fabricated, the stone abutment teeth can be easily broken off, which makes subsequent steps more difficult.

The first pour from an elastomeric impression is the most accurate, and it is essential to readapt the margins of the wax pattern on the first-pour die immediately before the pattern is invested.

*Dental Ventures of America, Inc., Corona, California.
†Amann Girrbach GmbH, Koblach, Austria.

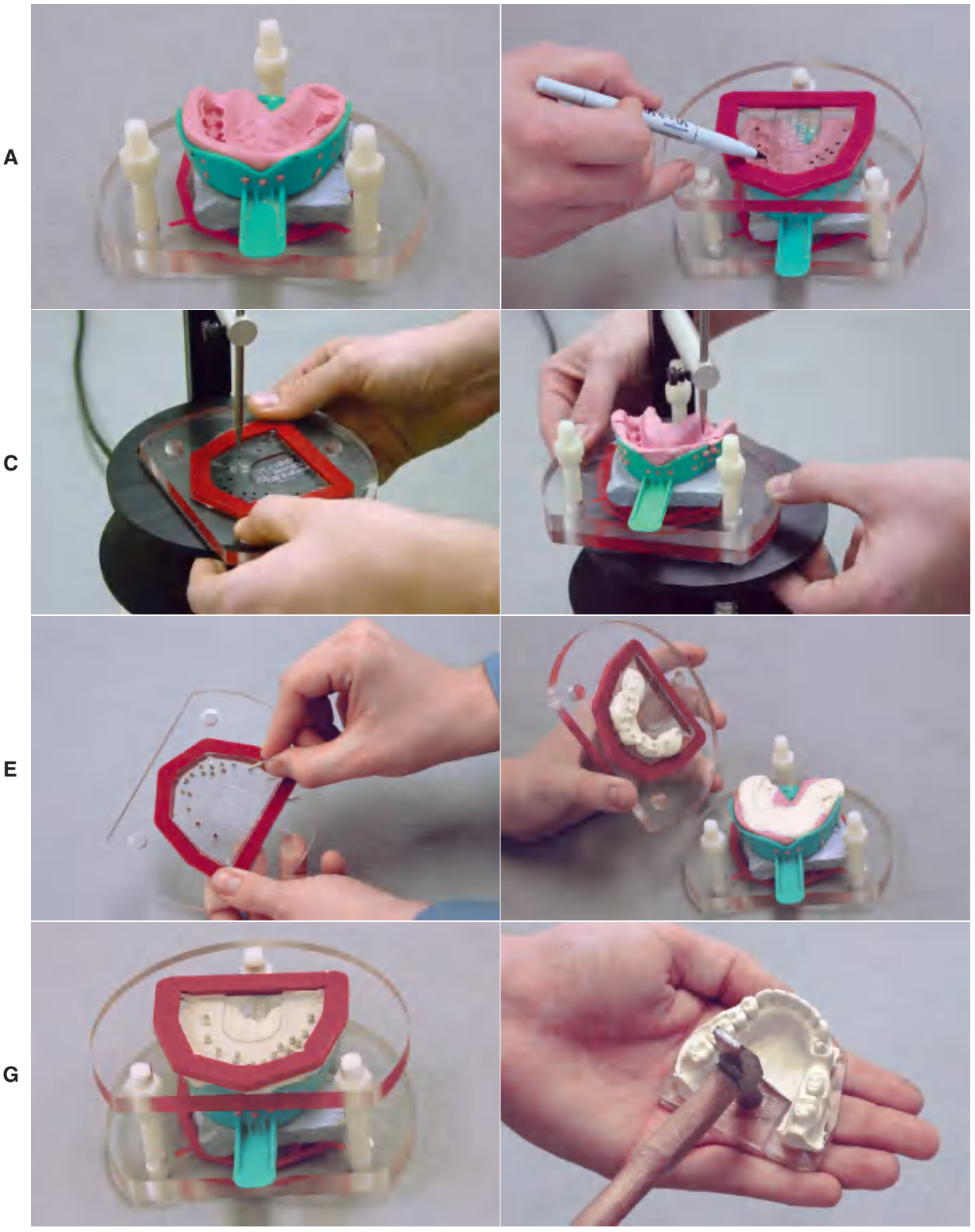


Fig. 17-10
DVA Model System. **A,** Trimmed impression on alignment fixture. **B,** Marking dowel pin locations on clear plate. **C,** Drilling holes for dowel pins as marked. **D,** Alternatively, the holes can be drilled with the top/base plate positioned on the underside of the fixture base. The pointer identifies the pin location. **E,** Inserting dowels in the baseplate. An adhesive is not required. **F,** The impression is poured and stone is placed around the dowel pins. **G,** The alignment fixture is replaced over poured impression. **H,** Set cast is removed from the baseplate with gentle tapping.



Fig. 17-10, cont'd
I, The cast is trimmed. **J,** Cast is sectioned. **K** and **L,** Definitive casts trimmed with the DVA Model System. (***A*** *to* ***K,*** *Courtesy of Dental Ventures of America, Inc., Corona, California;* ***L,*** *courtesy of Dr. A. G. Wee.)*

A dowel-and-removable die system's main advantage is that it requires less manipulation of the wax pattern, which thus reduces the chances of breakage during transfer. In addition, the handling of porcelain restorations is easier, particularly if a porcelain labial margin is used. For these reasons, most technicians believe that the extra steps involved in making a cast with dowels and a removable die are worthwhile.

Nevertheless, the procedures are technically quite difficult. It is not rare to encounter dies that do not seat properly or that have poorly placed dowels. Difficulty also may be encountered in sawing the die out of the cast. Interproximal margins can easily be damaged during this procedure, particularly if clearance between a proximal preparation margin and the adjacent tooth is minimal.

In the Pindex system, a special drilling unit is used to ensure accurate pin placement. Careful model trimming of the initially poured cast is necessary before the holes for the pins are drilled. If the trimming is done properly, highly accurate and stable removable dies result; however, the cost of the additional equipment must be considered.

The advantages and disadvantages of these cast-and-die systems are summarized in Table 17-2.

TECHNIQUE

The techniques for pouring stone dies are similar for most of the popular systems. To avoid repetition, the procedure involving single dowel pins is described in detail, with an emphasis on the differences between the solid cast (multiple-pour) system and the Pindex system.

Armamentarium (Fig. 17-12)

- Impression
- Small camelhair brush
- Type IV or V stone
- Water
- Surfactant
- Dowel pins
- Retention devices
- Orientation aids
- Vacuum mixer and bowl
- Mixing spatula

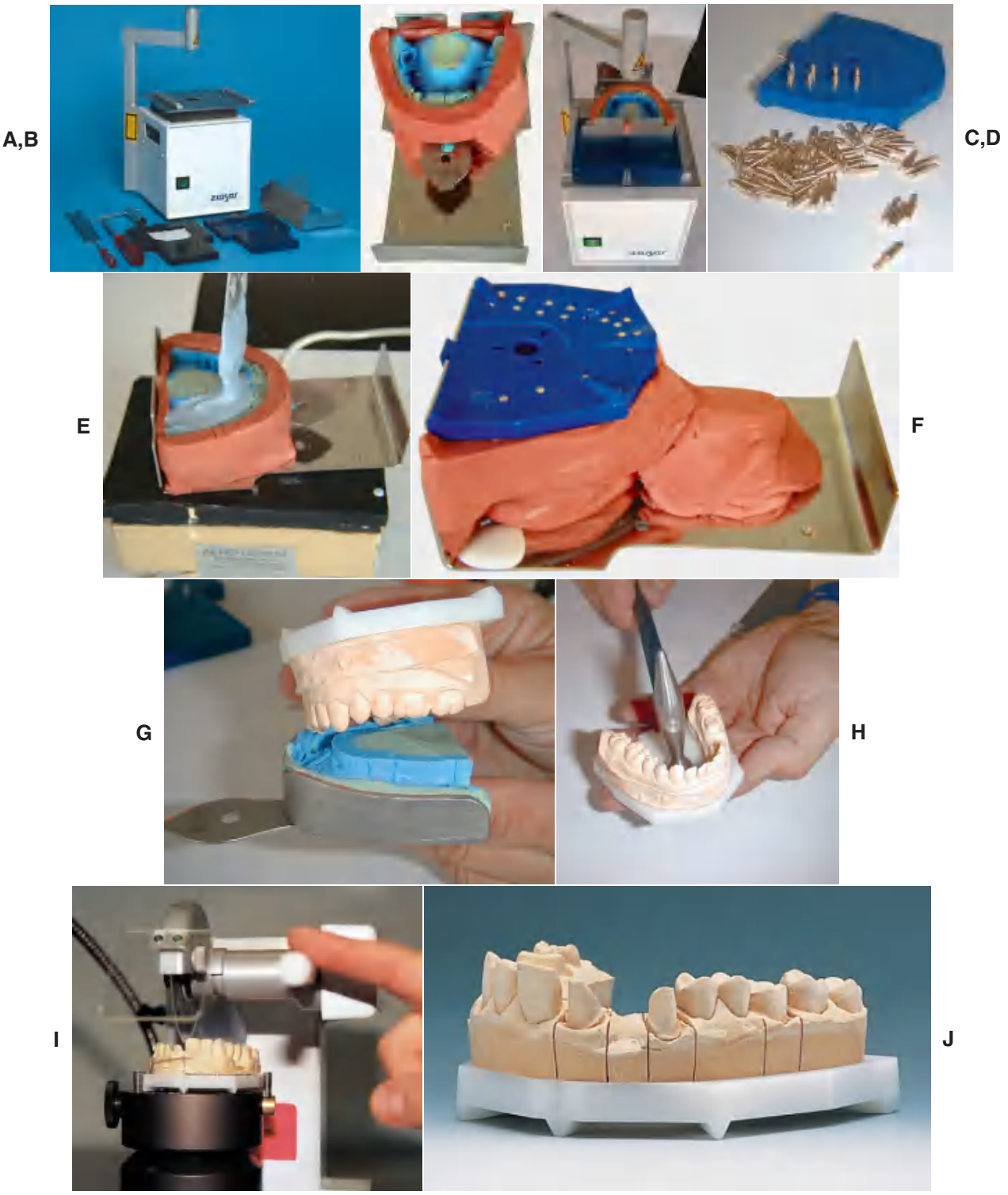


Fig. 17-11

A, Zeiser model system. **B**, The impression is leveled, blocked out with silcone putty, and positioned over the baseplate. **C**, The pin locations are determined and the pinholes drilled in the base. **D**, Pins are inserted into the base. The impression is poured (**E**) and the base inverted into the stone (**F**). **G** and **H**, The cast is separated from the impression when set and then separated from the base. **I**, A precision saw aids sectioning. **J**, The sectioned cast. *(Courtesy of Amann Girrbach GmbH, Koblach, Austria.)*

Table **17-2** **DIE SYSTEMS**

	Advantages	Disadvantages	Recommended use	Precautions
Solid cast with individual die	Straightforward procedure No special equipment	Awkward wax and porcelain manipulation	Most situations Can be indexed with confidence from cast	Stone fixed dental prosthesis abutment easily broken
Brass dowel pin	Removable die facilitates waxing and porcelain No special equipment	Difficult to master	Most situations	Care needed in cast pouring and dowel placement
Pindex (Whaledent)	Removable die Cast pouring unimpeded	Special equipment needed	Excellent if equipment is well maintained	Careful attention to detail needed
Di-Lok (DentiFax/ Di-Equi)	Removable die Cast pouring unimpeded Much less costly than Pindex	Bulky Care needed during reassembly	Awkward to use on some articulators	Care needed when second pour is made
DVA Model System (DVA)	Removable die Cast pouring unimpeded Compensates for expansion of cast Single pour	Special equipment needed Quite technique sensitive	Excellent if carefully done	Care needed when seating pins
Zeiser (Girrbach)	Removable die Cast pouring unimpeded Compensates for expansion of cast Single pour	Special equipment needed	Excellent if carefully done	–



Fig. 17-12
Armamentarium for pouring dies depending on system used.

- Vibrator
- Petrolatum
- Pencil
- Die saw

After the impression has been removed from the patient's mouth, it is washed under running tap water, blown dry, inspected, and disinfected (see Chapter 14). When it is judged to be satisfactory, it is taken to the laboratory, where the necessary armamentarium should have been prepared for use before impression making. A vacuum mixer (e.g., the Vac-U-Spat*) is strongly recommended. At this time the impression can be sprayed with a surfactant or,

*Whip Mix Corporation, Louisville, Kentucky.

in the case of hydrocolloid, placed in a K_2SO_4 solution (if recommended by the manufacturer).

Step-by-Step Procedure

1. If dowels are to be used, position them over the prepared teeth with one of the methods illustrated in Figure 17-13. Their correct location and orientation are important. For example, placing the head of a dowel too deep in the impression may weaken the die; positioning the dowel at an incorrect angle may make die removal impossible. At this stage, some technicians mark the best locations for the dowels in the buccal and lingual sulci or on the palate and place the dowels in the stone after it is poured, because prepositioning the dowels makes pouring more difficult. In addition, the relatively brittle sticky wax commonly used to lute the pins in place can break loose during vibration. If dowels are not prepositioned, the viscosity of the stone should be carefully gauged before dowel placement. If the stone is too runny, the dowels do not remain in place, and a new impression often must be made.
2. Measure the proper proportions of type IV or V stone and water. To reduce air bubbles in the mix, the water should be placed in the mixing

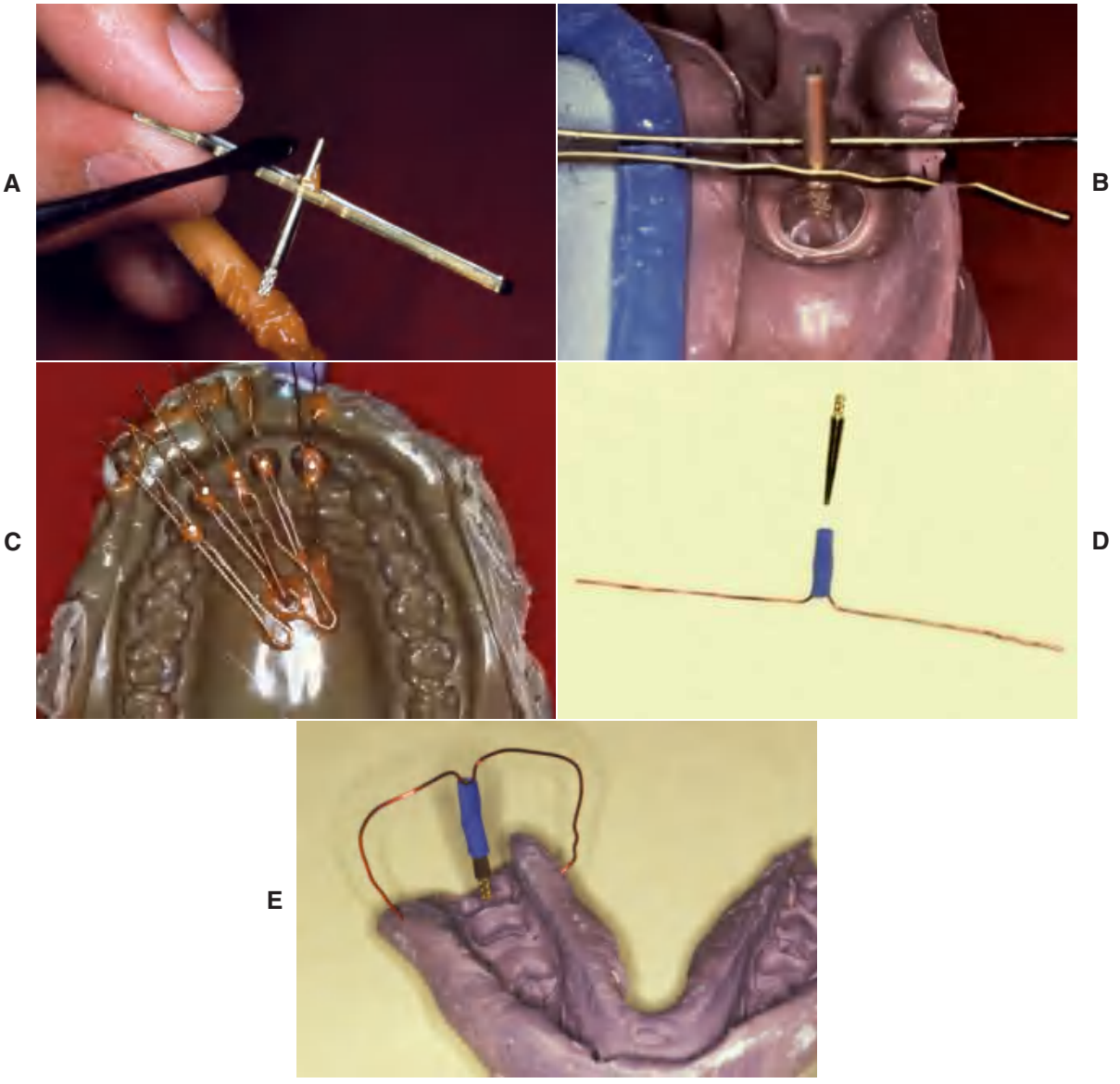


Fig. 17-13
Positioning dowel pins before cast pouring can be accomplished with bobby pins and sticky wax (**A** to **C**) or with prefabricated wire-tube aid (**D** and **E**).

bowl first. The powder is then added and quickly incorporated by hand spatulation (Fig. 17-14*A* and *B*). The spatula should be wiped clean on the blade of the mechanical mixer rather than on the edge of the mixing bowl, where stone can interfere with the vacuum seal.

3. Close the mixing bowl, attach the vacuum hose, and turn on the pump (Fig. 17-14*C*).
4. Insert the drive shaft into the chuck of the mixer and mix the stone for the recommended time. The mix is vibrated to allow the stone to settle in the bowl. The hose should be pulled out of the bowl before the vacuum is turned off; otherwise, stone is sometimes sucked into the vacuum hose. Whip Mix recommends leaving the mixer on for approximately 1 minute after removal of the hose, to purge the pump of moisture (Fig. 17-14*D*).
5. Blow any excess surfactant out of the impression, pick up a small amount of stone with a suitable brush or instrument, and place it in the most critical area (usually the occlusal aspect of narrow preparations or immediately adjacent to the sulcus area). For small preparations, a thin instrument (e.g., a periodontal probe) may prove helpful with this procedure. Bubbles are trapped if too much stone is added abruptly or if two sizable masses of stone meet (Fig. 17-15). Therefore, small quantities of stone should be added incrementally in one area, allowing the stone to seek its own path (Fig. 17-16). During pouring, the tray should be held on a vibrator. For easy cleanup, the vibrator table can be covered with a paper towel or plastic bag.
6. Slowly tease the stone into the preparation along the axial walls by tilting the impression and guiding the material with the instrument. Be absolutely sure that the stone flows onto the margins of the preparation without trapping any air bubbles. Bubbles and voids are always a problem when impressions are poured. If the first pour is defective, do not pour a second, because some accuracy is lost. In addition, thin areas of the impression near the margin are torn when the first pour is separated. For this reason,



Fig. 17-14

Vacuum mixing type IV stone. **A,** The mixing bowl is rinsed and excess water shaken out. Measured distilled water is poured into the bowl, and weighed powder is added, or premeasured envelopes are used. The powder/liquid ratio should be according to the manufacturer's recommended proportions. **B,** The mixture is spatulated by hand for approximately 60 seconds or until all powder is incorporated. **C,** The mixture is then mechanically spatulated under vacuum for an additional 20 to 30 seconds. **D,** The vacuum is broken slowly, excess mixture is removed from paddles, and the impression is poured. *(Courtesy of Whip Mix Corporation, Louisville, Kentucky.)*

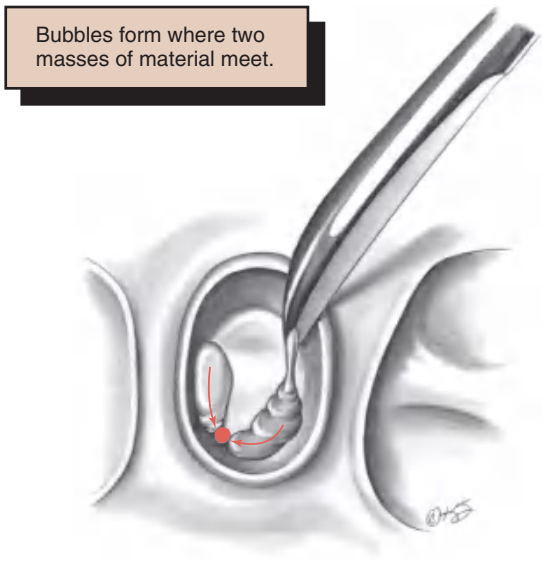


Fig. 17-15
Incorrect technique for pouring an impression. An air bubble (*arrows*) is trapped if two masses of stone are allowed to meet.



Fig. 17-16
Pouring an impression. **A** and **B,** To avoid trapping air, start with a very small amount of stone.

pouring a bubble-free cast is essential, to avoid having to make a new impression. The ease with which an impression can be poured without bubble formation depends on the contact angle that the advancing die stone makes when the impression is wetted. Of the elastomers, polyethers have the lowest contact angle, which means they are the easiest to pour[29,30]; silicones have the highest contact angle and are the most difficult to pour, although the newer "surface activated" or "hydrophilic" formulations are better.[31] Overall, however, these materials do not seem to greatly facilitate impression making.[32]

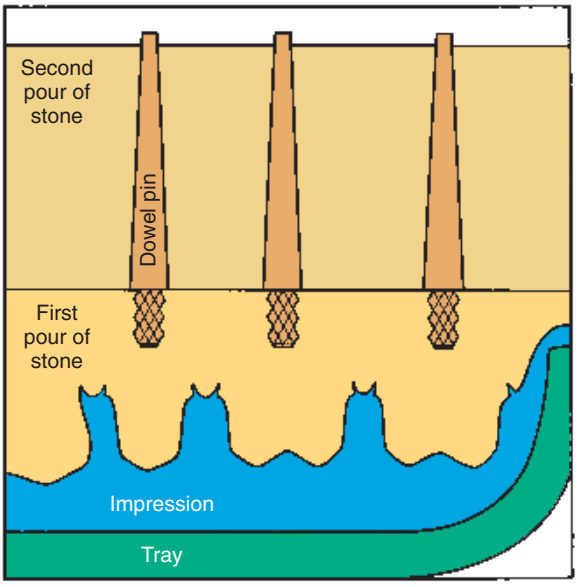


Fig. 17-17
Dowel pins must be carefully positioned so the first pour of stone completely covers the knurled head; otherwise, the parts do not separate cleanly. However, the stone should not extend onto the shaft and reduce stability.

7. Place a second amount of stone on top of the first and continue with a third and so forth until the preparation is completely filled. The rest of the impression can then be filled to a height of at least 5 mm beyond the free gingival margins. In areas where individual dowels are used, the head of each dowel must be covered with stone (Figs. 17-17 and 17-18).

Solid Cast-Multiple Pour System

For individual die pours, the stone mass must be built up to a height of approximately 25 mm to obtain a die handle of adequate length. The occlusal surfaces of teeth immediately adjacent to the preparation will be filled with stone, but this is of no concern (see Fig. 17-18). When the first pour has set, the cast is separated and repoured. The first pour is then sectioned into individual dies.



Fig. 17-18
Pouring an impression for individual dies and solid cast (multiple-pour system). **A,** Be sure that the critical margin area is covered. **B,** Stone added in the preparation area only. **C,** Sufficient bulk for the die handles. **D,** Pours 1 and 2 (individual dies) and 3 (definitive cast). **E,** Sectioning the individual dies. **F,** The trimmed dies and definitive cast before articulation.

8. Place retentive devices[33] in areas where there are no dowels so that the two layers of stone do not separate in the wrong place (Fig. 17-19).
9. Allow the stone to set for the recommended time (usually 30 minutes).
10. Inspect the area where separation is required, smooth it as necessary, and coat it with a separating medium (e.g., 10% sodium silicate). Then pour another layer to act as a base and retain the dowels. This second layer should not cover the tips of the dowels. If for some reason the base must be built up more, wax or rubber tubing can be placed on the tip of the dowel to facilitate its retrieval later. Before the base of a mandibular impression is poured, the lingual aspect should be blocked out with a suitable molding material (e.g., Mortite Weatherstrip*); otherwise, the stone will lock around the tray and hamper removal of the cast from the impression. This is much easier than grinding excess stone away later to gain access to the lingual aspect of mandibular preparations (Figs. 17-20 and 17-21). When the cast is separated from the impression, it must be carefully inspected for voids. If any are found in the marginal area of a prepared tooth, the cast is unusable, and a new impression must be made. Careful pouring pre-

*Thermwell Products Co., Inc., Mahwah, New Jersey.

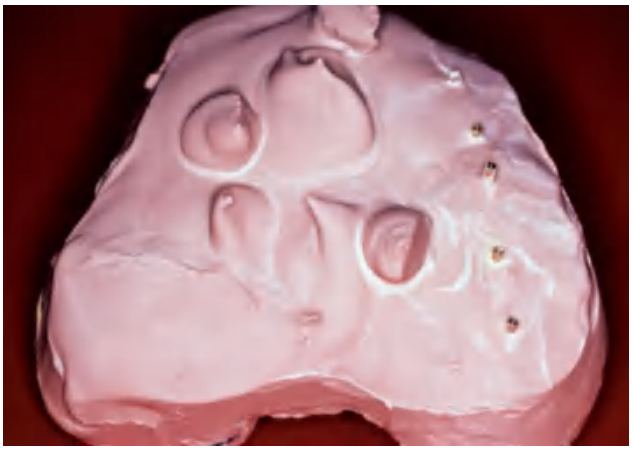


Fig. 17-19
Blobs of stone provide retention in parts of the cast where separation is not desired.

A



B

Fig. 17-20
A, Use a molding material to block out the lingual aspect before pouring a mandibular impression. **B,** Otherwise, excess stone will have to be ground away to obtain access to the lingual surfaces, which is a tedious process.

A



B,C

Fig. 17-21
The Pindex system consists of a special drill press (**A**) and brass dowels and plastic sleeves (**B**). **C,** The impression is poured in stone, separated when set, and trimmed to a horseshoe shape. The base must be absolutely flat (a trimmer is provided).



Fig. 17-21, cont'd

D, The location of each dowel is marked on the occlusal surface. Two dowels are needed to stabilize each segment. (Alternative single pins are available for small preparations.) **E,** The cast is positioned on the drill stage; a light indicates the location of the drill. The cast is held firmly and the lever depressed; this activates the drill, which penetrates into the cast. **F,** Each hole should be cleanly drilled; a hand reamer is available if necessary. **G,** The pins are tried in and cemented in place. For accessibility, the short locating dowels should be used on the lingual surface. **H,** The assembly is coated with petrolatum to ensure clean separation. **I,** The plastic sleeves are positioned. **J,** The assembly is placed in the special mold. **K,** The second pour of stone is made into the mold. After some stone has been painted between the pins, the first pour is placed into this mix. **L,** Sawing the dies. **M,** With the Pindex system, it is sometimes helpful to remove the first pour, use it as a block, and commence sawing from the base. Marking all the saw cuts with a pencil is recommended. **N,** The Pindex cast after sectioning. *(**A** to **M,** Courtesy of Dr. J.O. Bailey; **N,** Courtesy of Coltène/Whaledent AG, Altstatten, Switzerland.)*

Pindex* System

When the Pindex system is being used, the first pour of stone is removed from the impression once it has set. The base is then ground flat in a plane that must be perpendicular to the intended position of the Pindex pins. The periphery of the cast is trimmed to fit in a special mold. After the cast is dried, the location of the pins is marked, and their holes are drilled with a special drill press. The pins are cemented in place with cyanoacrylate resin, special sleeves are positioned over the cemented pins, and the cast is positioned in the second pour that is made in the mold (see Fig. 17-21).

Sawing between adjacent prepared teeth is difficult, particularly with small anterior teeth. If this procedure is not performed carefully, the saw cuts can contact the dowel pin, leading to an unusable die. When the Pindex system is used, it is advantageous to remove the part of the first pour that contains the adjacent prepared teeth in one piece before making the critical saw cuts. Then the cuts can be carefully marked and started from the base and the tooth side (see Fig. 17-21M). When sawing from the base, it is important to protect the fragile dies with a soft cloth.

*Coltène/Whaledent, Inc., Cuyahoga Falls, Ohio.

vents this. If the cast is satisfactory, it is ready for sectioning and trimming.

11. Trim the buccal and lingual sulcal areas adjacent to the removable sections first so that the dies will separate cleanly.
12. Mark the position of each saw cut (which should be parallel to the dowel) with a pencil.
13. Carefully insert the saw blade between the preparation and the adjacent tooth; make sure that neither the margin nor the proximal contact is damaged (Fig. 17-22). The cuts must pass completely through the first layer of stone. If this is not done, the die will not separate cleanly. When the saw cuts are made, the dies can be tapped out and are ready for trimming for waxing. (Typical trimmed and untrimmed dies are shown in Fig. 17-23.)

All excess stone, with the exception of the critical few millimeters immediately adjacent and cervical to the margin, should be removed with an Arbor band or another cutter in a lathe. The stone that is closer to the margin is removed with a large carbide bur. (Easy access to the margin is mandatory for waxing.) Any residual flash is trimmed away with a sharp scalpel. The margin must not be touched. A binocular microscope is helpful during this step. It is important not to create a ditch apical to the margin, which could lead to poor gingival contour in the completed restoration (Fig. 17-24).

When **die trimming** is completed, the dies are repositioned in the definitive cast, and their accurate and precise repositioning is verified. The definitive cast is then mounted on an articulator. Trimmed dies must be handled carefully. To minimize potential breakage, they should be secured in a container lined with foam plastic, gauze, or cotton.

MOUNTING CASTS ON AN ARTICULATOR

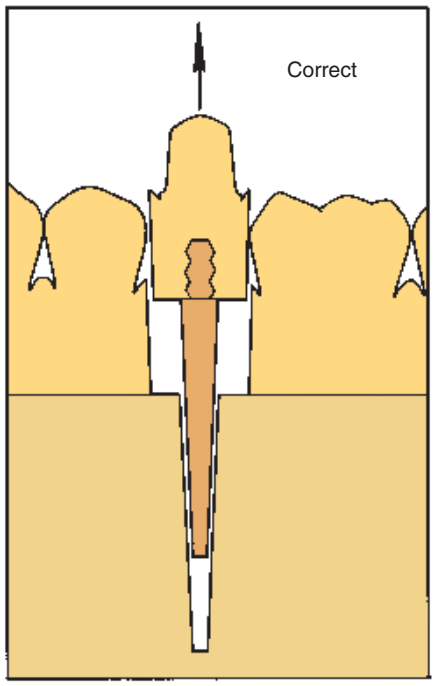
The articulation of diagnostic casts is discussed in Chapter 2. The technique for **mounting** a solid definitive (master) cast is identical. The procedure for attaching a definitive cast with removable dies to an articulator differs only in that access must be allowed to the area of the base into which the dowels penetrate. This expedites removal of the dowels (Fig. 17-25).

Definitive Casts versus Diagnostic Casts

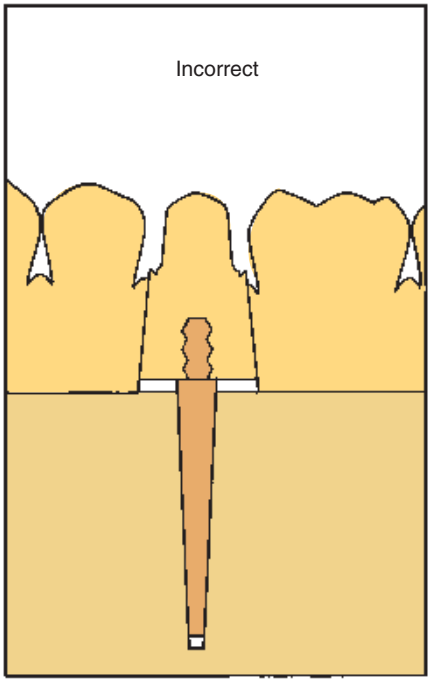
The accuracy of the casts and their mounting is even more crucial for definitive casts than for diagnostic casts. Although diagnostic casts can still provide the necessary information even when mounted slightly inaccurately, definitive casts must be precisely mounted if lengthy chairside adjustment is to be avoided.

Diagnostic casts are most effectively mounted with a centric relation (CR) record (see Chapter 2). This allows the practitioner to visualize the full range of mandibular movement for occlusal diagnosis. The CR record is made at an increased vertical dimension (see Chapter 2). Closing the articulator upon removal of the record induces error if an arbitrary facebow is used.[34] There is a slight error even if a kinematic facebow is used.[35] Although such errors are probably not clinically significant with diagnostic casts, they are significant when definitive casts are involved, because the degree of inaccuracy is transferred to restorations fabricated and adjusted on the casts. Whenever possible, definitive casts should be mounted with a record made at the occlusal vertical dimension, by using maximum intercuspation (MI) of unprepared teeth.[36] If this is not possible, a kinematic facebow recording is recommended. Problems associated with mounting casts with a CR record by using an arbitrary facebow were analyzed by Weinberg.[37] He calculated that a 3-mm thick record can create an occlusal discrepancy in the first molar

A



B



C



D



Fig. 17-22

Sectioning removable dies. **A,** The saw cuts should converge slightly toward the dowel; otherwise, the die will be locked in by undercuts (**B**). **C,** Mark the intended saw cuts in pencil and carefully position the saw blade. It must not touch the prepared tooth. **D,** Saw completely through the first pour. Finishing the cut short of the second pour will prevent a clean separation.

When sectioning the die, the saw cuts should be parallel to each other or should slightly converge (A). Be careful not to create an undercut (B), because the die then will not be readily removable from the cast. Cutting into a pin when sectioning the cast will render it useless, and a new cast will need to be made.

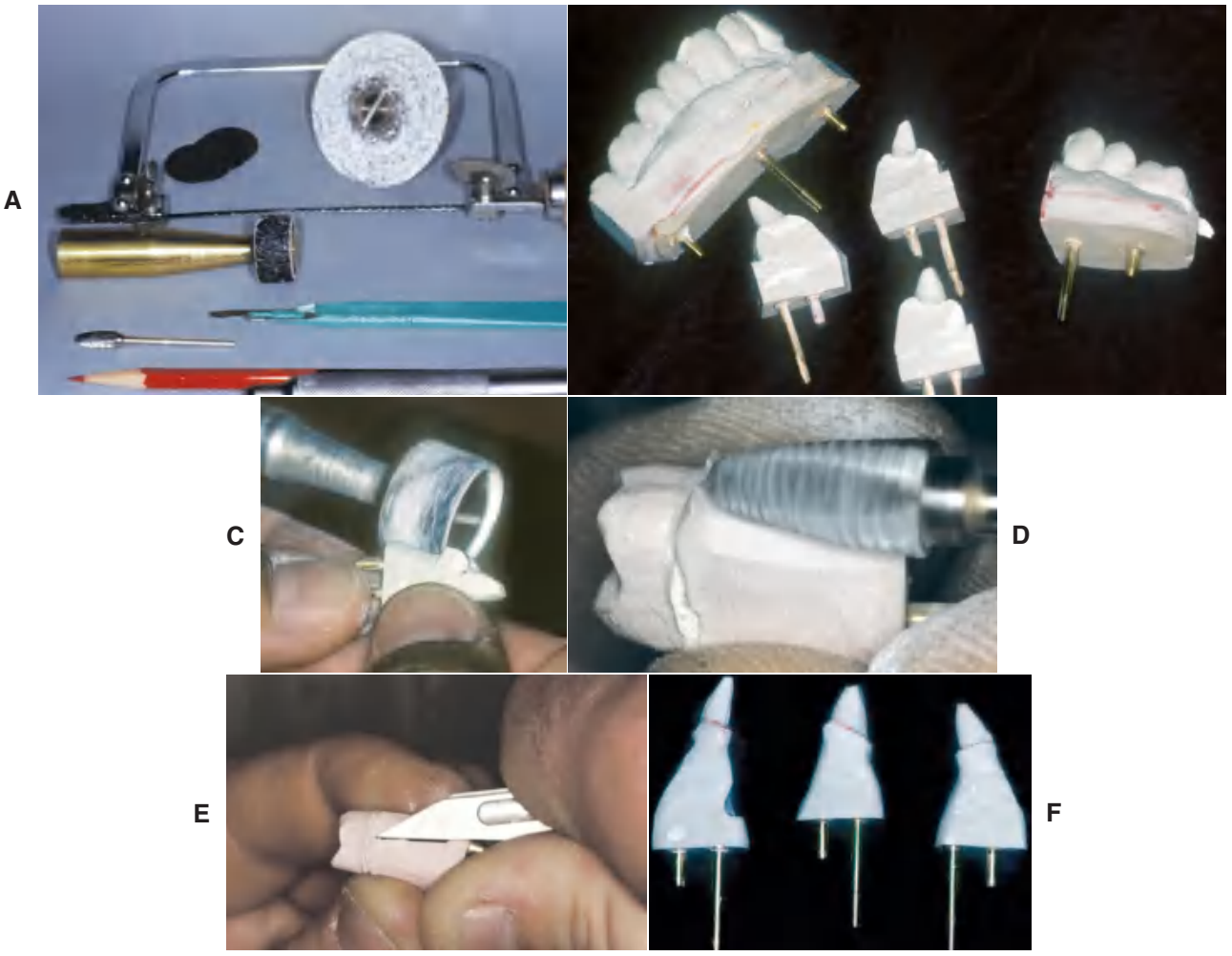


Fig. 17-23

Trimming dies. A, Armamentarium. **B,** Sectioned dies. In this instance, the Pindex system has been used. **C,** Bulk trimming is accomplished with an Arbor band on a lathe equipped with efficient dust collection. **D,** An acrylic-trimming bur is used near the margin. **E,** A sharp scalpel is used to trim to final contour, working away from the margin. **F,** The trimmed dies. *(B, C, and F, Courtesy of Dr. W. V. Campagni.)*

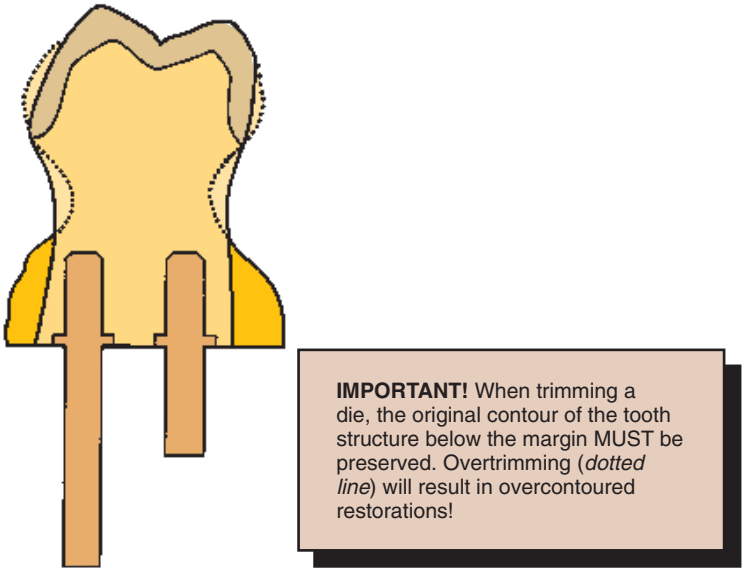


Fig. 17-24

Excessive trimming leads to a bulky crown, because the trimmed die acts as a guide to gingival contour when the restoration is being waxed.



Fig. 17-25
A, Definitive cast attached to an articulator. **B,** To facilitate removal, the mounting should allow access to the end of each dowel. This is achieved by adding wax or weather stripping to the tips of the pins.

region of 0.2 mm when the arbitrary axis differs from the true hinge axis by 5 mm (a common error).

In addition, an elastomeric (rather than an irreversible hydrocolloid) impression should be made for the opposing cast. The elastomer's improved precision results in a more accurate opposing cast, which reduces the need to adjust the restoration at evaluation.

Reorganized Occlusion

The decision to reorganize a patient's occlusion (e.g., by making CR coincide with MI) is made at the treatment-planning stage (see Chapter 3). Treatment steps may then include occlusal adjustment of the existing dentition by selective reshaping (see Chapter 6) and reorganization of the anterior (incisal) guidance before tooth preparation for definitive cast restorations.

The following question should be asked during treatment planning: Is there any discernible pathologic process that may have arisen from malocclusion? In the presence of wear facets, widened periodontal ligament spaces, and muscle tenderness, the potential benefits of occlusal adjustment should be weighed. Another question must also be asked: Will reorganization of the occlusion benefit the patient? If the answer is yes, occlusal adjustment can be performed (see Chapter 6), after which definitive tooth preparation for fixed prosthodontics should be initiated.

The definitive casts can then be related at the occlusal vertical dimension with one of several techniques. Autopolymerizing resin may be used to record the relationship (Fig. 17-26). Alternative materials include impression plaster, zinc oxide–eugenol impression paste on a suitable carrier (e.g., autopolymerizing acrylic resin or gauze), and some of the stiffer elastomers (polyether or poly[vinyl siloxane]).

These records are optimal if they include only the cusp tips (Fig. 17-27). If more detail of the grooves is inadvertently captured, it should be carefully trimmed away. Otherwise, the cast will not seat properly and the restoration will be in supraclusion.

Conformative Occlusion

On many occasions, a cast restoration that conforms to the patient's existing occlusion is made, even if a discrepancy exists between CR and MI positions. Typically, if no significant signs of clinical pathology processes are detected, fabricating simple prostheses in the stable MI position is acceptable. The objective is to maintain rather than reorganize a healthy masticatory apparatus.

When a patient has a symptom-free occlusion and requires relatively few cast restorations (i.e., when only a small part of the dentition needs to be restored), the MI position is the most desirable treatment. Therefore, in many patients who need only one or two single crowns (or a small FDP), the best restorations conform with their existing occlusion.

Articulating a definitive cast for a restoration that is to be waxed conformatively poses certain problems. If the cast is mounted with a CR record (as described for diagnostic casts in Chapter 2), the MI position is not reproduced accurately enough for precise waxing because it is in a translated mandibular position. This position cannot be reached with absolute precision on a semiadjustable articulator. In addition, during closing of the instrument, the stone cast can be easily damaged.

Probably the most practical solution is to articulate the definitive cast in maximum intercuspation by using a small interocclusal record (e.g., with poly[vinyl siloxane]) interposed between the tooth preparation and the opposing arch in the closed position (Fig. 17-28). At evaluation, after the restora-

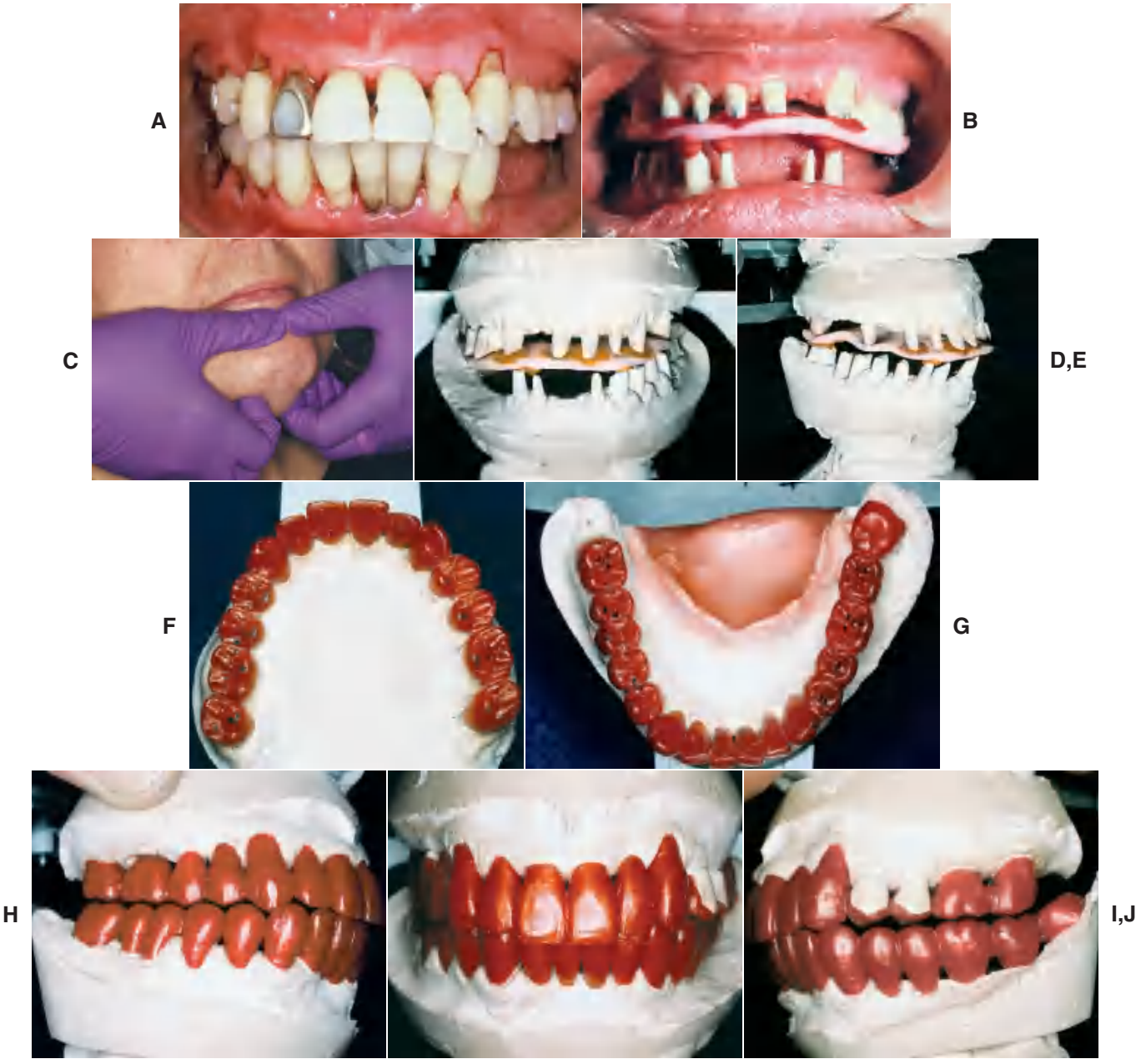


Fig. 17-26

Mounting definitive casts on the articulator. **A,** When a dentition requires extensive fixed prosthodontic care, accuracy of the articulation is essential for successful treatment. **B,** Recording centric relation at the occlusal vertical dimension minimizes the error inherent in a facebow transfer. Autopolymerizing acrylic resin was used as the recording medium. **C,** Manipulation of the mandible into centric relation. **D** and **E,** Definitive casts articulated with the CR record interposed. **F** to **J,** Restorations waxed to anatomic contour, with anterior guidance.



Fig. 17-26, cont'd
K to **M,** Metal-ceramic restorations on the definitive cast. **N** to **R,** The completed restorations (see Fig. 32-44).

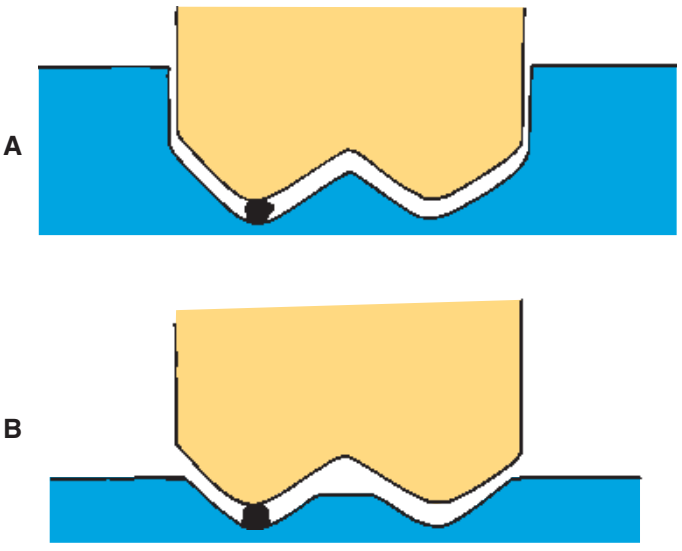


Fig. 17-27
Trimming the centric relation record. An untrimmed record (**A**) makes assessment of proper cast seating much more difficult than a properly trimmed record (**B**).

tion has been fabricated, the patient's CR closure is examined clinically to ascertain that the restoration conforms to the preexisting occlusion. No premature contacts should occur on the new restoration. In CR closure, new occlusal interferences can be introduced on the restoration, and the discrepancy between CR and MI may be effectively increased, which leads to new problems (Fig. 17-29). It is then necessary to adjust the restoration to allow the original closing movement of the patient and to provide a smooth transition from the CR to the MI position.

Verification of Mounting

It is essential to check the accuracy of the articulation before proceeding with the laboratory phase of treatment. For less complex fixed prosthodontics, this can be accomplished simply by comparing the occlusal contacts in the patient's mouth with those made by the casts. (Mylar shim stock or articulating film is suitable.) Occlusal wax (see Chapter 6) is also

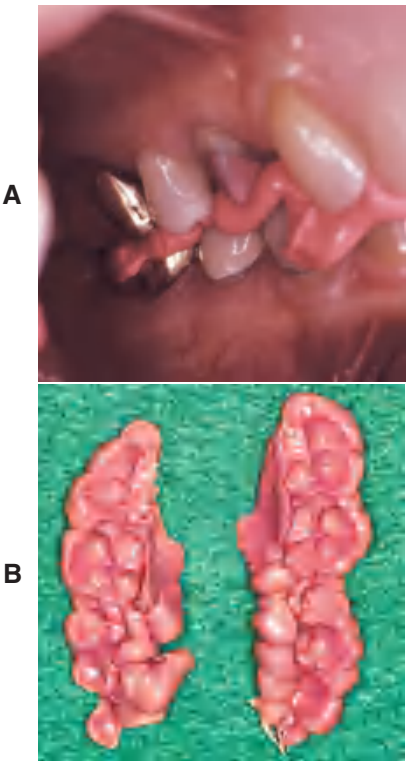


Fig. 17-28
A, Conformative interocclusal record made with poly(vinyl siloxane) polymer. **B,** The records before trimming.

useful. For more extensive procedures, a second occlusal record is needed that can be compared with the first by using a **split-cast mounting technique** (Fig. 17-30) or a system such as the Denar Vericheck* (see Fig. 2-26).

TECHNIQUE FOR CLOSED-MOUTH IMPRESSIONS

The closed-mouth impression technique, also called the dual-arch or triple-tray technique, is popular for making impressions for single units and limited restorations made to conform to the existing occlusion[38,39] (see Chapter 14). The importance of the laboratory stages cannot be overstressed. The procedure is different depending on the articulator used. This description is for the V2 Quadrant Articulator (Fig. 17-31).†

Step-by-Step Procedure

1. Trim the double-sided impression flat and parallel to the occlusal plane (see Fig. 17-31*A*).

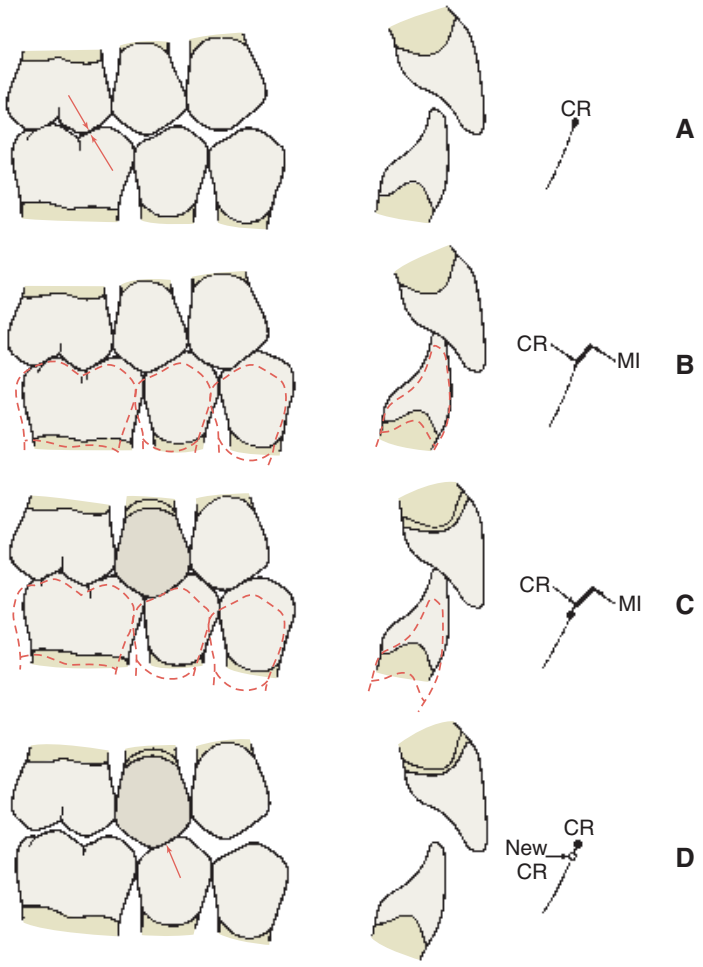


Fig. 17-29
When providing a restoration that conforms to an existing occlusion, it is important to assess both centric relation (CR) and maximum intercuspation (MI) carefully. **A,** Before treatment, the CR contact in this patient was on the first molar (*arrows*). **B,** Preoperative MI. **C,** The new restoration conforms to MI satisfactorily, but notice that a new CR interference (**D,** *arrow*) has been created.

2. Pour the prepared tooth side of the impression and the articulator base with die stone (see Fig. 17-31*B*).
3. Invert the impression and align it onto the articulator base (see Fig. 17-31*C*).
4. Pour the opposing side of the impression and articulator base.
5. Engage the hinge and close the articulator (see Fig. 17-31*D*).
6. Once the die stone has fully set, remove the base wall formers (see Fig. 17-31*E*).
7. Eject the die side of the cast by grasping the cast and tapping the base (see Fig. 17-31*F* and *G*).

*Denar Corp., Anaheim, California.
†Monotrac Articulation, Salt Lake City, Utah.



Fig. 17-30
A, Magna-Split system mounting procedure. **B** and **C,** In this system, indexed magnetic plastic mounting plates are used to facilitate split-cast mounting. **D** to **F,** The system used to attach the maxillary cast. The second record is confirmed if the indices align precisely. *(Courtesy of Panadent Corporation, Grand Terrace, California.)*

8. Section and trim the cast. The individual dies can be accurately returned to the articulator (see Fig. 17-31*H* and *I*).

SUMMARY

Accurate definitive casts and dies are essential to successful cast restorations. There are various materials and techniques that provide an extremely precise reproduction of the prepared teeth. Type IV stone is recommended in most instances, although it requires careful handling to avoid chipping or abrading margins. Epoxy resin and electroplated silver or copper are durable alternatives. The die of the prepared tooth can be made removable by the use of dowels or the more convenient Pindex system. Alternatively, a solid definitive cast and separate die can be used. Whatever system is chosen, it must articulate precisely with an accurately made opposing cast.

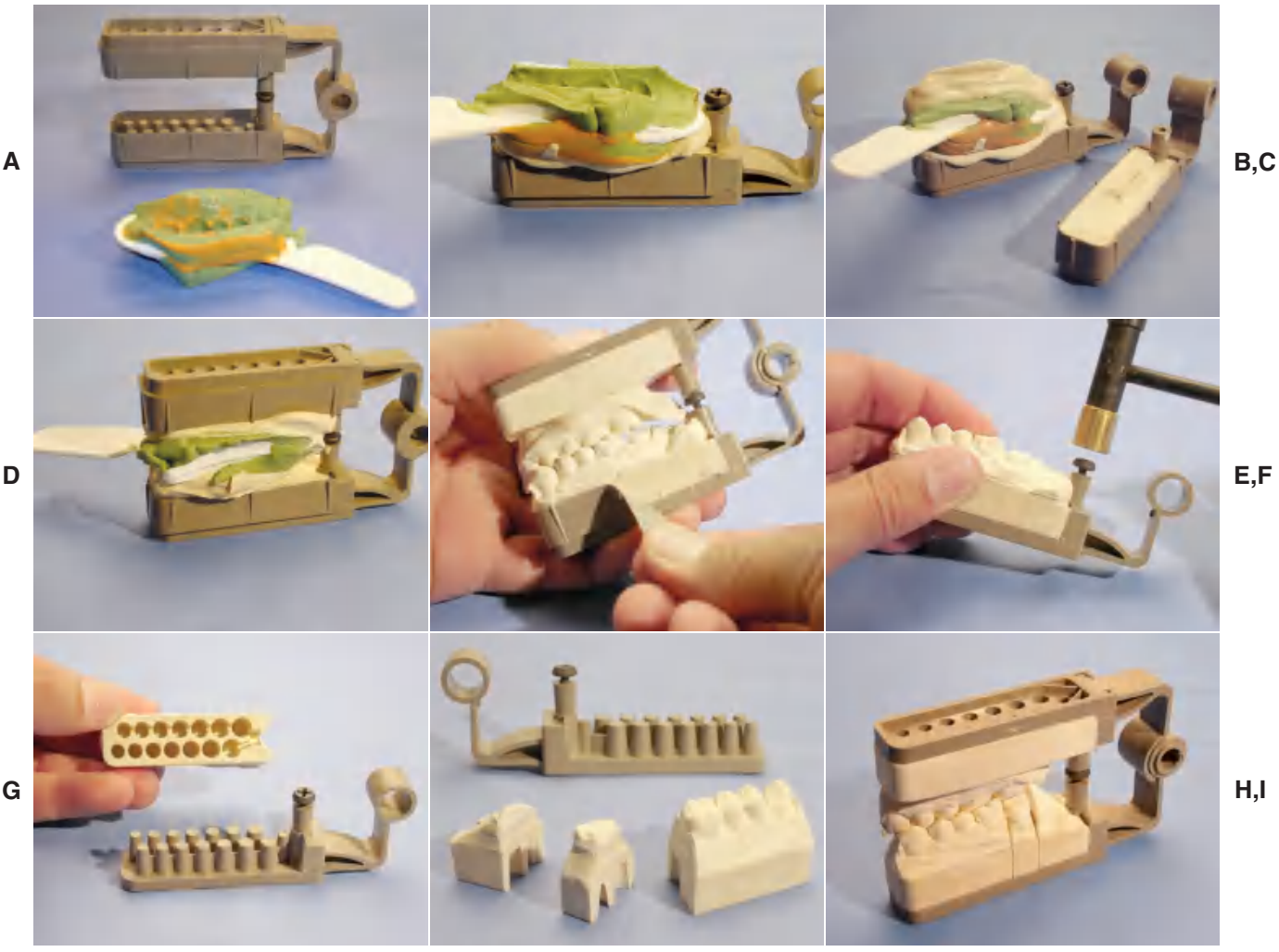


Fig. 17-31

The closed-mouth impression technique using the V2 Quadrant Articulator. **A,** Trim the double-sided impression flat and parallel to the occlusal plane. **B,** Pour the prepared tooth side of the impression and the articulator base with die stone. **C,** Invert the impression and align it onto the articulator base. **D,** Pour the opposing side of the impression and articulator base. Engage the hinge and close the articulator. **E,** Once the die stone has fully set, remove the base wall formers. **F** and **G,** Eject the die side of the cast by grasping the cast and tapping the base. **H** and **I,** Section and trim the cast. The individual dies can be accurately returned to the articulator. *(**A** to **I,** Courtesy of Monotrac Articulation, Salt Lake City, Utah.)*

STUDY QUESTIONS

1. Discuss the material considerations for gypsum, resin, and electroplated die systems. Provide advantages, disadvantages, and typical indications for each category.
2. Contrast the advantages, disadvantages, and limitations of the following definitive cast-and-die systems:
   A. Solid cast with individual die
   B. Single brass dowel pin
   C. Pindex
   D. Di-Lok
   E. DVA
3. Discuss the Pindex system in a step-by-step manner. Identify critical steps and precautions.
4. When articulating definitive casts, which interocclusal record system results in the most accurate mounting? Why?

GLOSSARY*

block out \blŏk out\ *adj*: 1: elimination of undesirable undercuts on a cast, 2: the process of applying wax or another similar temporary substance to undercut portions of a cast so as to leave only those undercuts essential to the planned construction of a prosthesis. A blocked out cast may also include other surface modifications needed relative to the construction of the prosthesis

calcium sulfate plaster \kă′sē-um sŭl′fāt′ plăs′ter\: compounds occurring in anhydrous form as anhydrite, and in the natural form as gypsum or gypsum dehydrate. The term "plaster" also applies to a mixture consisting of water and calcium sulfate hemihydrate ($CaSo_4 . ½H_2O$)

[2]cast \kăst\ *n* (14c): a life-size likeness of some desired form. It is formed within or is a material poured into a matrix or impression of the desired form—see DENTAL C., DIAGNOSTIC C., FINAL C., PRELIMINARY C., REFRACTORY C., REMOUNT C.

castable \kăst′a-bl\ *n* (1998): any refractory material that has a bonding agent added and can be mixed with water or other liquid agents and poured in a mold to set

cy·ano·acryl·ate \sī′a-nō-ăk′ra-lāt\ *n* (20c): a single component, moisture activated, thermoplastic group of adhesives characterized by rapid polymerization and excellent bond strength

definitive cast \dĭ-fĭn′ĭ-tĭv kăst\: a replica of the tooth surfaces, residual ridge areas, and/or other parts of the dental arch and/or facial structures used to fabricate a dental restoration or prosthesis; called also *final cast*

dental cast \dĕn′tl kăst\: a positive life size reproduction of a part or parts of the oral cavity

dental plaster \dĕn′tl plăs′ter\: the beta-form of calcium sulfate hemihydrate. It is a fibrous aggregate of fine crystals with capillary pores that are irregular in shape and porous in character

dental stone \dĕn′tl stōn\: the alpha-form of calcium sulfate hemihydrate with physical properties superior to the beta-form (dental plaster). The alpha-form consists of cleavage fragments and crystals in the form of rods or prisms, and is therefore more dense than the beta-form

die \dī\ *n* (14c): the positive reproduction of the form of a prepared tooth in any suitable substance

dowel pin \dou′al pĭn\: a metal pin used in stone casts to remove die sections and replace them accurately in the original position

e·lec·tro·plat·ing \ĭ-lĕk′tro-plā′tĭng\ *vt* (ca. 1864): the process of covering the surface of an object with a thin coating of metal by means of electrolysis

epoxy resin die \ĕp′ŏk′sē, ĭ-pŏk′- rĕz′ĭn dī\: a reproduction formed in epoxy resin

gyp·sum \jĭp′sum\ *n* (14c): the natural hydrated form of calcium sulfonate, $CaSO_4\ 2H_2O$ gypsum dehydrate

master cast: see DEFINITIVE CAST

[1]mount·ing \moun′tĭng\ *v*: the laboratory procedure of attaching a cast to an articulator or cast relater

[2]mount·ing \moun′-tĭng\ *n*: the relationship of dental casts to each other and the instrument to which they are attached; see also—SPLIT-CAST M.

plas·ter \plăs′tar\ *n*: a paste-like composition (usually of water, lime, and sand) that hardens on drying and is used for coating walls, ceilings, and partitions—*slang:* in dentistry, a colloquial term applied to dental plaster of paris

split-cast method \splĭt-kăst mĕth′ad\ *obs*: **1:** a procedure for placing indexed casts on an articulator to facilitate their removal and replacement on the instrument **2:** the procedure of checking the ability of an articulator to receive or be adjusted to a maxillomandibular relation record (GPT-4)

split-cast mounting \splĭt-kăst moun′tĭng\: a method of mounting casts wherein the dental cast's base is sharply grooved and keyed to the mounting ring's base. The procedure allows verifying the accuracy of the mounting, ease of removal and replacement of the casts

surface tension \sûr′fas tĕn′shun\: a property of liquids in which the exposed surface tends to contract to the smallest possible area, as in the spherical formation of drops. This is a phenomenon attributed to the attractive forces, or cohesion, between the molecules of the liquid.

tin·foil \tĭn′foil′\ *n* (15c): **1:** paper thin metal sheeting usually of a tin-lead alloy or aluminum (a misnomer) **2:** a base-metal foil used as a separating material between the cast and denture base material during flasking and polymerizing

vacuum mixing \văk′yōō-um mĭks′ĭng\: a method of mixing a material such as plaster of paris or casting investment below atmospheric pressure

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REFERENCES

1. American Dental Association, Council on Dental Materials and Devices: Specification no. 19 for non-aqueous, elastomeric dental impression materials. J Am Dent Assoc 98:733, 1977.

2. Schelb E, et al: Compatibility of type IV dental stone with polysulfide impression materials. J Prosthodont 1:32, 1992.
3. Omana HM, et al: Compatibility of impressions and die stone material. Oper Dent 15:82, 1990.
4. Toreskog S, et al: Properties of die materials: a comparative study. J Prosthet Dent 16:119, 1966.
5. Fukui H, et al: Effectiveness of hardening films on die stone. J Prosthet Dent 44:57, 1980.
6. Campagni WV, et al: Measurement of coating agents used for surface protection of stone dies. J Prosthet Dent 55:470, 1986.
7. Zakaria MR, et al: The effects of a liquid dispersing agent and a microcrystalline additive on the physical properties of type IV gypsum. J Prosthet Dent 60:630, 1988.
8. Alsadi S, et al: Properties of gypsum with the addition of gum arabic and calcium hydroxide. J Prosthet Dent 76:530, 1996.
9. Wee AG, et al: Evaluation of the accuracy of solid implant casts. J Prosthodont 7:161, 1998.
10. Yaman P, Brandau HE: Comparison of three epoxy die materials. J Prosthet Dent 55:328, 1986.
11. Chaffee NR, et al: Dimensional accuracy of improved dental stone and epoxy resin die materials. I. Single die. J Prosthet Dent 77:131, 1997.
12. Schaffer H, et al: Distance alterations of dies in sagittal direction in dependence of the die material. J Prosthet Dent 61:684, 1989.
13. Chaffee NR, et al: Dimensional accuracy of improved dental stone and epoxy resin die materials. II. Complete arch form. J Prosthet Dent 77:235, 1997.
14. Derrien G, Le Menn G: Evaluation of detail reproduction for three die materials by using scanning electron microscopy and two-dimensional profilometry. J Prosthet Dent 74:1, 1995.
15. Nomura GT, et al: An investigation of epoxy resin dies. J Prosthet Dent 44:45, 1980.
16. Stackhouse JA: Electrodeposition in dentistry: a review of the literature. J Prosthet Dent 44:259, 1980.
17. Crispin BJ, et al: Silver-plated dies. II. Marginal accuracy of cast restorations. J Prosthet Dent 51:768, 1984.
18. Cassimaty EM, Walton TR: Effect of three variables on the accuracy and variability of electroplated copper dies. Int J Prosthodont 9:547, 1996.
19. Crispin BJ, et al: Silver-plated dies. I. Platability of impression materials. J Prosthet Dent 51:631, 1984.
20. Nash RW, Rhyne KM: New flexible model technique for fabricating indirect composite inlays and onlays. Dent Today 9:26, 1990.
21. Roberts DB: Flexible casts used in making indirect interim restorations. J Prosthet Dent 68:372, 1992.
22. Rada RE: In-office fabrication of indirect composite-resin restorations. Pract Periodont Aesthet Dent 4:25, 1992.
23. Trushkowsky RD: One-visit composite onlay utilizing a new flexible model material. Am J Dent 1:55, 1997.
24. Gerrow JD, Price RB: Comparison of the surface detail reproduction of flexible die material systems. J Prosthet Dent 80:485,1998.
25. Smith CD, et al: Fabrication of removable stone dies using cemented dowel pins. J Prosthet Dent 41:579, 1979.
26. Serrano JG, et al: An accuracy evaluation of four removable die systems. J Prosthet Dent 80:575, 1998.
27. Aramouni P, Millstein P: A comparison of the accuracy of two removable die systems with intact working casts. Int J Prosthodont 6:533, 1993.
28. Covo LM, et al: Accuracy and comparative stability of three removable die systems. J Prosthet Dent 59:314, 1988.
29. Chong YH, et al: Relationship between contact angles of die stone on elastomeric impression materials and voids in stone casts. Dent Mater 6:162, 1990.
30. Lepe X, et al: Effect of mixing technique on surface characteristics of impression materials. J Prosthet Dent 79:495, 1998.
31. Vassilakos N, Fernandes CP: Surface properties of elastomeric impression materials. J Dent 21:297, 1993.
32. Boening KW, et al: Clinical significance of surface activation of silicone impression materials. J Dent 26:447, 1998.
33. Balshi TJ, Mingledorff EB: Matches, clips, needles, or pins. J Prosthet Dent 34:467, 1975.
34. Walker PM: Discrepancies between arbitrary and true hinge axes. J Prosthet Dent 43:279, 1980.
35. Bowley JF, et al: Reliability of a facebow transfer procedure. J Prosthet Dent 67:491, 1992.
36. Peregrina A, Reisbick MH: Occlusal accuracy of casts made and articulated differently. J Prosthet Dent 63:422, 1990.
37. Weinberg LA: An evaluation of the face-bow mounting. J Prosthet Dent 11:32, 1961.
38. Wilson EG, Werrin SR: Double arch impressions for simplified restorative dentistry. J Prosthet Dent 49:198, 1983.
39. Donovan TE, Chee WWL: A review of contemporary impression materials and techniques. Dent Clin North Am 48:445, 2004.

18

WAX PATTERNS



KEY TERMS

anteroposterior curve
connector
curve of Spee
curve of Wilson
cusp-fossa
cusp-marginal ridge
emergence profile
lost-wax process
luting agent space
proximal contact

A large percentage of time and effort spent in fabricating fixed prostheses is devoted to producing a very accurate wax pattern. From this pattern, the finished cast restoration is duplicated by using the **lost-wax process** as part of the indirect procedure.

This technique consists of obtaining an accurate impression of the prepared tooth (Fig. 18-1*A*) and making a cast from the impression (Fig. 18-1*B*) on which a wax pattern that resembles the shape of the final restoration is shaped (Fig. 18-1*C*). A mold is then made around the wax pattern with a refractory investment material (Fig. 18-1*D*). When the investment has set, the wax is vaporized in an electric furnace. The hollow mold is then filled with molten casting alloy, reproducing every detail of the wax pattern (Fig. 18-1*E*). The metal casting is retrieved, excess metal is removed, and after polishing, the cast restoration is ready for clinical evaluation (Fig. 18-1*F*).

As the solidifying metal (casting) cools to room temperature, it shrinks. Dimensional accuracy of the casting is achieved by balancing this shrinkage against precisely controlled expansion of the mold (see Chapter 22). Wax is used to make the patterns because it can be conveniently manipulated and precisely shaped. By heating, it can be completely eliminated from the mold after investing.

The lost-wax technique is widely used in industrial and jewelry manufacturing. The first bronze castings reportedly were made in the third millennium B.C.E. with beeswax and clay refractory materials. Ancient lost-wax castings such as Chinese bronzes, Egyptian deities, and Greek statues have withstood the centuries, yielding information about ancient societies and cultures. The lost-wax method may have been used in Sumer as early as the Second Early Dynastic Period for figurines and even larger body parts.[1]

In dentistry, *successful results depend on careful handling of the wax.* The practitioner must understand that every defect or void in the wax will appear in the casting. Most defects can be corrected easily in wax, but not in a metal casting. More often than not, compensating for an error in waxing technique is impossible once the metal casting has been formed. Careful evaluation of the pattern, preferably under magnification, is crucial for obtaining a good casting.

This chapter approaches the waxing procedure in a logical sequence. As with most aspects of fixed

The "lost-wax" casting technique dates to the Bronze Age (approximately 3000-3500 BCE), when sandstone molds were used to cast molten metal. Today, the underlying principles remain virtually identical.

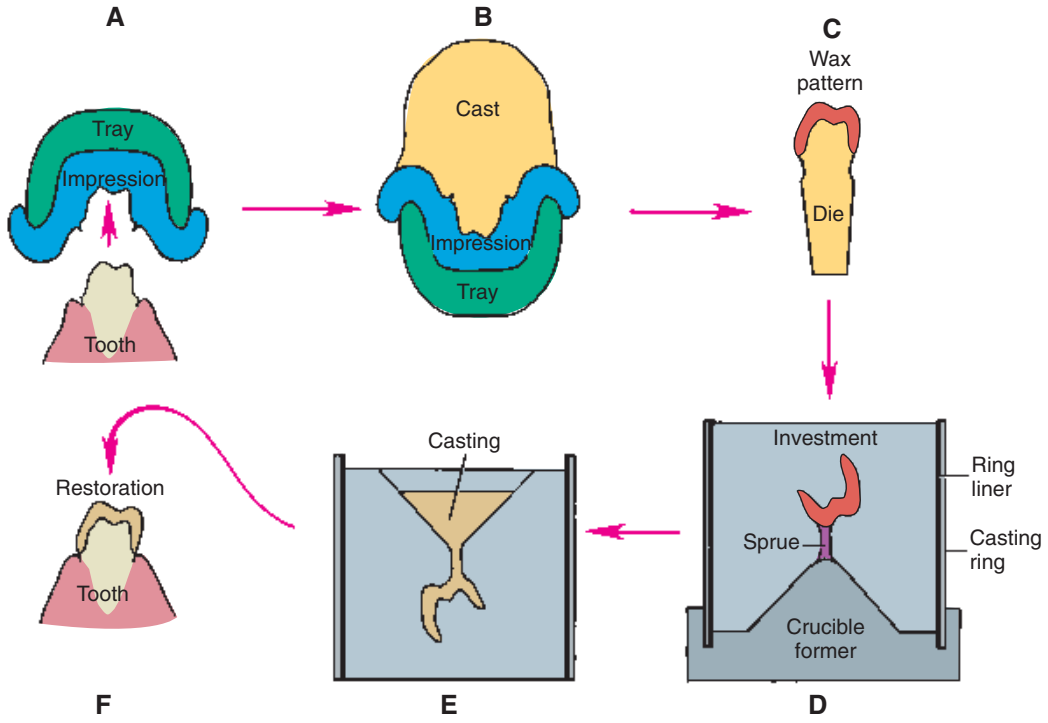


Fig. 18-1
Most dental castings are made indirectly by the lost-wax process. **A,** Impression. **B,** Cast. **C,** Wax pattern on die. **D,** The pattern is attached with sprue to a rubber crucible former and invested. **E,** Casting. **F,** Luted restoration.

prosthodontics, a successful restoration is possible only if each step is carefully followed and evaluated before the dentist moves on to the next.

PREREQUISITES

The definitive die and cast may require small modifications before waxing is started. Depending on the procedure, the size of the die can be slightly increased by applying a thin layer of painted-on spacer, which helps obtain a slightly larger internal diameter of the restoration.

Correction of Defects

Even a very small undercut on the die of a tooth preparation results in an inability to remove the wax pattern. There may be small dimples in the die (resulting from caries removal or loss of a previous restoration) that are undercut in relation to the path of placement of the new restoration. Normally such areas are blocked out intraorally with glass ionomer or restored with amalgam or another suitable foundation material as part of the mouth preparation phase (see Chapter 6). On occasion, however, blocking them out on the working die may be more practical and convenient, as long as the defect does not extend to within 1 mm of the cavity margin. Zinc phosphate cement is a suitable material (see Chapter 31), but other commercial products (e.g., resin) are available for this purpose (Fig. 18-2).

Provision of Adequate Luting Agent Space

Since the 1920s,[2] practitioners have recognized that a space should exist between the internal surface of the casting and the prepared surface of the tooth everywhere except immediately adjacent to the margin. The space provides room for the **luting agent** (a material that on hardening fills the space



Fig. 18-2
Blocking out undercuts on a die. **A,** Photopolymerizing resin being applied. **B,** Resin light-cured. **C,** Alternatively, autopolymerizing resin can be used. **D,** Resin is applied. **E,** Monomer spray results in an almost instantaneous cure.

and binds the tooth and crown together) and allows complete seating of the restoration during cementation (see Chapters 7 and 31). At the preparation margin, there should be a band of close adaptation (about 1 mm wide) to prevent disintegration and dissolution of the luting agent. The ideal dimension[3-5] for the **luting agent space** has been suggested at 20 to 40 μm for each wall, which implies that a complete crown should have an internal diameter between 40 and 80 μm larger than the diameter of the prepared tooth. Through the use of available techniques in an appropriately standardized manner, such a degree of casting adaptation can routinely be obtained, independent of the geometry of the finish line.[6,7]

If the luting agent space is too narrow, the casting does not seat properly during cementation because of hydraulic pressure that develops when the viscous mass of luting agent cannot escape through the narrow gap between crown and preparation as the restoration is seated. Conversely, if the luting agent space is too wide, the casting is loose on the tooth, resistance form (see Chapter 7) is reduced, and the position of the casting is difficult to maintain accurately during evaluation and occlusal adjustment. In addition, the risk of the crown loosening during function increases considerably, and its longevity is adversely affected. The precise amount of luting agent space obtained depends on the materials and techniques used in the indirect process, particularly the choice of impression material (see Chapter 14), die material (see Chapter 17), investment (see Chapter 22), and casting alloy (see Chapters 19 and 22 and Fig. 18-1). These factors directly affect the size of the cement space.

Increasing the luting agent space

A number of factors increase the luting agent space for a complete crown:

1. Increased thermal and polymerization shrinkage of the impression material (see Chapter 14).
2. Use of a solid cast with individual stone dies (see Chapter 17).
3. Use of an internal (initial) layer of soft wax in the wax pattern.
4. Use of die spacers.
5. Increased expansion of the investment mold (see Chapter 22).
6. Removal of metal from the fitting surface by grinding, airborne-particle abrasion, etching with aqua regia, or electrochemical milling.

All other factors remaining equal, each of these factors individually results in an increased distance between the internal surface of the casting and the surface of the prepared tooth. Although the dentist has little control over the polymerization shrinkage

of impression materials, die system selection has a direct influence on the size of the wax pattern. With some impression materials, using a multiple-pour system for fabrication of a solid definitive cast and a separate die yields a die that is slightly larger than the prepared tooth. The pattern is, in effect, stretched during manipulation, which results in a proportionally larger internal casting diameter. An internal layer of soft wax is subject to slightly more compression by the setting refractory investment material, leading to a looser fit. Spacers enlarge the die by coating the occlusal surface and vertical axial walls with a thin layer of rapidly drying paint. The expansion of the investment mold can be increased by heating the mold to a slightly higher temperature during the wax elimination phase, and metal can be removed from the internal surface of a cast crown through air abrasion, etching, or milling procedures.

Reduction of the luting agent space

A number of factors reduce the cement space:

1. Reduced thermal and polymerization shrinkage of the impression material (see Chapter 14).
2. Use of resin or electroplated dies.
3. Use of alloys with a higher melting range.
4. Reduced expansion of the investment.

Resin and electroplated dies are slightly smaller than stone dies and therefore result in a smaller casting. As alloys cool over a larger temperature range, the additional shrinkage that takes place also results in a smaller casting. There are multiple ways in which to reduce investment expansion. Technique selection, burnout temperature, and water/powder ratio are the most convenient (see Chapter 22). If the investment is mixed with an adjusted water/powder ratio, which results in less setting expansion, the size of the resulting casting is again reduced. When problems routinely surface with castings that are either too loose or too tight, any of the previously mentioned variables may be altered, leading to more predictable results.

Problems with fitting castings become apparent at two stages of the indirect procedure: when the casting is evaluated on the die and when it is cemented. Recognizing problems at each stage and correcting them before proceeding is crucial. Difficulty with seating the casting on the die is generally caused by *wax distortion*, the presence of *flash* extending cervical to the preparation margin (excess wax that was not removed before the investing and casting procedure), *improper investment expansion* (underexpansion) (Fig. 18-3), or a *casting nodule*. Modification of the investing and casting protocol solves these problems (see Chapter 22). Consistent problems with castings that do not seat completely when evaluated on the prepared tooth may be corrected by changing just one variable in the protocol. Although many technicians advocate the routine use of die spacer, this is just one of many options to influence the size of the resulting cement space.



Fig. 18-3
This experimental near-cylindrical casting failed to seat because of inadequate expansion of the investment, not inadequate die spacing.

Die spacer

This material (Fig. 18-4) (similar to model airplane paint[8]) is applied to the die to increase the cement space between axial walls of the prepared tooth and the restoration. It is formulated to maintain constant thickness when painted on the die. However, it should not coat the entire preparation. For adequate marginal adaptation, a band of about 1 mm immediately adjacent to the preparation margin must be left unpainted.[9] Thinner is provided to replace the solvent, which tends to evaporate, resulting in an excessive thickness of spacer.

Marking the Margins

The technician's awareness of the precise location of the preparation margin is crucial. By marking it with colored pencil, the technician can pinpoint this location (Fig. 18-5). The color should contrast with that of the wax that will be used (e.g., a red pencil can be used for a green wax). An ordinary lead pencil is not recommended, because it can abrade the die, its darker color can interfere with efforts to verify that the wax has been properly adapted at the margin, and traces of the graphite (an antiflux) can prevent complete casting of the margins. The marked margins can be coated with *low-viscosity* cyanoacrylate resin and immediately blown dry. If performed properly, this procedure adds no more than a micrometer[10] to the die. Although removing the



Fig. 18-4
Applying die spacer. A, The material is available in contrasting colors to facilitate applying the required number of coats. B, Care must be taken to keep the material at least 1 mm from the margin. C, Some technicians prefer a pen-application product. *(C, Courtesy of Kerr Lab Corporation, Orange, California.)*



Fig. 18-5
Marking the preparation margin. Note that the side of the colored pencil tip is used to keep line width to a minimum.

excess with acetone is sometimes possible, care must be taken not to create a thick layer of cyanoacrylate, which can result in an unacceptable fit of the final cast restoration. For this reason, higher viscosity resins must be avoided.

MATERIALS SCIENCE

M. H. Reisbick

Inlay casting wax (the name given all wax used in forming the pattern for cast restorations) is actually composed of several waxes. Paraffin is usually the main constituent (40% to 60%). The remaining balance consists of dammar resin (to reduce flaking) plus carnauba, ceresin, or candelilla wax (to raise the melting temperature) or beeswax. Sometimes a synthetic wax is substituted for the natural material. Dyes are added to provide color contrasts. Exact formulations are trade secrets, but Coleman[11] published the formula for an experimental compound.

The American National Standards Institute (ANSI) and the American Dental Association (ADA)[12] have categorized waxes into two types:

1. Type I: a medium-hardness wax (generally used with the direct technique for making patterns in the oral cavity).
2. Type II: a softer wax (generally used for the indirect fabrication of castings).

Waxes used with direct techniques must not flow appreciably at mouth temperature. Those used with indirect techniques must resist flow at room temperature to maintain their newly shaped forms.

Specifications of the ANSI and ADA govern use of the important properties of residue, flow, and expansion. Because the mold must burn out cleanly to allow the escape of gases and the complete entry of molten alloy, there can be no residual ash. However, the specifications allow a 0.1% residue, which apparently is effectively negligible. Flow requirements, as previously stated, are necessary to control the stability of the wax once it has reached the temperature at which it is carved, burnished, and polished (37° C [99° F] for type I waxes, 25° C [77° F] for type II waxes). In addition, the wax must flow well at typical forming temperatures. Curves of temperature plotted against percentage flow (Fig. 18-6) are furnished by reputable manufacturers and should be consulted when a casting wax is chosen. All waxes expand and contract when heated and cooled, respectively. Manufacturers' curves of percentage expansion and contraction at various working temperatures (Fig. 18-7) are helpful when methods to use in the investing and casting process are considered. For example, a wax that solidifies at a higher temperature shrinks more and therefore requires more compensation to control fit than does a wax that solidifies at a lower temperature (a reason for not interchanging type I and type II waxes within an established technique). These properties can be adversely affected by repeated heating of the wax, which drives off the more volatile components.[13] When waxes are selected for optimal casting accuracy, the use of waxes with different properties for the margin and occlusal portions may be necessary.[14] If a casting is to be accurate, the wax pattern must not become significantly distorted. One reason for distortion is that wax has "memory," which means that it exhibits some elasticity unless it is thoroughly liquefied. This problem can be overcome by applying the initial layer of wax in melted increments or drops. As an alternative, the initial coping can be made by dipping the die into thoroughly melted wax.

However, a serious problem exists when the added wax incorporates strain within the pattern as each increment solidifies. This strain tends to be released with time and subsequently distorts the wax

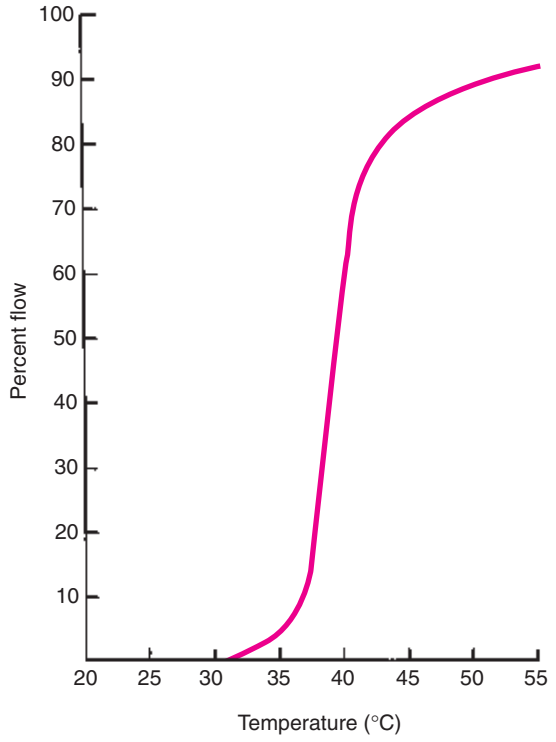


Fig. 18-6
Wax flow curve.

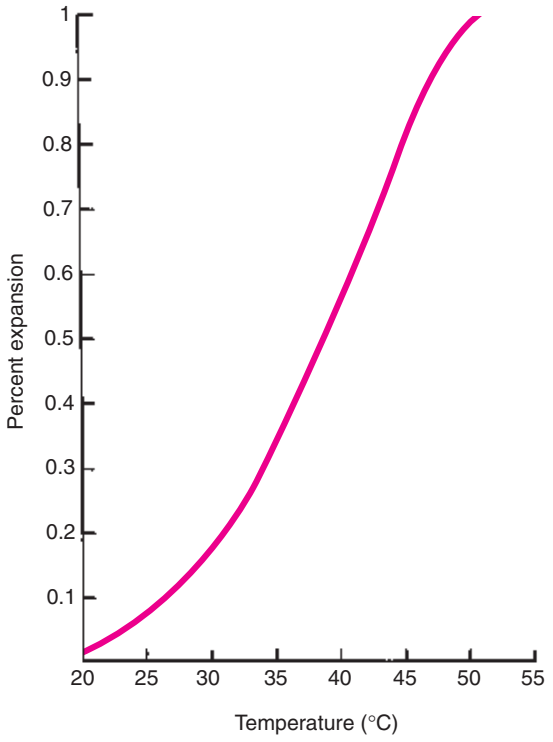


Fig. 18-7
Wax expansion curve.

pattern. The rate of wax change is temperature dependent, which means that it increases at higher ambient temperatures. Because wax has a relatively high coefficient of thermal expansion and changes dimension subject to air temperature changes, and because the pattern tends to release its incorporated strain, the margins must be remelted, readapted, and resmoothed immediately before investing. The internal fit of the remelted portion is then closer to the prepared surface of the tooth than is the rest of the casting and therefore may help obtain the necessary space for the luting agent.

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TECHNIQUE

A step-by-step waxing technique is recommended. Each step is evaluated before the dentist proceeds to the next, which allows corrections and minimizes extra work. The finished wax patterns should be an accurately shaped anatomic replica of the original teeth. Information needed to shape the restoration correctly is derived from the contours of the unprepared tooth surface, adjacent tooth surfaces, and the opposing occlusal surfaces; however, additional input is needed. This stems from a thorough knowledge of tooth anatomy and the ability to copy three-dimensional structures accurately.

When making a drawing or painting, artists constantly refer to the real-life scene they are trying to reproduce. Similarly, when waxing a restoration, the dentist or technician should refer to a suitable model (e.g., diagnostic casts, unworn extracted teeth, a contralateral tooth) or casts of the unworn natural teeth. It is unwise to copy reproductions of natural teeth (plastic teeth or casts of restored mouths), no matter how skillfully they are made. This would be like an artist trying to render a scene from another artist's painting, rather than from real life.

Evaluating a three-dimensional shape with accuracy is difficult. The finished wax pattern for a tooth may be too bulbous or too flat. Although it appears "wrong," pinpointing and correcting the exact problem is a skill achieved only after in-depth study of what constitutes "normal" anatomic form and after learning how to interpret that shape. To evaluate occlusal structure, breaking down the complex surfaces into individual components is helpful. When evaluating axial contours, the practitioner should assess a series of two-dimensional outlines by rotating the wax pattern. These can easily be compared with an appropriate model, and any aberrations can be corrected. It is helpful to recognize that the human eye excels at interpreting even very small differences in height and width of objects



Fig. 18-8
A, Incorrect midfacial contour is difficult to determine by looking directly at a three-dimensional object. **B,** It is more easily seen by sequential evaluation of the profile of the pattern as it is rotated.

(two dimensional), but is not as adept at interpreting similarly subtle differences in depth. Therefore, assessment is facilitated by systematically looking at cross-sections through the pattern and evaluating its silhouette (Fig. 18-8). Rotation of the pattern and repeating this process from all angles of observation speeds up this intricate process.

Armamentarium (Fig. 18-9)

- Bunsen burner
- Inlay wax
- Waxing instruments
- Cotton cleaning cloth
- Sharp colored pencil (contrasting color to wax)
- Separating liquid
- Occlusal indicator powder (zinc stearate* or powdered wax)
- Soft toothbrush
- Double-sided brushes (soft/rigid)
- Cotton balls
- Fine nylon hose

*Zinc stearate may present a health hazard if it is inhaled. Powdered wax is a safer alternative.

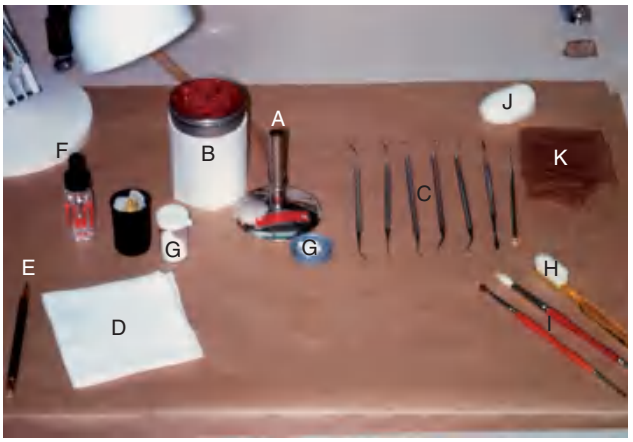


Fig. 18-9
Waxing armamentarium. ***A,*** Bunsen burner; ***B,*** inlay wax; ***C,*** waxing instruments; ***D,*** cotton cleaning cloth; ***E,*** sharp colored pencil; ***F,*** separating liquid; ***G,*** occlusal indicator powder; ***H,*** soft toothbrush; ***I,*** double-sided brushes; ***J,*** cotton balls; ***K,*** fine nylon hose.

Waxing Instruments

Waxing instruments can be categorized by the intent of their design: wax addition, carving, or burnishing. Of the popular PKT instruments (Fig. 18-10*A* to *F*) (designed by Dr. Peter K. Thomas specifically for the additive waxing technique), No. 1 and No. 2 are wax addition instruments, No. 3 is a burnisher for refining occlusal anatomy, and Nos. 4 and 5 are wax carvers.

Wax is added by heating the instrument in the Bunsen flame, touching it to the wax, and quickly reheating its shank in the flame. Wax flows away from the hottest part of the instrument, so that if the shank is heated, a bead of wax flows off the tip (Fig. 18-11). However, if the tip is heated, the wax flows up the shank of the instrument (to the considerable annoyance of inexperienced operators). The PKT No. 1 instrument is used for large increments; the smaller No. 2 is used for lesser additions. A No. 7 or

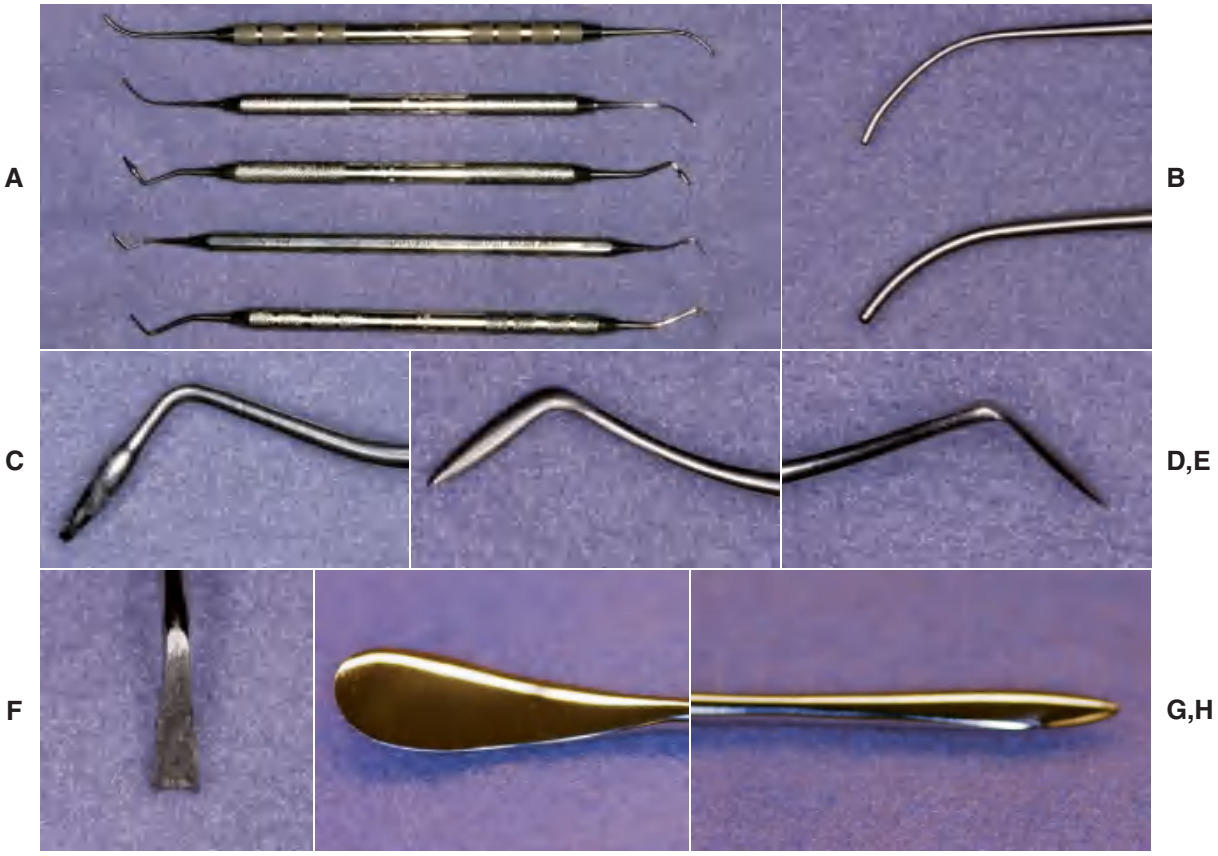


Fig. 18-10
Waxing instruments. **A,** Top to bottom: PKT Nos. 1 to 5. **B,** Top to bottom: PKT Nos. 1 and 2. **C,** PKT No. 3. **D** and **E,** PKT No. 4. **F,** PKT No. 5. **G** and **H,** The No. 7 waxing spatula.

7A waxing spatula (see Fig. 18-10*G* and *H*) is useful for adding large amounts of wax, particularly in forming the initial coping (the thimble-like layer of wax that covers all prepared surfaces). Electric waxing instruments (Fig. 18-12) are preferred by some technicians because they allow precise temperature control of the wax, which is important for proper manipulation. Another advantage is that carbon buildup can be kept to a minimum, which easily results from overheating a waxing instrument in a Bunsen flame.

Wax carvers should be kept sharp and should never be heated. In addition to the PKT instruments, the Nos. ½ and 3 Hollenback and the No. 2 Ward carvers (Fig. 18-13) are popular. When carving wax, light pressure should be used to obtain the desired smooth surface.

Burnishing is an alternative to carving for obtaining a smooth wax pattern of the desired contour. Burnishing consists of slightly warming a blunt instrument and rubbing the wax. The instrument should not be so hot that it melts the wax surface. The PKT No. 3 instrument is useful for burnishing the occlusal surfaces. The PKT Nos. 1 and 2 can be used for burnishing as well as for wax addition. Another popular burnisher is based on the DPT6 Darby Perry trimmer* (Fig. 18-14).

For removing wax, burnishing is less effective than carving, but it is probably easier to control. It

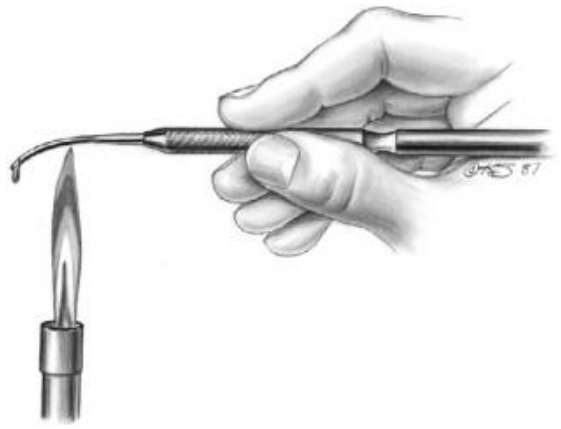


Fig. 18-11
Always heat the shank of the instrument so that wax flows off its tip.

*This instrument is available to special order (PF-Land) from Hu-Friedy, Chicago, Illinois.



Fig. 18-12
A to C, Electric waxing instruments. *(Courtesy of Kerr Lab Corporation, Orange, California.)*



Fig. 18-13
Wax carvers. **A,** Top to bottom, No. 2 Ward and Nos. ½ and 3 Hollenback. **B,** Left to right, closer view of these three instruments.



Fig. 18-14
DPT6 Darby Perry trimmer (wax burnisher).

leaves a smoother surface, which can be particularly important when excess wax is trimmed near the margin. Careless (excessive) carving in this area can result in abrasion of the die, resulting in a ledge at the margin of the finished casting.

Posterior Teeth

The following sequence is recommended for waxing posterior teeth:

1. Internal surface.
2. Wax pattern removal and evaluation.
3. Proximal surfaces.
4. Axial surfaces.
5. Occlusal surfaces.
6. Margin finishing.

Internal surface

Forming a closely adapted internal surface is the first step in waxing. The wax *must* reproduce all retention features of the restoration.

Step-by-step procedure

1. Apply die lubricant generously with a clean brush (Fig. 18-15*A*). Allow it to dry, and paint on a second coat (repeat periodically as needed). Waxing should not begin until the lubricant has soaked in completely.
2. Where pinholes have been prepared, fit in plastic pins that match the bur used to sink the hole. Seat the pins in the die, and use a heated No. 7 instrument to flatten their tops to provide retention in the wax (Fig. 18-15*B*).
3. Flow wax onto the die from a well-heated, large waxing instrument (Fig. 18-16*A*), making sure that any previous application is partially remelted. A large instrument holds sufficient heat to partially remelt previous wax increments and to prevent folds or lines from developing

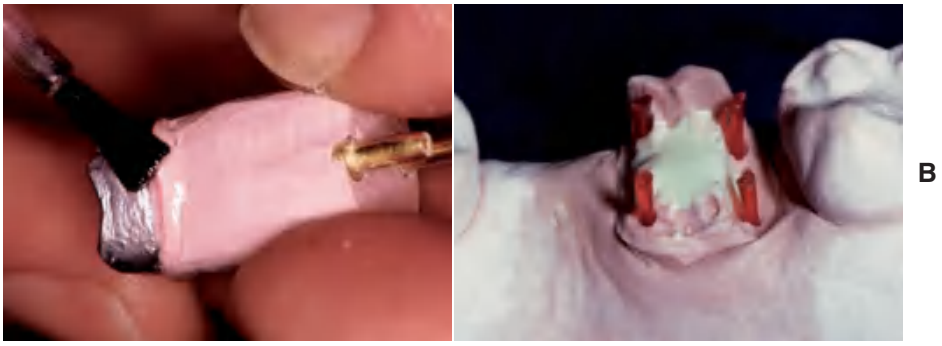


Fig. 18-15
Starting the waxing procedure. **A,** Lubricating the die. **B,** Adapting plastic pins.

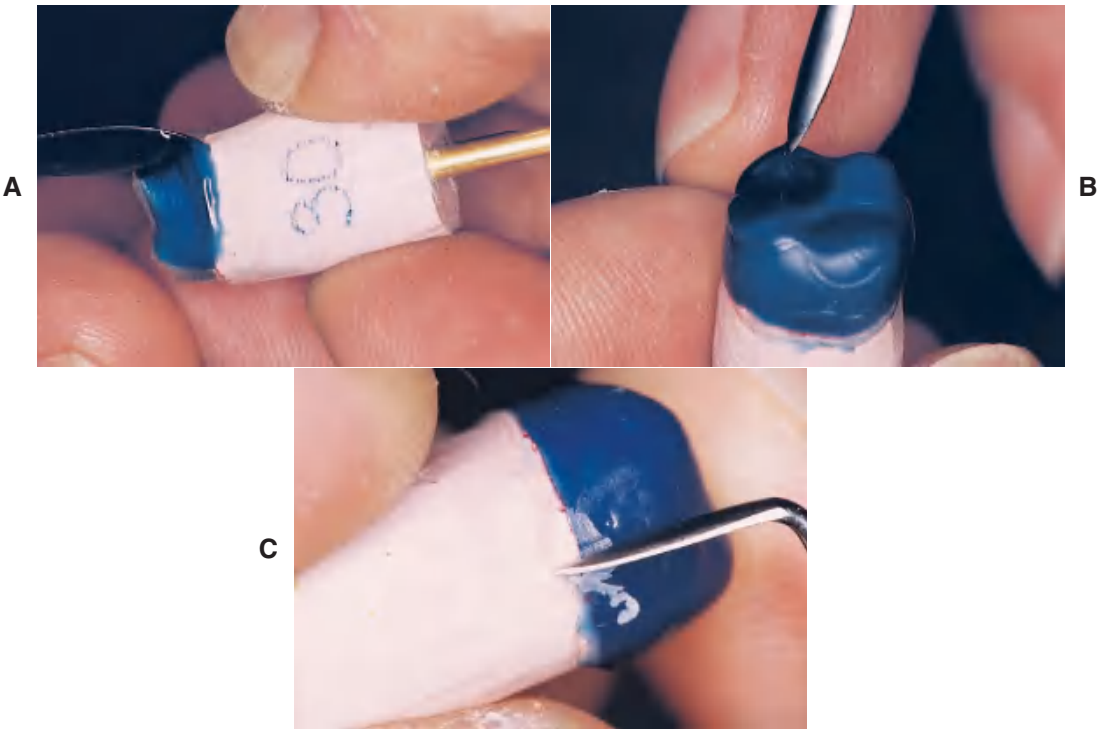


Fig. 18-16
Forming the initial copings. **A,** Use a large instrument to keep the wax sufficiently hot. Ensure that previous applications are remelted as additional wax is added. **B,** Build up adequate bulk for rigidity. **C,** Trim the wax very carefully to the margin.

in the fitting surface. Waxing is easier if the instrument is kept clean and only its shank is heated.

4. When applying the initial layer, be sure that the wax is fully molten. If it is not, wax "memory" may cause distortion. Very hot wax flows rapidly over the die. Subsequent waxing of external anatomic details is accomplished with cooler instruments, which allows small additions to be placed accurately. Dipping the lubricated die in a pot of melted wax is an alternative method for making well-adapted internal surfaces (Fig. 18-17). This method is particularly suitable for complete-coverage restorations.
5. Add sufficient wax with a large instrument to allow the coping to be handled without deformation or breakage (see Fig. 18-16*B*). A large instrument keeps the wax hot more effectively than does a small instrument.
6. Give the proximal areas extra bulk to help grip the coping and prevent its distortion when it is removed from the die. The wax should cool between applications. At this point, no attempt should be made to contour the axial walls.
7. Trim the wax back to the margin (see Fig. 18-16*C*) so the coping can be removed and evaluated. Excess bulk can be removed safely with a carving instrument. When only a thin excess layer remains, trimming is performed most safely with a burnisher. Careless use of a sharp carver at this stage may scratch the fragile margin of the die or chip it. Therefore, a slightly warmed blunt instrument should be used and the margins rubbed with a burnishing action. A carver can be used, but meticulous technique and great care are required.



Fig. 18-17
Wax dipping pot. *(Courtesy of Kerr Lab Corporation, Orange, California.)*

Wax pattern removal

The wax should be allowed to cool thoroughly before the coping is removed from the die (Fig. 18-18). This is done by maintaining a constant light grip on the pattern by the thumb and forefinger of one hand while applying pressure against them with the thumb and forefinger of the other hand, which also holds the die (see Fig. 18-18*B*). A small square of washed rubber dam increases friction between the fingers and the pattern. If the pattern fails to move, there may be excess wax beyond the margin, locking the pattern in place.

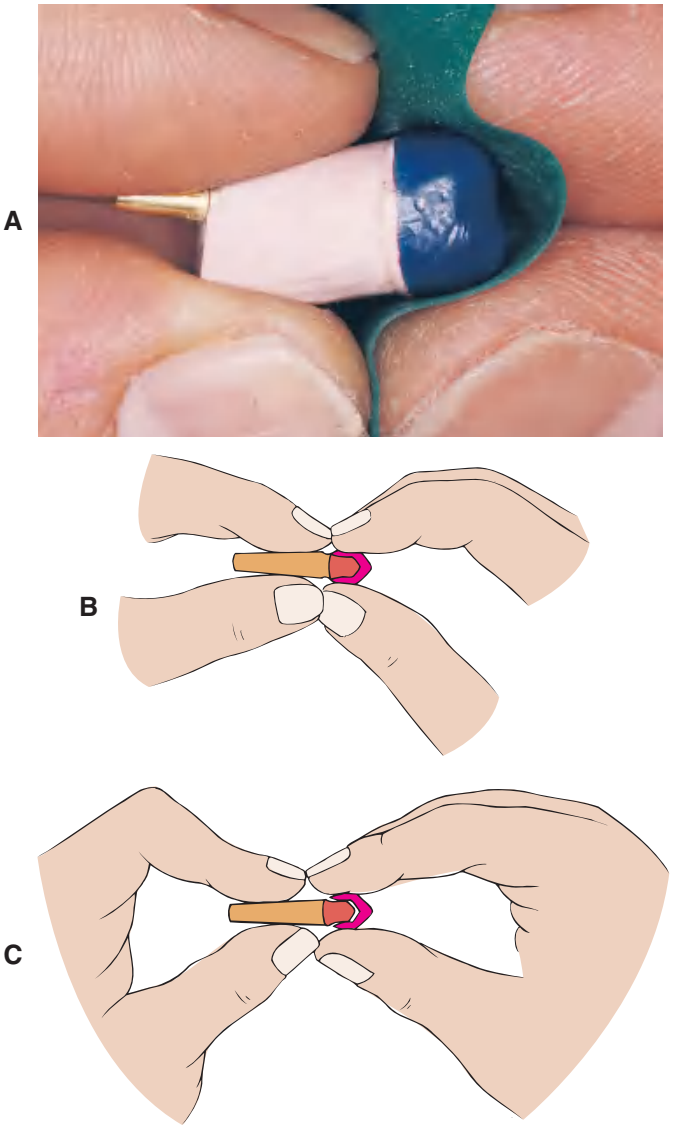


Fig. 18-18
Wax pattern removal. **A,** A sheet of washed rubber dam increases friction and aids removal. **B,** The fingers of the left hand hold the die. The right hand holds the pattern. **C,** The die is pulled from the pattern by bending the fingers of the left hand.

Evaluation

The objective of the first waxing step is a perfectly adapted reproduction of the prepared tooth surfaces. Identifying defects may take some practice. The examiner rotates the pattern under a bright light and looks for shadows formed by folds or creases (Fig. 18-19). A binocular microscope or high-quality magnifying loupe is helpful not only for this step but also throughout the laboratory phase. Ten-power magnification is practical and helpful. Using higher power interferes with maintaining orientation.

Proximal surfaces

The proximal surfaces of natural teeth are not convex (Fig. 18-20). They tend to be flat or slightly concave from the contact area to the cementoenamel junction, and any restoration must reproduce this feature. Overcontouring often makes maintaining good periodontal health difficult, particularly if drifting of teeth has led to increased root proximity.[15] Excessively concave or undercontoured proximal surfaces also make flossing ineffective and must be avoided.[16]

Contact areas

The size and location of the contact areas should be established before the remainder of the proximal surfaces are waxed. Reference is made to contacts between the contralateral teeth and knowledge of anatomic form.

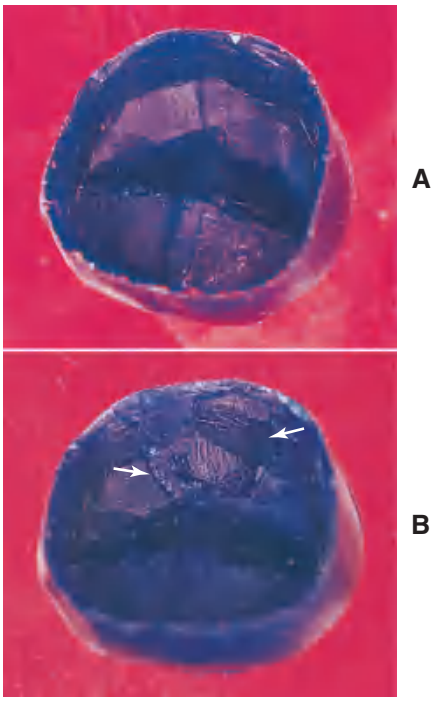


Fig. 18-19
Evaluation. **A,** Well-adapted pattern. **B,** Poor adaptation. Folds and creases (*arrows*) indicate that the wax was not hot enough when applied.

Abnormally large proximal contact areas make plaque control more difficult and can lead to periodontal disease. Very small (point) contacts may be unstable and cause drifting. Deficient contacts can also lead to food impaction; although this is not a direct cause of chronic periodontal disease, it can be very uncomfortable and painful to the patient.

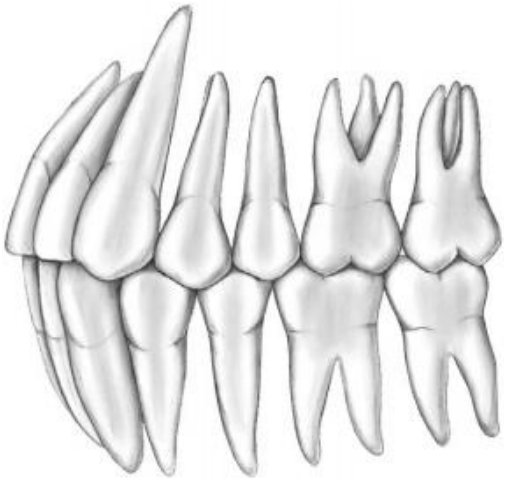


Fig. 18-20
Proximal surfaces gingival to the contact area are normally flat or concave. Note the triangular shape of the posterior embrasures.

Most posterior contact areas (Fig. 18-21) are located in the occlusal third of the crown. However, contact between the maxillary first and second molar occurs in the middle third.[17] The contact areas between mandibular teeth and maxillary molars are generally central. Between maxillary premolars and molars, the contact areas are usually toward the buccal surface (which makes the lingual embrasure larger than the buccal).

Step-by-step procedure

1. Replace the wax coping on the lubricated definitive cast or removable die. When a removable die system is used, extreme care must be taken to ensure that the locating pin and stone surfaces are absolutely free of excess wax or other debris that could prevent complete seating of the die (Fig. 18-22). To ensure that proximal contacts are not deficient, the adjacent proximal surface should be relieved slightly by scraping.
2. Adjust the coping as necessary to be completely clear of the opposing occlusal surfaces. They will be developed with a wax additive technique later.

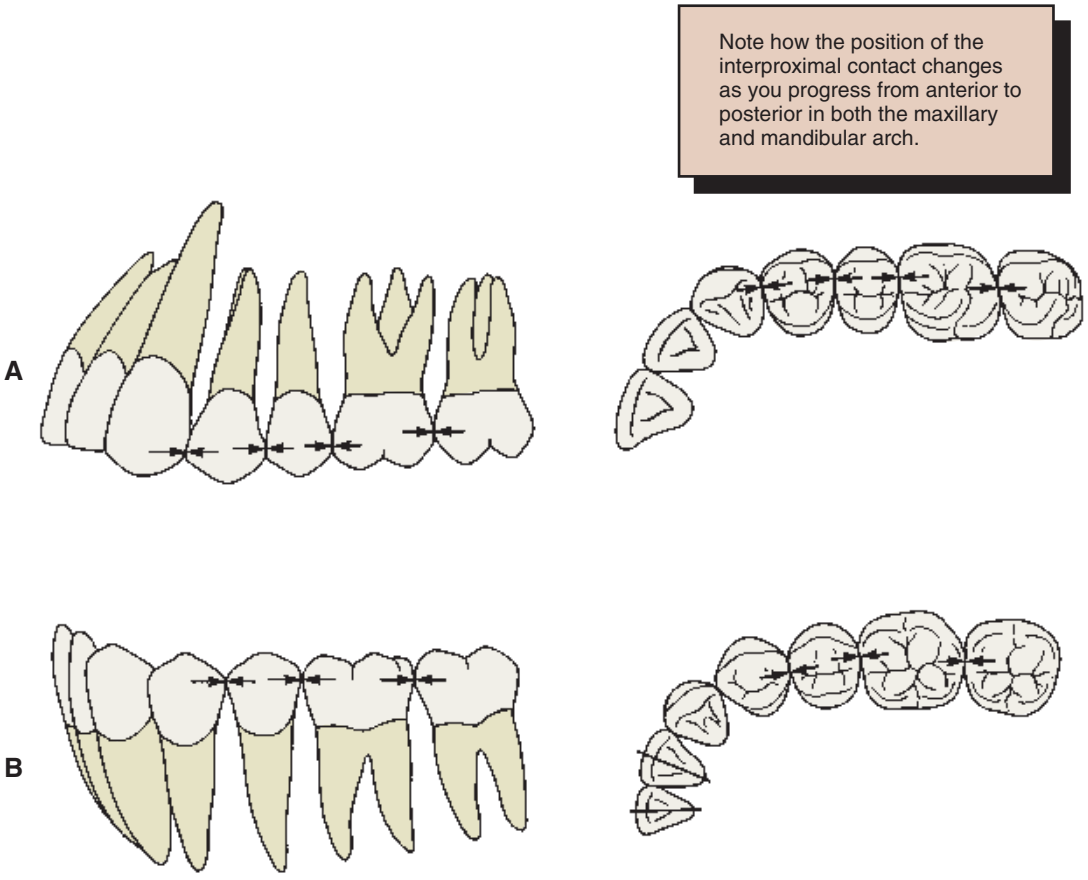


Fig. 18-21
Location of the proximal contact areas. **A,** On maxillary teeth: progressively more occlusal and buccal the more anterior the tooth. **B,** On mandibular posterior teeth: central.



Fig. 18-22
Wax chips that accumulate on the dowel pin or in the sleeve prevent a die from seating. Periodic cleaning with a brush is recommended.

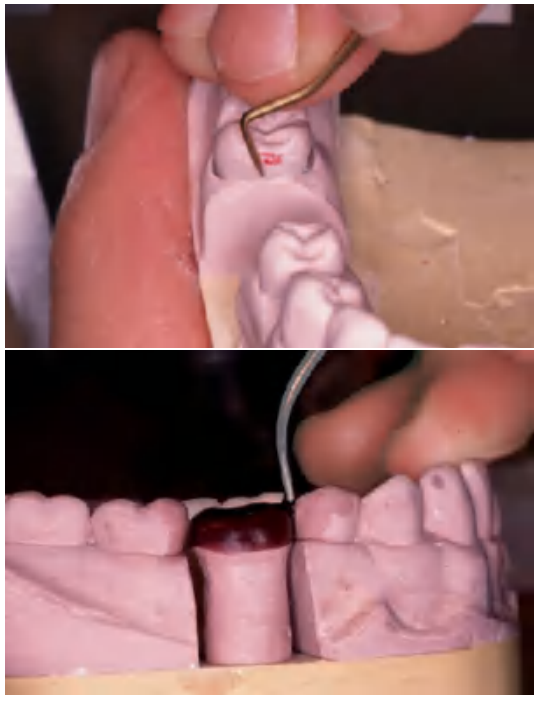


Fig. 18-23
A, To ensure that proximal contacts are not deficient, a slight amount of stone is scraped from the adjacent tooth prior to waxing. **B,** Wax is added to the contact area to establish a correctly located proximal contact.

3. Add wax to the contact areas until they are the correct size, properly located, and consistent with anatomic form (Fig. 18-23).
4. When this has been accomplished, shape the proximal surfaces gingival to the contacts to the correct contour. A properly trimmed die is of great assistance in accomplishing this. The unprepared tooth structure that was reproduced in the "cuff" of the impression now serves as an effective guide to orienting the waxing instrument properly.

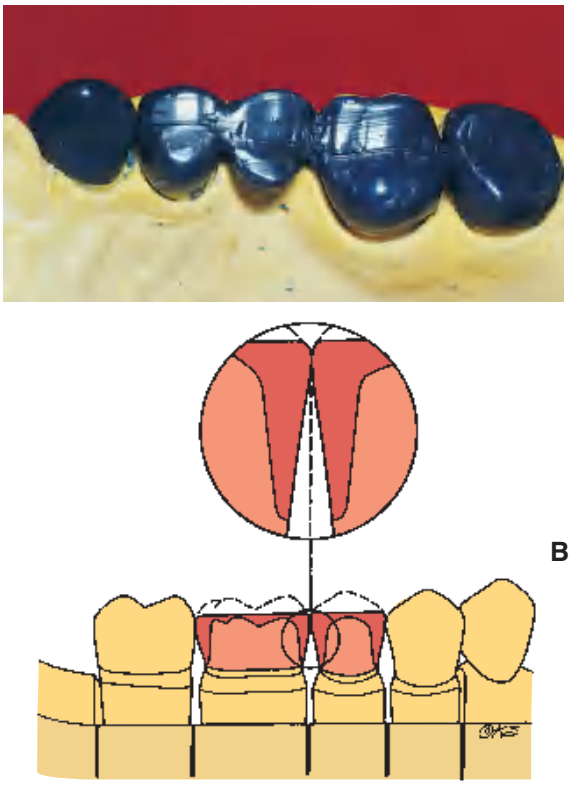


Fig. 18-24
A, From the occlusal view, proper buccal and lingual embrasure form have been established. **B,** The contact areas should be shaped so that the gingival embrasures are symmetric.

Evaluation

The location of the contact area is checked once again. Where multiple restorations are being made, the proximal embrasure is shaped symmetrically to provide adequate room for the free gingival tissues of adjacent teeth (Fig. 18-24). The proximal surfaces should be flat or slightly concave and should be shaped to eliminate any directional change between the root surface and the finished restoration. The cervical contour of the restoration should be continuous, with the contour of the unprepared tooth structure immediately cervical to the preparation margin.

Axial surfaces

The buccal and lingual surfaces should be shaped to follow the contours of the adjacent teeth. The location of the height of contour (or, alternatively, the survey line for retainers for removable dental prostheses) is particularly important. It is generally located in the gingival third of most teeth, although on mandibular molars it is usually in the middle third of the lingual surface.

Restorations are often made too bulky. Natural teeth are rarely more than 1 mm wider at their

height of contour than at the cementoenamel junction. This width should not be exaggerated when a tooth is re-created in wax. The tooth surface gingival to its height of contour immediately adjacent to the gingival soft tissues, sometimes called the **emergence profile,**[18] is usually flat or concave. Creation of a convexity in this area or a shelf or ledge[19] makes bacterial plaque removal more difficult and has been shown to cause inflammatory and hyperplastic changes in the marginal gingiva. Before dental plaque was identified as the direct etiologic agent in periodontal disease,[20] an excessive axial contour was considered necessary to keep food from entering the gingival sulci.[21] However, there is no evidence to support this concept. Indeed, artificially reduced axial contours (as when a prepared tooth is left unprotected for an extended period)[22] are associated with healthy gingival tissue. Overcontoured axial surfaces result if there has been insufficient axial reduction during tooth preparation. Special care is needed where bone loss has occurred as a result of periodontal disease, particularly when this has caused exposure of the root near the furcation. The axial contour should then be modified to improve access for plaque removal (Fig. 18-25).

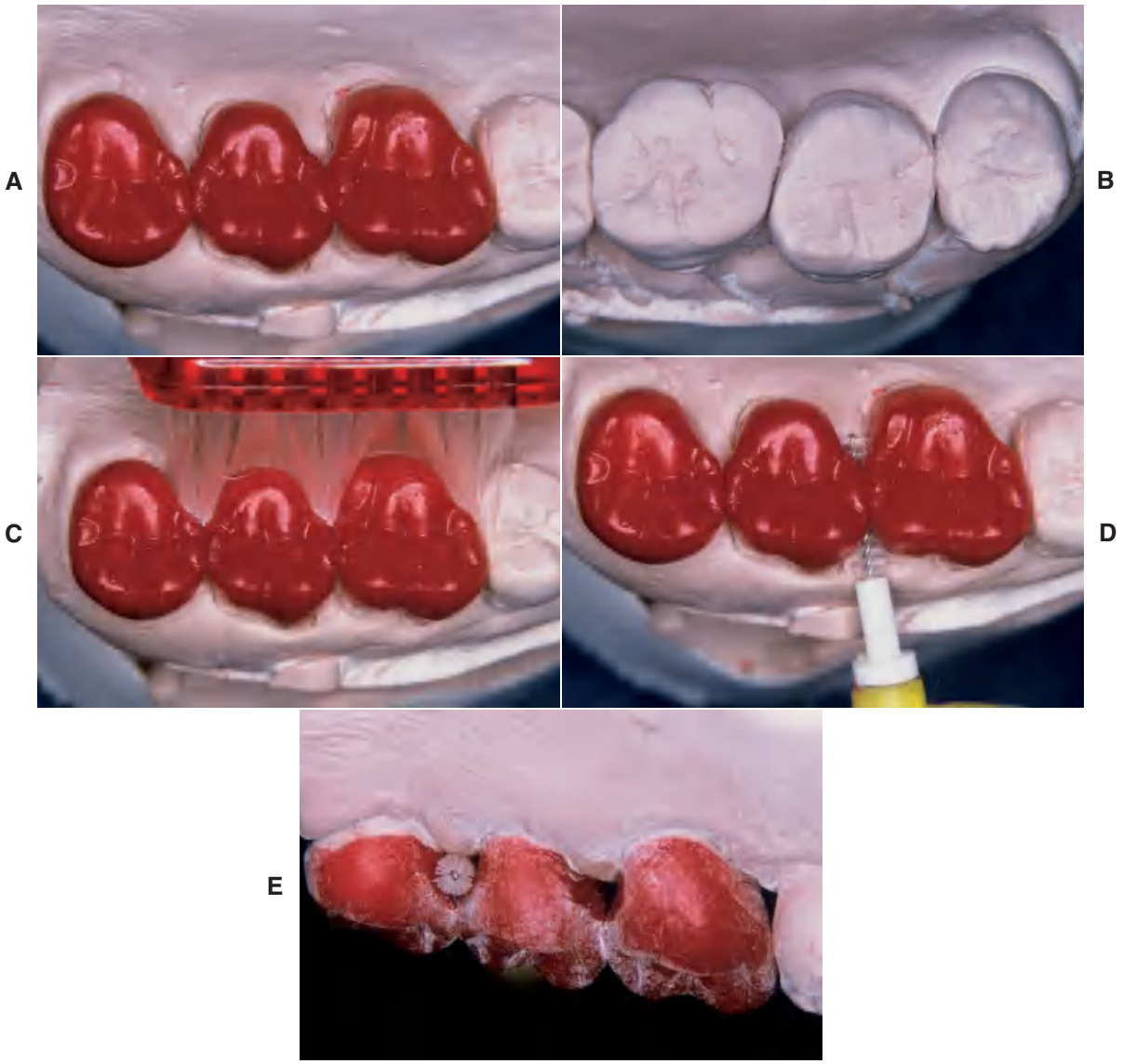


Fig. 18-25
As the cervical margin is placed near root furcations, the axial contour is modified to improve access for plaque control in patients with extensive bone loss. **A,** Modified wax patterns for a periodontally compromised patient. Note the change in the outline form of the occlusal tables. **B,** The contralateral teeth have normal axial contour. **C** to **E,** Modified contour allows better access for oral hygiene.

Step-by-step procedure

Axial contours

1. Establish the location, position, and overall outline of the contour, using the adjacent and contralateral teeth as a guide.
2. Wax the axial surfaces gingivally to form a smooth, flat profile. There should be no change of direction from unprepared tooth structure to the axial restoration contour.
3. Shape the middle third of the axial surface, using the adjacent tooth as a guide (Fig. 18-26*A*).
4. Add wax to join the axial and proximal surfaces. and smooth them, paying particular attention to the location and shape of the mesial and distal transitional line angles. A Boley gauge may prove helpful. The line angles should correspond to those on the contralateral teeth if those are intact (see Fig. 18-26*B*).

Evaluation

The examiner should evaluate the shape of the tooth at its greatest convexity by looking at the wax pattern and comparing its shapte with that of the contralateral tooth. Each part of the outline should be carefully scrutinized. If the outline is too square or too round, this is modified. The buccal and lingual contours and the embrasures should all be assessed. Initially, assessing individual components rather than the entire contour or outline is helpful. The practitioner should try to relate the shape under evaluation to a "neutral" reference point, such as the midsagittal plane when viewing from the occlusal surface. With more experience, the practitioner will find it easier to review multiple forms simultaneously.

Each contact area has four embrasures: gingival, buccal, lingual, and occlusal. All but the occlusal will have been completed by this stage. The embrasures are normally symmetric about a line drawn through the contact area (Fig. 18-27).

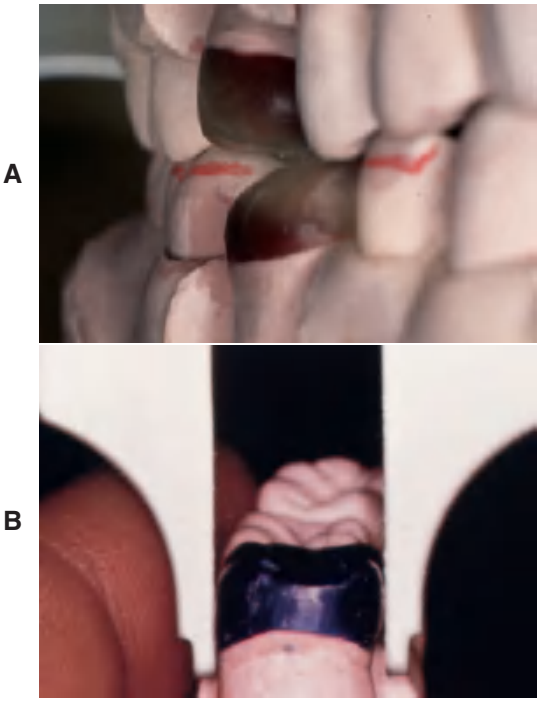


Fig. 18-26
A, Waxing axial contours. **B,** Evaluate the buccolingual dimension with a Boley gauge. This instrument is also helpful in assessing axial shape and height of contour.

Occlusal surfaces

The cusps and ridges of the occlusal surfaces should be shaped to allow even contact with the opposing teeth while stabilizing the teeth and directing forces along their long axes (see Chapter 4). Nonfunctional cusps (buccal cusps of the maxillary teeth, lingual cusps of the mandibular teeth) should overlap vertically and horizontally, preventing accidental biting of the cheek or tongue and keeping food on the occlusal table.

Point contacts between opposing teeth are preferable to broad, flat occlusal contacts because wear of the restorations is minimized and mastication of tough or fibrous foods is improved. The occlusal

Establishing the correct embrasure form is essential. Only when proper anatomical form is obtained can the patient maintain plaque control.

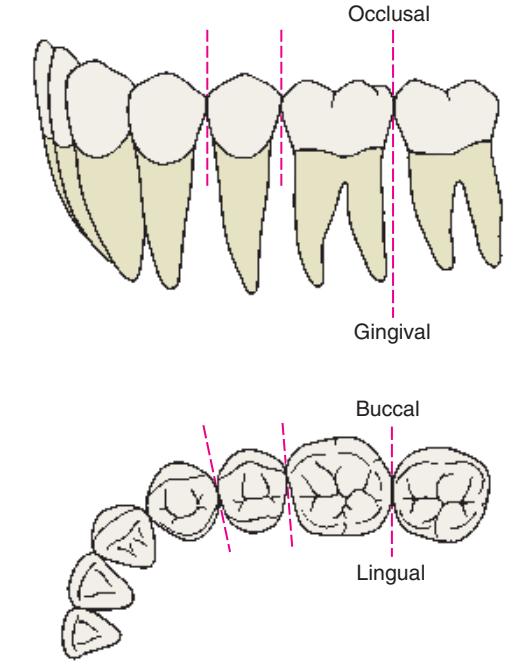


Fig. 18-27
Symmetry of embrasures.

surfaces of natural teeth consist of a series of convexities with developmental grooves where the convex ridges meet. The opposing cusps should travel through pathways paralleling these grooves without tooth contact in excursive jaw movements. The occlusal surfaces can be precisely developed with a wax addition technique similar to the one devised by Payne[23] that is used in many schools to teach occlusal morphology and function[24-26] (Figs. 18-28 and 18-29).

Occlusal scheme

Two occlusal schemes are generally recognized and should be understood when the restorations are planned: cusp-marginal ridge and cusp-fossa (see Chapter 4). In the cusp-marginal ridge scheme, the buccal cusps of the mandibular premolars and the mesiobuccal cusps of the mandibular molars contact the embrasures between the maxillary teeth (i.e., they each contact two teeth). In the cusp-fossa scheme, these mandibular functional

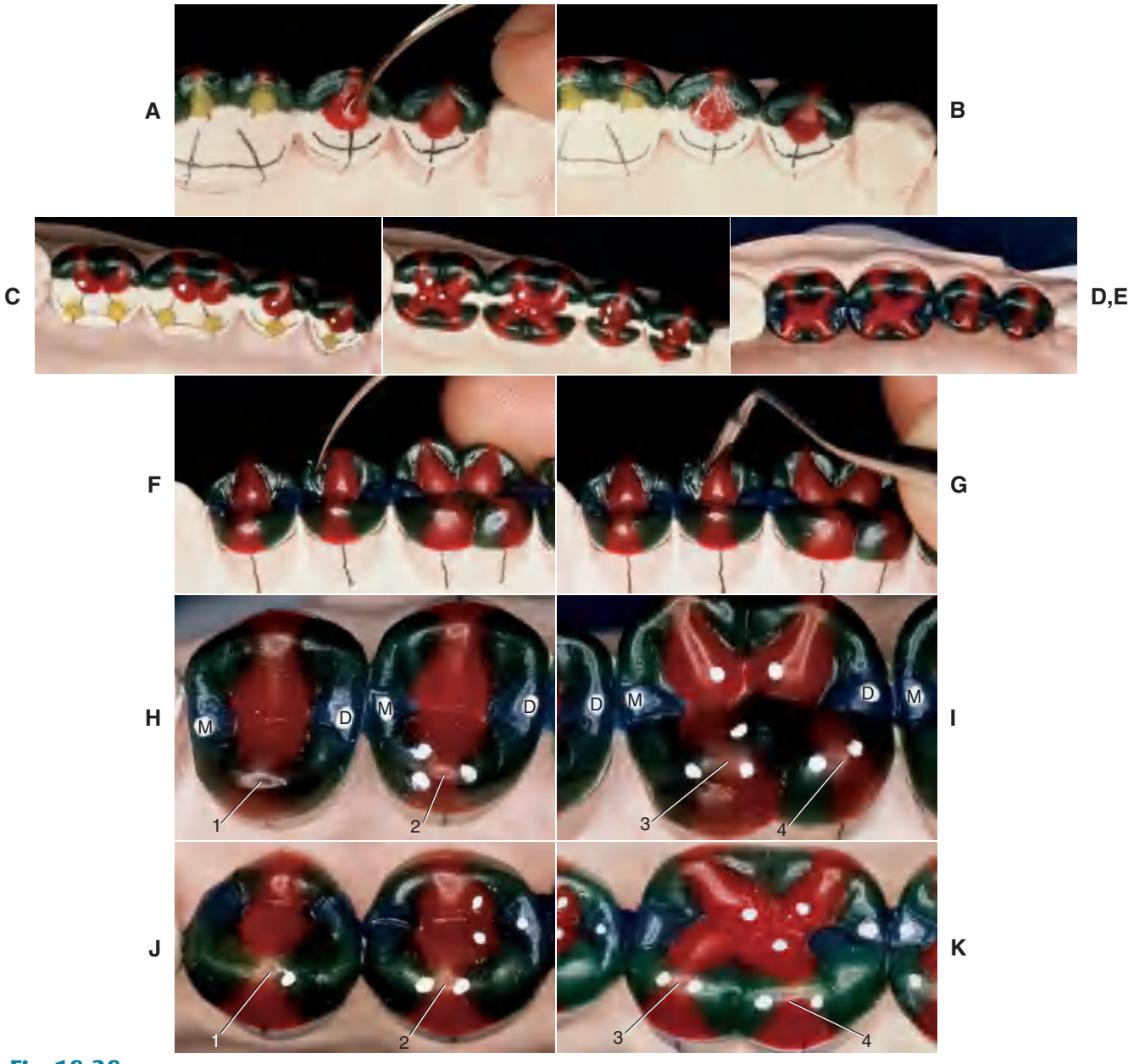


Fig. 18-28

Occlusal waxing with the sequential wax addition technique. **A,** Accurate occlusal contacts are developed by adding small increments of wax and closing the articulator while the addition is still soft. **B,** Powder is used to verify the location and size of the contact. **C,** Cones are used to determine the location of the lingual cusp tips. **D** and **E,** The various features of the occlusal surface are developed sequentially in wax. **F** and **G,** Secondary occlusal features can be refined by reflowing the wax and burnishing the fissures. **H** to **K,** Completed waxing with occlusal contacts marked. (For the cusp-marginal ridge scheme, numbers refer to cusp position in Table 18-1.)

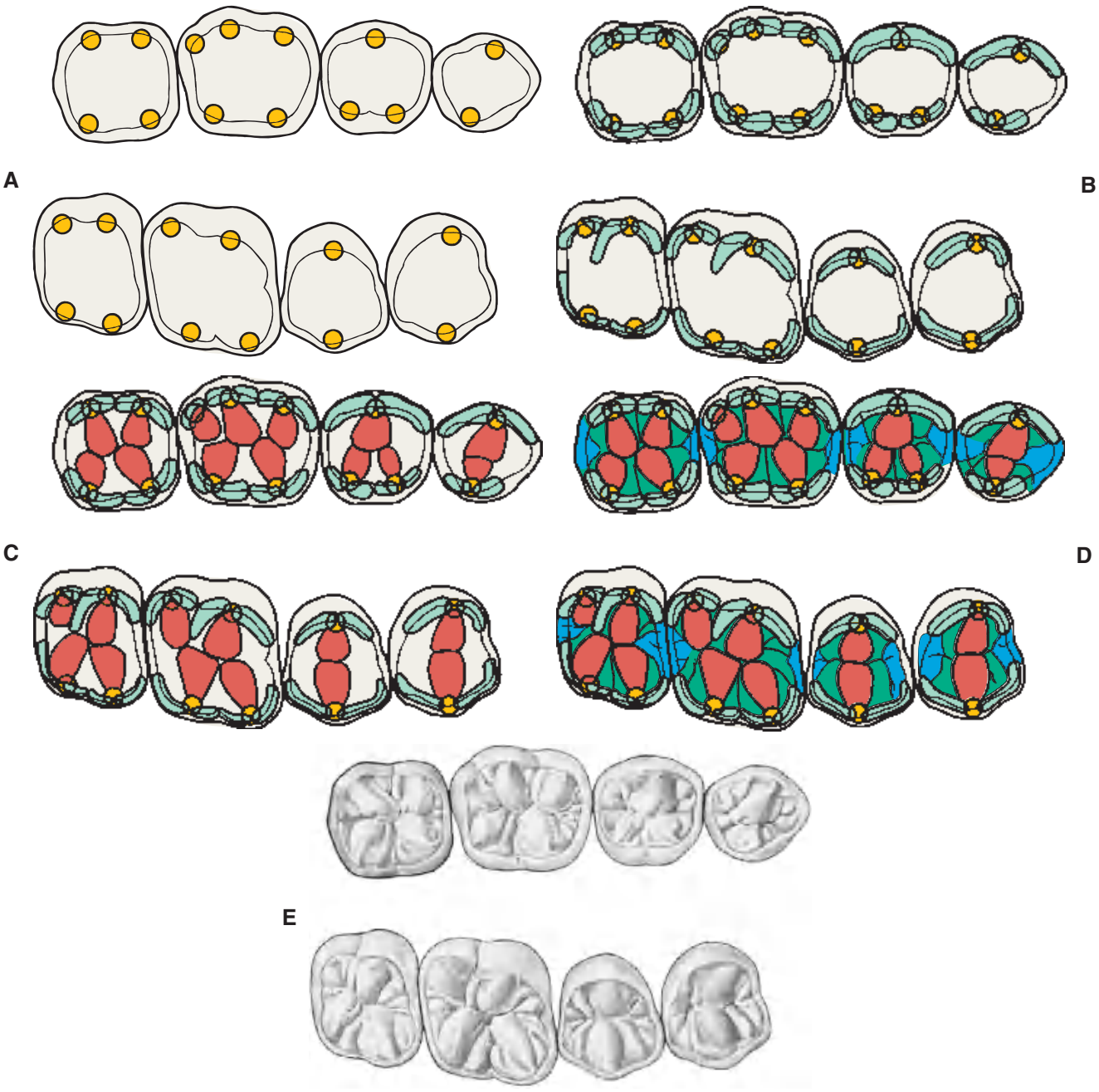


Fig. 18-29
Sequence of occlusal wax addition. **A,** Step 1: cone placement. **B,** Step 2: cuspal ridges superimposed. **C,** Step 3: cones, cuspal ridges, and triangular ridges. **D,** Step 4: cones, cuspal ridges, triangular ridges, and secondary and marginal ridges. **E,** Step 5: occlusal waxing complete.

cusps contact farther distally into the fossa of the maxillary tooth and contact only one tooth (Tables 18-1 and 18-2). The lingual functional cusps of the maxillary teeth contact the fossae of the mandibular teeth in both schemes.

Most adults with a Class I occlusion and unworn teeth have a cusp-marginal ridge scheme. In natural dentitions, the cusp-fossa arrangement is found only when a slight Class II malocclusion is present. However, for the following reasons, the cusp-fossa arrangement has been recommended over the cusp-marginal ridge when occlusal reconstruction is undertaken:

1. Food impaction is prevented.
2. Centric relation closure forces are nearer the long axes of the teeth.
3. Improved stability results from the tripod contacts for each functional cusp.

When the mesiodistal relationships of opposing teeth favor it, the cusp-fossa scheme is optimal. If

Table **18-1** **FEATURES OF CUSP-MARGINAL RIDGE SCHEME: FUNCTIONAL CUSP ARTICULATION***

Tooth	Cusp position	Functional cusp	Opposing fossa	Opposing marginal ridge (same tooth unless otherwise specified)
MAXILLA				
First premolar	1	L	D	–
Second premolar	2	L	D	–
First molar	3	ML	C	–
	4	DL	–	D and M (second molar)
Second molar	5	ML	C	–
	6	DL	–	D
MANDIBLE				
First premolar	1	B	–	M
Second premolar	2	B	–	D and M (first premolar)
First molar	3	MB	–	D and M (second premolar)
	4	DB	C	–
Second molar	5	MB	–	D and M (first molar)
	6	DB	C	–

*See Figure 18-31A.
B, buccal; C, central; D, distal; DB, distobuccal; DL, distolingual; L, lingual; M, mesial; MB, mesiobuccal; ML, mesiolingual.

Table **18-2** **CUSP-FOSSA SCHEME: FUNCTIONAL CUSP ARTICULATION***

Tooth	Cusp position	Centric cusp	Opposing marginal ridge (same tooth)
MAXILLA			
First premolar	1	L	D
Second premolar	2	L	D
First molar	3	ML	C
	4	DL	D
Second molar	5	ML	C
	6	DL	D
MANDIBLE			
First premolar	1	B	M
Second premolar	2	B	M
First molar	3	MB	M
	4	DB	C
	5	D	D
Second molar	6	MB	M
	7	DB	C

Courtesy Dr. A. G. Gegauff.
*See Figure 18-31B.
B, buccal; C, central; D, distal; DB, distobuccal; DL, distolingual; L, lingual; M, mesial; MB, mesiobuccal; ML, mesiolingual.

these relationships are not present, the choice is between (1) distorting coronal axial form to accommodate the preferred occlusal scheme and (2) altering the occlusal structure to accommodate normal axial form. Significant deviation from normal axial form by overcontouring invariably results in periodontal consequences. Altering axial form by undercontouring rarely causes such problems. Depending on the specific spatial relationship between the antagonists, the cusp-marginal ridge scheme may be a better choice in such situations. However, the decision is not always a clear one. Tooth size and posi-

tion variations among patients produce a continuum between the optimal cusp-marginal ridge and cusp-fossa schemes. Common sense dictates using the scheme that produces the best overall functional and esthetic result. In many cases, this can be determined only by trial and error. The placement of cones before any other occlusal waxing is often the most efficient way to accomplish this.

Cusp height and location

1. Determine the position and height of the cusps with wax cones (Fig. 18-30). This is done so that necessary modifications can be made rapidly.

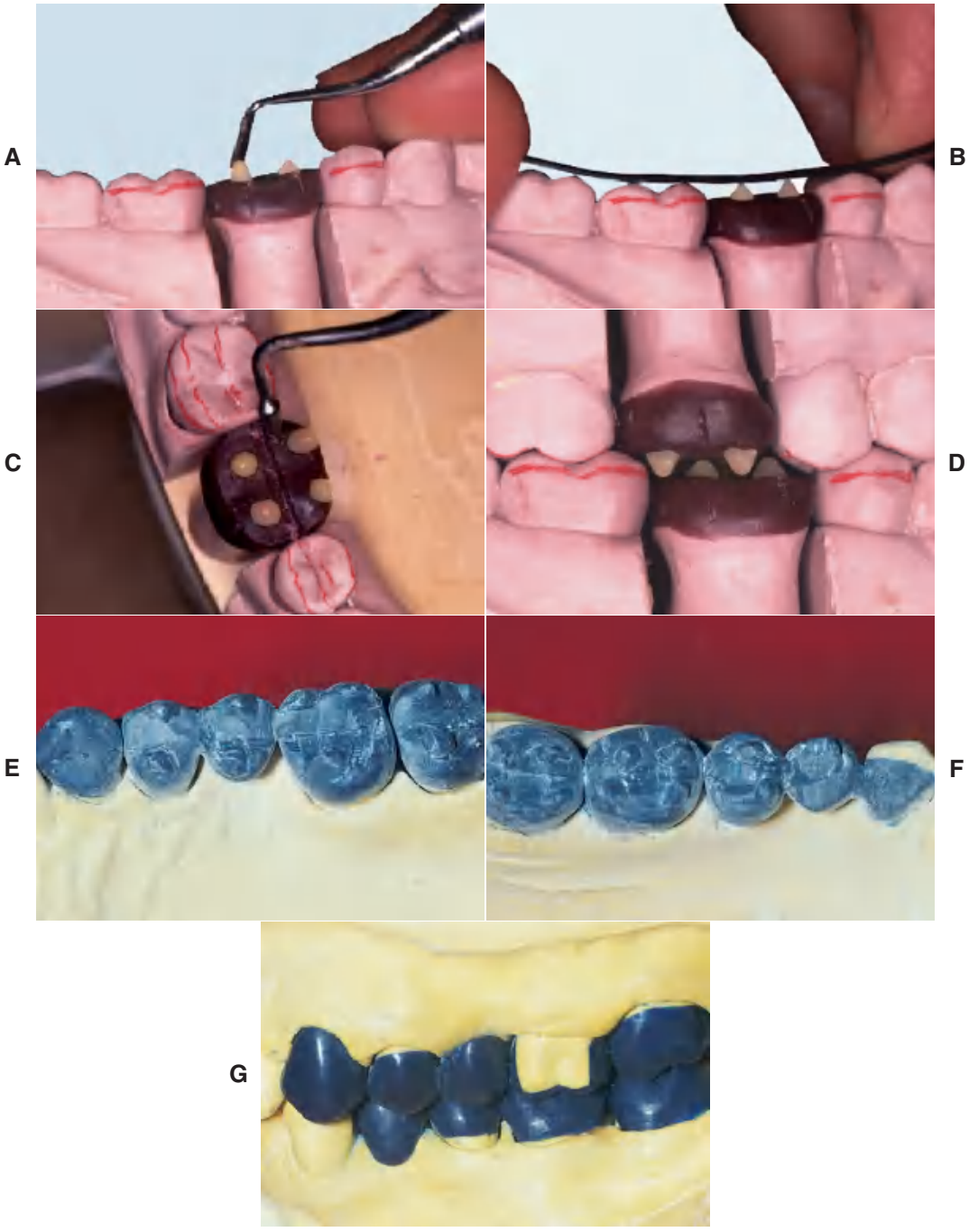


Fig. 18-30

A, Adding wax cones to determine cusp height and location. **B,** The cusp's height is determined by the anteroposterior curve (curve of Spee). **C,** Marking the central fossae of opposing teeth helps position the functional cusps correctly. **D,** All cones are positioned and tested for interferences in all excursions. **E** to **G,** The wax additive technique is especially useful when multiple restorations are provided simultaneously.

Add wax cones for each cusp, and mark the central fossae of opposing teeth to help position the cusps correctly.

2. Position the centric or functional cusps (mandibular buccal and maxillary lingual) so that they occlude along the buccolingual center of the opposing tooth. The actual cusp tips do not contact the opposing tooth. Greater stability and reduced wear are possible with small points of contact distributed around the cusp tips.
3. Use the mesiodistal location of the cones to determine the type of occlusal scheme to be attempted: cusp-marginal ridge or cusp-fossa (Fig. 18-31; see also Fig. 18-28*H* to *K* and Tables 18-1 and 18-2).

Evaluation

The cones should be positioned so they follow the anteroposterior curve (sometimes referred to as the **curve of Spee**) (Fig. 18-32). This is the anatomic curve established by the occlusal alignment of the teeth, as projected onto the median plane, beginning with the cusp tip of the mandibular canine and following the buccal cusp tips of the premolar and molar teeth, continuing through the anterior border of the mandibular ramus, ending with the most anterior portion of the mandibular condyle. The

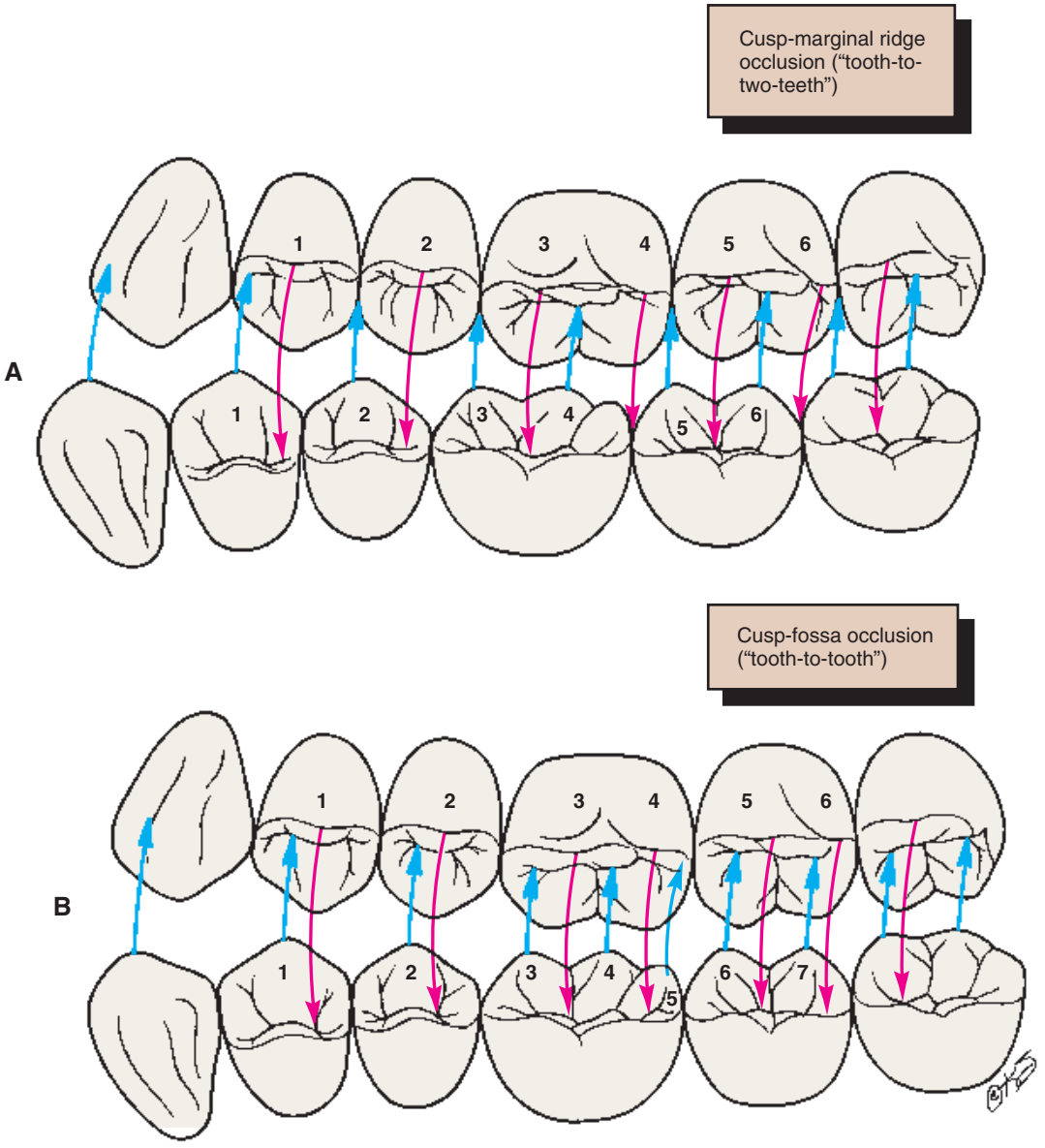


Fig. 18-31

A, Cusp-marginal ridge occlusion. **B,** Cusp-fossa occlusion. (The numbers refer to those in Tables 18-1 and 18-2.)

mandibular cusps should become taller farther distally, and the maxillary cusps should become shorter. They should also follow a mediolateral curve (sometimes referred to as the **curve of Wilson**). In the mandibular arch, this is the curve (viewed in the frontal plane) that is concave above and contacts the buccal and lingual cusp tips of the mandibular molars; in the maxillary arch, it is the curve (viewed in the frontal plane) that is convex below and contacts the buccal and lingual cusp tips of the maxillary molars. When viewed from the front, the nonfunctional cusps are slightly shorter than the centric cusps. All eccentric movements should be reproduced on the articulator; if unwanted contact results in protrusive, working, and nonworking excursions, they should be eliminated by either reducing or repositioning the cones. Proper cone height and position are key to the development of proper occlusal form.

The most critical step in waxing occlusal surfaces is the correct placement of the cusp tips. Use the information provided by adjacent and opposing teeth to determine the optimal position for each cone.

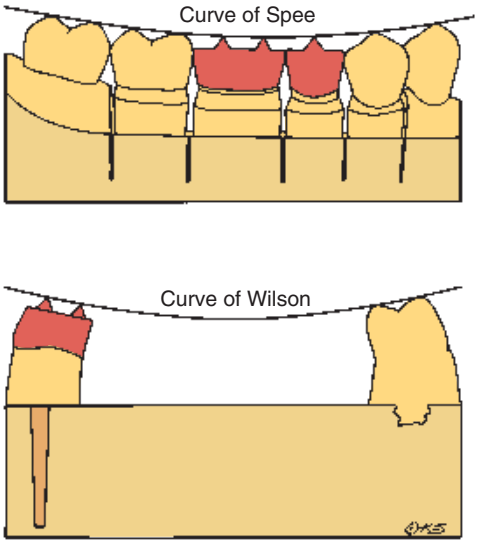


Fig. 18-32
Cones should follow the anteroposterior curve (curve of Spee) and the mediolateral curve (curve of Wilson).

Completion of axial contours

4. Complete the axial contours (marginal ridges and cuspal ridges) (Fig. 18-33). Be especially careful not to alter the location or height of the cusps as previously determined with the cones.
5. After each addition of wax, check for occlusal contact by closing the articulator. Do not increase the occlusal vertical dimension.

Evaluation

At this stage, the buccal, mesial, lingual, and distal surfaces have been completed (Fig. 18-33). When viewed from these perspectives, the wax pattern should appear identical to an intact tooth. When viewed from the buccal perspective, each cusp should have a distinct profile, with the cusp tip highest and a gentle slope down to the marginal ridges. Adjacent marginal ridges should be of the same height. Occlusal contacts in excursive movements must also be evaluated. If there is unwanted contact, grooves can be created in the cuspal ridges to allow the passage of opposing cusps.

Triangular ridges

6. Give each cusp a triangular ridge (Fig. 18-34; see also Fig. 18-28A) that runs toward the center of the occlusal surface. The apex (or point) of the triangle should be at the cusp tip, and the base should be in the center of the occlusal surface.

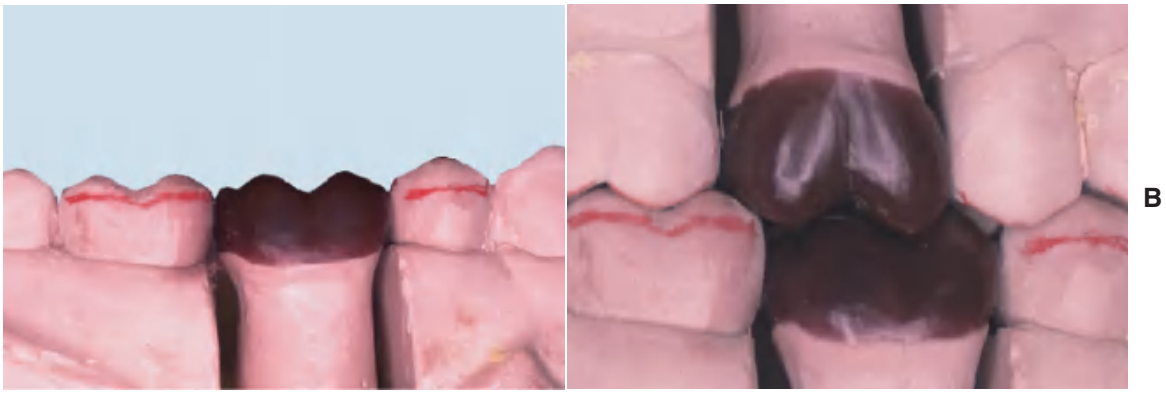


Fig. 18-33
Completed axial contours. **A** The maxillary buccal cusp ridges. **B,** At this stage, the buccal surface is complete and should be evaluated for correct contour.



Fig. 18-34
Waxing maxillary triangular ridges.



Fig. 18-35
Evaluating occlusal contacts.

7. Make the bases of the buccal and lingual triangular ridges convex mesiodistally and buccolingually.
8. As each ridge is added, close the articulator. Where the occlusal surface meets an opposing tooth, note the small depression and adjust this to form a convex surface so that pinpoint contact exists.

Evaluation

The triangular ridges are dusted with zinc stearate or powdered wax (Fig. 18-35; see also Fig. 18-28*B*). The cusps should still have their correct sharp contour and should not be rounded by improper polishing.

Secondary ridges

9. Make two secondary or supplemental ridges adjacent to each triangular ridge (Fig. 18-36; see also Fig. 18-28*F*). All cusps should have a single triangular ridge and two secondary ridges. The degree of specific delineation between the triangular and secondary ridges varies, depending on the prominence of the cusp within the occlusal table of the tooth that is being waxed.
10. Make the secondary ridges convex with grooves where they meet the convexities of the triangular ridges. The most mesial and most distal secondary ridges are often contiguous with the marginal ridges.

Evaluation

If the ridges have been carefully formed, only a small amount of finishing is needed at this stage (Figs. 18-37 and 18-38). Any pits can be filled with

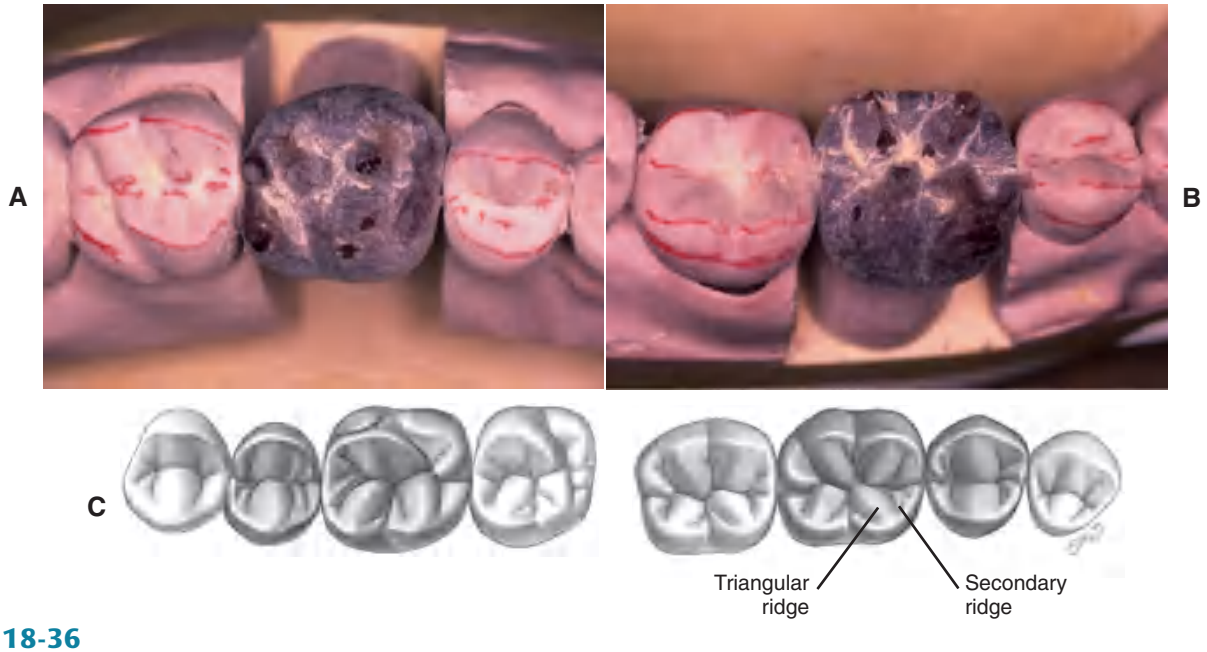


Fig. 18-36
Adding secondary ridges.



Fig. 18-37
A to **C,** Evaluating the completed wax patterns.



Fig. 18-38
Completed cusp-marginal ridge waxing. **A** and **B,** The occlusal contacts have been marked.

wax and the grooves carefully smoothed (see Fig. 18-28G). Initially, obtaining smooth transitions between the occlusal components may be difficult. Smoothing from the grooves onto the individual occlusal features, rather than back and forth, prevents unnecessary accumulations of wax residue in the grooves.

The occlusal surfaces are redusted with zinc stearate or powdered wax, and the occlusal contacts are checked. If a contact has inadvertently been polished away, it can be quickly reformed by adding a drop of wax, closing the articulator to verify that contact was restored, and subsequently reflowing and reshaping the occlusal feature to reestablish a convex contour.

Margin finishing

To optimize the adaptation of the wax pattern (and the cast restoration) to the die, the margins must be reflowed and refinished immediately before investing the wax pattern. The two principal objectives are (1) minimizing dissolution of the luting agent and (2) facilitating plaque control.

If a zone of superior adaptation (i.e., minimum marginal gap width) between the casting and the prepared tooth surface is created, cement dissolution is reduced.[27] To obtain this superior adaptation, the pattern should be reflowed over a band approximately 1 mm wide, measured from the margin onto the prepared surface (Fig. 18-39).

Plaque control is facilitated by producing cast restorations that exhibit a smooth transition from restoration to tooth without any sudden directional change. In addition, the axial surface of the restoration must be highly polished (see Chapter 29). Because the use of any metal polishing compound or abrasive results in removal of material, metal finishing procedures should be kept to a minimum near

the margin. The best way to prepare for this step is to ensure superior smoothness of the wax pattern when the reflowing process is complete. This should be verified under magnification with loupes or a binocular microscope.

Step-by-step procedure

1. Relubricate the die and reseat the wax pattern (Fig. 18-40*A*). Because of the time and attention devoted to developing occlusal and axial form, the margins of the pattern are not properly adapted at this stage. A large, well-heated waxing instrument is used to melt completely through the wax.
2. Push the heated instrument through the pattern and completely remelt the marginal 1 to 2 mm (Fig. 18-39).
3. Draw the instrument along the margin until resistance is felt because the instrument has begun to cool and no longer easily melts the wax.

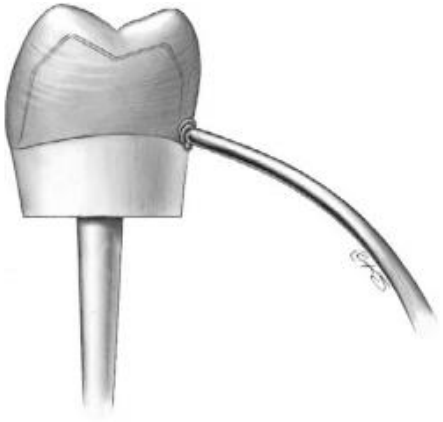


Fig. 18-39
Reflowing the margins. The objective is to create a well-adapted, 1-mm zone to prevent cement dissolution.

4. Reheat the instrument and repeat the procedure, always overlapping with the previously melted area to remelt it and to preclude internal folds, voids, and defects. When the entire margin has been reflowed circumferentially, a depression is seen around the margin as a result of the readaptation.
5. Fill the depression with additional wax (Fig. 18-40*B*).
6. Trim excess wax from beyond the margin (Fig. 18-40*C*).
7. Rectify any pits or defects in the axial surfaces, and smooth the wax pattern. Wax chips can be removed from the occlusal surface with a cotton pellet; however, the surface should not be rubbed. Otherwise, the occlusal contacts that were so carefully generated will be destroyed.

The wax pattern is removed from the die without distortion and may be replaced for final evaluation before investing. However, if the pattern is not repositioned in exactly the same direction as that in which it was removed, reburnishing of the margins may be necessary.

Evaluation

Being thorough at this stage will pay dividends later. Because of the wax pattern's color and glossy surface, small defects can be difficult to identify. If they are not noticed, a later remake may be necessary.

Avoid overwaxing. Very little finishing of a cast metal margin is possible without damaging the die. Any flash of wax that extends beyond the finish line *must* be trimmed at this stage. Otherwise, it will cause distortion as the pattern is removed, or it will prevent the cast metal restoration from completely seating. A gap between the wax and the die, resulting in an open margin, can be difficult to detect. The die should be oriented so that the observer's line of sight is precisely along the wax-die interface. If the

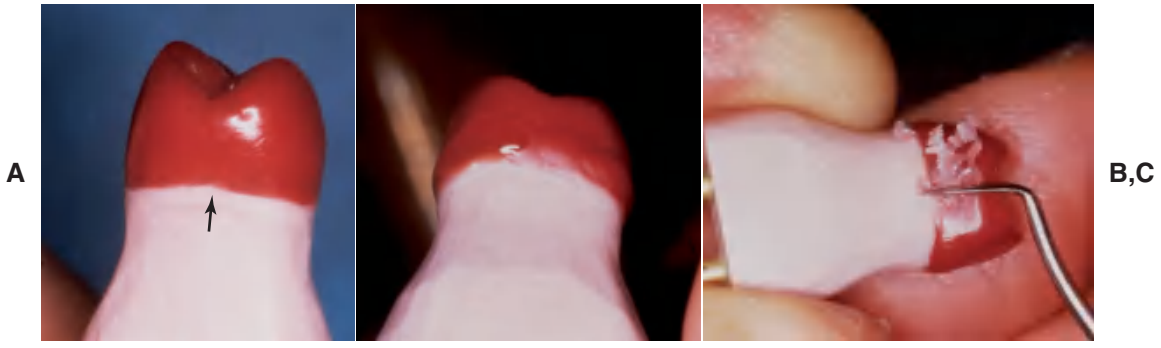


Fig. 18-40
Reflowing margins. **A,** After waxing, a marginal discrepancy is normally apparent (*arrow*). This must be corrected before investing. **B,** Use a large, well-heated instrument to melt completely through the wax. *Then* continue around the preparation margin; then add wax to fill the depression. **C,** When the pattern has cooled, carefully trim or burnish the marginal excess.

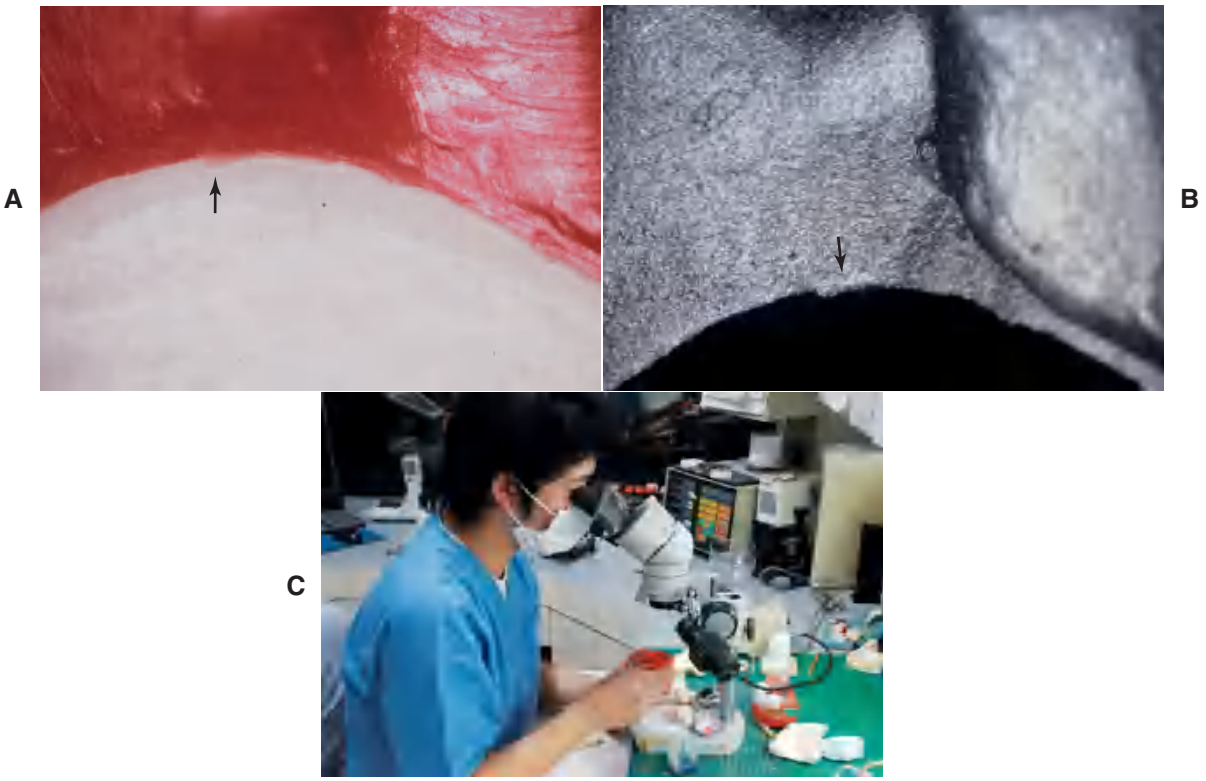


Fig. 18-41
Evaluation. Defects must be identified and corrected before investing. **A,** Marginal excess or flash (*arrow*) is difficult to see in wax but must be carefully removed. **B,** A small defect (*arrow*) is easier to see in the metal but harder to correct. **C,** Magnification is the most practical way to finish margins properly.

wax is not well adapted, a black shadow line will be visible. This is hard to see in wax but easier to see (but too late) in metal. A binocular microscope or loupe is very helpful for this stage (Fig. 18-41). To ensure that new debris has not accumulated during the finishing procedures, a final evaluation of the occlusal and axial surfaces is performed. The pattern is now ready for investing (see Chapter 22).

Waxing inlays and onlays

The sequence of steps for fabricating a wax pattern for an inlay or onlay is similar to that for a complete crown, although the unprepared tooth can often serve as a guide to axial and occlusal contour (Fig. 18-42). Sometimes manipulation of a small inlay can be difficult. One approach is to embed a loop of floss into the pattern for easier removal.

Anterior Teeth

The approach to waxing anterior teeth is slightly different than the approach to waxing posterior teeth. Anatomic contour waxing is recommended for metal-ceramic restorations, because there is better control over the thickness of porcelain and the smoothness of the metal-ceramic junction. When several anterior teeth are to be restored, a guide to the lingual and labial contours is essential (Fig. 18-43). The contour of the palatal and incisal surfaces significantly influences the articulation. They are most effectively recreated by using a custom anterior guide table (see Chapter 2). This can be made from diagnostic casts (if their initial form was satisfactory) or from a diagnostic waxing or cast made from an impression of interim restorations. The latter can be used when the interim restorations resulted in clinically satisfactory function and appearance. The shape of the anterior teeth affects the patient's speech, lip support, and appearance. They should be determined carefully and with as many diagnostic aids as necessary.

Lingual and incisal surfaces

The position of the incisal edges is determined by the overall arch form of the anterior teeth and the functional occlusal requirements (Fig. 18-44). As with waxing of posterior occlusal surfaces, cones can be used to initially delineate the approximate

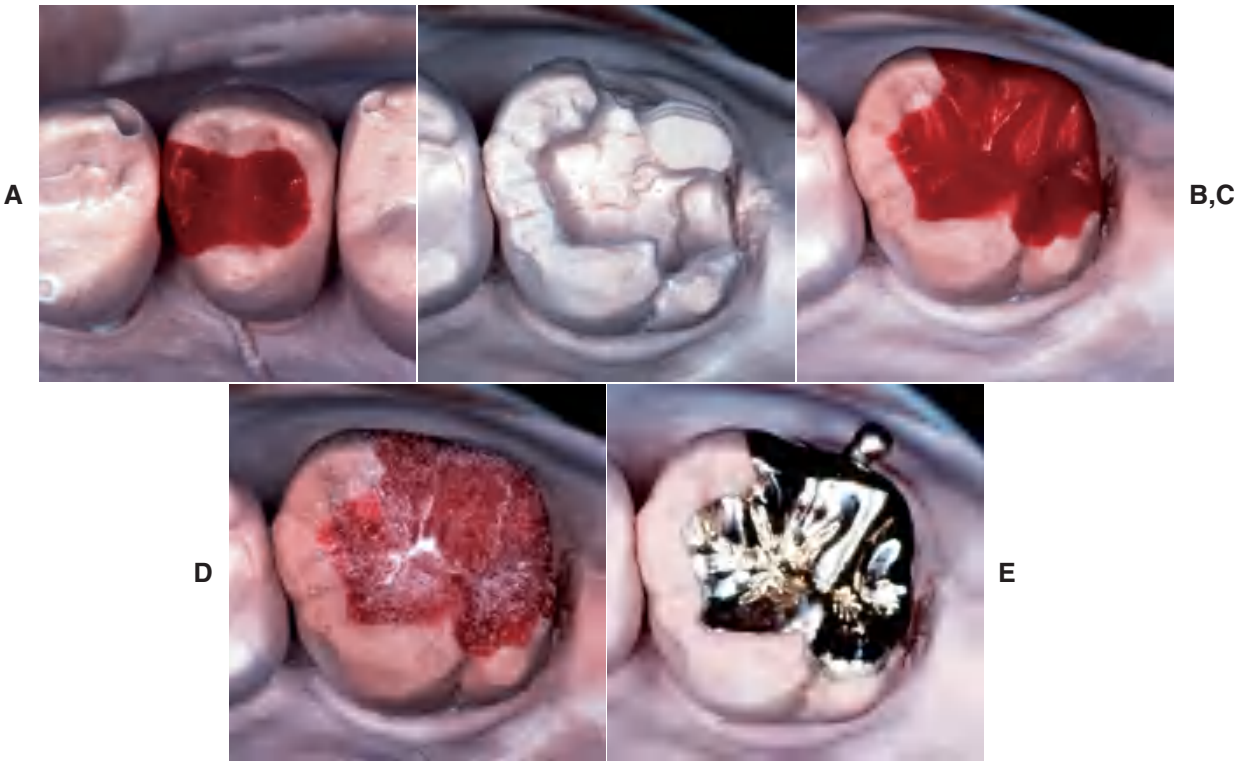


Fig. 18-42
Waxing inlay and onlay restorations. **A,** Mesio-occlusal inlay wax pattern. **B** to **E,** Disto-occlusal-buccal onlay wax pattern and casting.

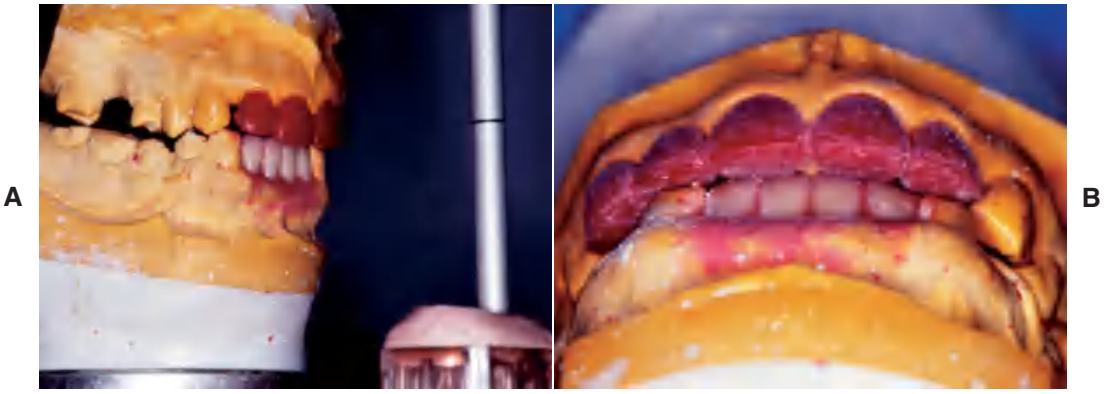


Fig. 18-43
A and **B,** Optimum contours for anterior restorations are developed with the aid of a custom anterior guide table (see Fig. 19-5).



Fig. 18-44
When the lingual surface of an anterior tooth is waxed, the contralateral tooth should be used as a guide.

position of the incisal edge. Additional wax can then be applied as necessary.

Opposing incisors should contact evenly during protrusive movements but not during lateral excursions. This is achieved by making a concavity in the lingual surface of maxillary incisors. The ability to make this concavity smooth is very important. As a result, the patient is given a smooth envelope of motion, and potential neuromuscular disturbances are avoided. In maximum intercuspation, anterior teeth ideally should be just out of contact. Mylar shim stock should just "drag" between the patterns. The lingual surfaces of mandibular incisors and canines are noncontacting surfaces. Nevertheless, they should be shaped for easy plaque control. They should not be overcontoured.

Labial surfaces

The shape of the labial surfaces, particularly the location of the mesiolabial and distolabial line angles, determines the appearance of anterior teeth (Fig. 18-45). If the labial surface is too bulbous, plaque control may be difficult, and there may be lingual tilting of the tooth caused by the force exerted by the upper lip. When individual anterior teeth are waxed, careful study of the embrasure form of adjacent teeth can be particularly helpful.

Wax Cut-Back

If a ceramic veneer is to be used, once the final contour of the wax pattern has been completed, the pattern is cut back over an even thickness—usually about 1 mm—to provide room for the porcelain fused onto the cast metal substructure (Fig. 18-46). The design and technique are discussed in Chapter 19.

Waxing Connectors

The connectors that join the separate components of a fixed dental prosthesis are created in wax just before the margins are finalized (Fig. 18-47). Whether the connectors are cast or soldered, they must be shaped in wax so that their size, position, and configuration are controlled precisely. Connector size is important primarily from a mechanical perspective. To ensure optimal strength, the connector should be as large as possible. However, from a biologic perspective, connectors should not impinge on the gingival tissues and should be at least 1 mm above the crest of the interproximal soft tissue. Embrasure form gingival to the connectors must enable optimal plaque control. The cervical aspect of the connector must be shaped to a smooth arch-like configuration. In esthetic areas (i.e., anterior fixed dental prostheses), connectors should be hidden behind the esthetic ceramic veneer. Therefore, connectors are often placed slightly lingually when connectors are waxed for anterior prostheses (Fig. 18-48). Connector form and design are discussed in detail in Chapter 28.

REVIEW OF TECHNIQUE

Figure 18-49 summarizes the steps for waxing to anatomic form.

1. The die is modified as necessary and lubricated (see Fig. 18-49*A*).
2. An initial coping is waxed, forming the internal surface (see Fig. 18-49*B*).
3. The proximal surfaces are developed, with correctly located contact areas (see Fig. 18-49*C*).
4. The axial surfaces are waxed. Overcontouring near the gingival margin must be avoided (see Fig. 18-49*D*).
5. The occlusal surfaces are developed with a wax addition technique, which makes it easier to determine the best location of cusps and occlusal contacts (see Fig. 18-49*E*).
6. The margins are reflowed, and the wax pattern is finished (see Fig. 18-49*F*).

SUMMARY

If the waxing procedure is followed in a sequential order, inexperienced but conscientious operators should have no problem achieving excellent results. With more experience, they can combine and modify some of these steps; however, waxing up teeth "from memory" is not advised. Even the most experienced technician should copy the shape of natural teeth rather than redesign them.

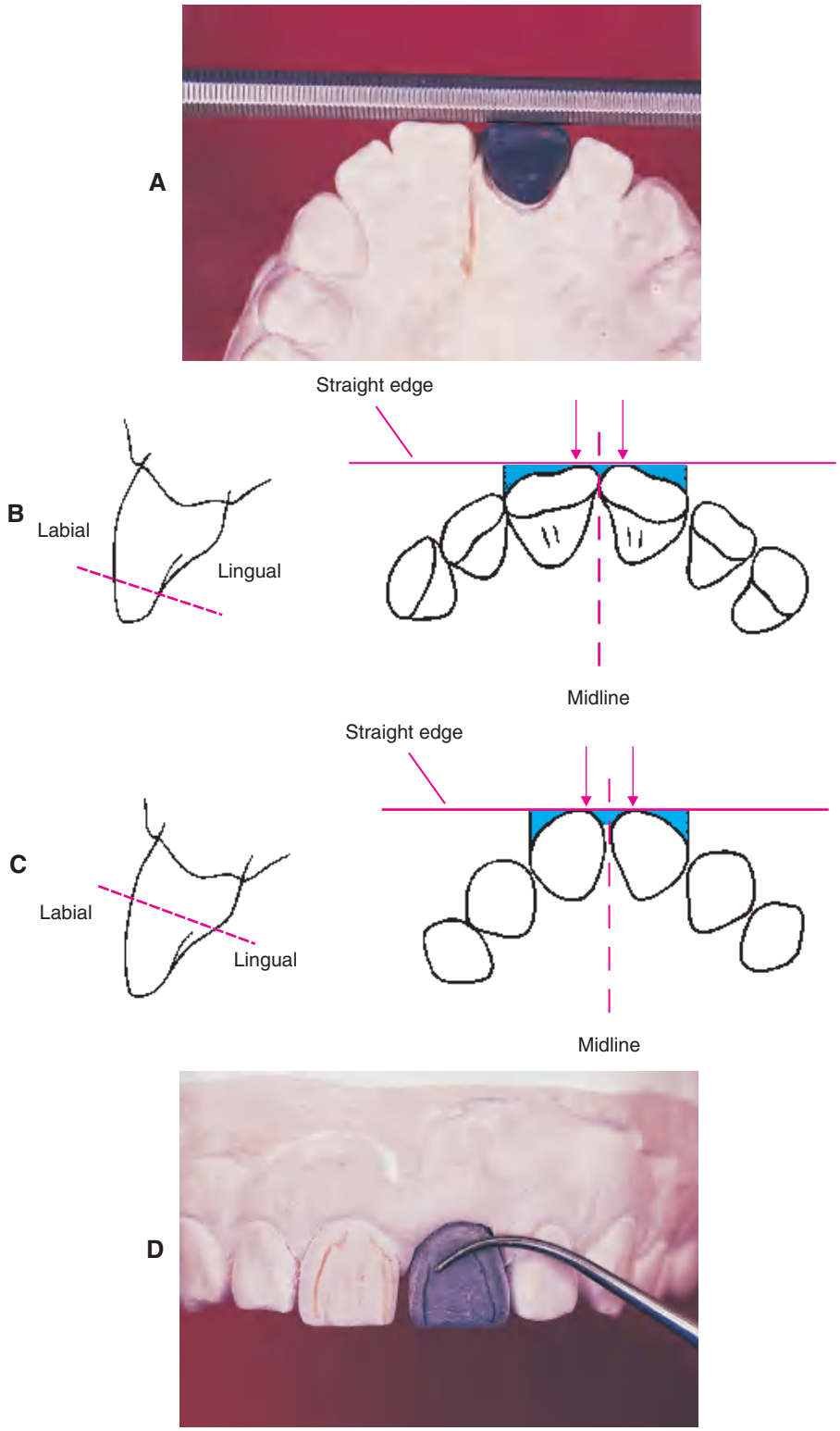


Fig. 18-45

Waxing the labial surfaces of maxillary incisors. Typically, the two central incisors should possess mirror symmetry around the midline. **A,** As the waxing progresses, symmetry can be judged by placing a straight edge near the incisal edge and exactly perpendicular to the palatal midline. **B,** The straight edge should contact each central incisor at precisely the same distance from the midline (*arrows*). The wax can be easily adjusted if proper contact does not occur. Then the spaces between the straight edge and the wax pattern (*blue areas*) are evaluated. The left and right teeth should be mirror images both mesially and distally. **C,** The straight edge is repositioned farther apically, and the analysis is repeated. Note how the form of the embrasures varies at the different locations. **D,** Dusting the wax pattern and marking the mesial and distal line angles. These should correspond to the line angles marked on the contralateral tooth.



Fig. 18-46
A to **D,** Wax patterns cut back to provide room for the porcelain. (See Chapter 19.)

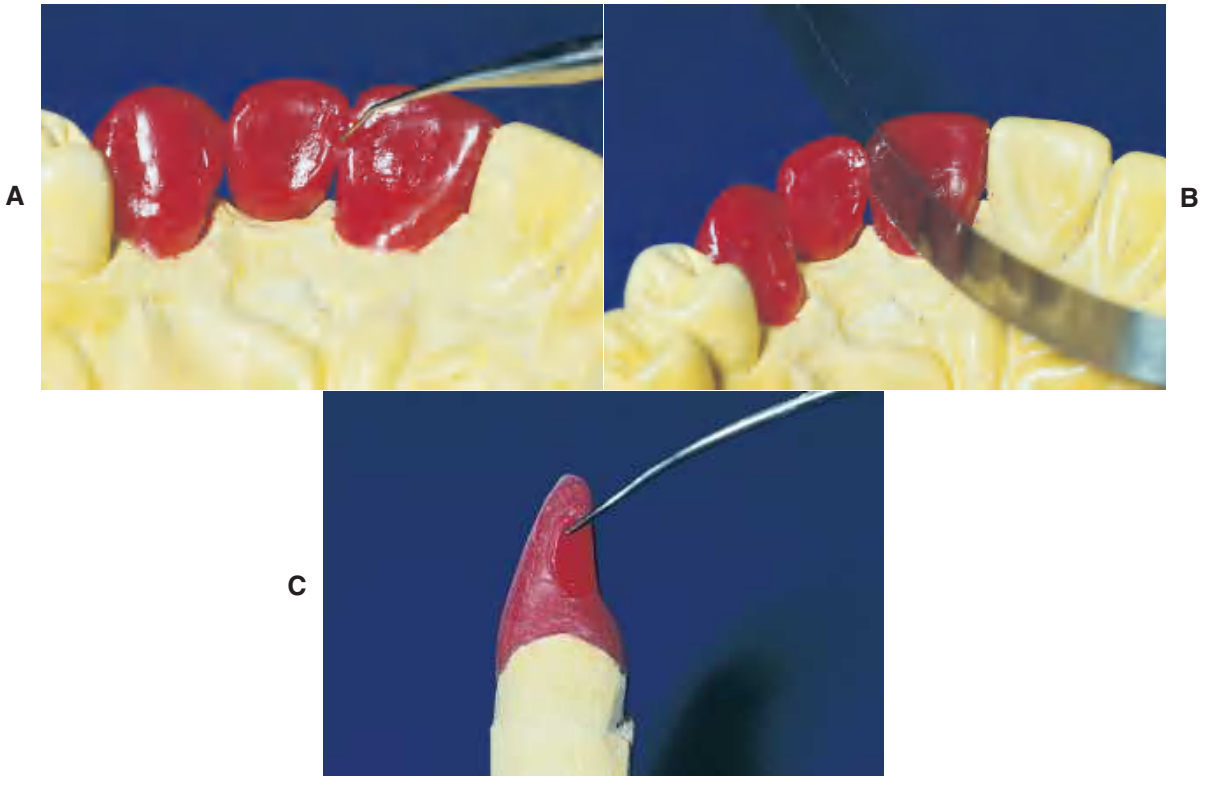


Fig. 18-47
Waxing connectors. **A,** The shape, size, and location of connectors can be controlled by forming them in wax. **B,** A ribbon saw is then used to section them. **C,** The correct cross-sectional configuration of an anterior connector.

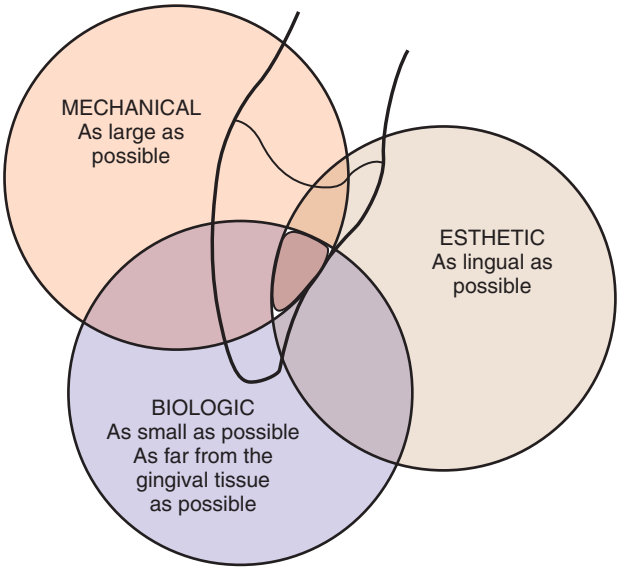


Fig. 18-48
Considerations for anterior connector placement. Mechanically, the connector should be as large as possible for strength. From a biologic perspective, the connector is most effectively placed in the incisal half of the proximal wall. For esthetics, the connector should be placed in the lingual (palatal) half of the proximal wall.

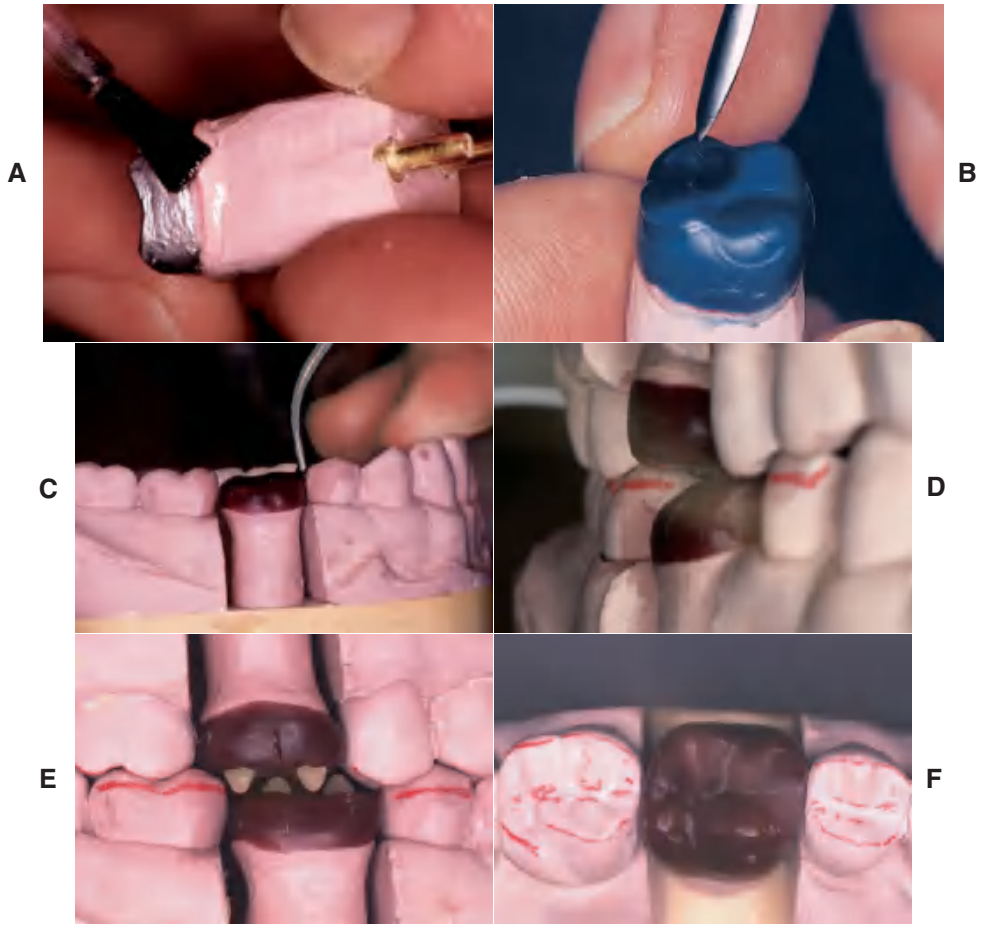


Fig. 18-49
Technique review. **A,** The die is modified as necessary and lubricated. **B,** An initial coping is waxed, forming the internal surface. **C,** The proximal surfaces are developed, with correctly located contact areas. **D,** The axial surfaces are waxed. **E,** The occlusal surfaces are developed with a wax addition technique. **F,** The margins are reflowed, and the wax pattern is finished.

STUDY QUESTIONS

1. Discuss and explain the various techniques used to reduce or increase the resulting luting agent space. What is considered a desirable cement space?
2. What are the primary components of inlay casting waxes? What is "memory," and how does it affect the various technical procedures?
3. What is the recommended procedure and sequence for waxing a complete cast crown on a mandibular first molar?
4. What is the best way to evaluate wax pattern adaptation and contour?
5. Discuss how the location of posterior proximal contacts changes as a function of tooth position in the arch.
6. What are the fundamental differences between the cusp-marginal ridge and cusp-fossa occlusal schemes? What are the primary reasons for selecting one scheme over the other? Does one have advantages over the other? If so, what are they?
7. Define the curve of Wilson and the curve of Spee. What is their importance as it relates to occlusal form?
8. Why is it necessary to wax connectors as a separate step in fixed dental prosthesis fabrication?

GLOSSARY*

adaptation \ăd′ăp-tā′shun\ *n* (1610)**: 1:** the act or process of adapting; the state of being adapted **2:** the act of purposefully adapting two surfaces to provide intimate contact **3:** the progressive adjustive changes in sensitivity that regularly accompany continuous sensory stimulation or lack of stimulation **4:** in dentistry, (**a**) the degree of fit between a prosthesis and supporting structures, (**b**) the degree of proximity of a restorative material to a tooth preparation, (**c**) the adjustment of orthodontic bands to teeth

anatomic crown \ăn′a-tŏm′ĭk kroun**:** the portion of a natural tooth that extends coronal from the cemento-enamel junction—called also *anatomical crown*

an·tag·on·ist \ăn-tăg′a-nĭst\ *n* (1599)**: 1:** a tooth in one jaw that articulates with a tooth in the other jaw—called also dental antagonist **2:** a substance that tends to nullify the actions of another, as a drug that binds to cell receptors without eliciting a biologic response **3:** a muscle whose action is the direct opposite of another muscle

anteroposterior curve \ăn-ter-o-pŏ-stîr′ē-or kûrv**:** the anatomic curve established by the occlusal alignment of the teeth, as projected onto the median plane, beginning with the cusp tip of the mandibular canine and following the buccal cusp tips of the premolar and molar teeth, continuing through the anterior border of the mandibular ramus, ending with the anterior most portion of the mandibular condyle. First described by Ferdinand Graf Spee, German anatomist, in 1890—see CURVE OF SPEE

bees' wax \bēz wăks′\ *n* (1676)**:** a low-melting wax obtained from honeycomb and used as an ingredient of many dental impression waxes

Bonwill triangle \Bŏn′wĭl trī′ăng′gl\ [William Gibson Arlington Bonwill, American dentist, 1833-1899]**:** *eponym* for a 4 inch equilateral triangle bounded by lines connecting the contact points of the mandibular central incisor's incisal edge (or the mid-line of the mandibular residual ridge) to each condyle (usually its mid point) and from one condyle to the other, first described by Bonwill in 1858 while introducing his Anatomical Articulator

casting wax \kăs′tĭng wăks**:** a composition containing various waxes with desired properties for making wax patterns to be formed into metal castings

centric stop \sĕn′trĭk stŏp**:** opposing cuspal/fossae contacts that maintain the occlusal vertical dimension between the opposing arches

curve of Monson \kûrv ŭv Mŏn-son\ [George S. Monson, St. Paul, Minnesota, U.S. dentist, 1869-1933]**:** *eponym* for a proposed ideal curve of occlusion in which each cusp and incisal edge touches or conforms to a segment of the surface of a sphere 8 inches in diameter with its center in the region of the glabella

Monson GS. Occlusion as applied to crown and bridgework. J Nat Dent Assoc 1920;7:399-417.

Monson GS. Some important factors which influence occlusion. J Nat Dent Assoc 1922;9:498-503.

curve of occlusion \kûrv ŭv a-klōō′shun**:** the average curve established by the incisal edges and occlusal surfaces of the anterior and posterior teeth in either arch

curve of Spee [Ferdinand Graf Spee, Prosector of Anatomy, Kiel, Germany, 1855-1937]**:** *eponym* for ANTEROPOSTERIOR CURVE

Spee FG. Die Verschiebrangsbahn des Unterkiefers am Schadell. Arch Anat Physiol (Leipz) 1890;16:285-94.

curve of Wilson [George H. Wilson, Cleveland, Ohio, U.S. dentist, 1855-1922]**: 1:** *eponym* for the MEDIOLATERAL CURVE **2:** in the theory that occlusion should be spherical, the curvature of the cusps as projected on the frontal

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plane expressed in both arches; the curve in the lower arch being concave and the one in the upper arch being convex. The curvature in the lower arch is affected by an equal lingual inclination of the right and left molars so that the tip points of the corresponding cross-aligned cusps can be placed into the circumferences of a circle. The transverse cuspal curvature of the upper teeth is affected by the equal buccal inclinations of their long axes

Wilson GH. A manual of dental prosthetics. Philadelphia Lea & Febiger, 1911:22-37.

cusp angle \kŭsp ăng′gal**:** the angle made by the average slope of a cusp with the cusp plane measured mesiodistal or buccolingually

cusp-fossa articulation scheme: an occlusal arrangement where the maxillary and mandibular centric cusps articulate with the opposing fossae in maximum intercuspation

cusp height \kŭsp hīt**:** the perpendicular distance between the tip of a cusp and its base plane

cusp-marginal ridge articulation scheme: an occlusal arrangement where the mandibular second premolar buccal cusp and mandibular molar mesiobuccal cusps articulate with the opposing occlusal embrasures in maximum intercuspation

cusp plane \kŭsp plān**:** the plane determined by the two buccal cusp tips and the highest lingual cusp of a molar

cusp plane angle \kŭsp plān ăng′gal**:** the incline of the cusp plane in relation to the plane of occlusion

die spacer \dī spās′er**:** an agent applied to a die to provide space for the luting agent in the finished casting

em·bra·sure \ĕm-brā′zher\ *n* (1702)**: I:** the space formed when adjacent surfaces flair away from one another **2:** in dentistry, the space defined by surfaces of two adjacent teeth; there are four embrasure spaces associated with each proximal contact area: occlusal/incisal, mesial, distal, and gingival

emergence profile \ĭ-mûr′jens prō′fīl**:** the contour of a tooth or restoration, such as a crown on a natural tooth or dental implant abutment, as it relates to the adjacent tissues

fossa \fŏs′a\ *n, pl* **fossae** \fŏs′ē′\ (1771)**:** an anatomical pit, groove, or depression

height of contour \hīt ŭv kŏn′tŏŏr′**:** a line encircling a tooth and designating its greatest circumference at a selected axial position determined by a dental surveyor; a line encircling a body designating its greatest circumference in a specified plane

intercuspal contact \ĭn′ter-kŭs′păl kŏn′tăkt**:** the contact between the cusps of opposing teeth

interproximal contact \ĭn′ter-prŏk′sa-mal kŏn′tăkt**:** the area of a tooth that is in close association, connection, or touch with an adjacent tooth in the same arch

lobe \lōb\ *n* (1525)**:** a curved or rounded projection or division, especially of a body organ or part

luting agent: any material used to attach or cement indirect restorations to prepared teeth

marginal ridge \mär′ja-nal rĭj**:** a component of the tooth structure forming the occlusal proximal margin of a premolar or molar

mediolateral curve \mē′dē-ō-lăt′ar-al kûrv**:** in the mandibular arch, that curve (viewed in the frontal plane) which is concave above and contacts the buccal and lingual cusp tips of the mandibular molars; in the maxillary arch, that curve (viewed in the frontal plane) which is convex below and contacts the buccal and lingual cusp tips of the maxillary molars

oblique ridge \ō-blēk′, a-blēk′ rĭj**:** the elevation in the enamel that runs obliquely across the occlusal surface of a maxillary molar

occlusal embrasure \a-klōō′zal, -sal ĕm-brā′zhar**:** the interdental space that is coronal to the contact area

occlusal pattern \a-klōō′zal, -sal păt′arn**:** the form or design of the masticatory surfaces of a tooth or teeth based on natural or modified anatomic or nonanatomic teeth

occlusal plane \a-klōō′zal, -sal plān**: 1:** the average plane established by the incisal and occlusal surfaces of the teeth. Generally, it is not a plane but represents the *planar mean* of the curvature of these surfaces **2:** the surface of wax occlusion rims contoured to guide in the arrangement of denture teeth **3:** a flat metallic plate used in arranging denture teeth—comp to CURVE OF OCCLUSION

occlusal surface \a-klōō′zal, -sal sûr′fas\ *obs***:** a surface of a posterior tooth or occlusion rim that is intended to make contact with an opposing occlusal surface (GPT-1)

occlusal table \a-klōō′zal, -sal tā′bal**:** the portion of the occlusal surfaces of posterior teeth that lies within the perimeter of the cusp tips and marginal ridges; the functional portion(s) of the occlusal surface(s) of a posterior tooth (teeth)

pat·tern \păt′urn\ *n* (14c)**:** a form that is used to make a mold; a model for making a mold—see OCCLUSAL P.

plane \plān\ *n* (1570)**:** a flat surface defined by three points—see AXIS ORBITAL P., CAMPER'S P., CORONAL P., CUSP P., FRANKFORT HORIZONTAL P., FRONTAL P., HORIZONTAL P., INCLINED P., MANDIBULAR P., MEDIAN P., OCCLUSAL P., SAGITTAL P.

separating medium \sĕp′a-rāt′ĭng mē′dē-am**: 1:** a coating applied to a surface and serving to prevent a second surface from adhering to the first **2:** a material, usually applied on an impression, to facilitate removal of the cast

supporting cusps \sa-pôrt′ĭng kŭsps\: those cusps or incisal edges of teeth that contact in and support maximum intercuspation. Usually facial cusps of the mandibular posterior teeth, the maxillary palatal cusps, and the incisal edges of the mandibular anterior teeth

tri·pod·i·za·tion \trĭp′a-dĭ-zā′shun\ *n*: an occlusal scheme characterized by a cusp to fossa relationship in which there are three points of contact about the cusp and opposing fossa with no contact on the cusp tip

wax \wăks\ *n* (bef. 12c): one of several esters of fatty acids with higher alcohols, usually monohydric alcohols. Dental waxes are combinations of various types of waxes compounded to provide desired physical properties—see BASEPLATE W., BOXING W., CASTING W., DENTAL IMPRESSION W., MODELING W.

wax expansion \wăks ĭk-spăn′shun\: a method of expanding a wax pattern to compensate for the shrinkage of gold during the casting process

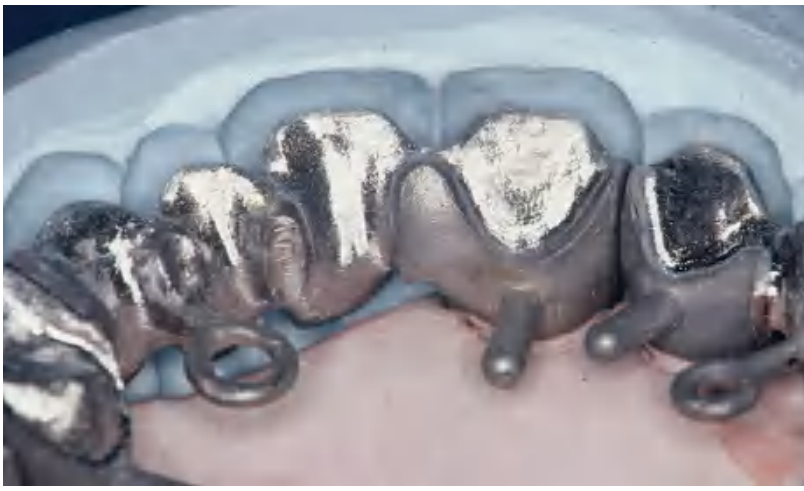
wax pattern \wăks păt′urn\: a wax form that is the positive likeness of an object to be fabricated

wax·ing \wăks′ĭng\ *v obs*: the contouring of a wax pattern or the wax base of a trial denture into the desired form (GPT-1)

REFERENCES

1. Frankfort H: The Art and Architecture of the Ancient Orient, p 26 ff. Harmondsworth-Middlesex, UK, Penguin Books, 1956.
2. Black GV: The technical procedures in filling teeth. In Operative Dentistry, vol 2. New York, Medico-Dental Publishing, 1924.
3. Cherberg JW, Nicholls JI: Analysis of gold removal by acid etching and electrochemical stripping. J Prosthet Dent 42:638, 1979. (Quoting BJ Parkins: The effect of electropolishing on the unprotected margins of gold castings. Thesis, Northwestern University, 1969.)
4. Fusayama T, et al: Relief of resistance of cement of full cast crowns. J Prosthet Dent 14:95, 1964.
5. Eames WB, et al: Techniques to improve the seating of castings. J Am Dent Assoc 96:432, 1978.
6. Byrne G: Influence of finish-line form on crown cementation. Int J Prosthodont 5:137, 1992.
7. Syu JZ, et al: Influence of finish-line geometry on the fit of crowns. Int J Prosthodont 1:25, 1993.
8. Campagni WV, et al: Measurement of paint-on die spacers used for casting relief. J Prosthet Dent 47:606, 1982.
9. Emtiaz S, Goldstein G: Effect of die spacers on precementation space of complete-coverage restorations. Int J Prosthodont 10:131, 1997.
10. Fukui H, et al: Effectiveness of hardening films on die stone. J Prosthet Dent 44:57, 1980.
11. Coleman RL: Physical properties of dental materials [U.S. Bureau of Standards research paper 32]. J Res Natl Bur Stand 1:867, 1928.
12. Council on Dental Materials, Instruments, and Equipment: Revised ANSI/ADA specification No. 4 for inlay wax. J Am Dent Assoc 108:88, 1984.
13. Kotsiomiti E, McCabe JF: Stability of dental waxes following repeated heatings. J Oral Rehabil 22:135, 1995.
14. Ito M, et al: Effect of selected physical properties of waxes on investments and casting shrinkage. J Prosthet Dent 75:211, 1996.
15. Jameson LM, Malone WFP: Crown contours and gingival response. J Prosthet Dent 47:620, 1982.
16. Burch JG: Ten rules for developing crown contours in restorations. Dent Clin North Am 15:611, 1971.
17. Burch JG, Miller JB: Evaluating crown contours of a wax pattern. J Prosthet Dent 30:454, 1973.
18. Stein RS, Kuwata M: A dentist and a dental technologist analyze current ceramo-metal procedures. Dent Clin North Am 21:729, 1977.
19. Perel ML: Axial crown contours. J Prosthet Dent 25:642, 1971.
20. Löe H, et al: Experimental gingivitis in man. J Periodontol 36:177, 1965.
21. Wheeler RC: Complete crown form and the periodontium. J Prosthet Dent 11:722, 1961.
22. Herlands RE, et al: Forms, contours, and extensions of full coverage restorations in occlusal reconstruction. Dent Clin North Am 6:147, 1962.
23. Payne EV: Functional occlusal wax-up. In Eissmann HF, et al, eds: Dental Laboratory Procedures, vol 2: Fixed Partial Dentures. St. Louis, Mosby, 1980.
24. Lundeen HC: Introduction to Occlusal Anatomy. Lexington, University of Kentucky Press, 1969.
25. Thomas PK: Syllabus on Full-Mouth Waxing Technique for Rehabilitation. San Diego, Instant Printing Service, 1967.
26. Shillingburg HT, et al: Guide to Occlusal Waxing, 2nd ed. Chicago, Quintessence Publishing, 1984.
27. Jacobs MS, Windeler AS: An investigation of dental luting cement solubility as a function of the marginal gap. J Prosthet Dent 65:436, 1991.
28. Monson GS: Occlusion as applied to crown and bridgework. J Natl Dent Assoc 7:399, 1920.
29. Monson GS: Some important factors which influence occlusion. J Natl Dent Assoc 9:498, 1922.
30. Spee FG: Die Verschiebrangsbahn des Unterkiefers am Schadell. Arch Anat Physiol (Leipz) 16:285, 1890.
31. Wilson GH: A Manual of Dental Prosthetics, pp 22-37. Philadelphia, Lea & Febiger, 1911.

19



FRAMEWORK DESIGN AND METAL SELECTION FOR METAL-CERAMIC RESTORATIONS

KEY TERMS

alloy
compressive stress
coping
creep
cut-back
ductility
elastic limit
hardness
modulus of elasticity
percentage elongation
proportional limit
tensile strength
tensile stress
toughness
yield strength

All patients want a pleasing smile, and so esthetics is an essential part of restorative practice, in which attention must be given to color, shape, surface texture, and proportion. Because anterior and maxillary posterior teeth are the most visible, they require the greatest attention to esthetic detail.

Tooth-colored restorative materials have evolved from the soluble silicate cements of the past to the composite resin materials and resin-modified glass ionomer cements of today. Currently, metal-ceramic prostheses are widely accepted and are the most commonly used extracoronal restoration.[1,2] They combine the superior fit of a casting with the outstanding esthetics of dental porcelain. Because the ceramic veneer is chemically bonded to the metal substructure, this restoration is not subject to the discoloration problems associated with acrylic resin veneer crowns and, when appropriate clinical and laboratory protocols are followed, excellent longevity can be predicted.[3] In addition, the material properties of dental porcelain are better able than resin to withstand wear under functional loading.

The concept of combining a brittle material with an elastic material to arrive at more desirable physical properties has many engineering applications.

Dental porcelains (which are, chemically speaking, glasses) resist compressive loading but tend to succumb to **tensile stress.** Therefore, the metal substructure must be designed so that any tensile stresses in the porcelain are minimized.

To avoid fracture, the thickness of a ceramic veneer must not exceed 2 mm; however, a minimum thickness of 1 mm is needed for an esthetically pleasing restoration.

Restorations with porcelain occlusal surfaces must be planned carefully. Although they are esthetically very acceptable, these restorations have disadvantages, especially wear of the opposing enamel.[4] Ideally, an esthetic restoration should wear at approximately the same rate as the enamel it replaces (about 10 µm per year[5]). In addition, the restoration should not increase the wear rate of an opposing enamel surface. Dental porcelain is more abrasive of enamel than of other restorative materials (e.g., gold or amalgam[6-10]) and has been implicated in severe occlusal wear, particularly when the porcelain is not glazed or highly polished (Fig. 19-1).[11] This factor should be considered whenever a metal-ceramic restoration is being designed,[12] and the practitioner should realize that although abrasiveness may be correlated with the composition of the ceramic material, the selection of a lower fusing ceramic (sometimes labeled by the manufacturer as "low-wear") does not necessarily mean less enamel wear.[13] Less wear on opposing teeth was cited as the most important need for improvement of posterior tooth-colored crowns.[1] In addition, porcelain occlusal coverage leads to restorations with lower strength,[14] and anatomically correct occlusal form with sharp cusps can be difficult to obtain in dental porcelain.

Some technicians may attempt to fabricate a framework by dipping the die into molten wax, obtaining an even thickness. After the excess wax is trimmed away, a gingival collar is added, and the pattern is sprued, invested, and cast. When this is completed, the veneer is then applied. This technique almost always produces an uneven porcelain thickness, with an increased potential for material fracture as a result of the porcelain's lack of proper support (Fig. 19-2). If porcelain thickness is not well controlled, appearance suffers as well, because the shade of the final crown depends on porcelain thickness.[15] For predictable success, the framework must be carefully designed and shaped.

PREREQUISITES

The framework design for a fixed prosthesis should be considered during the treatment planning stage (see Chapter 3) and should be evaluated at the diagnostic tooth preparation and waxing stages, particularly in more complex treatments. A properly



Fig. 19-1
A to D, Destructive enamel wear associated with metal-ceramic restorations. *(Courtesy of Dr. M. T. Padilla.)*

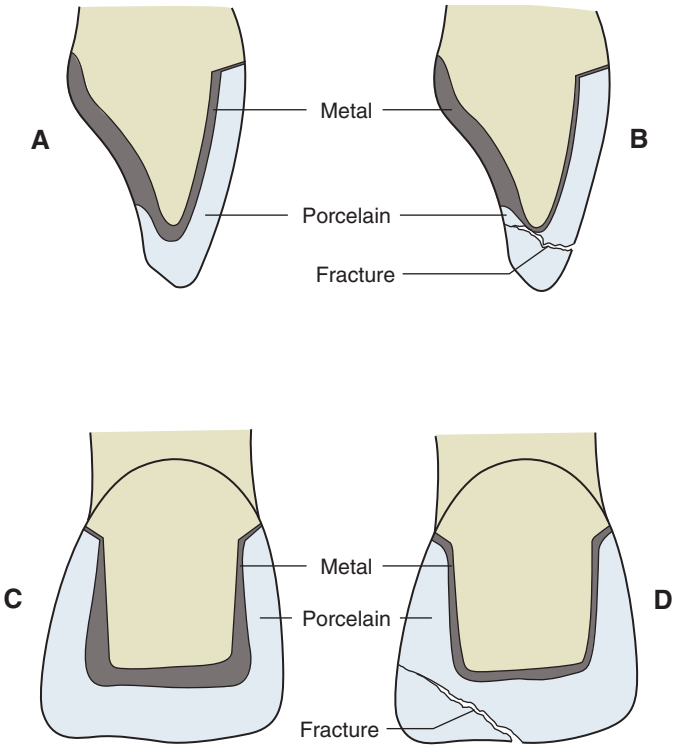


Fig. 19-2
A and **C,** Cross section through a metal-ceramic restoration. Ideal porcelain thickness is ensured by waxing to the full anatomic contour and cutting back. **B** and **D,** Incorrect framework design has insufficient support for the incisal porcelain. This can lead to fracture.

designed framework for a metal-ceramic crown or fixed dental prosthesis (FDP) can be achieved routinely only by waxing the restoration to complete anatomic contour first and then cutting back a consistent amount for the veneer. This allows an even thickness of porcelain, proper porcelain-metal interfaces, good connector design, and optimally placed occlusal contacts.

Waxing to Anatomic Contour

The main objective in waxing a framework is a substructure that supports a relatively even thickness of porcelain. Simultaneously, if the retainer is to serve as part of an FDP, it must allow for proper connector configuration and location. Furthermore, the restoration must conform to the normal anatomic configuration of the tooth that is being replaced. At the porcelain-metal interface, the ceramic material should be at least 0.5 mm thick. The framework should be shaped to allow for a distinct margin so that the porcelain is not overextended (Fig. 19-3). There should be no abrupt contour change between the metal and the adjacent porcelain.

The most effective way to consistently meet these criteria, with a minimum number of failures, is to develop the final contours of the proposed restoration in wax (Fig. 19-4). Once completed, the area to be veneered can be demarcated and an even thickness of wax removed. If this technique is not followed, one or more of the objectives is almost certainly missed, and the contours of the framework are not in harmony with the required ceramic configuration (Fig. 19-5).

Occlusal Analysis

The centric stops of any metal-ceramic restoration can be located on either porcelain or metal. However, they must be at least 1.5 mm away from the junction[16] to prevent porcelain fracture from deformation of the metal (Fig. 19-6). Care is needed to minimize sliding contacts over the porcelain-metal interface. When this is not possible, the framework must be modified so that the porcelain is well supported in the area of functional contact.

Existing restorations in the opposing arch can influence framework design. Because sliding contact of a porcelain restoration with a cast crown abrades the gold, the framework design must be modified as necessary. A complete cast crown in the mandibular arch presents little difficulty. It can be opposed by a maxillary restoration with only a metal occlusal surface and a facial ceramic veneer (Fig. 19-7). An existing metal crown on a maxillary molar, however, restricts the design of a mandibular metal-ceramic restoration if metal-to-porcelain contact is to be avoided (Fig. 19-8). Here the facial veneer can no longer be extended to include the buccal cusp tips and associated centric stops without contacting the opposing restoration. A complete cast crown is usually preferred because most patients do not show the facial surfaces of their mandibular posterior teeth. In other situations, particularly on mandibular first premolars, a facial veneer is esthetically essential, and the design of opposing restorations should allow for it (Fig. 19-9).

CUTTING BACK

The criteria for waxing to anatomic contour are discussed in Chapter 18. This section deals with cutting back the veneering area.

Armamentarium

- Bunsen burner
- Inlay wax
- Cloth

Text continues on page 595

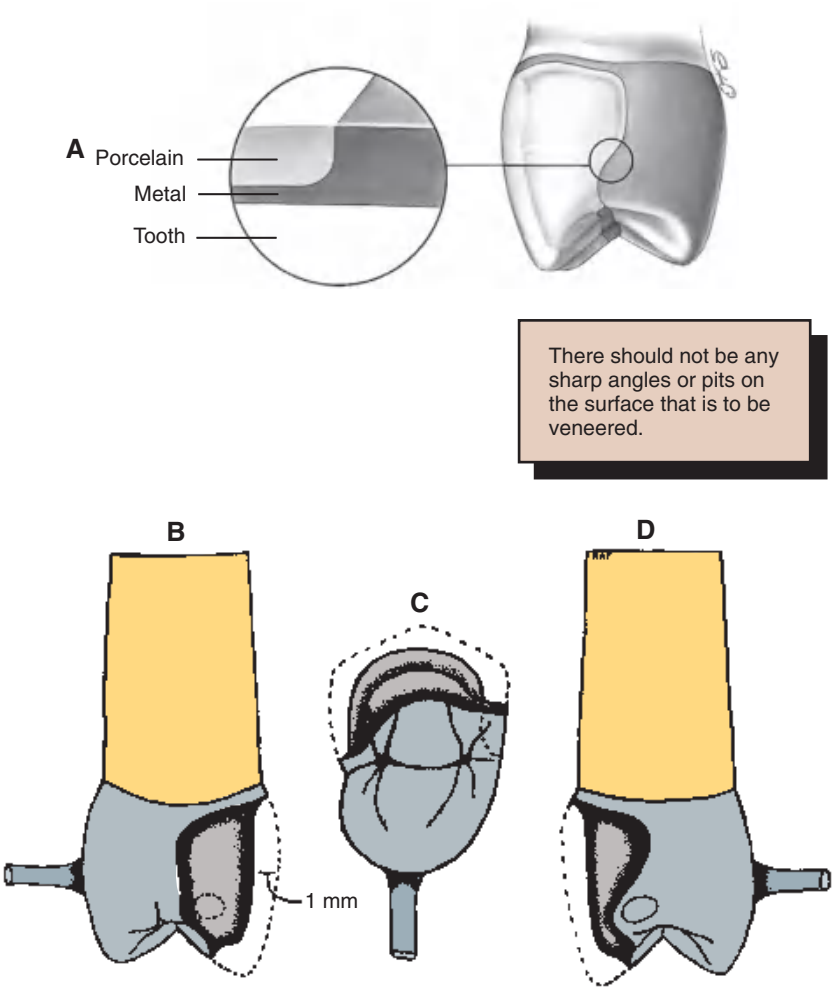


Fig. 19-3

A, The metal substructure should have a distinct margin for finishing the veneer. The location of the ceramic-metal interface varies, depending on the material chosen to contact adjacent and opposing teeth. **B,** Cutback for proximal contact in porcelain. **C,** Occlusal contact in metal. **D,** Proximal contact in metal. *(**B** to **D**, Courtesy of Dr. R. Froemling.)*



Fig. 19-4

A and **B,** Waxing anterior metal-ceramic restorations. **C,** Right lateral excursion. **D,** Left lateral excursion. **E,** The anterior guidance is determined with a custom table fabricated from the diagnostic waxing procedure.

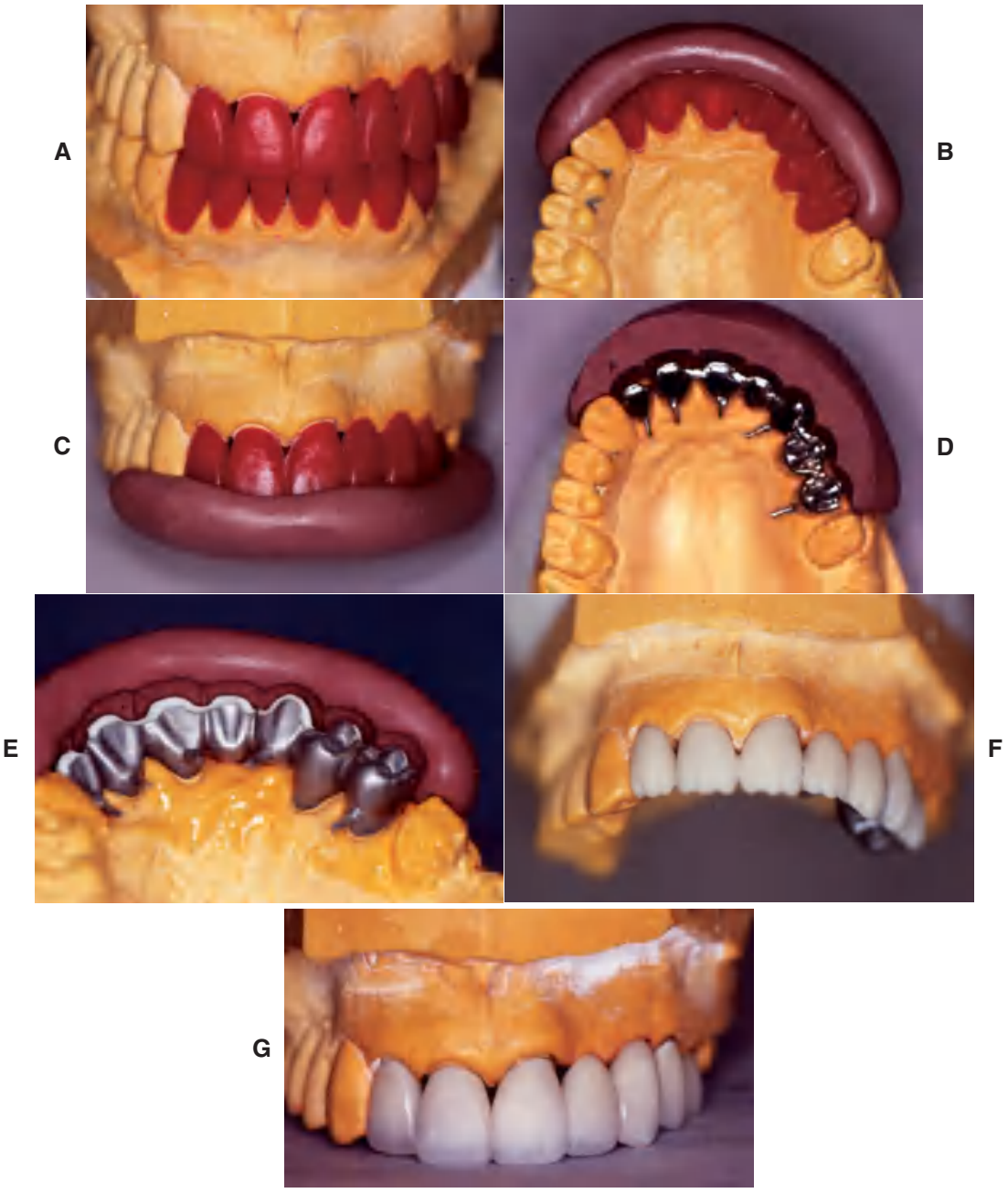


Fig. 19-5
Predictable esthetic result ensured by waxing to anatomic contour. **A,** Anatomic contour wax patterns. **B** and **C,** Incisal and labial indices were used to verify even cut-back. **D,** Cast substructures. **E,** The labial index is reused during porcelain application. **F,** The porcelain application. **G,** After contouring, the restorations are ready for clinical evaluation. The metal-ceramic restorations. *(Courtesy of Dr. M. Chen.)*



Fig. 19-6
A, The metal-ceramic junction must be carefully placed to avoid areas of high stress near occlusal contacts. **B,** Waxing to the anatomic contour ensures a smooth transition from porcelain to metal.

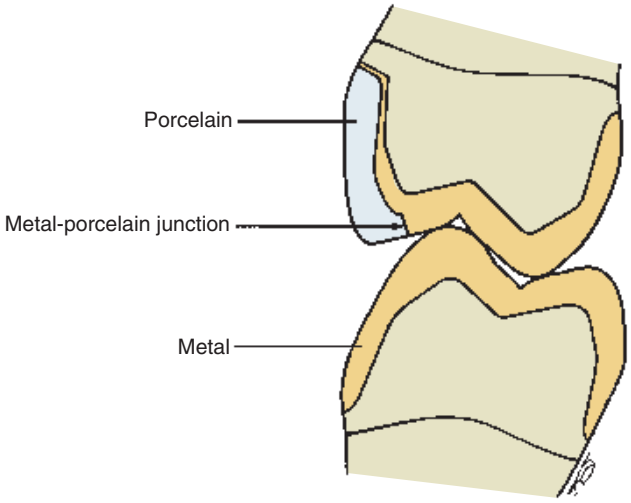


Fig. 19-7
The metal-ceramic restoration should be designed so that porcelain does not oppose an existing gold restoration. This presents few problems in the maxillary arch because the less visible lingual cusps are in cuspal contact.

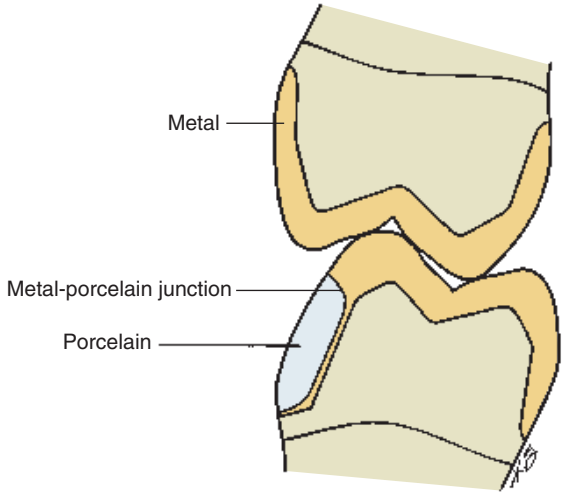


Fig. 19-8
In the mandibular arch, the functional cusps are visible, and only a buccal window of porcelain can be made without contacting an opposing metal crown. Under these circumstances, it must be decided whether the patient should accept an esthetic or functional compromise.

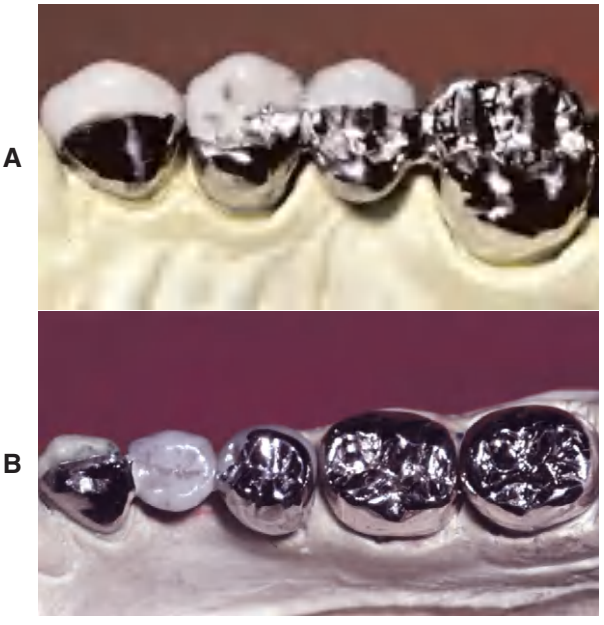


Fig. 19-9
A and **B,** Opposing restorations must be carefully planned so that contacting surfaces are of the same material (i.e., metal opposing metal, porcelain opposing porcelain).

- Sharp pencil
- Die-wax separating liquid
- Powdered wax
- Waxing instruments
- Nylon hose and silk cloth
- **Cut-back** instrument
- Scalpel
- Discoid carver
- Wax saw
- Waxing brushes

Step-by-Step Procedure

Designing the cut-back

Esthetic and functional needs govern the design of the veneering surface. The ceramic veneer should extend far enough interproximally, particularly in the cervical half of the restoration, to avoid metal display. Wherever possible, the functional occlusal surfaces should be designed in metal, because an accurate occlusion is then easier to achieve (Fig. 19-10).

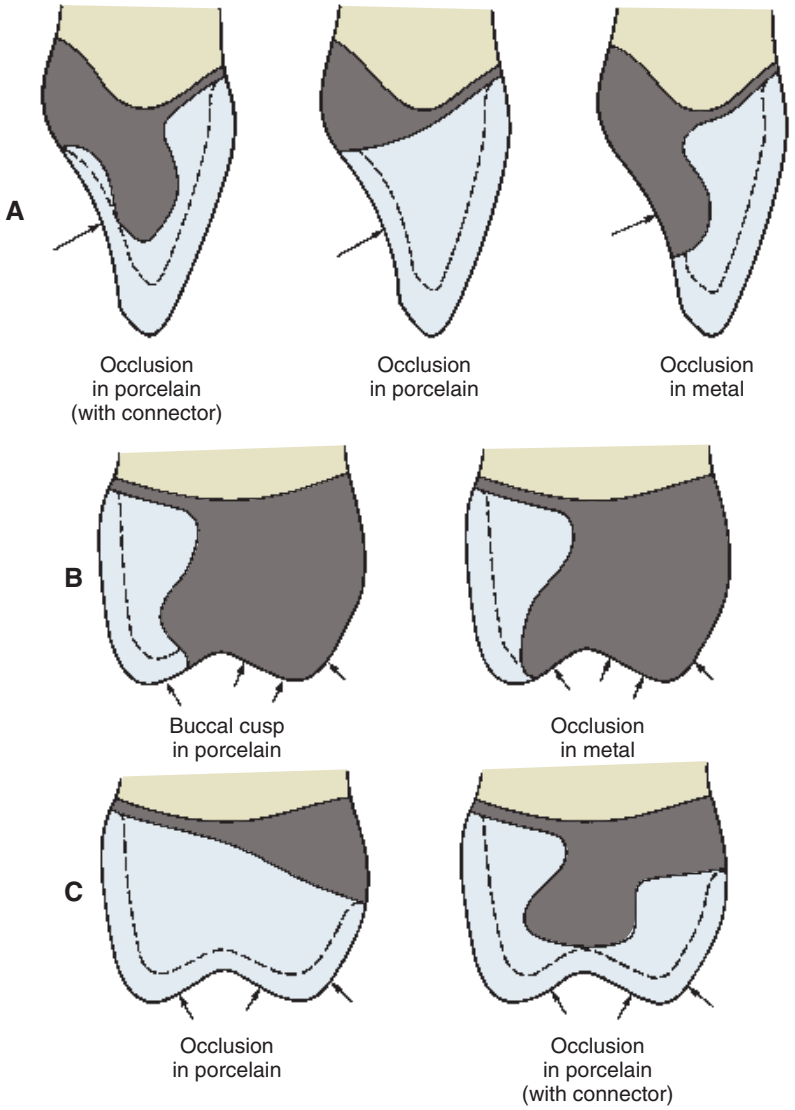


Fig. 19-10
Framework designs for a maxillary incisor (**A**) and a maxillary posterior tooth (**B**). The cut-back should be designed so the occlusal contacts are 1.5 mm away from the metal-porcelain junction. **C,** Framework designs for porcelain occlusal surfaces.

However, esthetic demands may require extension of the porcelain veneer (e.g., on the mesial incline of a mandibular buccal cusp). The extent to which a restoration can be veneered is determined largely by the location of the centric stops.

1. Do not place any proximal contacts on the junction between metal and porcelain. Plaque accumulation there may result in caries of the adjacent tooth. Normally, for good appearance and because it is more easily cleaned, proximal contacts are placed in porcelain. On some posterior teeth, however, where the interproximal area cannot be easily seen, a more conservative preparation may be possible, with the contacts entirely in metal (see Fig. 19-3*D*).
2. Once the extent of the cut-back area has been determined, use a sharp instrument (e.g., an explorer or scalpel) to mark a line delineating the porcelain interface.
3. Dust the pattern with powdered wax, and close the articulator to determine the location of the centric contacts.
4. Inspect the design to verify that the proposed junction is far enough away from the contacts (1.5 mm) to prevent distortion of the metal and porcelain fracture.

Troughing the pattern

Just as guiding grooves are used to mark the amount of substance to be removed in tooth preparation, depth cuts (*troughing*) can be used to standardize the amount of wax to be removed from the veneering area.

5. Modify an old or damaged hand instrument with a separating disk to serve as a cut-back instrument (Fig. 19-11).* The cutting edge should resemble the tip of a straight chisel. There should be a shoulder exactly 1 mm from the cutting edge.
6. Make depth cuts around the periphery of the cut-back area that are perpendicular to the surface of the wax pattern. Depending on the size of the cut-back area, one or more vertical and horizontal cuts can also be made.
7. Remove the islands in between with a scalpel or another carving instrument (Fig. 19-12*A* to *E*).

Finishing

8. Once the bulk reduction has been completed, smooth the veneering surface of the wax. This ensures a rounded design and minimizes the time spent on metal finishing. Sharp angles on the veneering surface concentrate stresses, which may lead to fracture of the restoration.[17] Smoothing is much easier in wax than in metal, although this is not always appreciated initially.
9. Finish the porcelain-metal interface to a 90-degree butt joint (Fig. 19-12*F* to *J*). Reflowing the margin is essentially the same as for conventional wax patterns (see Chapter 18).
10. Reestablish the collar (obliterated during reflowing) immediately before investing. Make it slightly thicker (approximately 0.5 mm) to ensure an undistorted complete casting (Fig. 19-13). When waxing for the porcelain labial margin technique (see Chapter 24), some technicians prefer to wax a collar and cut back the metal; others wax to the collarless shape, but care should be exercised to avoid distorting the fragile pattern.

Connector design

11. Establish the connectors in wax as described in Chapters 18 and 28. Properly shaped and positioned connectors are very important. If pre- or post-ceramic application soldering is planned, the patterns are separated with a fine saw.
12. If only a facial veneer is involved, make the connectors identical to those for a conventional restoration. If the incisal or occlusal aspect is involved in the porcelain veneer, do not displace the connector cervically, because access for oral hygiene will be impeded (Fig. 19-14).

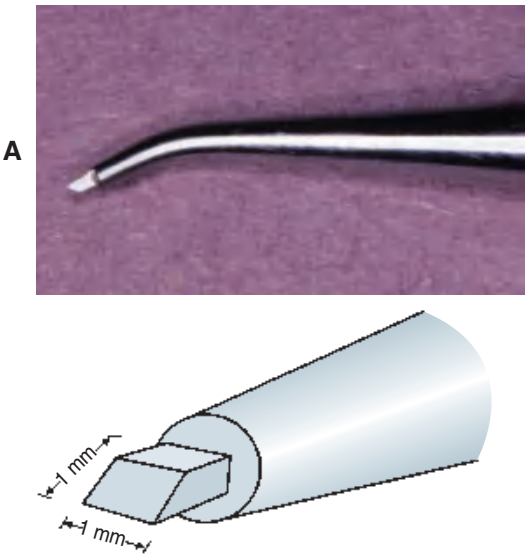


Fig. 19-11
A cut-back instrument can be readily made from a damaged hand instrument.

*A suitable instrument is available from Hu-Friedy Manufacturing Co., Inc, Chicago, Illinois.

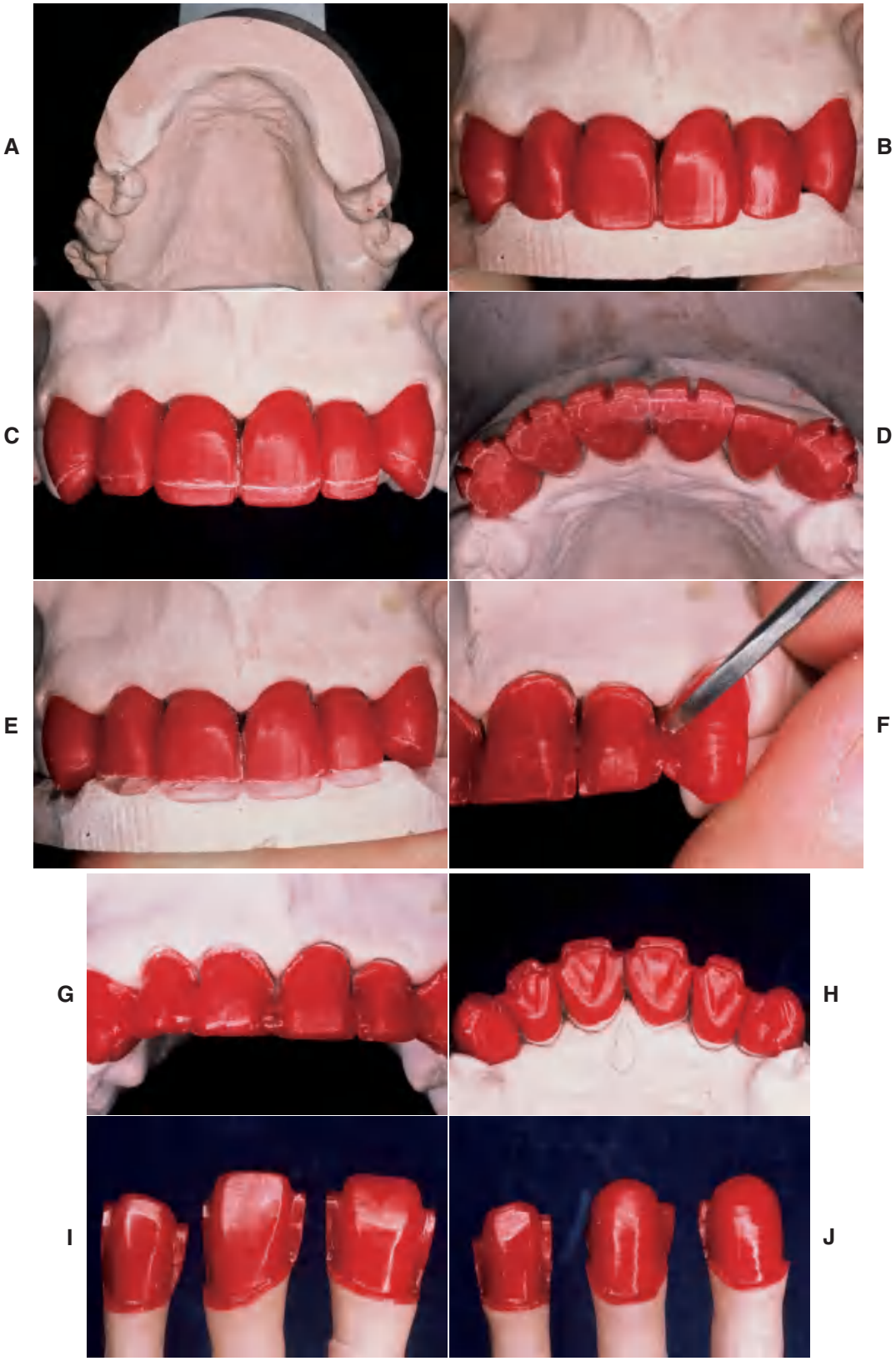


Fig. 19-12

Cut-back procedure. **A** and **B,** For extensive restorations, a matrix or index can be made to assist with the evaluation of the cut-back and subsequent porcelain application. **C,** It is important to follow the incisal contour carefully. **D,** Guiding troughs prepared in the area to be veneered. **E,** Wax is removed from between the troughs. **F,** The porcelain-metal interface is carved to a distinct butt joint. **G,** Note the correctly shaped proximal. These units will have soldered connectors. **H,** The finished cut-back. **I** and **J,** Patterns before reflowing of the margins.



Fig. 19-13
A, Margins reflowed. This ensures optimum adaptation of the wax pattern in the critical margin area. **B,** Patterns before investing.

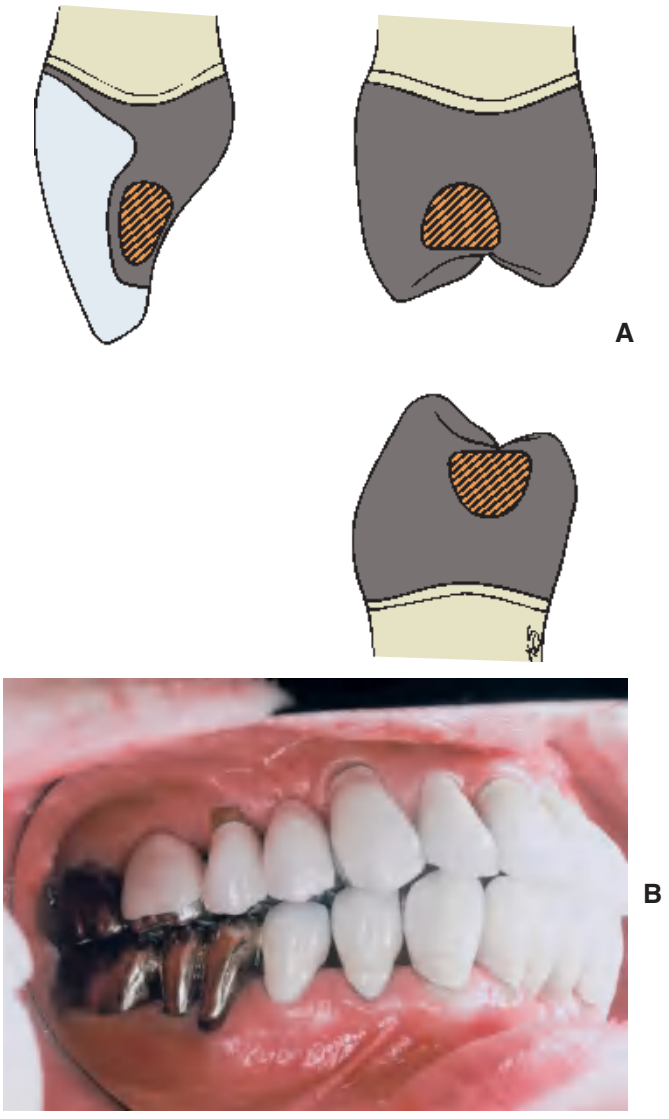


Fig. 19-14
A and **B,** Connectors should be located where they do not impede oral hygiene measures.

Pontics

13. Because glazed vacuum-fired porcelain is easy to keep clean, include the tissue-contacting surfaces of pontics in the veneering surface (Fig. 19-15).
14. To improve handling and stability of the wax pattern, be sure to cut back this area last (see Chapter 20).

Evaluation

Immediately before the investing stage, the following criteria should have been met:

1. The pattern should conform to normal anatomic form. Centric stops should be located at least 1.5 mm from the porcelain-metal junction.
2. The angle between the veneering surface and the metal framework should be 90 degrees.
3. The internal surface of the veneering area should be smooth and rounded.
4. The collar height should be about 0.5 mm in wax with connectors of adequate size, but it should not impinge on the soft tissue in the interproximal areas.
5. The pattern should be smooth, so that metal-finishing procedures are minimized.

METAL SELECTION

William A. Brantley
Leon W. Laub

Clinicians and dental laboratories face a potentially bewildering set of choices when selecting **alloys** for metal-ceramic restorations. Both noble metal and base metal casting alloys exist, and there are different alloy types for each of these two major groups. There are advantages and disadvantages for each alloy type, including significant differences in cost. Successful clinical practice depends on the selection



Fig. 19-15
A and **B,** The tissue contact on the pontics of this extensive fixed prosthesis was established in porcelain.



Fig. 19-16
Failure caused by improper material selection.

of a compatible metal-porcelain combination that provides predictable results, depending on the particular patient's case. Improper selection can cause catastrophic failure (Fig. 19-16). For a better understanding of the different properties provided on the packaging of casting alloys, the meanings and clinical relevance of these properties are discussed next.

Dental Connotations of Mechanical and Physical Properties for Ceramic Alloys

Mechanical properties of major clinical relevance are **modulus of elasticity, yield strength** (or **proportional limit**), **hardness,** and **creep** or distortion at elevated temperatures. Ultimate **tensile strength** (UTS), **ductility,** and **toughness** should also be reviewed, although these properties have less relevance for metal-ceramic restorations. Except for hardness (and elevated temperature creep or distortion), all these mechanical properties are determined by loading a cast specimen of the alloy to the point of failure in a tension test at room temperature. The physical property of thermal contraction is crucial in choosing an alloy that is compatible with the porcelain selected. From a practical standpoint, the density is important in both the economics of alloy selection and the dental laboratory procedure with the casting machine.

Modulus of elasticity

Figure 19-17 illustrates schematically the tensile stress-strain plot for a ductile casting alloy that undergoes substantial permanent deformation before fracture. This plot consists of two portions: (1) a linear or elastic region that ends at the proportional limit, where the stress is proportional to strain, and (2) a subsequent curved region corresponding to plastic or permanent deformation (which terminates when the test specimen fractures). The modulus of elasticity (also called *Young's modulus*) is the slope of the stress-strain plot in the elastic region. The elastic modulus has the same value for tensile and compressive strains, which occur during bending of a prosthesis, in which regions on opposite sides of the neutral axis (centerline for a symmetric cross section) undergo opposite senses of deformation. An alloy with a higher modulus of elasticity has greater stiffness or rigidity for elastic deformation. For the fabrication of a long-span FDP, an alloy with a relatively high modulus of elasticity to reduce the amount of bending deflection under loading is preferred, because excessive flexure can cause fracture of the brittle porcelain (Fig. 19-18). The modulus of elasticity has units of stress/strain and is reported for dental alloys in units of gigapascals (1 GPa = 10^9 Pa = 145,000 psi [pounds per square inch]). The unit of 1 Pa = 1 N/m^2 is much too small to be useful for the elastic modulus of materials.

Proportional limit and yield strength

In standard testing practice, the proportional limit of an alloy is determined by placing a straight edge on the stress-strain plot (or performing this operation

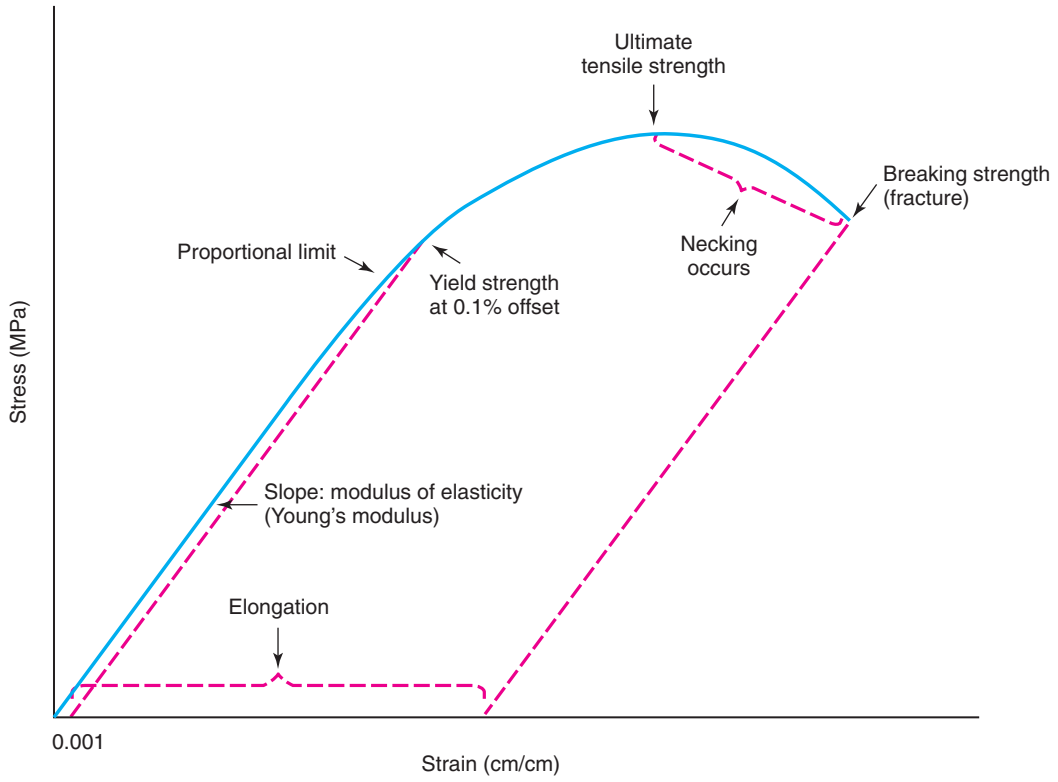


Fig. 19-17
Stress-strain curve.

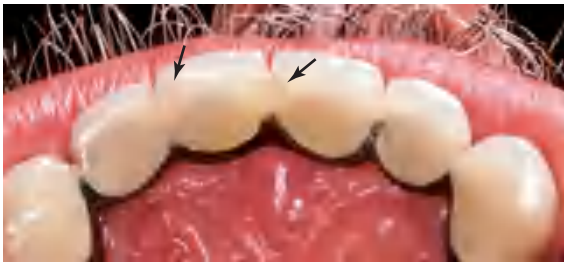


Fig. 19-18
Fracture (*arrow*) resulted from flexing of the substructure of this long-span partial fixed dental prosthesis.

with computer software) and noting the value at which the plot first deviates from a straight line. The proportional limit is often considered synonymous with the **elastic limit,** which corresponds to the value of stress at which permanent deformation occurs. However, the value of the elastic limit is highly dependent on the sensitivity of the strain-measuring apparatus. Moreover, precise location of the proportional limit on the stress-strain plot is somewhat problematic. Consequently, dental alloy manufacturers generally report the yield strength (sometimes called *offset yield strength*), which corresponds to the amount of stress for a very small designated amount of permanent deformation, at 0.1% or 0.2% (permanent strains of 0.001 or 0.002, respectively). The unit for yield strength is megapascal: 1 MPa = 10^6 Pa = 145 psi. As shown in Figure 19-17, the yield strength is obtained by constructing a line parallel to the initial straight-line portion of the stress-strain plot, starting with the specified value of offset on the horizontal strain axis and then noting the point of intersection with the curved portion of the plot. Because the 0.2% yield strength can be substantially higher than the 0.1% yield strength for a given alloy, depending on the rate of work hardening (slope of the curved portion of the stress-strain plot), manufacturers specify the offset value at which the yield strength was determined on the alloy packaging. The yield strength is often called the *useful strength* of a dental alloy, because stresses caused by biting forces should not exceed the yield strength and result in permanent deformation of the alloy. Although a sufficiently high value of yield strength is essential for a ceramic alloy, values that are too high create difficulties when the casting is adjusted in the dental laboratory or dental office.

Hardness

The Vickers hardness number (VHN) is generally measured for dental alloys by means of a symmetric diamond pyramidal indenter. The VHN is the quo-

tient of the indenting load and the surface area of the indentation, for which the square of the mean diagonal length is multiplied by a constant related to the indenter geometry. The Knoop hardness number (KHN), obtained with a diamond indenter having long and short axes, is sometimes reported for dental alloys. For the KHN, only the length of the long diagonal of an indentation is measured, and the indenting load is divided by the unrecovered projected area of the indentation. Harder alloys, which have smaller indentations, have higher VHN and KHN values. Conversion scales available for the two different hardness tests should be used with caution, because such conversions are alloy dependent. Both the VHN and KHN are measures of the microhardness, in contrast to the older Brinell and Rockwell tests, in which much larger indenters are used to measure the macrohardness. When measuring the Vickers hardness of an alloy, an understanding of the microstructure is crucial. Use of the large indenting load of 1 kg stipulated in standards for dental alloys provides information about the overall hardness of the alloy microstructure, whereas light indenting loads (e.g., 10 g) can be used to obtain information about the hardness of individual grains, constituents, or phases. The hardness is an important practical property, inasmuch as very high values of hardness cause difficulty in the dental laboratory when the casting is ready to be finished. Alloys with VHN or KHN values exceeding that of enamel (approximately 350) cause abrasive wear of opposing teeth.

Elevated-temperature creep and distortion

Castings undergo elevated-temperature dimensional changes during the porcelain firing cycles. These changes have many causes, such as bulk creep of the alloy from several metallurgical mechanisms, distortion of the alloy as a result of the relief of residual stresses from the casting process, and alloy oxidation. The latter may be higher for high-palladium and other alloys that undergo internal (bulk and grain boundary) oxidation with the formation of oxide precipitate particles, in addition to the formation of an external oxide layer. Measuring the dimensional changes that occur in alloys during the porcelain bonding sequence is tedious, but concern has been expressed about the clinical fit for castings prepared from certain alloys. Nevertheless, in most cases, an experienced dental laboratory should be able to vary techniques and obtain successful results.

Ultimate tensile strength

The UTS (also called *tensile strength* or simply *strength*) is the maximum point on the stress-strain curve (see Fig. 19-17) and represents the greatest value of stress that can be developed in the alloy without fracture. The unit of measure for UTS is megapascal. Two types of stress-strain curves are observed for tensile testing of casting alloys. Alloys of high ductility undergo substantial necking between the UTS and the breaking strength, as shown in Figure 19-17. Other alloys of more limited ductility undergo much less necking, and the stress continues to increase after the yield strength until fracture occurs at the UTS. The UTS has minimal practical importance for a ceramic alloy, because the corresponding permanent strain does not occur under clinical conditions for a restoration. Nevertheless, this property is easy to measure, inasmuch as a strain-gauge extensometer does not need to be attached to the specimen, and manufacturers often quote the UTS.

Percentage elongation

For metals, the ductility—the capability of undergoing permanent tensile deformation—is measured in two ways when the test specimen is loaded to fracture: as percentage elongation or as reduction in area. For dental alloy castings, the ductility is measured as the percentage of permanent elongation of the starting gauge length, after the two portions of the fractured specimen are placed back together. This is done because the castings typically fracture on inclined planes whose locations are determined by porosity, and a well-defined area for the fracture surface is not available for measurement of the reduction in area. Obtaining precise registration of the two fractured portions and defining the location of the original gauge length are difficult, and therefore determining the percentage elongation to better than the nearest 1% is difficult to achieve, although values to the nearest 0.1% have been quoted. In principle, the percentage elongation can be obtained during the stress-strain test if a breakaway extensometer is attached to the specimen. However, such extensometers are rarely available in dental materials laboratories. Figure 19-17 exaggerates the more important elastic range of the stress-strain curve, inasmuch as the values of percentage elongation for current casting alloys used for porcelain veneering generally exceed 10% (Table 19-1). It is instructive to draw the stress-strain plots for some alloys listed in Table 19-1, because it is readily seen that the region of permanent deformation is much more extensive on the strain axis than the region of elastic deformation. When considering the ease of adjustment for cast restorations, the practitioner must remember that both yield strength and percentage elongation are involved.[18] Alloys with high yield strength

TABLE 19-1 ALLOYS FOR PORCELAIN VENEERING

	HIGH-NOBLE METAL											
	GOLD-PLATINUM-PALLADIUM (AU-PT-PD)				GOLD-PALLADIUM-SILVER (AU-PD-AG)				GOLD-PALLADIUM (AU-PD)			
	Jelenko O (Heraeus Kulzer)	**Image 2 (DENTSPLY Ceramco)**	**Will-Ceram Y (Ivoclar Vivadent)**	**Argedent Y86 (Argen)**	**Cameo (Heraeus Kulzero)**	**Veritas (DENTSPLY Ceramco)**	**Will-Ceram W-2 (Ivoclar Vivadent)**	**Argedent 52 (Argen)**	**Olympia (Heraeus Kulzer)**	**Eclipse (DENTSPLY Ceramco)**	**Will-Ceram W-3 (Ivoclar Vivadent)**	**Argedent 65SF (Argen)**
Composition (weight %)	Au 87.3 Pt 4.5 Pd 5.9 Ag 1.0	Au 84.5 Pt 6.9 Pd 5.0 Ag 1.0	Au 84.0 Pt 7.1 Pd 5.7 Ag 1.5	Au 86 Pt 10 Pd 1.9 In 2	Au 52.4 Pd 26..9 Ag 16.0 In 2.5 Sn 2.0	Au 40.0 Pd 45.0 Ag 5.0	Au 44.8 Pd 40.5 Ag 5.9 In 3.3 Sn 2.2 Ga 1.8	Au 52.5 Pd 26.9 Ag 16 In 2.5 Sn 2	Au 51.5 Pd 38.4 In 8.5 Ga 1.5	Au 52.0 Pd 37.5	Au 48.7 Pd 39.6 In 10.6	Au 65 Pd 26 In 8.7
Yield strength (MPa)	480	670	440	470	450	420	540	590	550	580	500	550
($\times 10^3$ psi)	70	97	64	68	65	62	78	86	80	83	72	80
Modulus of elasticity (GPa)	93	–	–	76	130	–	–	120	120	–	–	120
($\times 10^6$ psi)	14	–	–	11	19	–	–	17	17	–	–	17
Ultimate tensile strength (MPa)	550	–	–	530	690	–	–	690	790	–	–	690
($\times 10^3$ psi)	80	–	–	77	100	–	–	100	120	–	–	100
Elongation (%)	5	7	10	9	12	40	20	10	20	23	17	15
Hardness: Vickers hardness number (VHN)	200	230	170	200	240	230	200	220	260	250	220	250
Density (g/cm^3)	18.2	18.0	17.4	18.4	14.1	13.0	13.4	14.2	13.7	13.8	13.8	15.2

	NOBLE METAL							
	PALLADIUM-SILVER (PD-AG)				PALLADIUM-COPPER-GALLIUM (PD-CU-GA)			
	Jelstar (Heraeus Kulzer)	**Applause (DENTSPLY Ceramco)**	**Will-Ceram W-1 (Ivoclar Vivadent)**	**Argelite 55 (Argen)**	**Liberty (Heraeus Kulzer)**	**Option (DENTSPLY Ceramco)**	**Spartan Plus (Ivoclar Vivadent)**	**Argelite 76+ (Argen)**
Composition (weight %)	Pd 59.8 Ag 28.0 Sn 6.0 In 6.0	Pd 54.9 Ag 35.0	Pd 53.3 Ag 37.7 Sn 8.5	Pd 55 Ag 34 In 6 Sn 3 Zn 1	Pd 75.9 Cu 10.0 Ga 5.5 Sn 6.0 Au 2.0	Pd 79 Cu 10 Ga 9* Au 2 B ≪ 1*	Pd 78.8 Cu 10.0 Ga 9.0 Au 2.0 B 0	Pd 75.7 Cu 7.5 Ga 6.3 In 8 Au 1.8
Yield strength (MPa)	440	590	480	720	690	900	800	1100
($\times 10^3$ psi)	64	86	70	100	100	130	120	160
Modulus of elasticity (GPa)	120	–	–	120	140	–	–	130
($\times 10^6$ psi)	18	–	–	17	20	–	–	19
Ultimate tensile strength (MPa)	660	–	–	970	1,000	–	–	1,300
($\times 10^3$ psi)	95	–	–	140	140	–	–	190
Elongation (%)	18	10	11	10	20	23	20	16
Hardness: Vickers hardness number (VHN)	220	240	240	330	340	420	310	320
Density (g/cm^3)	10.7	10.8	11.1	11.1	10.7	10.6	10.7	11.2

Table **9-1—cont'd**

	Noble Metal			Predominantly Base Metal				
	Palladium-Gallium (Pd-Ga)			Nickel-Chromium (Ni-Cr)			Cobalt-Chromium (Co-Cr)	
	Legacy (Heraeus Kulzer)	**Protocol (Ivoclar Vivadent)**	**Argelite 80 + 5 (Argen)**	**Argeloy NP (Argen)**	**Argeloy NP (Be-Free) (Argen)**	**Will-Ceram Lite-Cast (Ivoclar Vivadent)**	**Genesis II (Heraeus Kulzer)**	**Argeloy NP Special (Argen)**
Composition (weight %)	Pd 85.2 Ga 10.0 In 1.1 Au 2.0	Pd 75.2 Ga 6.0 In 6.0 Au 6.0 Ag 6.5	Pd 79.9 Ga 6.3 In 6.5 Au 5 Ag 1.8	Ni 76 Cr 14 Mo 6 Al 2 Be 1.8	Ni 54 Cr 22 Mo 9 Fe 4 Nb 4 Ta 4	Ni 68.5 Cr 15.5 Mo 14.0 Al 1.0	Co 52.6 Cr 27.5 W 12.0 Ru 2.5 Ga 2.5 Cu 1.0 Fe 1.0	Co 59.5 Cr 31.5 Mo 5 Si 2 Mn 1
Yield strength (MPa) ($\times 10^3$ psi)	720 100	500 72	590 86	550 80	360 52	310 45	520 75	450 65
Modulus of elasticity (GPa) ($\times 10^6$ psi)	130 19	– –	120 17	190 28	– –	– –	170 25	– –
Ultimate tensile strength (MPa) ($\times 10^3$ psi)	930 140	– –	810 120	1,100 160	580 84	– –	760 110	760 110
Elongation (%)	25	34	33	12-15	6-7	28	15	9
Hardness: Vickers hardness number (VHN)	280	240	260	240	240	180	350	280
Density (g/cm^3)	10.9	11.0	11.5	7.8	8.6	8.5	8.8	8.8

Notes: Composition information was obtained from manufacturer websites except as noted. Small amounts (<1 wt. %) of grain-refining elements (ruthenium, iridium, and rhenium) in noble alloys and other elements are not shown. Mechanical properties are taken from websites and correspond to the porcelain-fired or hardened condition, or equivalently testing according to American National Standards Institute/American Dental Association Specification No. 38/International Organization for Standardization (ISO) Standard 9693. Yield strength values generally correspond to 0.2% offset, and values of mechanical properties have been rounded to two significant figures to reflect the level of accuracy for experimental measurement. No values for modulus of elasticity and ultimate tensile strength are now provided for some alloys because of difficulty in determining accurate values for the former and lack of clinical relevance for the latter.

Heraeus Kulzer (Armonk, New York; www.heraeus-kulzer-us.com) now markets the former Jelenko alloys.

DENTSPLY Ceramco (York, Pennsylvania; www.ceramco.com) now markets the former Ney alloys.

DENTSPLY Austenal (York, Pennsylvania; www.austenal.dentsply.com) also markets Ni-Cr and Co-Cr alloys for ceramic veneering, but detailed compositions and mechanical properties are not given on the website.

Ivoclar Vivadent (Amherst, New York; www.ivoclarvivadent.us.com) now markets the former Williams/Ivoclar alloys.

Argen (San Diego, California; www.argen.com) has purchased the division of Pentron Corporation that made dental alloys. The alloys in this table are different from those in the third edition.

*The amount of gallium in Option is not provided on the DENTSPLY Ceramco website but is known to be approximately 9% from Carr and Brantley.[20] The very low amount of boron was provided in a private communication with the manufacturer.

Al, aluminum; B, boron; Be, beryllium; Fe, iron; In, indium; Mn, manganese; Mo, molybdenum; Nb, niobium; Ru, ruthenium; Si, silicon; Sn, tin; Ta, tantalum; W, tungsten; Zn, zinc.

cannot be burnished by hand, even if they have high values of percentage elongation.

Toughness

Historically, toughness, which is the total area under the stress-strain curve, was considered an important property of casting alloys. However, with the focus on stresses that do not exceed the yield strength, this property no longer receives as much attention. The toughness represents the total energy per unit volume necessary to fracture the alloy and has units of stress × strain, or megapascals. For an alloy that does not work harden greatly and has substantial ductility, toughness is approximately equal to UTS × elongation. Determining toughness from stress-strain plots is laborious, and manufacturers do not report this property.

Thermal expansion/contraction

The linear coefficient of thermal expansion is a crucial property for an alloy that is to be bonded to dental porcelain. These coefficients should be closely matched to within about 0.5×10^{-6}/° C below the glass transition temperature of the porcelain (approximately 500° to 600° C, depending on the cooling rate), at which the ceramic can no longer undergo viscous flow to relieve thermal incompatibility stresses. The thermal contraction coefficient (α), generally assumed to be the same as that for thermal expansion, should be slightly higher for the metal so that the ceramic is in a state of beneficial residual **compressive stress** at room temperature. Values of α typically range from 13.5 to 14.5×10^{-6}/° C for metals and 13.0 to 14.0×10^{-6}/° C for porcelains.

Density

Density is the ratio of mass to volume; specific gravity is the ratio of the density of a substance to the density of water. Densities for the important types of noble and base metal casting alloys are provided in Table 19-1. The high-gold content alloys have much higher densities than the low-gold content, palladium-based, and base metal casting alloys. This is because gold has a much higher density (19.3 g/cm^3) than palladium (12.0 g/cm^3), nickel (8.9 g/cm^3), and cobalt (8.8 g/cm^3). These differences in density have two consequences. First, for cast restorations of the same size and configuration, less mass of metal is required for the lower density alloy; the difference in the metal cost for a restoration can be substantial when both the unit metal cost and the density difference are considered. Second, additional winding of the spring on the centrifugal casting machine is necessary to achieve the needed casting pressure for the lower density alloys.

Available Alloy Systems

The nomenclature for dental casting alloys usually creates confusion. Classifying noble and base metal casting alloys according to the mechanism for corrosion resistance is the preferred method of categorization. The gold-based and palladium-based noble metal casting alloys achieve corrosion resistance because of the inherent nobility of the gold and palladium atoms, which do not form stable oxides at room temperature. In contrast, the conventional base metal casting alloys, in which nickel and cobalt are the principal elements and chromium is present to provide corrosion resistance, oxidize rapidly to form a passivating chromium oxide surface layer that blocks the diffusion of oxygen and prevents corrosion of the underlying metal.

Historically, terms such as *precious, semiprecious,* and *nonprecious* have been used to describe dental casting alloys. Such precious or semiprecious alloys usually contained a greater quantity of silver, along with more palladium and a reduced gold content. Silver, which is not a noble metal in the oral environment, assumes some noble metal character in the presence of palladium. The terms *precious, semiprecious,* and *nonprecious,* which refer to unit metal cost, are now less preferable than the terms *noble* and *base* metals, which refer to the electrochemical character of the alloys.

The major noble metals in dental alloys are gold, platinum, and palladium. (The other noble metals are iridium, ruthenium, rhodium, and osmium.) The total percentage of gold, platinum, and palladium in a dental alloy is referred to as the *noble metal content.* Iridium (much less than 1% by weight) and ruthenium (up to about 1%) are used as grain-refining elements in gold-based and palladium-based casting alloys, respectively. The original metal-ceramic alloy compositions (e.g., Jelenko "O," described in Table 19-1) had approximately 98% noble metal content by weight. Rapid increases in the price of gold during the 1970s stimulated the development of lower gold content (from about 85% to 50% by weight) alloys and base metal alloys for fixed prosthodontics.[19] During the 1980s, the high-palladium alloys were developed as economic alternatives to the gold-based alloys.[20*]

*In January 2006, the price of palladium was approximately $275 per Troy ounce, in comparison with a price of approximately $555 per Troy ounce for gold. In January 1997, the price of palladium was $120 an ounce, which increased to approximately $1000 per ounce by January 2001 and then began to decline thereafter. The corresponding rapid increases in palladium dental alloy prices caused many problems for alloy selection by dentists and the dental laboratory industry.

Table **19-2 CLASSIFICATION FOR DENTAL CASTING ALLOYS**

	Noble metal content: Au, Pt, Pd (minimum percentage by weight)
High-noble metal	60% (>40% gold)
Noble metal	25% (no gold requirement)
Predominantly base metal	<25% (no gold requirement)

Au, gold; Pd, palladium; Pt, platinum.

A classification system[21] developed by the American Dental Association for casting alloys is presented in Table 19-2 and includes alloys for all-metal and metal-ceramic restorations. Because the classification is based solely on noble metal content and ignores other, often crucial alloying elements, general statements cannot be made about mechanical properties, clinical performance, and biocompatibility, even within each of the three groups in Table 19-2. Hundreds of dental alloys are commercially available, and appropriate testing is necessary to characterize the properties, safety, and efficacy of each. However, when each of these major groups is further subdivided into alloy types, some accurate generalizations are possible. They are discussed in the following sections.

High-noble metal alloys

The high-noble metal content alloys contain a minimum of 60% by weight of noble elements; at least 40% is gold. There are three systems in this class: gold-platinum-palladium (Au-Pt-Pd), gold-palladium-silver (Au-Pd-Ag), and gold-palladium (Au-Pd), in the historical order of their development. Table 19-1 lists some mechanical properties and the density for representative alloys of each system.

Au-Pt-Pd

As previously noted, these were the first casting alloys formulated to bond with dental porcelain. Because of concern about adverse effects on the color of dental porcelain, copper, which was traditionally used for strengthening the high-gold casting alloys for all-metal restorations, could not be incorporated in the ceramic alloy compositions. Instead, these alloys were strengthened by precipitates of an iron-platinum (Fe-Pt) intermetallic compound.[22] Porcelain adherence was achieved by incorporating tin and indium in the alloys, in addition to the contribution from iron. During the initial alloy oxidation step for the porcelain firing cycles, tin and indium (as well as some iron) diffused to the alloy surface and became oxidized. Subsequent chemical bonding was achieved between this oxide layer and the dental porcelain (see Chapter 24). Although these alloys have excellent corrosion resistance, they are susceptible to some dimensional changes during the porcelain firing cycles and are not recommended for multiple-unit FDP restorations.

Au-Pd-Ag

These were the first lower gold content alternative alloys to be widely used in the 1970s. Platinum was eliminated from the alloy compositions, and the gold content was reduced to about 50%, with corresponding increases in the amounts of palladium and silver.[23,24] Some alloy strengthening was achieved by solid solution hardening from the dissimilar atomic sizes of the three major elements (gold, palladium, and silver), which form solid solutions with each other. Additional solid solution strengthening was hypothesized to be caused by tin or indium, which were again incorporated as oxidizable elements to provide porcelain bonding. Further alloy strengthening may be caused by precipitates formed by these elements. Although these alloys have excellent mechanical properties and porcelain adherence, green discoloration (resulting from diffusion of silver atoms into the porcelain) has been reported for some alloy-porcelain combinations.[25] Possible reasons for this effect may be the high sodium concentration of the porcelain or the relative sizes of the metal ions in the porcelain. The discolored region can be ground away, but this involves an additional processing step. In addition, silver vapor generated in the porcelain furnace during processing can contaminate the muffle, and periodic purging of the furnace with a carbon block is required. Green discoloration has apparently been eliminated in some porcelain compositions by substituting potassium ions for sodium ions; the larger potassium ions impede the diffusion of silver into the porcelain.

Au-Pd

Gold-palladium alloys that are silver-free were developed during the late 1970s and have become very popular. Alloy strengthening is achieved with a combination of solid solution hardening and microstructural precipitates. The hardness (assumed to be related to strength) of these alloys is independent of heat-treatment temperature within the porcelain-firing range, unlike that of Au-Pd-Ag alloys.[24] The Au-Pd alloys have excellent mechanical properties, elevated-temperature creep behavior,[26] and porcelain adherence,[27] without the green discoloration associated with Au-Pd-Ag alloys.

Discussion

The data in Table 19-1 show that the Au-Pd and Au-Pd-Ag alloys, in comparison with the Au-Pt-Pd alloys, generally have higher values of yield strength and

modulus of elasticity, along with lower density. Consequently FDP restorations fabricated from alloys in the former two groups are more resistant to masticatory forces and undergo less bending deflection. They also have the economic advantage of providing more restorations per unit of alloy cost. Selection of the proper porcelain for Au-Pd-Ag alloys is essential if discoloration problems are to be avoided.

Noble metal alloys

The noble metal alloys have a minimum of 25% by weight of noble metal, with no requirement for gold percentage. There are three alloy systems in this class: palladium-silver (Pd-Ag), palladium-copper-gallium (Pd-Cu-Ga), and palladium-gallium (Pd-Ga), in the historical order of their development. Table 19-1 lists some mechanical properties and the density for representative alloys of each system.

Pd-Ag

These alloys, developed in the 1970s, continued the trend by manufacturers of reducing the gold content (to between 0% and 2% by weight), with corresponding increases in the palladium and silver contents.[28] A small percentage of gold in these alloys and the high-palladium alloys has little effect on their properties but may facilitate third-party payments. As previously noted, in the presence of palladium, silver appears to assume noble metal character, which is beneficial for corrosion resistance. Because of their high silver content (approximately 30% to 35% by weight), these alloys have been called *semiprecious,* a term that should no longer be used. In comparison with the Au-Pd-Ag and Au-Pd alloys, the Pd-Ag alloys have similar values of yield strength and modulus of elasticity and much lower density values. Because of their high silver contents, porcelain greening and furnace contamination can result during fabrication of partial FDP restorations, unless the porcelain is carefully selected. Nevertheless, these alloys are frequently chosen as a compromise between the more expensive high-noble alloys and the relatively inexpensive base metal alloys.

Pd-Cu-Ga

The Pd-Cu-Ga alloys contain more than 70% by weight of palladium and were developed in the early 1980s as economical alternatives to the gold-based alloys.[20] The melting point of palladium (1555° C) is much higher than that of gold (1064° C); gallium has a melting point of 30° C. The addition of gallium to palladium yields high-palladium alloys that can be fused and cast with the same dental laboratory technology developed for the gold-based casting alloys. Multiorifice torches are necessary to fuse the high-palladium alloys, and the use of ceramic crucibles dedicated to individual alloys is recommended.[20] Carbon-containing investments should not be used, because the incorporation of very small amounts of carbon in these alloys degrades the bond strength with porcelain.[29] The Pd-Cu-Ga alloys appear to have casting accuracy comparable with that of the high-noble metal alloys.[30]

Measurements[31,32] of the mechanical properties of some Pd-Cu-Ga alloys have produced values of yield strength, modulus of elasticity, and percentage elongation that differ from values in Table 19-1. This suggests some technique sensitivity in the fabrication of cast specimens for the tension test. Although a near-surface eutectic structure was present in Pd-Cu-Ga alloy castings that simulated **copings** for maxillary incisors,[20] this constituent was absent in the 3-mm diameter cast specimens for the tension test.[31,32] Some Pd-Cu-Ga alloys have hardness values comparable with or exceeding that of tooth enamel, and castings from these alloys may be difficult to finish in the dental laboratory. In addition, chairside adjustments may be difficult for patients. However, substitution of indium for tin yields Pd-Cu-Ga alloys with much lower hardness (VHN ≈ 270).[33] All these alloys achieve substantial hardening by solid-solution incorporation of other elements within the palladium crystal structure. The hardest Pd-Cu-Ga alloys (VHN > 300) contain a hard grain boundary phase whose composition is close to that of Pd_5Ga_2.[33] Transmission electron microscopic studies indicate that representative high-palladium alloys have the same bulk ultrastructure.[34] Analyses of x-ray diffraction patterns have revealed that oxidized Pd-Cu-Ga alloys have complex internal oxidation regions that can contain up to five different oxide phases.[35] Oxides of copper, gallium, tin, indium, and even palladium that were formed under the conditions present in the porcelain furnace were subsequently detected in the oxidized alloys at room temperature. The results of creep experiments on the Pd-Cu-Ga alloys have been mixed.[26] The creep rates associated with relatively high thermal incompatibility stresses near the glass transition temperature of dental porcelain were high for two Pd-Cu-Ga alloys, whereas these alloys had excellent creep resistance at high temperatures and low stresses simulating the deflection of a long-span FDP as a result of gravity during processing.

Pd-Ga

The copper-free Pd-Ga alloys were subsequently developed during the 1980s to provide compositions with lower hardness than that of the initial Pd-Cu-Ga formulations. The hard Pd_5Ga_2 phase is absent in these alloys, which are strengthened by solid solution hardening.[33] The alloys have a complex fine precipitate structure at the grain

boundaries,[20,36] and their mechanical properties are generally more similar to those of Pd-Ag alloys than to the Pd-Cu-Ga alloys. In comparison with the Pd-Ga alloys, porcelain adherence is superior for the Pd-Cu-Ga alloys.[27] A palladium-gallium-cobalt (Pd-Ga-Co) alloy[37] has a particularly dark oxide that is more difficult to mask with dental porcelain, and this alloy did not achieve widespread clinical acceptance.

Discussion

In one study in which the dimensional changes at various stages of the simulated porcelain firing cycles were compared for copings for metal-ceramic single-unit restorations of selected high-palladium alloys, investigators found that most of the selected high-palladium alloys had acceptable high-temperature distortion.[31,38] Because of the considerable price volatility for palladium since the mid-1990s, dentists and dental laboratories have tended to select gold-palladium, palladium-silver, and lower gold content alloys, rather than high-palladium alloys. Currently, the unit metal cost of gold is substantially higher than that of palladium, and high-palladium alloys again have a significant economic advantage over gold-palladium alloys. When the high-palladium alloys were introduced in the 1980s, the unit metal cost was between half and one third of the Au-Pd alloys.[20] However, caution is needed with the Pd-Ag alloys to prevent porcelain from acquiring green discoloration. Some biocompatibility concerns have been raised about the high-palladium alloys, particularly in Germany with the Pd-Cu-Ga alloys. Review articles[39,40] suggest that there are minimal health hazards associated with the high-palladium alloys, and this has been borne out by extensive research[41] involving cell culture[42,43] and animal implantation[44] methods.

Predominantly base metal alloys

Table 19-2 defines these alloys (sometimes termed *nonprecious*) as having less than 25% by weight of noble metal with no requirement for gold. Most of these alloys used for fixed prosthodontics are nickel-chromium (Ni-Cr) alloys, but some cobalt-chromium (Co-Cr) alloys have also been formulated for porcelain application. The complex metallurgy of these alloys is described in a review article.[45]

Ni-Cr

Yield strength, hardness, and modulus of elasticity can be greatly affected by small differences in weight percentages of minor elemental components among the compositions of these alloys. Table 19-1 illustrates some of these variations. For example, values of yield strength for the representative alloys listed vary from 310 to 550 MPa, and the VHN varies from 180 to 240. Consequently, the selection of a specific brand of Ni-Cr alloy depends on the clinical application. If burnishing or extended finishing of a crown is anticipated, a brand with a relatively low yield strength and hardness should be used.

One benefit of these alloys is that their values of modulus of elasticity are much higher than those of the noble metal alloys. Therefore, long-span fixed prostheses fabricated from Ni-Cr alloys undergo much less flexure than do similar prostheses fabricated from noble metal alloys, with less likelihood of fracture of the brittle dental porcelain component. These base metal casting alloys are generally considered more technique sensitive and difficult to cast than the noble metal casting alloys. However, this assessment may reflect the lack of experience of some dental laboratories with the Ni-Cr alloys, because excellent results for castability of these alloys have been published.[46] Therefore, the choice of dental laboratory is particularly important when these alloys are selected.

Beryllium

Many Ni-Cr alloy formulations contain up to 2% by weight of beryllium. The major reason for incorporating this element in the alloy is to lower the melting range and to decrease the viscosity of the molten alloy, thereby improving its castability. Beryllium also provides strengthening and affects the thickness of the oxide layer, when the alloy is oxidized for porcelain firing. The latter is an important consideration for base metal casting alloys, which can form much thicker oxide layers than noble metal casting alloys. Fracture through the oxide layer may occur and cause failure of the base metal-ceramic restoration.

The use of beryllium has created some doubt about the safety of some Ni-Cr alloys. Of importance: When the densities of nickel (8.9 g/cm^3) and chromium (7.2 g/cm^3) are compared with that of beryllium (1.8 g/cm^3), 2% by weight of beryllium in the alloy composition can be equivalent to nearly 10% beryllium on an atomic basis. Consequently, the atomic proportion of beryllium atoms in these alloy compositions can be relatively large.

Nickel

The U.S. Federal Standard for exposure to metallic nickel and soluble nickel compounds (1 mg/m^3 for an 8-hour time-weighted average concentration) is much higher than the National Institute for Occupational Safety and Health recommendation for such exposure (15 $\mu g/m^3$ for a 10-hour time-weighted average workday). Occupational exposure of refinery workers to nickel has been associated with lung and nasal cancer. Acute effects of exposure to nickel include skin sensitization that can lead to

chronic eczema. Therefore, as a health precaution, an operator should wear a mask and use efficient suction when grinding and finishing a dental nickel-base alloy.

It has been reported that 9% of the female population and 0.9% of the male population are sensitive to nickel.[47] This prompts a question: Are such individuals likely to manifest an adverse reaction to dental Ni-Cr alloys? In a 20-patient clinical study[48] to investigate this question, each of 10 controls (who had no known sensitivity to nickel) showed a negative dermal response and a negative intraoral response to a dental Ni-Cr alloy. Of 10 patients with a known sensitivity, 8 showed a positive dermal response to the alloy. When these patients wore an intraoral appliance containing the Ni-Cr alloy, 30% manifested an allergic response within 48 hours.

According to the American Dental Association's labeling requirement for base metal alloys that contain nickel, such alloys should not be used in individuals with known nickel sensitivity. Another question now arises: Can patients who are not allergic to nickel become sensitive to it from fixed prostheses made with nickel-containing alloys?

In one investigation,[49] researchers found that Ni-Cr alloys not containing beryllium were more resistant than beryllium-containing alloys to in vitro corrosion. The four alloys studied showed lower corrosion rates in cell culture solutions after cold solution sterilization. Although the corrosion products released from the alloys did not alter the cellular structure and viability of human gingival fibroblasts, reductions in cellular proliferation were observed. The authors concluded that there still exist biocompatibility concerns relating to the exposure of local and systemic tissues to elevated levels of corrosion products from the Ni-Cr alloys.

Co-Cr

The potential health problems associated with beryllium- and nickel-containing alloys have led to the development of another alternative base metal alloy system: cobalt-chromium.[50,51] The representative Co-Cr alloys listed in Table 19-1 have higher hardness than the Ni-Cr alloys listed, which suggests that finishing restorations made with the former alloys may be more difficult.

Titanium

Titanium-based alloys have been studied since the late 1970s as potential casting alloys.[52] Advantages of titanium and titanium alloys include excellent biocompatibility and corrosion resistance, which results from the presence of a thin, adherent, passivating surface layer of TiO_2. The low density (4.5 g/cm^3) of titanium, in comparison with that of gold or palladium, also results in lighter and potentially less expensive restorations.* Alloys studied have principally been commercially pure titanium, which contains an upper limit of 1% impurities for American Society for Testing and Materials (ASTM) Grade 4, and the highly popular engineering alloy titanium-6% aluminum-4% vanadium (Ti-6Al-4V).[53] There has been substantial interest in the titanium-6% aluminum-7% niobium (Ti-6Al-7Nb) alloy, which was advocated because of potential concern with cytotoxicity of vanadium and the poor wear resistance of commercially pure titanium.[54-56]

The dental casting of titanium and titanium alloys poses special problems because of the high melting point of titanium (1668° C) and its strong tendency to oxidize and react with other materials.[57] Special casting machines that provide either a vacuum environment or an argon atmosphere must be used. Both vacuum/argon pressure and centrifugal dental casting machines have been developed, and both argon-arc melting and induction melting have been used to fuse titanium and titanium alloys.[58,59] Studies have also discussed the use of face coats on the wax pattern,[57,60,61] casting into low-temperature (350° C) phosphate-bonded investments,[62] effects of the pressure differential for the argon gas pressure,[63] permeability of the investment,[64] and mold venting.[65] Good accuracy for titanium castings on their dies can be achieved with the proper choice of investment.[62,66] A study has compared commercially pure titanium cast with helium, argon, krypton, and xenon atmospheres and found that while the microstructure is not affected, porosity and mechanical properties depend upon gas type and pressure.[67] Selecting a dental laboratory experienced in fabricating these castings is essential, and such dental laboratories are not common in the United States. Further research is needed to optimize the metallurgical structure and casting technology for titanium alloys, which have a dendritic microstructure[57] resulting from the lack of a suitable grain-refining element. A very hard near-surface region (termed *α case*) that can exceed 50 μm in thickness is also present on the castings as a result of reaction of the titanium alloy with the investment (and perhaps also with the residual atmosphere in the casting machine).[57,60] One study[61] has shown that use of a zirconia-based coating on the wax pattern substantially reduced the thickness of the complex reaction layer with the investment and yielded titanium castings with a high-quality surface.

• • •

*However, the laboratory cost of fabricating cast restorations from titanium alloys may be high.



Fig. 19-19
Technique review. **A,** The restorations are waxed to anatomic contour. **B,** The patterns are troughed to obtain correct porcelain thickness in the completed restoration. **C,** The cut-back is completed. **D,** The margins are finalized before investing.

REVIEW OF TECHNIQUE

Figure 19-19 summarizes the steps involved in producing wax patterns for metal-ceramic restorations.

1. The restorations are waxed to anatomic contour (see Fig. 19-19*A*).
2. The patterns are troughed to obtain correct porcelain thickness in the completed restoration (Fig. 19-19*B*).
3. The cut-back is completed (Fig. 19-19*C*).
4. The margins are finalized before investing (Fig. 19-19*D*).

SUMMARY

Framework design for metal-ceramic restorations must be based on an understanding of fundamental material properties. Restorations should be waxed to anatomic contour and then cut back in the area that is to be veneered. This creates an even porcelain

STUDY QUESTIONS

1. Explain all reasons for full-contour waxing before cutting back a wax pattern for a metal-ceramic restoration.
2. Why should the framework of a metal-ceramic crown not be of consistent thickness on the veneering surface?
3. How does the practitioner determine the location of the metal-ceramic interface? Interproximally on a maxillary central incisor? Interproximally on a maxillary premolar? Occlusally on a mandibular premolar? Lingually on a maxillary canine?
4. Discuss the appearance of the stress-strain curve for a ductile dental alloy. What does it mean when the straight portion of the curve is steeper or more horizontal? What is the importance of a flatter curve versus a curve with a greater slope after the initial linear portion of the plot? What does it mean if the maximum point of the curve is higher or lower? What does the total surface area under the curve signify?
5. Explain the classification of alloy systems for metal-ceramic restorations. Select two categories, and give two examples of alloys in each category. Contrast the physical properties of the alloys chosen, and provide examples of recommended use.
6. Briefly discuss the health hazards that can be associated with the various alloys used in the metal-ceramic technique.

thickness, which provides superior mechanical properties in the completed restoration while simultaneously standardizing shade reproduction.

GLOSSARY*

airborne-particle abrasion \âr′bôrn′ pär′tĭ-kal a-brā′zhun**:** the process of altering the surface of a material through the use of abrasive particles propelled by compressed air or other gases

al·loy \ăl′oi′, a-loi′\ *n* (14c)**:** a mixture of two or more metals or metalloids that are mutually soluble in the molten state; distinguished as binary, ternary, quaternary, etc., depending on the number of metals within the mixture. Alloying elements are added to alter the hardness, strength, and toughness of a metallic element, thus obtaining properties not found in the pure metal. Alloys may also be classified on the basis of their behavior when solidified—*usage:* see BASE METAL, NOBLE METAL

alloying element \a-loi′ĭng ĕl′a-ment\ (1998)**:** metallic or non-metallic elements added to or retained by a pure metal for the purpose of giving that metal special properties

aluminum oxide \a-lōō′mi-num ŏk′sīd′**: 1:** a metallic oxide constituent of dental porcelain that increases hardness and viscosity **2:** a high strength ceramic crystal dispersed throughout a glassy phase to increase its strength as in aluminous dental porcelain used to fabricate aluminous porcelain crowns **3:** a finely ground ceramic particle (frequently 50 um) often used in conjunction with air-borne particle abrasion of metal castings before the application of porcelain as with metal ceramic restorations

an·neal \a-nēl′\ *vt* (1580)**: 1:** to heat a material, such as metal or glass, followed by controlled cooling to remove internal stresses and create a desired degree of toughness, temper, or softness to a material **2:** to heat a material, such as gold foil, to volatilize and drive off impurities from its surface, thus increasing its cohesive properties. This process is termed *degassing* **3:** to homogenize an amalgam alloy by heating in an oven

base metal \bās mĕt′l**:** any metallic element that does not resist tarnish and corrosion—see NOBLE METAL

bio·ac·cept·ability \bī′ō-ăk-sĕp′ta-bĭl′ĭ-tē′\ (1998)**:** the quality of compatibility in a living environment in spite of adverse or unwanted side effects

bio·com·pat·i·ble \bī′ō-kom-păt′a-bal\ *adj***:** capable of existing in harmony with the surrounding biologic environment

bur·nish·ibil·i·ty \bûr′nĭsh-a-bĭl′ĭ-tē\ *n***:** the ease with which a material can be burnished

butt \bŭt\ *v* (14c)**:** to bring any two flat-ended surfaces into contact without overlapping, as in a butt joint

car·at \kăr′at\ *n* (15c)**:** a standard of gold fineness. The percentage of gold in an alloy, stated in parts per 24. Pure gold is designated 24 carat

centric stop \sĕn′trĭk stŏp**:** opposing cuspal/fossae contacts that maintain the occlusal vertical dimension between the opposing arches

compressive stress \kŏm-prĕs′ĭv strĕs**:** the internal induced force that opposes the shortening of a material in a direction parallel to the direction of the stresses; any induced force per unit area that resists deformation caused by a load that tends to compress or shorten a body

[1]cop·ing \kō′pĭng\ *n***: 1:** a long, enveloping ecclesiastical vestment **2a:** something resembling a cope (as by concealing or covering) **2b:** coping

[2]cop·ing \kō′pĭng\ *n* (ca. 1909)**:** a thin covering or crown—*usage:* see C. IMPRESSION, TRANSFER C.

cor·rode \ka-rōd\ *vt* (15c)**: 1:** deterioration of a metal due to an electrochemical reaction within its environment **2:** to eat away by degrees as if by gnawing **3:** to wear away gradually usually by chemical action

cor·ro·sion \ka-rō′zhen\ *n* (15c)**:** the action, process, or effect of corroding; a product of corroding; the loss of elemental constituents to the adjacent environment

[2]creep \krēp\ *n* (1818)**:** the slow change in dimensions of an object due to prolonged exposure to high temperature or stress

de·gas \dē-găs′\ *vt;* **de·gassed** \dē-găsd′\ *pt., pp;* **de·gassing** \dē-găs′ĭng\ *ppr* (1920)**: 1:** to remove gas from an object or substance **2:** the name commonly used to denote the first heat cycle (oxidation cycle) in fabrication of a metal ceramic restoration that removes surface impurities from the metallic component and produces surface oxides prior to the application of opaque porcelain

de·pas·siv·a·tion \dē-păs′sĭ-vā′shun\ *n***:** loss of corrosion protection due to damage or removal of the protective oxide surface film on a passivated metal

duc·til·i·ty \dŭk-tĭl′ĭ-tē\ *n* (14c)**:** the ability of a material to withstand permanent deformation under a tensile load without rupture; ability of a material to be plastically

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strained in tension. A material is brittle if it does not have appreciable plastic deformation in tension before rupture

dwt: *abbr* [*denarius* + *weight*] pennyweight; called also *pennyweight;* a measurement of weight in the troy system equal to 24 grains, or 0.05 ounce. Its metric equivalent is 1.555 grams

elastic limit \ĭ-lăs′tĭk lĭm′it**:** the greatest stress to which a material may be subjected and still be capable of returning to its original dimensions when such forces are released

elastic modulus \ĭ-lăs′tĭk mŏj′a-lus**:** the stiffness or flexibility of a material within the elastic range. Within the elastic range, the material deforms in direct proportion to the stress applied as represented by Hooke's law

e·las·tic·i·ty \ĭ-lă-stĭs′ĭ-tē\ *n* (1664)**:** the quality that allows a structure or material to return to its original form on removal of an external force–see MODULUS OF E.

e·lon·ga·tion \ĭ-lông′gā′shun\ *n* (14c) **1:** deformation as a result of tensile force application **2:** the degree to which a material will stretch before breaking **3:** the over eruption of a tooth

fa·tigue \fa-tēg′**:** the breaking or fracturing of a material caused by repeated cyclic or applied loads below the yield limit; usually viewed initially as minute cracks followed by tearing and rupture; also termed *brittle failure* or *fracture* <metal~>–see FAILURE

fracture strength \frăk′chur strĕngkth**:** strength at fracture based on the original dimensions of the specimen

frame·work \frām′wûrk\ *n* (1644)**:** 1. an interior or imbedded , openwork, or structural frame used to support some other object or objects 2. the skeletal portion of prosthesis (usually metal, sometimes ceramic) around which and to which are attached the remaining portions of the prosthesis to produce a finished restoration–*usage:* for dental prostheses, the *framework* may be any metal or combination of metals, with various forms including designed slots, incorporated corrective angulation patterns etc. which provide ridgity to a prosthesis. Such a framework can be made in whole or made of component parts. Frequently used to anchor a prosthesis to natural teeth (by cementation) or dental implant abutments (by cementation, mechanical undercuts, screws) or both

Knoop hardness tests [Frederick Knoop, U.S. engineer, U.S. Department of Commerce]**:** *eponym* for a surface hardness test using a diamond stylus. It is used for harder materials and is characterized by the diamond or rhomboid shaped indentation. The indentation microhardness test uses a rhombic-based pyramidal diamond indenter. The long diagonal of the resulting indentation is measured to determine the hardness. This test is suitable for most classes of materials including brittle and elastomeric

Knoop F, Peters CG, Emerson WB. A sensitive pyramidal diamond tool for indentation measurements. J Res Nat Bur Stand 1939;12:39-45.

mal·le·a·ble \măl′ē-a-bal\ *adj* (14c)**:** capable of being extended or shaped with a hammer or with the pressure of rollers

[1]met·al \mĕt′l\ *n* (13c)**:** any strong and relatively ductile substance that provides electropositive ions to a corrosive environment and that can be polished to a high luster. Characterized by metallic atomic bonding

modulus of elasticity \mŏj′a-las ŭv ĭ-lă-stĭs′ĭ-tē, ē-lă-**:** in metallurgy, the coefficient found by dividing the unit stress, at any point up to the proportional limit, by its corresponding unit of elongation (tension) or strain. A ratio of stress to strain. As the modulus of elasticity rises, the material becomes more rigid

modulus of resilience \mŏj′a-las ŭv rĭ-zĭl-yans**:** the work or energy required to stress a cubic inch of material (in one direction only) from zero up to the proportional limit of the material, measured by the ability of the material to withstand the momentary effect of an impact load while stresses remain within the proportional limit

noble metal \nō′bal mĕt′l**:** those metal elements that resist oxidation, tarnish, and corrosion during heating, casting, or soldering and when used intraorally; examples include gold and platinum–*comp* BASE METAL

nonprecious metal: see BASE METAL

pas·si·vate \păs′ĭ-vāt\ *vt* **-at·ed**; **-at·ing** (1913)**: 1:** to render inactive or less reactive **2:** to protect against contamination by coating or surface treating

precious metal \prĕsh′as mĕt′l**:** a metal containing primarily elements of the platinum group, gold, and silver

precious metal alloy \prĕsh′as mĕt′l ăl′oi′, a-loi′**:** an alloy predominantly composed of elements considered precious, i.e., gold, the six metals of the platinum group (platinum, osmium, iridium, palladium, ruthenium, and rhodium), and silver

proportional limit \pra-pôr′sha-nal lĭm′ĭt**:** that unit of stresses beyond which deformation is no longer proportional to the applied load

shearing stress \shîr′ĭng strĕs**:** the internal induced force that opposes the sliding of one plane on an adjacent plane or the force that resists a twisting action

static fatigue \stăt′ĭk fa-tēg**:** the delayed failure of glass and ceramic materials resulting from stress enhanced

chemical reactions aided by water vapor acting on surface cracks. Analogous to stress corrosion occurring in metals

strain \strān\: change in length per unit length when stress is applied; the change in length/original length

stress \strĕs\ *n* (14c): force per unit area; a force exerted on one body that presses on, pulls on, pushes against, or tends to invest or compress another body; the deformation caused in a body by such a force; an internal force that resists an externally applied load or force. It is normally defined in terms of mechanical stress, which is the force divided by the perpendicular cross sectional area over which the force is applied—see COMPRESSIVE S., SHEARING S., TENSILE S.

tensile stress \tĕn′sal, -sĭl strĕs\: the internal induced force that resists the elongation of a material in a direction parallel to the direction of the stresses

ten·sion \tĕn′shun\ *n* (1533): the state of being stretched, strained, or extended

tough·ness \tŭf′nĕs\ *n*: the ability of a material to withstand stresses and strains without breaking

tox·ic·i·ty \tŏk-sĭs′ĭ-tē\ *n*: the adverse reactions (dose-response-time relationships) of tissues to selected foreign substances resulting in unacceptable in-vivo interactions. The toxicity can be at the local or systemic level depending on the amount, rate of release, and specific type of substance available to the tissues

ultimate strength \ŭl′ta-mĭt\: the greatest stress that may be induced in a material at the point of rupture—called also *ultimate tensile strength*

yield strength \yēld strĕngkth\: the strength at which a small amount of permanent (plastic) strain occurs, usually 0.1% or 0.2%, and most frequently measured in MPa or psi

REFERENCES

1. Christensen GJ: The use of porcelain-fused-to-metal restorations in current dental practice: a survey. J Prosthet Dent 56:1, 1986.
2. Seymour KG, et al: Metal ceramic crowns—a review of tooth preparation. Eur J Prosthodont Restor Dent 7:79, 1999.
3. Walton TR: A 10-year longitudinal study of fixed prosthodontics: clinical characteristics and outcome of single-unit metal-ceramic crowns. Int J Prosthodont 12:519, 1999.
4. Oh W-S, et al: Factors affecting enamel and ceramic wear: a literature review. J Prosthet Dent 87:451, 2002.
5. Pintado MR, et al: Variation in tooth wear in young adults over a two-year period. J Prosthet Dent 77:313, 1997.
6. Monasky GE, Taylor DF: Studies on the wear of porcelain, enamel, and gold. J Prosthet Dent 25:299, 1971.
7. Ekfeldt A, Øilo G: Occlusal contact wear of prosthodontic materials. Acta Odontol Scand 46:159, 1988.
8. Kelly JR, et al: Ceramics in dentistry: historical roots and current perspectives. J Prosthet Dent 75:18, 1996.
9. Hacker CH, et al: An in vitro investigation of the wear of enamel on porcelain and gold in saliva. J Prosthet Dent 75:14, 1996.
10. Ramp MH, et al: Evaluation of wear: enamel opposing three ceramic materials and a gold alloy. J Prosthet Dent 77:523, 1997.
11. Al-Wahadni AM, Martin DM: An in vitro investigation into the wear effects of glazed, unglazed and refinished dental porcelain on an opposing material. J Oral Rehabil 26:538, 1999.
12. Magne P, et al: Wear of enamel and veneering ceramics after laboratory and chairside finishing procedures. J Prosthet Dent 82:669, 1999.
13. Clelland NL, et al: Relative wear of enamel opposing low-fusing dental porcelain. J Prosthodont 12:168, 2003.
14. Marker JC, et al: The compressive strength of nonprecious versus precious ceramometal restorations with various frame designs. J Prosthet Dent 55:560, 1986.
15. Terada Y, et al: The influence of different thicknesses of dentin porcelain on the color reflected from thin opaque porcelain fused to metal. Int J Prosthodont 2:352, 1989.
16. Craig RG, et al: Stress distribution in porcelain-fused-to-gold crowns and preparations constructed with photoelastic plastics. J Dent Res 50:1278, 1971.
17. Warpeha WS, Goodkind RJ: Design and technique variables affecting fracture resistance of metal-ceramic restorations. J Prosthet Dent 35:291, 1976.
18. Moon PC, Modjeski PJ: The burnishability of dental casting alloys. J Prosthet Dent 36:404, 1976.
19. Valega TM, ed: Alternatives to Gold Alloys in Dentistry [DHEW Publication No. (NIH) 77-1227]. Washington, DC, U.S. Department of Health, Education, and Welfare, 1977.
20. Carr AB, Brantley WA: New high-palladium casting alloys. I. Overview and initial studies. Int J Prosthodont 4:265, 1991.
21. American Dental Association Report: Classification system for cast alloys. J Am Dent Assoc 109:838, 1984.
22. Fuys RA, et al: Precipitation hardening in gold-platinum alloys containing small quantities of iron. J Biomed Mater Res 7:471, 1973.

23. Civjan S, et al: Further studies on gold alloys used in fabrication of porcelain-fused-to-metal restorations. J Am Dent Assoc 90:659, 1975.
24. Vermilyea SG, et al: Observations on gold-palladium-silver and gold-palladium alloys. J Prosthet Dent 44:294, 1980.
25. Moya F, et al: Experimental observation of silver and gold penetration into dental ceramic by means of a radiotracer technique. J Dent Res 66:1717, 1987.
26. Anusavice KJ, et al: Interactive effect of stress and temperature on creep of PFM alloys. J Dent Res 64:1094, 1985.
27. Papazoglou E, et al: Porcelain adherence to high-palladium alloys. J Prosthet Dent 70:386, 1993.
28. Goodacre CJ: Palladium-silver alloys: a review of the literature. J Prosthet Dent 62:34, 1989.
29. Herø H, Syverud M: Carbon impurities and properties of some palladium alloys for ceramic veneering. Dent Mater 1:106, 1985.
30. Byrne G, et al: Casting accuracy of high-palladium alloys. J Prosthet Dent 55:297, 1986.
31. Papazoglou E: On porcelain bonding, oxidation, mechanical properties and high-temperature distortion of high-palladium dental casting alloys. PhD dissertation, The Ohio State University, 1999.
32. Papazoglou E, et al: Comparison of mechanical properties for equiaxed fine-grained and dendritic high-palladium alloys. J Mater Sci Mater Med 11:601, 2000.
33. Wu Q, et al: Heat-treatment behavior of high-palladium dental alloys. Cells Mater 7:161, 1997.
34. Cai Z, et al: Transmission electron microscopic investigation of high-palladium dental casting alloys. Dent Mater 13:365, 1997.
35. Brantley WA, et al: X-ray diffraction studies of oxidized high-palladium alloys. Dent Mater 12:333, 1996.
36. Brantley WA, et al: X-ray diffraction studies of as-cast high-palladium alloys. Dent Mater 11:154, 1995.
37. Syverud M, et al: A new dental Pd-Co alloy for ceramic veneering. Dent Mater 3:102, 1987.
38. Papazoglou E, et al: Evaluation of high-temperature distortion of high-palladium metal-ceramic crowns. J Prosthet Dent 85:133, 2001.
39. Cai Z, et al: On the biocompatibility of high-palladium dental alloys. Cells Mater 5:357, 1995.
40. Wataha JC, Hanks CT: Biological effects of palladium and risk of using palladium in dental casting alloys. J Oral Rehabil 23:309, 1996.
41. Sun D: On the corrosion behavior and biocompatibility of palladium-based dental alloys. PhD dissertation, The Ohio State University, 2004.
42. Sun D, et al: Influence of palladium alloy elements on cell proliferation and viability [Abstract no. 2698]. J Dent Res 84 (Special Issue A on CD-ROM), 2005.
43. Sun D, et al: Elemental release from palladium casting alloys to cell culture media [Abstract no. 2699]. J Dent Res 84 (Special Issue A on CD-ROM), 2005.
44. Sun D, et al: Initial biocompatibility evaluation of two palladium-based alloys and a high-gold alloy from animal study [Abstract no. 131]. J Dent Res 82 (Special Issue A on CD-ROM), 2003.
45. Baran GR: The metallurgy of Ni-Cr alloys for fixed prosthodontics. J Prosthet Dent 50:639, 1983.
46. O'Connor RP, et al: Castability, opaque masking, and porcelain bonding of 17 porcelain-fused-to-metal alloys. J Prosthet Dent 75:367, 1996.
47. American Dental Association, Council on Dental Materials, Instruments, and Equipment: Biological effects of nickel-containing dental alloys. J Am Dent Assoc 104:501, 1982.
48. Moffa JP, et al: An evaluation of nonprecious alloys for use with porcelain veneers. II. Industrial safety and biocompatibility. J Prosthet Dent 30:432, 1973.
49. Bumgardner JD, Lucas LC: Corrosion and cell culture evaluations of nickel-chromium dental casting alloys. J Appl Biomater 5:203, 1994.
50. Vermilyea SG, et al: Observations on nickel-free, beryllium-free alloys for fixed prostheses. J Am Dent Assoc 106:36, 1983.
51. Barakat MM, Asgar K: Mechanical properties and soldering of some cobalt base metal alloys. Dent Mater 2:272, 1986.
52. Waterstrat RM: Comments on casting of Ti-13Cu-4.5Ni alloy. In Valega TM, ed: Alternatives to Gold Alloys in Dentistry [DHEW Publ. No. (NIH) 77-1227, pp. 224–233]. Washington, DC, U.S. Department of Health, Education, and Welfare, 1977.
53. Donachie MJ Jr: Titanium: A Technical Guide, pp. 31 and 444. Metals Park, OH, ASM International, 1988.
54. Kobayashi E, et al: Mechanical properties and corrosion resistance of Ti-6Al-7Nb alloy dental castings. J Mater Sci Mater Med 9:567, 1998.
55. Wang TJ, et al: Castability of Ti-6Al-7Nb alloy for dental casting. J Med Dent Sci 46:13, 1999.
56. Iijima D, et al: Wear properties of Ti and Ti-6Al-7Nb castings for dental prostheses. Biomaterials 24:1519, 2003.
57. Taira M, et al: Studies of Ti alloys for dental castings. Dent Mater 5:45, 1989.

58. Takahashi J, et al: Effect of casting methods on castability of pure titanium. Dent Mater J 12:245, 1993.
59. Eliopoulos D, et al: Porosity of cpTi casting with four different casting machines. J Prosthet Dent 92:377, 2004.
60. Koike M, et al: Corrosion behavior of cast titanium with reduced surface reaction layer made by a face-coating method. Biomaterials 24: 4541, 2003.
61. Luo XP, et al: Titanium casting into phosphate bonded investment with zirconite. Dent Mater 18:512, 2002.
62. Takahashi J, et al: Casting pure titanium into commercial phosphate-bonded SiO_2 investment molds. J Dent Res 69:1800, 1990.
63. Watanabe I, et al: Effect of pressure difference on the quality of titanium casting. J Dent Res 76:773, 1997.
64. Syverud M, Herø H: Mold filling of Ti castings using investments with different gas permeability. Dent Mater 11:14, 1995.
65. Herø H, et al: Mold filling and porosity in casting of titanium. Dent Mater 9:15, 1993.
66. Hung CC, et al: Pure titanium casting into zirconia-modified magnesia-based investment molds. Dent Mater 20:846, 2004.
67. Zinelis S: Effect of pressure of helium, argon, krypton, and xenon on the porosity, microstructure, and mechanical properties of commercially pure titanium castings. J Prosthet Dent 84:575, 2000.
68. Knoop F, et al: A sensitive pyramidal diamond tool for indentation measurements. J Res Nat Bur Stand 12:39, 1939.

20

PONTIC DESIGN

R. Duane Douglas, Contributing Author



KEY TERMS

conical pontic
crest
emergence profile
hygienic pontic
modified ridge lap pontic
ovate pontic
residual ridge
residual ridge resorption
ridge augmentation
ridge lap
sanitary pontic

Pontics are the artificial teeth of a partial fixed dental prosthesis (FDP) that replace missing natural teeth, restoring function and appearance (Fig. 20-1). They must be compatible with continued oral health and comfort. The edentulous areas where a fixed prosthesis is to be provided may be overlooked during the treatment planning phase. Unfortunately, any deficiency or potential problem that may arise during the fabrication of a pontic is often identified only after the teeth have been prepared or even when the definitive cast is ready to be sent to the laboratory. Proper preparation includes a careful analysis of the definitive dimensions of the edentulous areas: mesiodistal width, occlusocervical distance, buccolingual dimension and location of the **residual ridge.** To design a pontic that meets hygienic requirements and prevents irritation of the residual ridge, particular attention must be given to the form and shape of the gingival surface. Merely replicating the form of the missing tooth or teeth is not enough. The pontic must be carefully designed and fabricated not only to facilitate plaque control of the tissue surface and around the adjacent abutment teeth but also to adjust to the existing occlusal conditions. In addition to these biologic considerations, pontic design must incorporate mechanical principles for strength and longevity, as well as esthetic principles for satisfactory appearance of the replacement teeth (Fig. 20-2).

The pontic, as it mechanically unifies the abutment teeth and covers a portion of the residual ridge, assumes a dynamic role as a component of the prosthesis and cannot be considered a lifeless insert of gold, porcelain, or acrylic.[1]

PRETREATMENT ASSESSMENT

Certain procedures enhance the success of an FDP. In the treatment-planning phase, diagnostic casts and waxing procedures may prove especially valuable for determining optimal pontic design (see Chapters 2 and 3).

Pontic Space

One function of an FDP is to prevent tilting or drifting of the adjacent teeth into the edentulous space. If such movement has already occurred, the space available for the pontic may be reduced and its fabrication complicated. At this point, creating an acceptable appearance without orthodontic reposi-



Fig. 20-1
A and **B,** A metal ceramic pontic in this three-unit partial fixed dental prosthesis replaces the maxillary first molar.

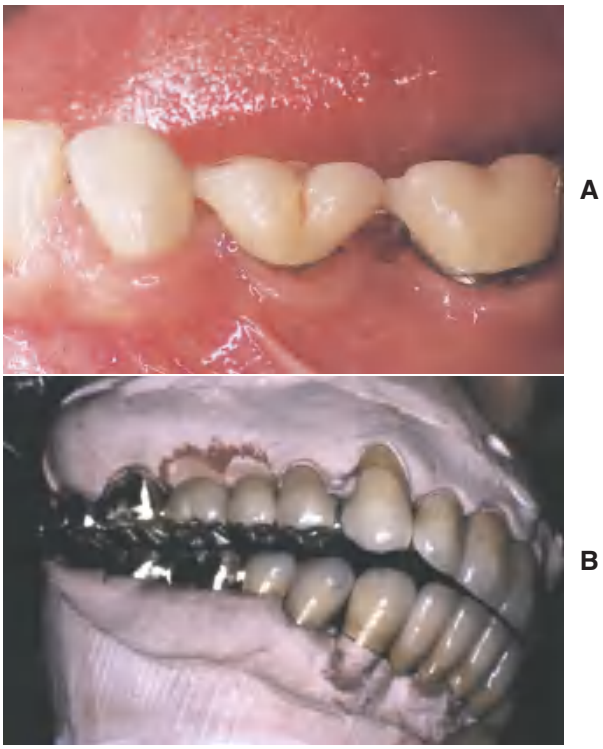


Fig. 20-3
Careful planning is always necessary in deciding how to restore an undersized pontic space where orthodontic treatment is not practical. **A,** In this patient, individual crowns of increased proximal contours were preferred to a partial fixed dental prosthesis with undersized pontics. Excellent plaque control had been demonstrated, and the design provided the optimum occlusal relationship. **B,** Here two small pontics were used to replace the missing maxillary teeth.

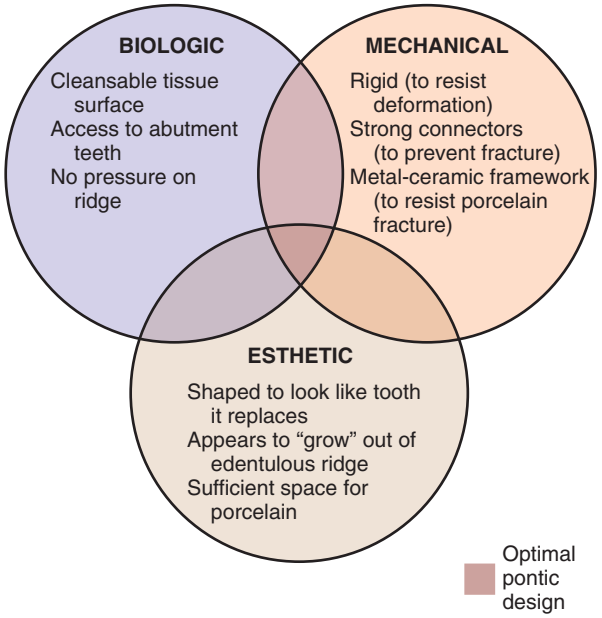


Fig. 20-2
Biologic, mechanical, and esthetic considerations for successful pontic design.

tioning of the abutment teeth is often impossible, particularly if esthetic appearance is important. (Modification of abutments with complete-coverage retainers is sometimes feasible.) Careful diagnostic waxing procedures help determine the most appropriate treatment (see Chapters 2 and 3). Even with a lesser esthetic requirement, as for posterior teeth, overly small pontics are unacceptable because they trap food and are difficult to clean. When orthodontic repositioning is not possible, increasing the proximal contours of adjacent teeth may be better than making an FDP with undersized pontics (Fig. 20-3). If there is no functional or esthetic deficit, the space can be maintained without prosthodontic intervention.

Residual Ridge Contour

The edentulous ridge's contour and topography should be carefully evaluated during the treatment

planning phase. An ideally shaped ridge has a smooth, regular surface of attached gingiva, which facilitates maintenance of a plaque-free environment. Its height and width should allow placement of a pontic that appears to emerge from the ridge and mimics the appearance of the neighboring teeth. Facially, it must be free of frenum attachment and be of adequate facial height to sustain the appearance of interdental papillae.

Loss of residual ridge contour may lead to unesthetic open gingival embrasures ("black triangles") (Fig. 20-4*A*), food impaction (Fig. 20-4*B*), and percolation of saliva during speech. Siebert[2] classified residual ridge deformities into three categories (Table 20-1 and Fig. 20-5):

- Class I defects: faciolingual loss of tissue width with normal ridge height
- Class II defects: loss of ridge height with normal ridge width
- Class III defects: a combination of loss in both dimensions

There is a high incidence (91%) of residual ridge deformity after anterior tooth loss[3]; the majority of these are Class III defects. Because patients with Class II and III defects are frequently dissatisfied with the esthetics of their FDPs,[4] preprosthetic surgery to augment such residual ridges should be carefully considered.



Fig. 20-4
Loss of residual ridge contour, leading to unesthetic open gingival embrasures (**A**) and food entrapment (*arrow*) (**B**).

Surgical Modification

Although residual ridge width may be augmented with hard tissue grafts, this is usually not indicated unless the edentulous site is to receive an implant (see Chapter 13).

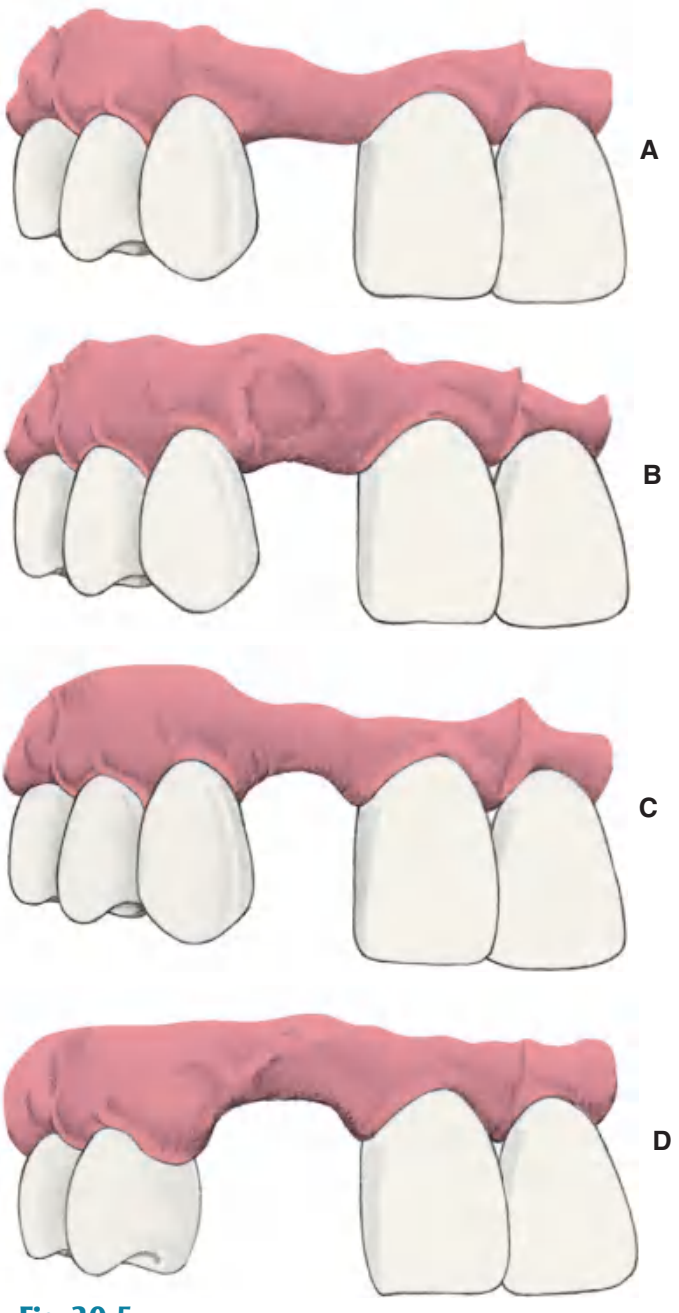


Fig. 20-5
Residual ridge deformities as classified by Siebert.[2] **A**, Class O, no defect. **B,** Class I defect. **C,** Class II defect. **D,** Class III defect.

Table **20-1** **INCIDENCE OF MAXILLARY ANTERIOR RESIDUAL RIDGE DEFECTS**

		INCIDENCE (%)	
Class	**Description**	**Abrams et al[3]**	**Siebert et al[2]**
0	No defect	12	0
I	Horizontal loss	36	13
II	Vertical loss	0	40
III	Horizontal and vertical loss	52	47

Adapted from Edelhoff D et al: A review of esthetic pontic design options. Quintessence Int 33:736, 2002.

Class I defects

Soft tissue procedures have been advocated for improving the width of a Class I defect; however, because Class I defects are infrequent and are not esthetically challenging, surgical augmentation of ridge width is uncommon. Paying careful attention to interim pontic contour helps the operator identify patients who would benefit from surgery. In the roll[5] technique, soft tissue from the lingual side of the edentulous site is used. The epithelium is removed, and the tissue is thinned and rolled back upon itself, thereby thickening the facial aspect of the residual ridge (Fig. 20-6). Pouches may also be prepared in the facial aspect of the residual ridge[6] into which subepithelial[7,8] or submucosal[9] grafts harvested from the palate or tuberosity may be inserted (Fig. 20-7).

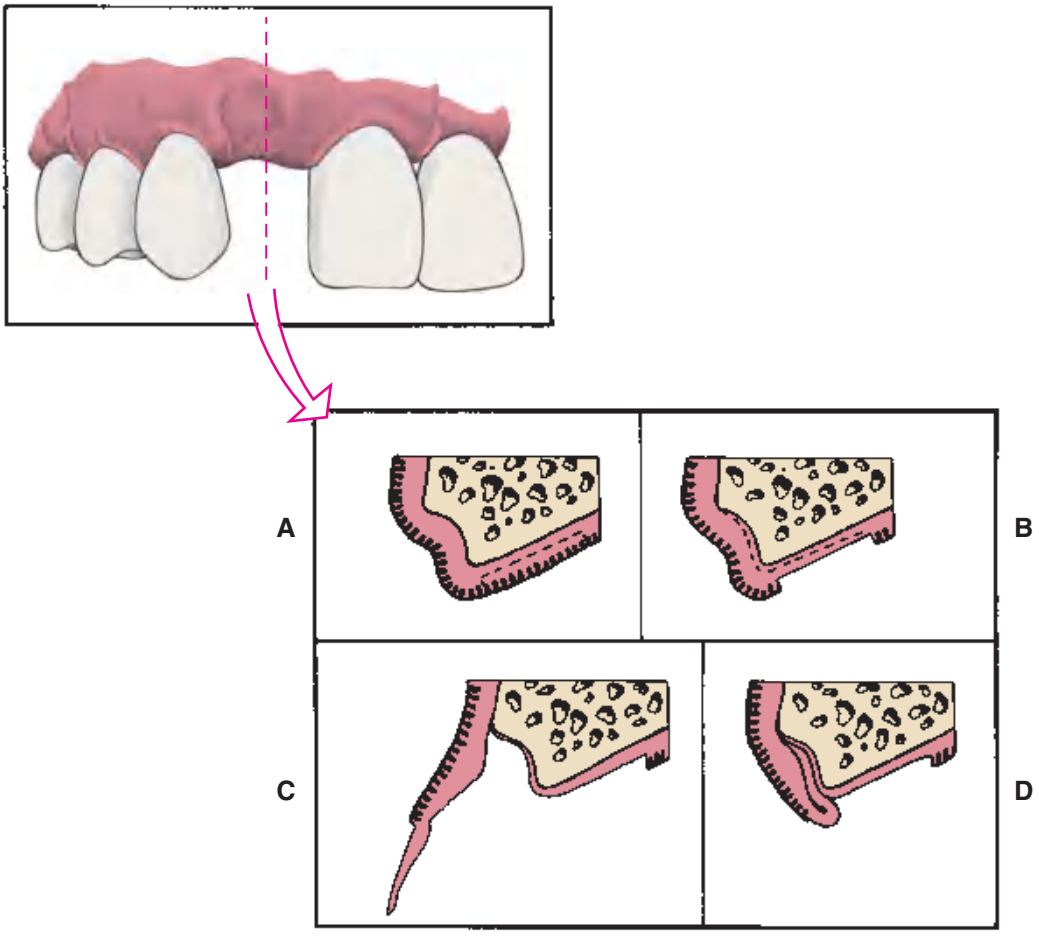


Fig. 20-6
The roll technique for soft tissue ridge augmentation. **A,** Cross-section of Class I residual ridge defect before augmentation. **B,** Epithelium removed from palatal surface. **C,** Elevation of flap, creating a pouch on the vestibular surface. **D,** The flap is rolled into the pouch, enhancing ridge width.

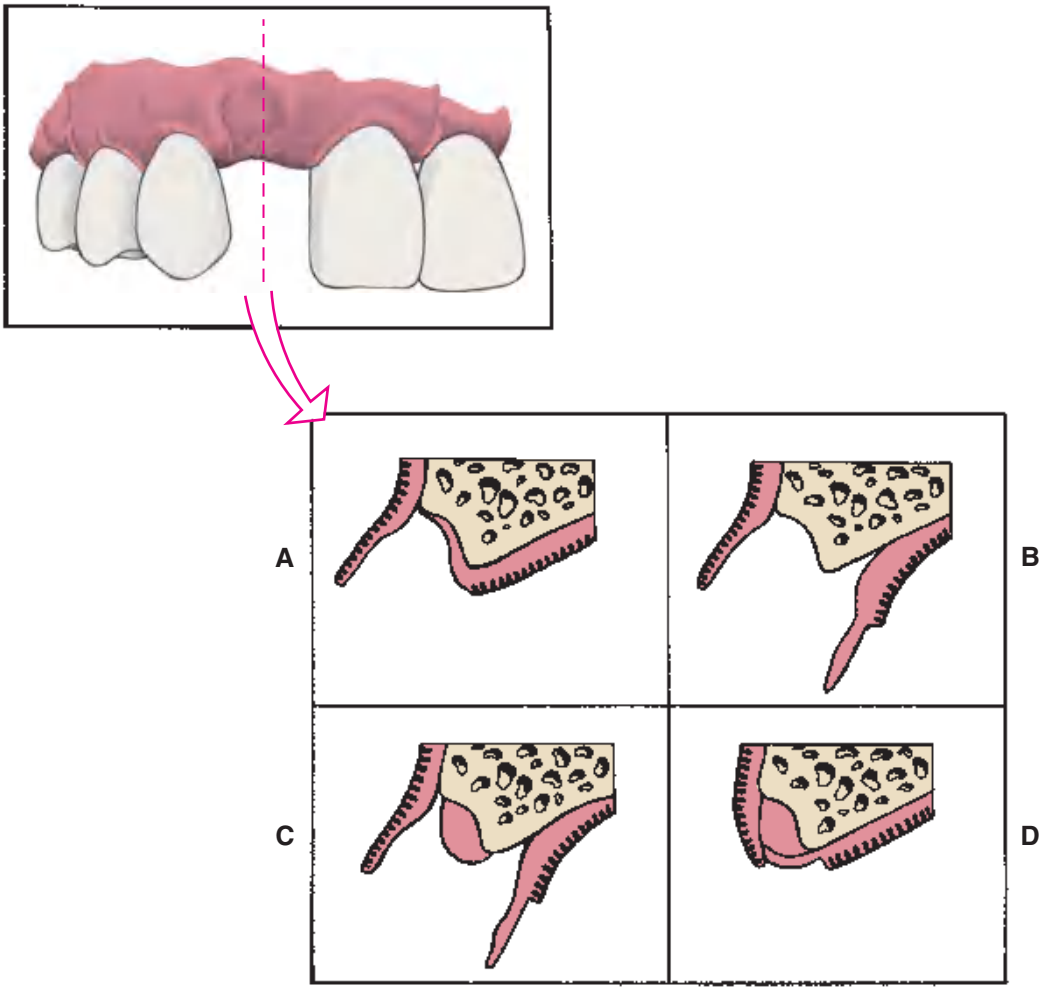


Fig. 20-7
The pouch technique for soft tissue ridge augmentation. **A** and **B,** Split-thickness flap is reflected. **C,** Graft material placed in the pouch increases ridge width. **D,** Flaps sutured in place.

Class II and III defects

Unfortunately, few soft tissue surgical techniques can increase the height of a residual ridge with predictability. The interpositional graft[2,10] is a variation of the pouch technique, in which a wedge-shaped connective tissue graft is inserted into a pouch preparation on the facial aspect of the residual ridge. The epithelial portion of the wedge may be positioned coronally to the surrounding epithelium if an increase of ridge height is desired (Fig. 20-8*A* and *B*). The onlay graft is designed to gain ridge height[2,11] but also contributes to ridge width, which makes it useful for treating Class III ridge defects (Fig. 20-9). It is a thick "free gingival graft" harvested from partial- or full-thickness palatal donor sites. Because the amount of height augmentation can be only as thick as the graft, the procedure may have to be repeated several times to reestablish normal residual ridge height. Although the onlay graft has greater potential for increasing ridge height than does the interpositional graft, its survival is greatly dependent on revascularization, which requires meticulous preparation of the recipient site. Therefore, it is more technique sensitive than the interpositional graft. In fact, connective tissue grafts have been demonstrated to achieve approximately 50% more ridge volume gain 3.5 months after surgery than do free gingival grafts in single-tooth residual ridge defects.[12]

Gingival Architecture Preservation

Although the degree of **residual ridge resorption** after tooth extraction is unpredictable, resulting deformities are not an inevitable occurrence. Preservation of the alveolar process can be achieved through immediate restorative and periodontal intervention at the time of tooth removal. By conditioning the extraction site and providing a matrix for healing, the pre-extraction gingival architecture, or "socket," can be preserved.

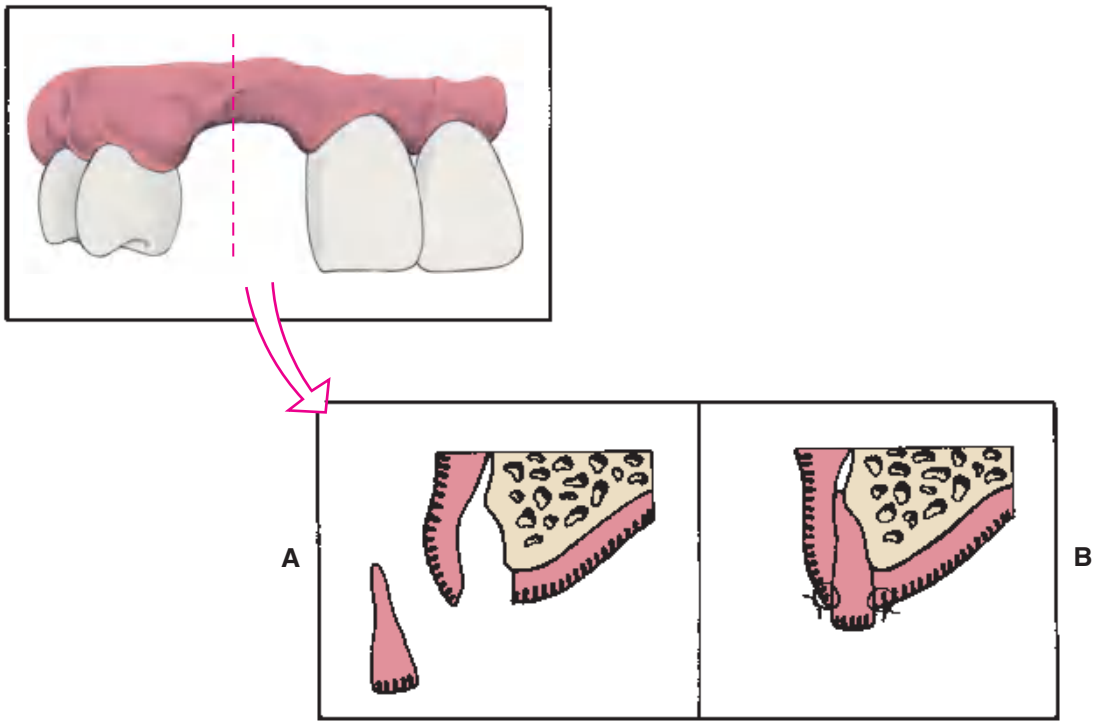


Fig. 20-8
An interpositional graft for augmentation of ridge width and height. **A,** Tissue reflected. **B,** Graft positioned and sutured in place.

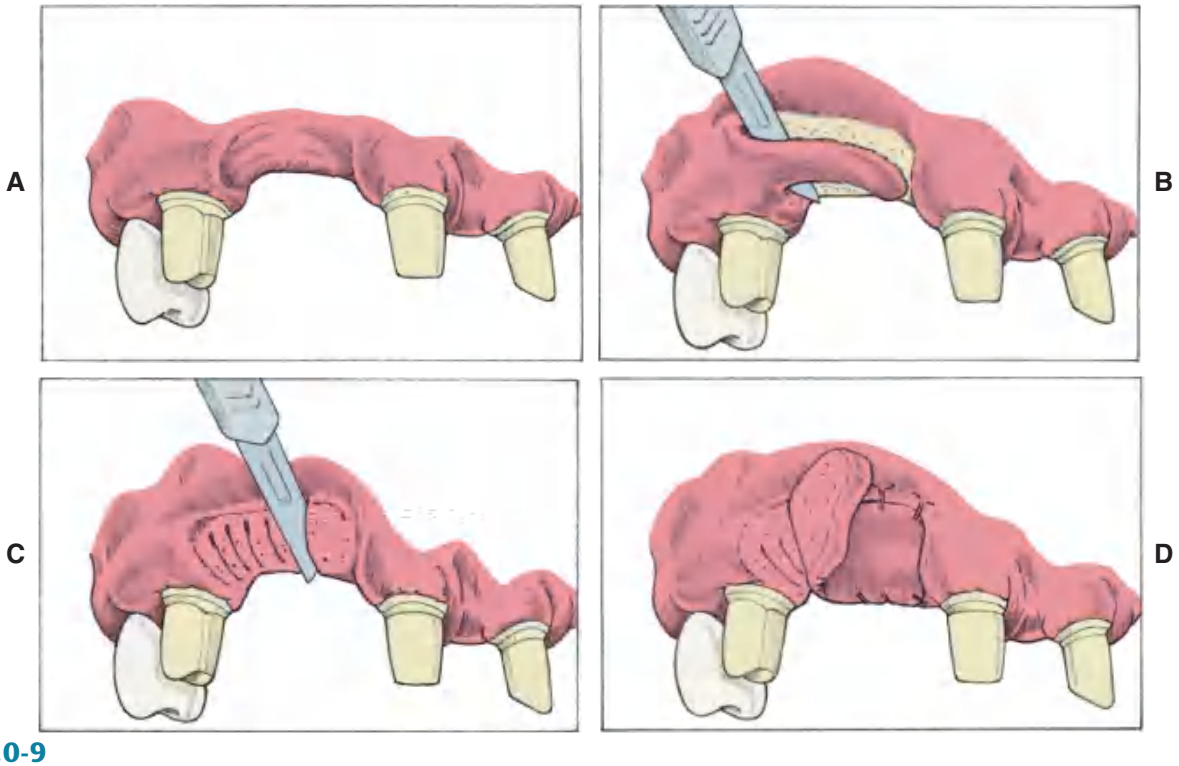


Fig. 20-9
An onlay graft for augmentation of ridge width and height. **A,** Presurgical view of Class III residual ridge defect with abutment teeth prepared. **B,** Recipient bed prepared by removing epithelium. **C,** Striation cuts are made in connective tissue to encourage revascularization. **D,** Onlay graft is sutured in place.





Fig. 20-9, cont'd

E, An interim partial fixed dental prosthesis with open embrasures is placed immediately to allow adaptation of tissue during healing. **F,** Cast with Class III residual ridge defect; the lateral incisor was unrestorable. **G,** Donor site for graft. **H,** Graft sutured in place. **I,** Augmented ridge. **J** and **K,** Final restoration with improved contours.

Preparing the abutment teeth before the extraction is the preferred technique. An interim FDP can be fabricated indirectly, ready for immediate insertion. Because socket preservation is dependent on underlying bone contour, the extraction of the tooth to be replaced should be atraumatic and aimed at preserving the facial plate of bone. The scalloped architecture of interproximal bone forming the extraction site is essential for proper papilla form, as are facial bone levels in the prevention of alveolar collapse. If bone levels are compromised before or during extraction, the sockets can be grafted with an allograft material (hydroxyapatite, tricalcium phosphate, or freeze-dried bone).[13–15]

Immediately after preparation of the extraction site, a carefully shaped interim FDP is placed (Fig. 20-10*A* and *B*). The tissue side of the pontic should be an ovate form, and, according to Spear,[16] it should extend approximately 2.5 mm apical to the facial free gingival margin of the extraction socket (Fig. 20-10*C* and *D*). Because the soft tissues of the socket begin to collapse immediately after the tooth extrac-



Fig. 20-10
Alveolar architecture preservation technique. **A,** Atraumatic tooth extraction. **B,** Cross-section view of the immediate interim partial fixed dental prosthesis, demonstrating ovate pontic form. **C,** Interim restoration. Note the 2.5-mm apical extension of the ovate pontic. **D,** The seated interim restoration should cause slight blanching of interdental papilla. **E,** Interim restoration 12 months after extraction. Note the preservation of interdental papilla. *(Courtesy of Dr. F.M. Spear and Montage Media, Mahwah, New Jersey.)*

tion, the pontic causes tissue blanching as it supports the papillae and facial/palatal gingiva. The contour of the ovate tissue side of the pontic is critical and must conform to within 1 mm of the interproximal and facial bone contour to act as a template for healing. Oral hygiene in this area is difficult during the initial healing period, and so the interim restoration should be highly polished to minimize plaque retention. After approximately 1 month of healing, oral hygiene access is improved by recontouring the pontic to provide 1 to 1.5 mm of relief from the tissue. When the gingival levels are stable (approximately 6 to 12 months), the final restoration can be fabricated (Fig. 20-10*E*).

Techniques involving orthodontic extrusions have also been employed to preserve ridge form before extraction. In these proactive methods, light forces are used to extrude the teeth destined to be extracted. As the teeth are extruded, apposition of bone occurs at the root apex, thereby filling the socket with bone as the tooth is slowly extracted orthodontically. First employed to avoid **ridge augmentation** and gain vertical ridge height before immediate implant placement,[17] the orthodontic extrusion technique has been used successfully to maintain ridge contour before treatment with conventional FDPs (Fig. 20-11). In addition to the additional time and expense of orthodontic treatment,



Fig. 20-11
Orthodontic extrusion to preserve alveolar architecture. **A,** Pretreatment (note gingival crest height discrepancy between the maxillary central incisors). **B,** Orthodontic extrusion. **C,** Pre-extrusion and post-extrusion radiographs. *Red line* denotes reference point; *blue* and *yellow lines* denote change in gingival crest height. **D,** Post-extraction evaluation of interim restoration with ovate pontics. **E,** Gingival architecture immediately prior to pression. **F,** Final restoration.

because the teeth to be extracted must continuously be adjusted as they are extruded, previous endodontic treatment is necessary.

Although maintenance of the residual ridge after extraction is admirable, socket-preservation techniques are technically challenging and require frequent patient monitoring and conscientious hygiene on the part of the patient. Even when the procedure is performed meticulously, success is unpredictable because of the variability in patients' healing response. Additional surgical augmentation of the ridge may still be necessary for some patients.

PONTIC CLASSIFICATION

Pontic designs are classified into two general groups: those that contact the oral mucosa and those that do not (Box 20-1). There are several classifications within these groups, based on the shape of the gingival side of the pontic. Pontic selection depends primarily on esthetics and oral hygiene. In the anterior region, where esthetic appearance is a concern, the pontic should be well adapted to the tissue to make it appear as if it emerges from the gingiva. Conversely, in the posterior regions (mandibular premolar and molar areas), contours can be modified in the interest of designs that are less esthetic but amenable to oral hygiene. The advantages and disadvantages of the various pontic designs are summarized in Table 20-2.

Sanitary or Hygienic Pontic

As its name implies, the primary design feature of the **sanitary pontic** allows easy cleaning, because its tissue surface remains clear of the residual ridge (Fig. 20-12*A*). This hygienic design permits easier plaque control by allowing gauze strips and other cleaning devices to be passed under the pontic and seesawed in a shoeshine manner. Disadvantages include entrapment of food particles, which may lead to tongue habits that annoy the patient. The **hygienic pontic** is the least

Box **20-1** Pontic Design Classification

MUCOSAL CONTACT
- Ridge lap
- Modified ridge lap
- Ovate
- Conical

NO MUCOSAL CONTACT
- Sanitary (hygienic)
- Modified sanitary (hygienic)

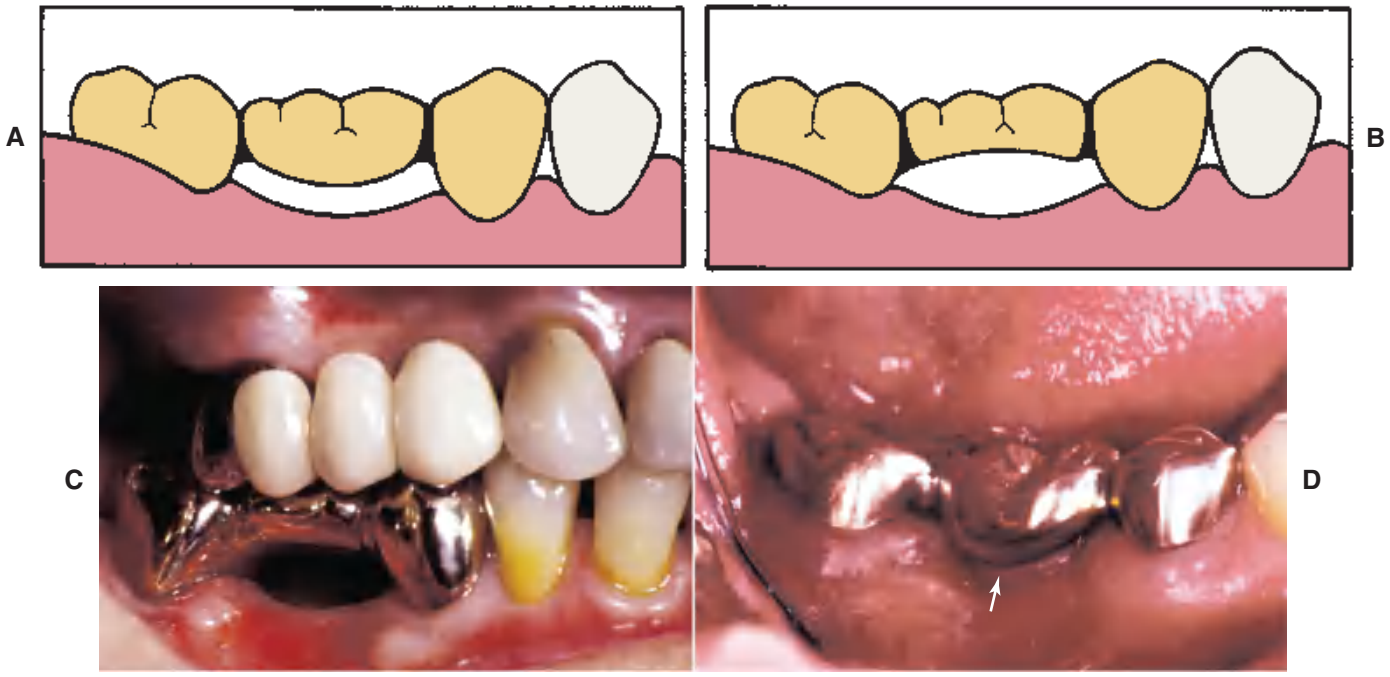
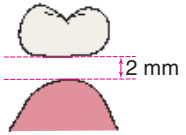
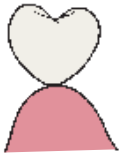
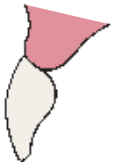
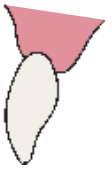


Fig. 20-12
A, Sanitary pontic. **B** and **C,** Modified sanitary pontic. **D,** Placement of the pontic, close to the ridge, has resulted in tissue proliferation (*arrow*).

Table **20-2 PONTIC DESIGN**

Pontic design	Appearance	Recommended location	Advantages	Disadvantages	Indications	Contraindications	Materials
Sanitary/ hygienic		Posterior mandible	Good access for oral hygiene	Poor esthetics	Nonesthetic zones Impaired oral hygiene	Where esthetics is important Minimal vertical dimension	All metal
Saddle-ridge-lap		Not recommended	Esthetic	Not amenable to oral hygiene	Not recommended	Not recommended	Not applicable
Conical		Molars without esthetic requirements	Good access for oral hygiene	Poor esthetics	Posterior areas where esthetics is of minimal concern	Poor oral hygiene	All-metal Metal-ceramic All-resin
Modified ridge-lap		High esthetic requirement (i.e., anterior teeth and premolars, some maxillary molars)	Good esthetics	Moderately easy to clean	Most areas with esthetic concern	Where minimal esthetic concern exists	Metal-ceramic All-resin All ceramic
Ovate		Very high esthetic requirement Maxillary incisors, canines, and premolars	Superior esthetics Negligible food entrapment Ease of cleaning	Requires surgical preparation Not for residual ridge defects	Desire for optimal esthetics High smile line	Unwillingness for surgery Residual ridge defects	Metal-ceramic All-resin All ceramic

"toothlike" design and is therefore reserved for teeth seldom displayed during function (i.e., the mandibular molars).

A modified version of the sanitary pontic has been developed[18] (Fig. 20-12*B* and *C*). Its gingival portion is shaped like an archway between the retainers. This geometry allows increased connector size while decreasing the stress concentrated in the pontic and connectors.[19] It is also less susceptible to tissue proliferation that can occur when a pontic is too close to the residual ridge (Fig. 20-12*D*).

Saddle or Ridge Lap Pontic

The saddle pontic has a concave fitting surface that overlaps the residual ridge buccolingually, simulating the contours and **emergence profile** of the missing tooth on both sides of the residual ridge. However, saddle or **ridge lap** designs should be avoided because the concave gingival surface of the pontic is not accessible to cleaning with dental floss, which leads to plaque accumulation (Fig. 20-13). This design deficiency has been shown to result in tissue inflammation[1] (Fig. 20-14).

Modified Ridge Lap Pontic

The **modified ridge lap pontic** combines the best features of the hygienic and saddle pontic designs, combining esthetics with easy cleaning. Figures 20-15 and 20-16 demonstrate how the modified ridge lap design overlaps the residual ridge on the facial side (to achieve the appearance of a tooth emerging from the gingiva) but remains clear of the

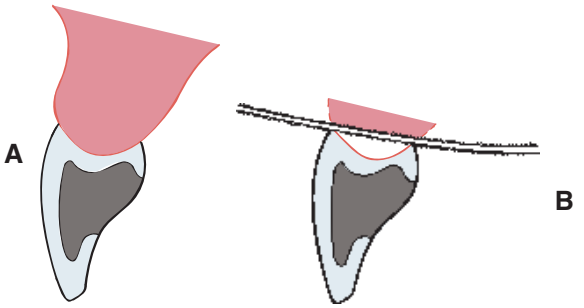


Fig. 20-13
A, Cross-section view of ridge lap pontic. **B,** The tissue surface is inaccessible to cleaning devices.



Fig. 20-14
A and **B**, Partial fixed dental prosthesis (FDP) with a ridge-lap (concave) gingival surface. **C**, When it was removed, the tissue was found to be ulcerated. **D**, The defective FDP was recontoured and used as an interim restoration while the definitive restoration was being fabricated. Within 2 weeks the ulceration had resolved.

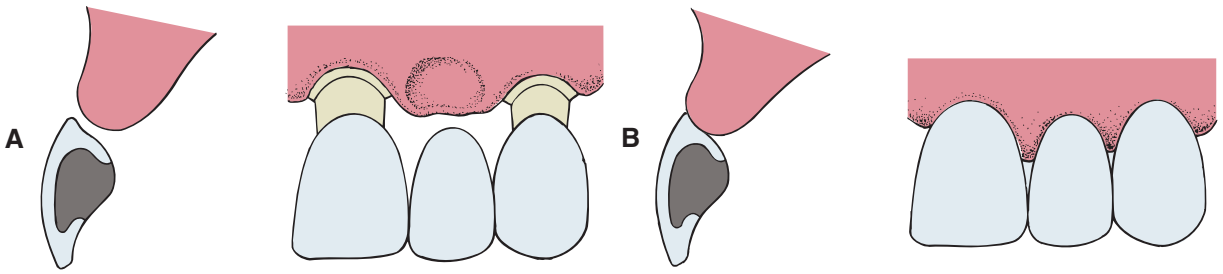


Fig. 20-15
Modified ridge lap pontic. **A,** Partial fixed dental prosthesis (FDP) partially seated. **B,** FDP seated.



Fig. 20-16
Three-unit partial fixed dental prosthesis replacing the maxillary lateral incisor. **A,** To facilitate plaque control, the lingual surface is made convex. **B,** The facial surface is shaped to simulate the missing tooth.

ridge on the lingual side. To enable optimal plaque control, the gingival surface must have no depression or hollow. Rather, it should be as convex as possible from mesial to distal aspects (the greater the convexity, the easier the oral hygiene). Tissue contact should resemble a letter T (Fig. 20-17) whose vertical arm ends at the **crest** of the ridge. Facial ridge adaptation is essential for a natural appearance. Although this design was historically referred to as *ridge-lap*,[20,21] the term *ridge-lap* is now used synonymously with the saddle design. The modified ridge lap design is the most common pontic form used in areas of the mouth that are visible during function (maxillary and mandibular anterior teeth and maxillary premolars and first molars).

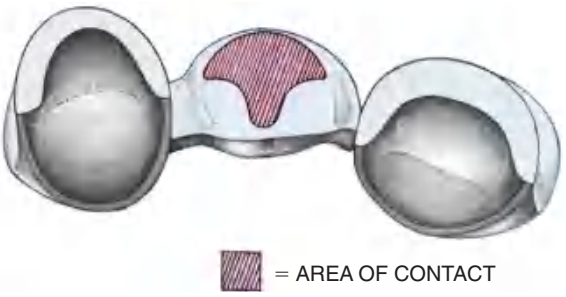


Fig. 20-17
Tissue contact of a maxillary partial fixed dental prosthesis (FDP) should resemble the letter T. This FDP is viewed from the gingival aspect.

Conical Pontic

Often called *egg-shaped*, *bullet-shaped*, or *heart-shaped*, the **conical pontic** (Fig. 20-18) is easy for the patient to keep clean. It should be made as convex as possible, with only one point of contact at the center of the residual ridge. This design is recommended for the replacement of mandibular posterior teeth, where esthetic appearance is a lesser concern. The facial and lingual contours are dependent on the width of the residual ridge; a knife-edged residual ridge necessitates flatter contours with a narrow tissue contact area. This type of design may be unsuitable for broad residual ridges, because the emergence profile associated with the small tissue contact point may create areas of food entrapment (Fig. 20-19). The sanitary or hygienic pontic is the design of choice in these clinical situations.

Ovate Pontic

The **ovate pontic** is the most esthetically appealing pontic design. Its convex tissue surface resides in a

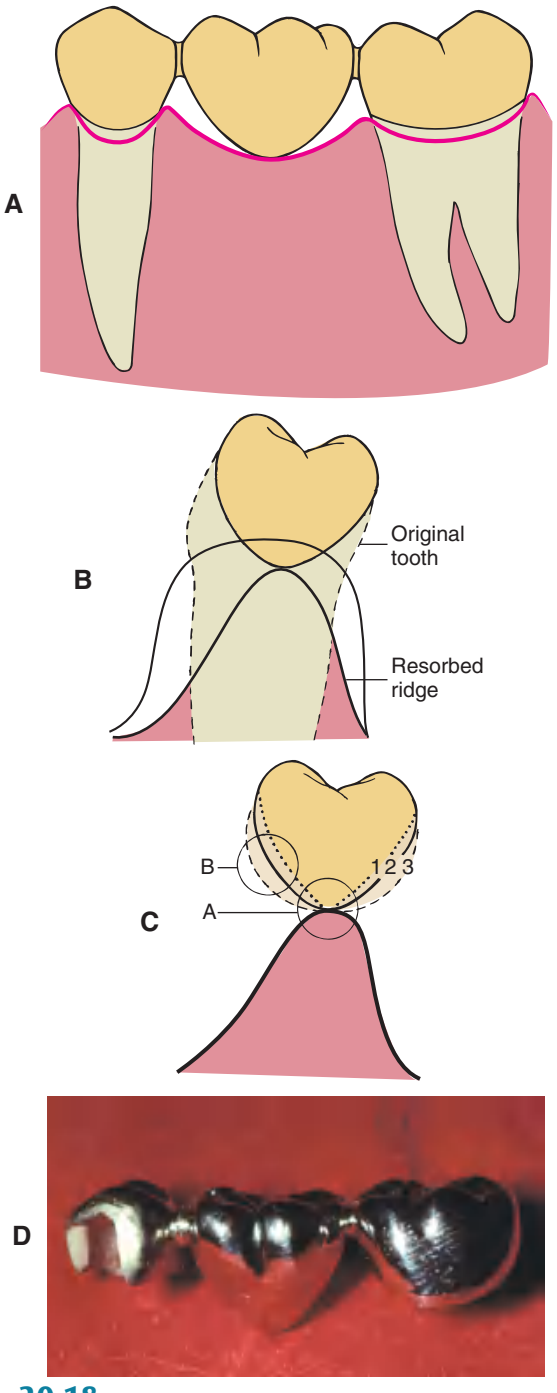


Fig. 20-18

A and **B,** A pontic with maximum convexity and a single point of contact with the tissue surface is the design easiest to keep clean. **C,** Evaluating the contour of three possible pontic shapes (*1*, *2*, and *3*). Contour *3* is the most convex in area *B* but is too flat in area *A*. Contour *1* is convex in area *A* but is too flat in area *B*. Contour *2* is the best. **D,** An all-metal partial fixed dental prosthesis with a conical pontic, suitable for replacement of a mandibular molar.

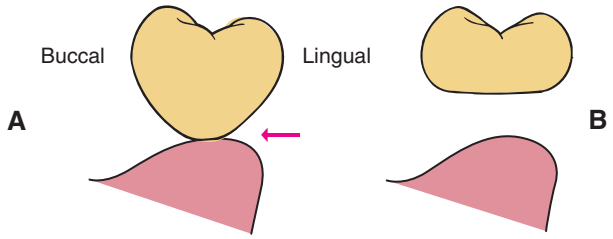


Fig. 20-19

A, Conical pontics may create food entrapment on broad residual ridges (*arrow*). **B,** The sanitary pontic form may be a better alternative.

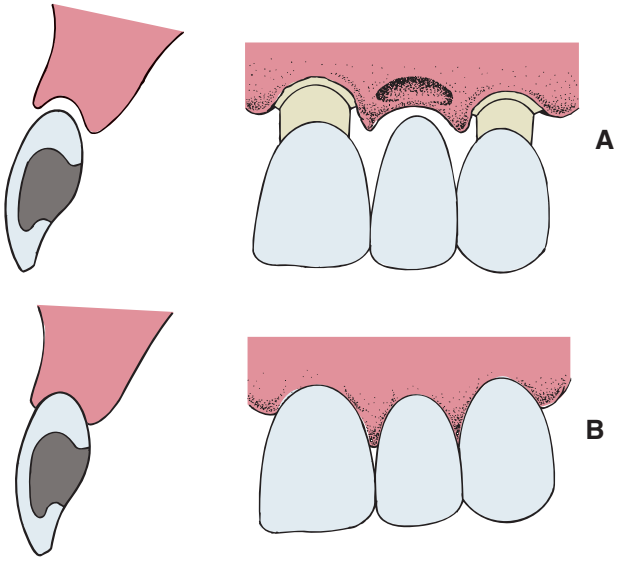


Fig. 20-20

Ovate pontic. **A,** Partial fixed dental prosthesis (FDP) partially seated. **B,** FDP seated.

soft tissue depression or hollow in the residual ridge, which makes it appear that a tooth is literally emerging from the gingiva (Fig. 20-20). Careful treatment planning is necessary for successful results. Socket-preservation techniques should be performed at the time of extraction to create the tissue recess from which the ovate pontic form will emerge. For a pre-existing residual ridge, soft tissue surgical augmentation is typically required. When an adequate volume of ridge tissue is established, a socket depression is sculpted into the ridge with surgical diamonds or electrosurgery. In either case, meticulous attention to the contour of the pontic of the interim restoration is essential when the residual ridge that will receive the definitive prosthesis is conditioned and shaped.

The ovate pontic's advantages include its pleasing appearance and its strength. When used successfully with ridge augmentation, its emergence from the

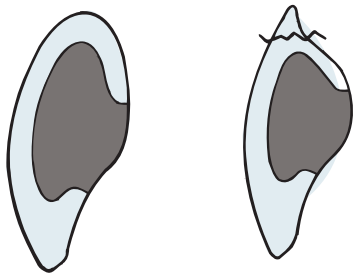


Fig. 20-21
The ovate pontic design eliminates the potential for unsupported porcelain in the cervical portion of an anterior pontic.



Fig. 20-22
Pressure inevitably leads to ulceration.



Fig. 20-23
Soft tissue blanching at evaluation indicates pressure.

ridge appears identical to that of a natural tooth. In addition, its recessed form is not susceptible to food impaction. The broad convex geometry is stronger than that of the modified ridge lap pontic, because the unsupported, thin porcelain that often exists at the gingivofacial extent of the pontic is eliminated (Fig. 20-21). Because the tissue surface of the pontic is convex in all dimensions, it is accessible to dental floss; however, meticulous oral hygiene is necessary to prevent tissue inflammation resulting from the large area of tissue contact. Other disadvantages include the need for surgical tissue management and the associated cost. Furthermore, an additional evaluation appointment is typically necessary to achieve an esthetic result. The socket depression, with its pseudopapillae, requires the support of the interim ovate pontic and will collapse when the interim restoration is removed before an impression is made. To compensate for this three-dimensional change in the socket that occurs during the impression, it is necessary to scrape the cast in this area to ensure positive contact and support of the pseudopapillae with the definitive pontic. Because these adjustment are made somewhat arbitrarily, it may also be necessary to make revisions to the tissue surface of the pontic (reshaping or porcelain additions) at the evaluation phase.

BIOLOGIC CONSIDERATIONS

The biologic principles of pontic design pertain to the maintenance and preservation of the residual ridge, abutment and opposing teeth, and supporting tissues. Factors of specific influence are pontic-ridge contact, amenability to oral hygiene, and the direction of occlusal forces.

Ridge Contact

Pressure-free contact between the pontic and the underlying tissues is indicated to prevent ulceration and inflammation of the soft tissues.[1,22] If any blanching of the soft tissues is observed at evaluation, the pressure area should be identified with a disclosing medium (e.g., pressure-indicating paste) and the pontic recontoured until tissue contact is entirely passive. This passive contact should occur exclusively on keratinized attached tissue. When a pontic rests on mucosa, some ulcerations may appear as a result of the normal movement of the mucosa in contact with the pontic (Fig. 20-22). Positive ridge pressure (hyperpressure) may be caused by excessive scraping of the ridge area on the definitive cast (Fig. 20-23). This was once promoted as a way to improve the appearance of the pontic-ridge relationship. However, because of the ulceration that inevitably results when flossing is not meticulously performed, the concept is not recommended[1,23,24] unless followed as previously described for an ovate pontic.[22,25] Although ovate pontics maintain positive tissue contact to support the pseudopapillae, healthy mucosa can be maintained, provided that the contact



Fig. 20-24
The patient must be instructed in how to clean the gingival surface of a pontic with floss.

to the mucosa is tight but noncompressive and the gingival portion of the pontic is regularly cleaned.[26]

Oral Hygiene Considerations

The chief cause of ridge irritation is the toxins released from microbial plaque, which accumulate between the gingival surface of the pontic and the residual ridge, causing tissue inflammation and calculus formation.

Unlike removable partial dental prostheses, FDPs cannot be taken out of the mouth for daily cleaning. Patients must be taught efficient oral hygiene techniques, with particular emphasis on cleaning the gingival surface of the pontic. The shape of the gingival surface, its relation to the ridge, and the materials used in its fabrication influence ultimate success.

Normally, where tissue contact occurs, the gingival surface of a pontic is inaccessible to the bristles of a toothbrush. Therefore, excellent hygiene habits must be developed by the patient. Devices such as proxy brushes, pipe cleaners, Oral-B Super Floss,* and dental floss with a threader are highly recommended (Fig. 20-24). Gingival embrasures around the pontic should be wide enough to permit oral hygiene aids. However, to prevent food entrapment, they should not be opened excessively. To enable passage of floss over its entire tissue surface, tissue contact between the residual ridge and pontic must be passive.

If the pontic has a depression or concavity in its gingival surface, plaque accumulates, because the floss cannot clean this area, and tissue irritation[27] follows. This is usually reversible; when the surface is subsequently modified to eliminate the concavity, inflammation disappears (see Fig. 20-14). Therefore, an accurate description of pontic design should be submitted to the laboratory, and the prosthesis should be checked and corrected if necessary before cementation. Prevention is the best solution for controlling tissue irritation.

Pontic Material

Any material chosen to fabricate the pontic should provide good esthetic results where needed: biocompatibility, rigidity, and strength to withstand occlusal forces; and longevity. FDPs should be made as rigid as possible, because any flexure during mastication or parafunction may cause pressure on the gingiva and cause fractures of the veneering material. Occlusal contacts should not fall on the junction between metal and porcelain during centric or eccentric tooth contacts, nor should a metal-ceramic junction occur in contact with the residual ridge on the gingival surface of the pontic.

Investigations into the biocompatibility of materials used to fabricate pontics have centered on two factors: (1) the effect of the materials and (2) the effects of surface adherence. Glazed porcelain is generally considered the most biocompatible of the available pontic materials,[28-30] and clinical data[23,31] tend to support this opinion, although the crucial factor seems to be the material's ability to resist plaque accumulation[32] (rather than the material itself). Well-polished gold is smoother, less prone to corrosion, and less retentive of plaque than an unpolished or porous casting.[33] However, even highly polished surfaces accumulate plaque if oral hygiene measures are ignored.[34,35]

Glazed porcelain looks very smooth, but when viewed under a microscope, its surface shows many voids and is rougher than that of either polished gold or acrylic resin[36] (Fig. 20-25). Nevertheless, highly glazed porcelain is easier to clean than other materials. For easier plaque removal and biocompatibility, the tissue surface of the pontic should be made in glazed porcelain. However, ceramic tissue contact may be contraindicated in edentulous areas where there is minimal distance between the residual ridge and the occlusal table. In these instances, placing ceramic on the tissue side of the pontic may weaken the design of the metal substructure, particularly with porcelain occlusal surface (Fig. 20-26). If gold is placed in tissue contact, it should be highly polished. Regardless of the choice of pontic material, patients can prevent inflammation around the pontic with meticulous oral hygiene.[37]

*Braun Oral-B, South Boston, Massachusetts.

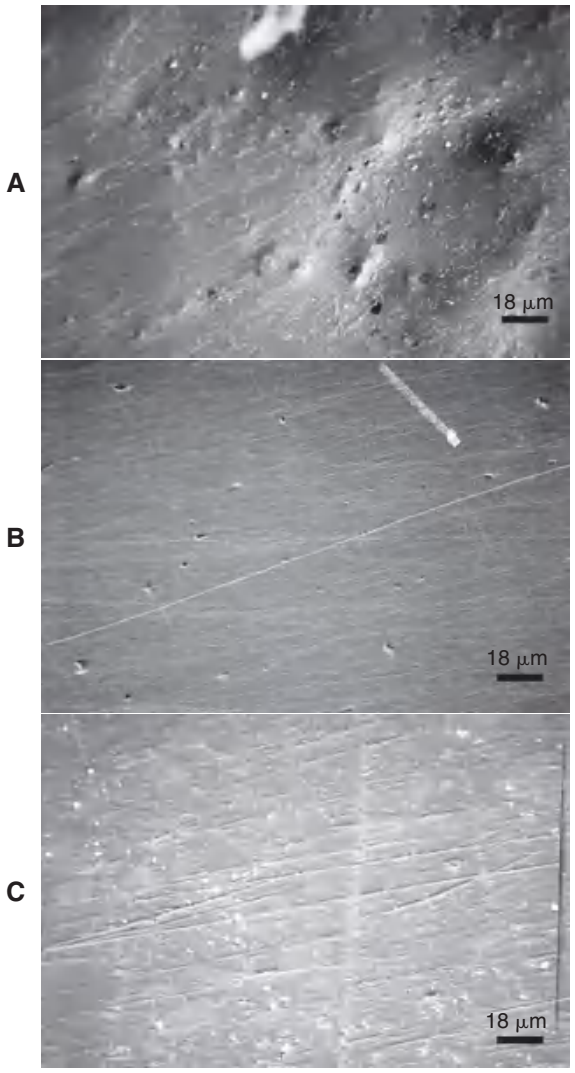


Fig. 20-25
Scanning electron micrographs of glazed porcelain (**A**), polished gold (**B**), and polished acrylic resin (**C**). *(Microscopy by Dr. J. L. Sandrik.)*

Occlusal Forces

Reducing the buccolingual width of the pontic by as much as 30% has been suggested[38,39] as a way to lessen occlusal forces on, and thus the loading of, abutment teeth. This practice continues today, although it has little scientific basis. Critical analysis[40] has revealed that forces are lessened only when food of uniform consistency is chewed and that a mere 12% increase in chewing efficiency can be expected from a one-third reduction of pontic width. Potentially harmful forces are more likely to be encountered if an FDP is loaded by the accidental biting on a hard object or by parafunctional activities such as bruxism, rather than by chewing of foods of uniform consistency. These forces are not reduced by narrowing the occlusal table.

In fact, narrowing the occlusal table may actually impede or even preclude the development of a harmonious and stable occlusal relationship. Like a malposed tooth, it may cause difficulties in plaque control and may not provide proper cheek support. For these reasons, pontics with normal occlusal widths (at least in the occlusal third) are generally recommended. One exception is if the residual alveolar ridge has collapsed buccolingually. Reducing pontic width may then be desired and would thereby lessen the lingual contour and facilitate plaque-control measures.

MECHANICAL CONSIDERATIONS

The prognosis of FDP pontics is compromised if mechanical principles are not followed closely. Mechanical problems may be caused by improper choice of materials, poor framework design, poor tooth preparation, or poor occlusion. These factors can lead to fracture of the prosthesis or displacement

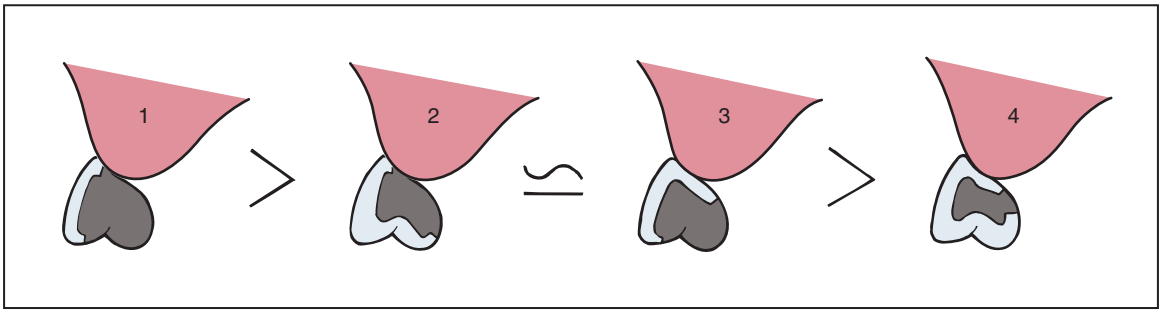


Fig. 20-26
Four pontic designs in descending order of strength, based on cross-sectional diameter of the metal substructure. When vertical space is minimal, design 4 (porcelain tissue and occlusal coverage) may be contraindicated.



Fig. 20-27
Failure of a long span metal-ceramic partial fixed dental prosthesis subjected to high stress.



Fig. 20-28
Failure resulting from improper laboratory technique.

of the retainers. Long-span posterior FDPs are particularly susceptible to mechanical problems. Inevitably, there is significant flexing from high occlusal forces and because the displacement effects increase with the cube of the span length (see p. 98). Therefore, evaluating the likely forces on a pontic and designing accordingly are important. For example, a strong all-metal pontic may be needed in high-stress situations, rather than a metal-ceramic pontic (Fig. 20-27), which would be more susceptible to fracture. When metal-ceramic pontics are chosen, extending porcelain onto the occlusal surfaces to achieve better esthetics should also be carefully evaluated. In addition to its potential for fracture, porcelain may abrade the opposing dentition if the occlusal contacts are on enamel or metal.



Fig. 20-29
Failure of unsupported gingival porcelain.

Available Pontic Materials

Some FDPs are fabricated entirely of metal, porcelain, or acrylic resin, but most consist of a combination of metal and porcelain. Acrylic resin-veneered pontics have had limited acceptance because of their reduced durability (wear and discoloration). The newer indirect composites, based on high inorganic-filled resins and the fiber-reinforced materials (see Chapter 27), have revived interest in composite resin and resin-veneered pontics.

Metal-ceramic pontics

Most pontics are fabricated by the metal-ceramic technique. If properly used, this technique is helpful for solving commonly encountered clinical problems. A well-fabricated metal-ceramic pontic is strong, is easy to keep clean, and looks natural. However, mechanical failure (Fig. 20-28) can occur and often is attributable to inadequate framework design. The principles of framework design are discussed in Chapter 19, but the following points are emphasized in this chapter:

1. The framework must provide a uniform veneer of porcelain (approximately 1.2 mm). Excessive thickness of porcelain contributes to inadequate support and predisposes to eventual fracture (Fig. 20-29). This is often true in the cervical portion of an anterior pontic. A reliable technique for ensuring uniform thickness of porcelain is to wax the fixed prosthesis to complete anatomic contour and then accurately cut back the wax to a predetermined depth (Fig. 20-30).
2. The metal surfaces to be veneered must be smooth and free of pits. Surface irregularities cause incomplete wetting by the porcelain slurry, which leads to voids at the porcelain-metal interface that reduce bond strength and increase the possibility of mechanical failure.
3. Sharp angles on the veneering area should be rounded. They produce increased stress concentrations that can cause mechanical failure.

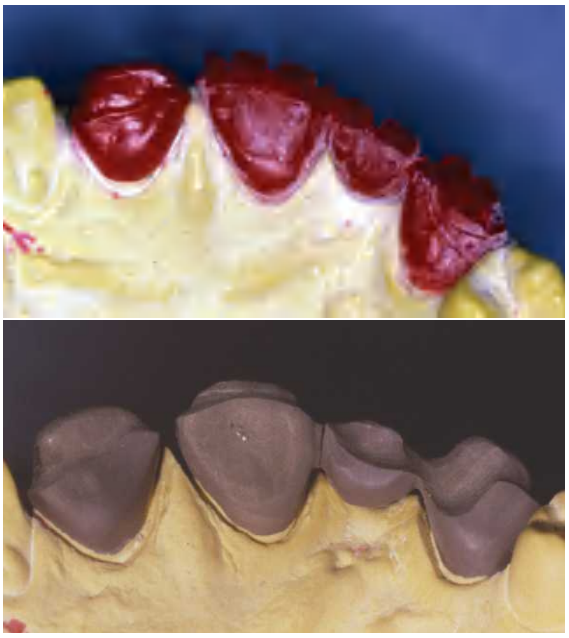


Fig. 20-30
A, Waxing to anatomic contour and controlled cut-back are the most reliable approaches to fabricating a satisfactory metal substructure (**B**).



Fig. 20-31
Failure caused by occlusal contact across the metal-ceramic junction.

4. The location and design of the external metal-porcelain junction require particular attention. Any deformation of the metal framework at the junction can lead to chipping of the porcelain (Fig. 20-31). For this reason, occlusal centric contacts must be placed at least 1.5 mm away from the junction. Excursive eccentric contacts that might deform the metal-ceramic interface must be evaluated carefully.

Resin-veneered pontics

Historically, acrylic resin-veneered restorations had deficiencies that made them acceptable only as longer term interim restorations. Their resistance to abrasion was lower than that of enamel or porcelain, and noticeable wear occurred with normal tooth-brushing (Fig. 20-32). Furthermore, the relatively high surface area/volume ratio of a thin resin veneer made dimensional change from water absorption and thermal fluctuations (thermocycling) a problem. Because no chemical bond existed between the resin and the metal framework, the resin was retained by mechanical means (i.e., undercuts). Continuous dimensional change of the veneers often caused leakage at the metal-resin interface, with subsequent discoloration of the restoration.

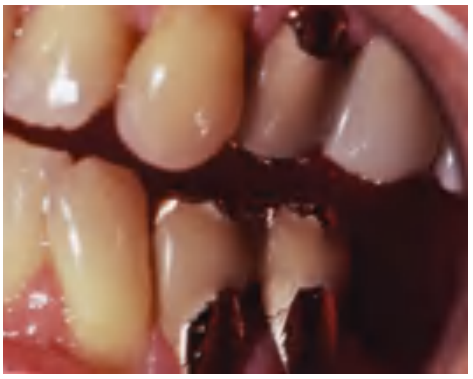


Fig. 20-32
Wear of an acrylic resin-veneered prosthesis.

Nevertheless, there are certain advantages to using polymeric materials instead of ceramics: They are easy to manipulate and repair and do not require the high-melting range alloys needed for metal-ceramic techniques. Indirect composite resin systems introduced since the 1990s have resolved some of the problems inherent in previous indirect resin veneers. These new-generation indirect resins have a higher density of inorganic ceramic filler than do traditional direct and indirect composite resins. Most are subjected to a post-curing process that results in high flexural strength, minimal polymerization shrinkage, and wear rates comparable with those of tooth enamel.[41] In addition, improvements in the bond between the composite resin and metal[42] may lead to a reappraisal of resin veneers.

Fiber-reinforced composite resin pontics

Composite resins can be used in partial FDPs without a metal substructure (see Chapter 27). A substructure matrix of impregnated glass or polymer fiber provides structural strength. The physical properties of this system, combined with its excellent marginal adaptation and esthetics, make it a possible metal-free alternative for FDPs, although long-term clinical performance is not yet known.

ESTHETIC CONSIDERATIONS

No matter how well biologic and mechanical principles have been followed during fabrication, the patient evaluates the result by how it looks, especially when anterior teeth have been replaced. Many esthetic considerations that pertain to single crowns also apply to the pontic (see Chapter 23). Several problems unique to the pontic may be encountered when achieving a natural appearance is attempted.

The Gingival Interface

An esthetically successful pontic replicates the form, contours, incisal edge, gingival and incisal embrasures, and color of adjacent teeth. The pontic's simulation of a natural tooth is most often betrayed at the tissue-pontic interface. The greatest challenge here is to compensate for anatomic changes that occur after extraction. Special attention should be paid to the contour of the labial surface as it approaches the pontic-tissue junction, to achieve a "natural" appearance. This cannot be accomplished by merely duplicating the facial contour of the missing tooth, because after a tooth is removed, the alveolar bone undergoes resorption and/or remodeling. If the original tooth contour were followed, the pontic would look unnaturally long incisogingivally (Fig. 20-33). To achieve the illusion of a natural tooth, an esthetic pontic must deceive observers into believing they are seeing a natural tooth.

The modified ridge-lap pontic is recommended for most anterior situations; it compensates for lost buccolingual width in the residual ridge by overlapping what remains. Rather than emerging from the crest of the ridge as a natural tooth would, the cervical aspect of the pontic sits in front of the ridge, covering any abnormal ridge structure resulting from tooth loss. Fortunately, because most teeth are viewed from only two dimensions, this relationship remains undetected. A properly designed, modified ridge-lap provides the required convexity on the tissue side, with smooth and open embrasures on the lingual side for ease of cleaning. This is difficult to accomplish. Clinically, many pontics are seen with less-than-optimal contour, which results in an unnatural appearance. This can be avoided with careful preparation at the diagnostic waxing stage (see Chapter 3). Sometimes the ridge tissue must be surgically reshaped to enhance the result.

In normal situations, light falls from above, and an object's shadow is below it. Unexpected lighting or unexpectedly placed shadows (Fig. 20-34) can be confusing to the brain. Because of past experience, the brain "knows" that a tooth grows out of the gingiva, and it therefore "sees" a pontic as a tooth unless telltale shadows suggest otherwise. Special care must be taken in studying where shadows fall around natural teeth, particularly around the gingival margin. If a pontic is poorly adapted to the resid-



Fig. 20-33
Correct incisogingival height is critical to esthetic pontic design. **A,** Esthetic failure of a four-unit partial fixed dental prosthesis (FDP) replacing the right central and lateral incisors. The pontics have been shaped to follow the facial contour of the missing teeth, but because of bone loss they look too long. **B,** The replacement FDP. Note that the gingival half of each pontic has been reduced. Esthetic appearance is much improved. **C,** This esthetic failure is the result of excessive reduction. The central incisor pontics look too short.

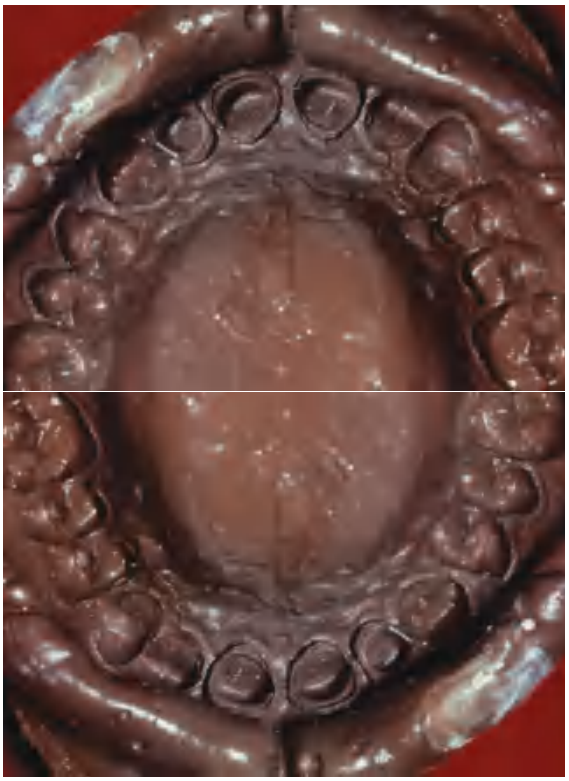


Fig. 20-34
Optical illusion. **A** and **B** are identical except that one image is upside down. Most people make different three-dimensional interpretations of each photograph, interpreting one as a negative impression and the other as a positive cast. (Verify the illusion by turning the book.) The interpretation is based on how shadows fall; in normal situations, objects are seen illuminated from above.

ual ridge, there is an unnatural shadow in the cervical area that looks odd and spoils the illusion of a natural tooth (Fig. 20-35). In addition, recesses at the gingival interface collect food debris, further betraying the illusion of a natural tooth.

When appearance is of utmost concern, the ovate pontic, used in conjunction with alveolar preservation or soft tissue ridge augmentation, can provide an appearance at the gingival interface that is virtually indistinguishable from that of a natural tooth. Because it emerges from a soft tissue recess, this pontic is not susceptible to many of the esthetic pitfalls applicable to the modified ridge lap pontic. However, in most cases, the patient must be willing to undergo the additional surgical procedures that an ovate pontic requires.

Incisogingival Length

Obtaining a correctly sized pontic simply by duplicating the original tooth is not possible. Ridge resorption makes such a pontic look too long in the cervical region. The height of a tooth is immediately obvious when the patient smiles and shows the gingival margin (Fig. 20-36). An abnormal labiolingual position or cervical contour, however, is not immediately obvious. This fact can be used to produce a pontic of good appearance by recontouring the gingival half of the labial surface (see Fig. 20-36). The observer sees a normal tooth length but is unaware of the abnormal labial contour. The illusion is successful.

Even with moderately severe bone resorption, obtaining a natural appearance by exaggerated contouring of the pontics may still be possible. In areas where tooth loss is accompanied by excessive loss of alveolar bone, however, a pontic of normal length would not touch the ridge at all.

One solution is to shape the pontic to simulate a normal crown and root with emphasis on the cementoenamel junction. The root can be stained to simulate exposed dentin (Fig. 20-37). Another approach is to use pink porcelain to simulate the gingival tissues (Fig. 20-38). However, such pontics then have considerably increased tissue contact and require scrupulous plaque control for long-term success. Ridge augmentation procedures have been successful in correcting areas of limited resorption. When bone loss is severe, the esthetic result obtained with a partial removable dental prosthesis is often better than with an FDP.

Mesiodistal Width

Frequently, the space available for a pontic is greater or smaller than the width of the contralateral tooth. This is usually because of uncontrolled tooth movement that occurred when a tooth was removed and not replaced.

If possible, such a discrepancy should be corrected by orthodontic treatment. If this is not possible, an acceptable appearance may be obtained by incorporating visual perception principles into the pontic design. In the same way that the brain can be confused into misinterpreting the relative sizes of shapes or lines because of an erroneous interpretation of perspective (Fig. 20-39), a pontic of abnormal size may be designed to give the illusion of being a more natural size. The width of an anterior tooth is usually identified by the relative positions of the mesiofacial and distofacial line angles, and the overall shape by the detailed pattern of surface contour and light reflection between these line angles. The features of the contralateral tooth (Fig. 20-40) should be duplicated as precisely as possible in the pontic, and the space discrepancy can be

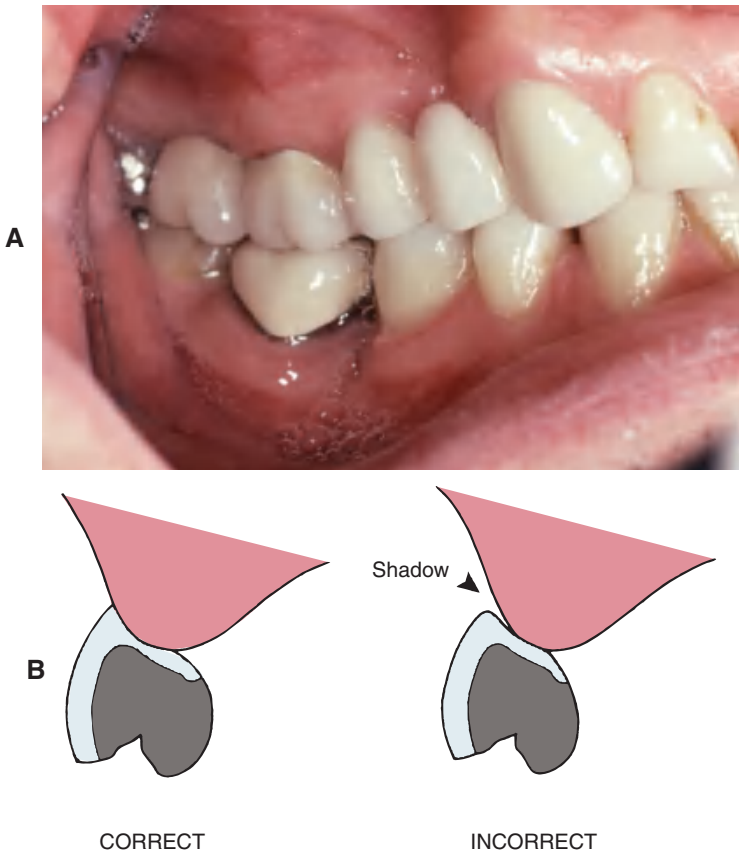
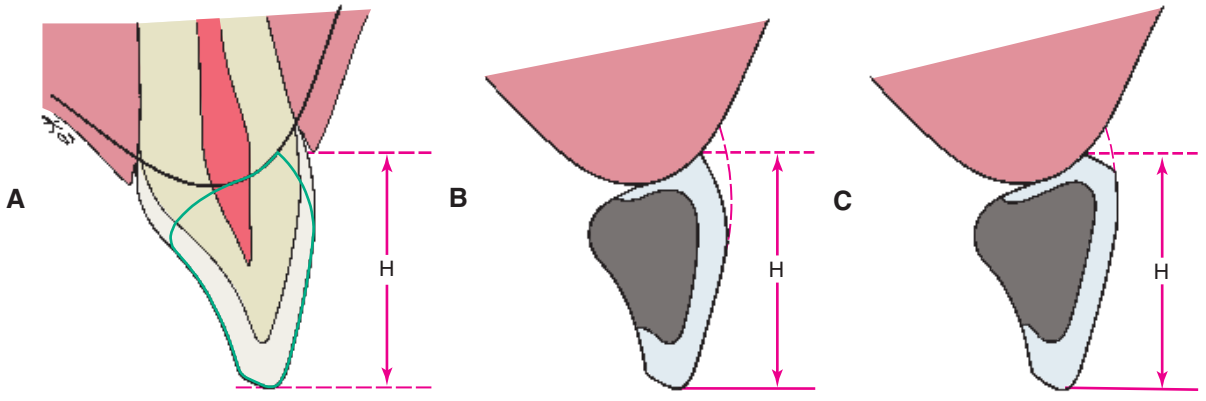


Fig. 20-35

A pontic should be interpreted as "growing" out of the gingival tissue. The second premolar pontic in the four-unit partial fixed dental prosthesis (**A**) is successful because it is well adapted to the ridge; however, the pontic for the first premolar is evident because of its poor adaptation to the ridge, which creates a shadow. **B,** Shadows around the gingival surface (*arrow*) spoil the esthetic illusion.



It is often necessary to recontour a substantial portion of the facial surface (**B**) to minimize a shadow or food trap at the cervical of the pontic (**C**).

Fig. 20-36

A, A pontic should have the same incisogingival height (*H*) as the original tooth. **B,** Correctly contoured pontic. **C,** Incorrectly contoured pontic. (The *dotted lines* in **B** and **C** show the original tooth contour.) The shelf at the gingival margin may trap food and create an esthetically unacceptable shadow.

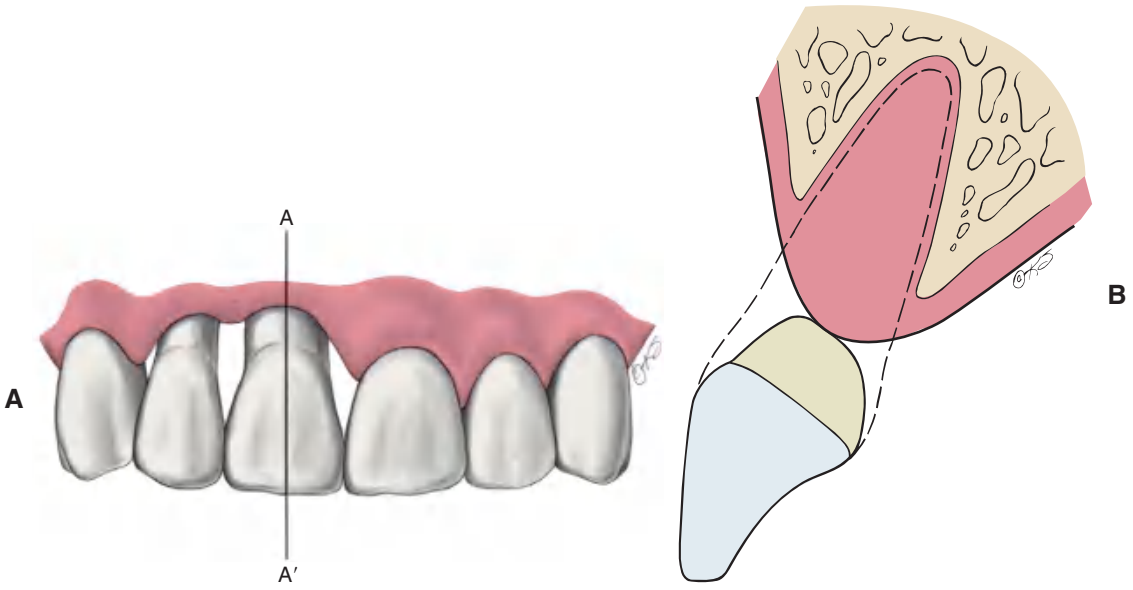


Fig. 20-37

It is difficult without surgical augmentation to fabricate an esthetic fixed prosthesis for a patient with extensive alveolar bone loss. A to D, One approach is to contour the crowns normally and shape and stain the apical extension to simulate exposed root surface. *(**A** and **B,** Redrawn from Blancheri RL: Optical illusions and cosmetic grinding. Rev Asoc Dent Mex 8:103, 1950.)*



Fig. 20-38

Partial fixed dental prosthesis replacing maxillary left central and lateral incisors. This patient had lost significant bone from the edentulous ridge. A and B, Appearance of the prosthesis was enhanced with the use of pink porcelain between the pontics to simulate gingival tissue. The patient has been able to maintain excellent tissue health through the daily use of Oral-B Super Floss.

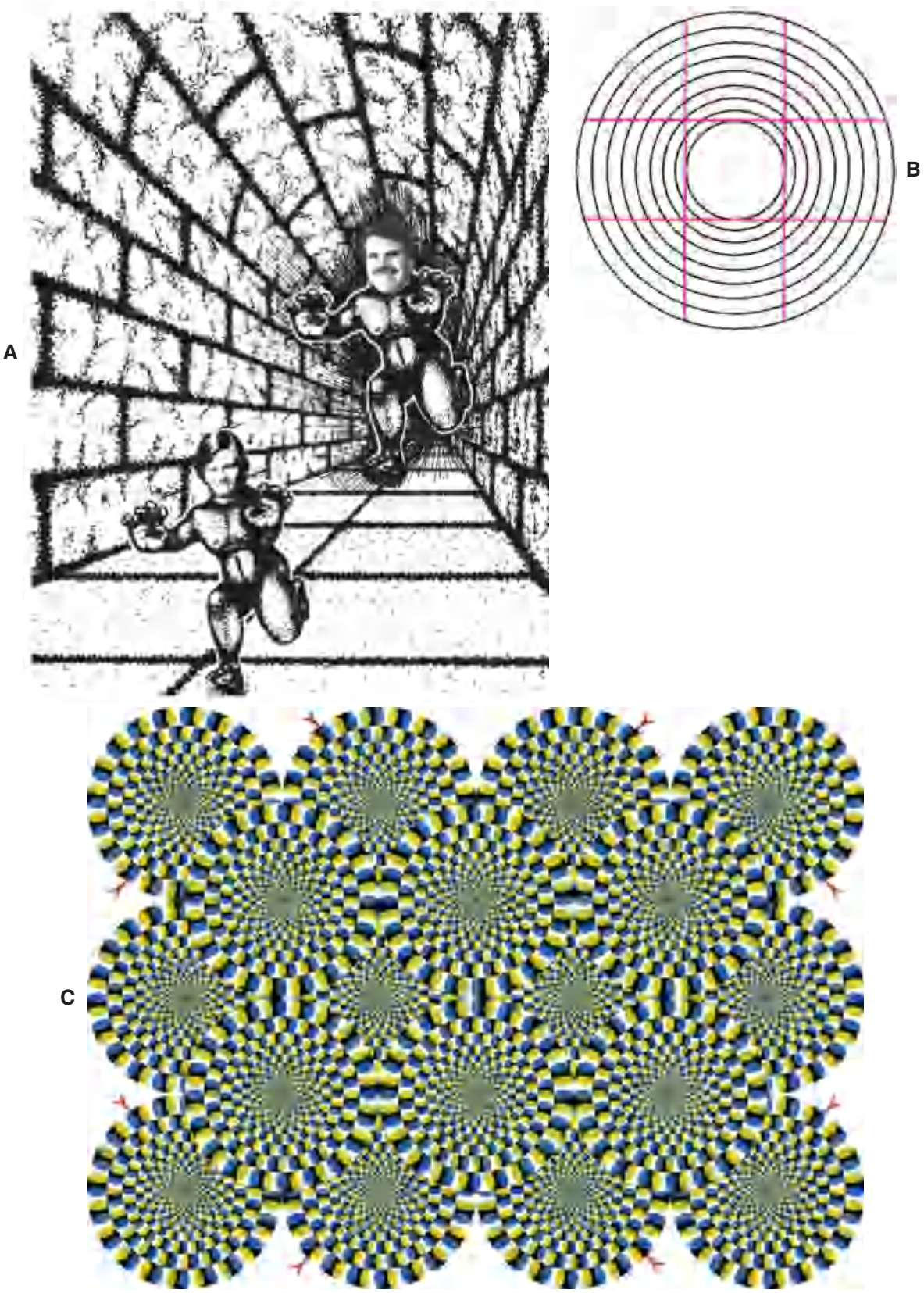


Fig. 20-39

Optical illusions. A, The authors are the same size. **B,** The lines are straight. (Tilt the book to verify this.) **C,** Kitaoka's "Rotating Snake" Illusion. Look at this one close up. Rotation of the "wheels" occurs in relation to eye movements. On steady fixation the effect vanishes.[44] (**A,** *Modified from Shepard RN: MindSights. New York, WH Freeman, 1990;* **C,** *© Akiyoshi Kitaoka 2003, reproduced by permission.*)

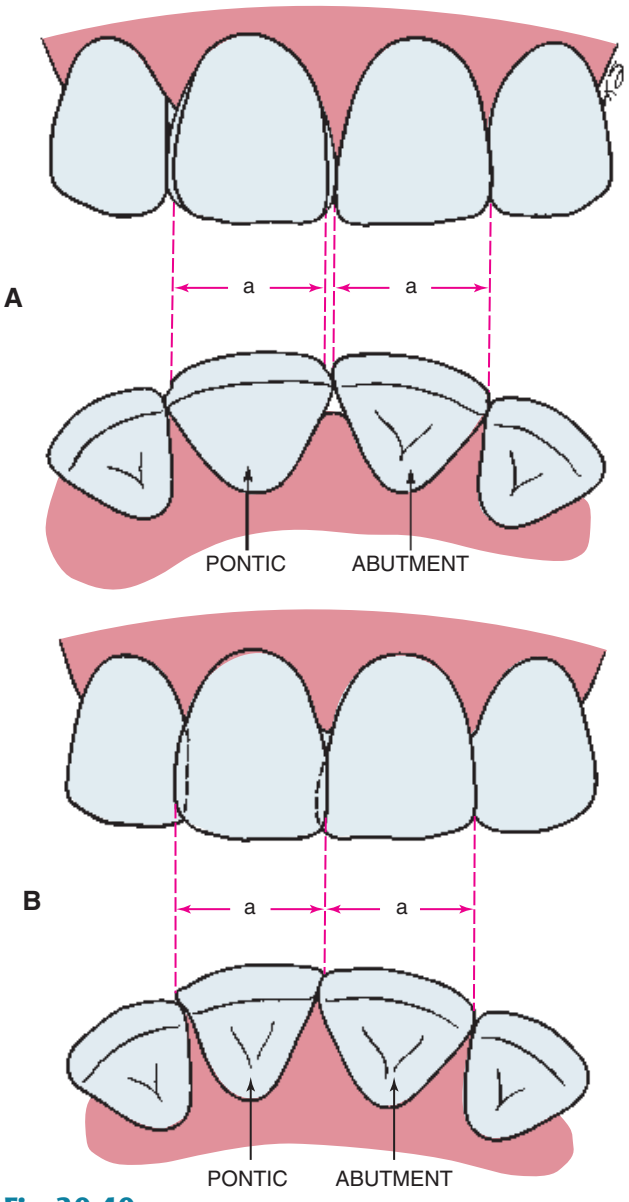


Fig. 20-40

An abnormally sized anterior pontic space can be restored esthetically by matching the location of the line angles and adjusting the interproximal areas. Large (A) and small (B) pontic spaces. Dimension *a* should be matched in the replacement. *(Redrawn from Blancheri RL: Optical illusions and cosmetic grinding. Rev Asoc Dent Mex 8:103, 1950.)*

compensated by altering the shape of the proximal areas. The retainers and the pontics can be proportioned to minimize the discrepancy. (This is another situation in which a diagnostic waxing procedure helps solve a challenging restorative problem.)

Space discrepancy presents less of a problem when posterior teeth are being replaced (Fig. 20-41) because their distal halves are not normally visible from the front. A discrepancy here can be managed

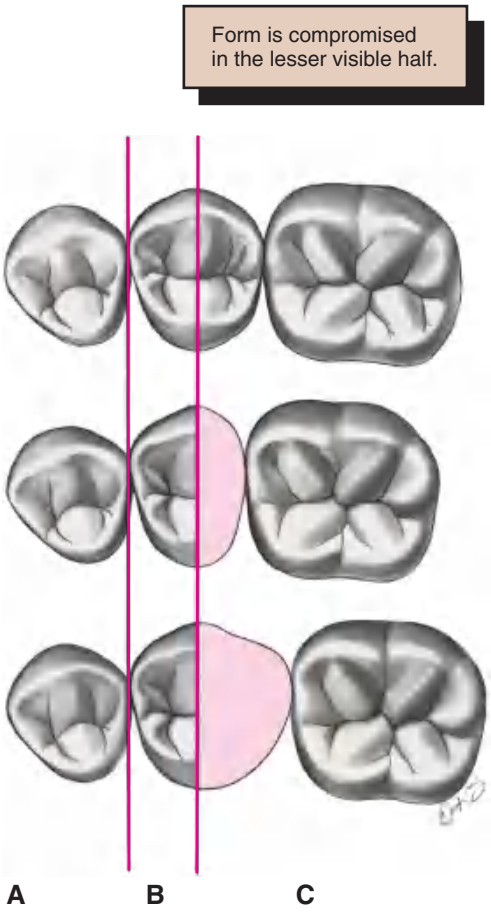


Fig. 20-41

When replacing a posterior tooth (A), duplicate the dimension of the more visible mesial half of the adjacent tooth. Narrow (B) and wide (C) pontic spaces. *(Redrawn from Blancheri RL: Optical illusions and cosmetic grinding. Rev Asoc Dent Mex 8:103, 1950.)*

by duplicating the visible mesial half of the tooth and adjusting the size of the distal half.

PONTIC FABRICATION

Available Materials

Over time, several techniques for pontic fabrication have evolved. Prefabricated porcelain facings were very popular for use with conventional gold alloys. As use of the metal-ceramic technique increased during the 1970s, prefabricated facings lost their popularity and essentially disappeared. Although an acceptable substitute, custom-made metal-ceramic facings never gained widespread acceptance. Table 20-3 summarizes the various techniques (Fig. 20-42).

Most pontics are now made with the metal-ceramic technique, which provides the best solution to the biologic, mechanical, and esthetic challenges

Table **20-3** **AVAILABLE PONTIC SYSTEMS**

	Advantages	Disadvantages	Indications	Contraindications
Metal-ceramic	Esthetics Biocompatible	Difficult if an abutment is not metal-ceramic Weaker than all-metal	Most situations	Long spans with high stress
All-metal	Strength Straightforward procedure	Nonesthetic	Mandibular molars, especially under high bite force	Where esthetics is important
Fiber-reinforced all-resin	Conservative when used with inlay procedures Esthetics Ease of repair	Long-term success unknown Limited to short spans	Areas of high esthetic concern	Long-span partial fixed dental prostheses
Facings	Rarely used; of historical interest only	Rarely used; of historical interest only	Rarely used; of historical interest only	Rarely used; of historical interest only



Fig. 20-42

A, Eight-unit partial fixed dental prosthesis (FDP) with porcelain facings. **B** and **C,** This three-unit posterior FDP has been fabricated by post-ceramic soldering of a metal-ceramic facing to conventional gold. **D,** Metal-ceramic FDP with a modified ridge lap pontic (canine) that appears to emerge from the gingiva.

encountered in pontic design. Their fabrication, however, differs slightly from the fabrication of individual crowns. These differences are emphasized in the ensuing paragraphs.

Metal-Ceramic Pontics

A well-designed metal-ceramic pontic allows for easy plaque removal, strength, wear resistance, and good esthetics (see Fig. 20-42*D*). Its fabrication is relatively simple if at least one retainer is also metal-ceramic. The metal framework for the pontic and one or both of its retainers is then cast in one piece. This facilitates pontic manipulation during the successive laboratory and clinical phases. In the following discussion, it is assumed that either one or both of the retainers are metal-ceramic complete crowns. When this is not the case, an alternative approach is necessary.

Anatomic contour waxing

For strength and esthetics, an accurately controlled thickness of porcelain is needed in the finished restoration. To ensure this, a wax pattern is made to the final anatomic contour. This also enables an assessment of connector design adequacy and the relationship between the connectors and the proposed configuration of the ceramic veneer (see Chapter 28).

Armamentarium (Fig. 20-43)

- Bunsen burner
- Inlay wax
- Sticky wax
- Waxing instruments
- Cotton cleaning cloth
- Die-wax separating liquid
- Zinc stearate or powdered wax
- Double-ended brushes
- Cotton balls
- Fine-mesh nylon hose

Step-by-step procedure

1. Wax the internal, proximal, and axial surfaces of the retainers as described in Chapter 18.
2. Soften the inlay wax, mold it to the approximate desired pontic shape, and adapt it to the ridge. This is the starting point for subsequent modification. Alternatively (and perhaps preferably), an impression may be made of the diagnostic waxing or interim restoration. Molten wax can then be poured into this to form the initial pontic shape. Prefabricated pontic shapes are also available as a starting point (Fig. 20-44).
3. If a posterior tooth is being replaced, leave the occlusal surface flat, because the occlusion is best developed with the wax addition technique outlined in Chapter 18.
4. Lute the pontic to the retainers and, for additional stability, connect its cervical aspect directly to the definitive cast with sticky wax. Then wax the pontic to proper axial and occlusal (or incisal) contour (Fig. 20-45).
5. Complete the retainers, and contour the proximal and tissue surfaces of the pontic for the desired tissue contact. The pontic is now ready for evaluation before cut-back.

Evaluation

The form of the wax pattern is evaluated (Fig. 20-46), and any deficiencies are corrected. Particular attention is given to the connectors, which should have the correct shape and size. The connectors provide firm attachment for the pontic so that it does not separate from the retainers during the subsequent cut-back procedure.



Fig. 20-43
Waxing armamentarium.



Fig. 20-44
Prefabricated wax pontics.

Cut-back

Armamentarium

- Bunsen burner
- Waxing instruments
- Cut-back instrument
- Scalpel
- Thin ribbon saw blade or sewing thread
- Explorer

Step-by-step procedure

1. Use a sharp explorer to outline the area that will be veneered with porcelain (Fig. 20-47*A*). The porcelain-metal junction must be placed sufficiently lingually to ensure good esthetics.
2. Make depth cuts or grooves in the wax pattern (see Chapter 19 and Fig. 20-47*B*).
3. Complete the cut-back as far as access allows, with the units connected and on the definitive cast.
4. Section one wax connector with a thin ribbon saw (sewing thread is a suitable alternative), and remove the isolated retainer from the definitive cast (Fig. 20-47*C*).
5. Finish the cut-back of this retainer, making sure there is a distinct 90-degree porcelain-metal junction.
6. Reflow and finalize the margins. The pontic is held in position by the other retainer during this procedure.
7. Refine the pontic cut-back where access is improved by removal of the first retainer.
8. Reseat the first retainer, reattach it to the pontic, section the other connector, and repeat the process.
9. Sprue the units, and do any final reshaping as needed.
10. Invest and cast in the manner described in Chapter 22.

When one connector of a three-unit FDP is to be cast and the other soldered, the cast connector should be sectioned first when the foregoing procedure is followed. The gingival surface of the pontic should be cut back in the metal rather than in the wax, because the tissue contact helps stabilize the pontic. Access is difficult, and it is easy to break the fragile wax connector.

Metal preparation

Armamentarium

- Separating disk
- Ceramic-bound finishing stones

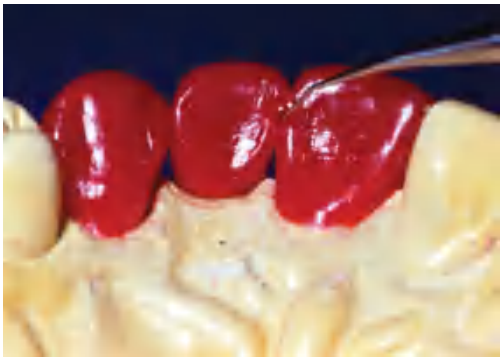


Fig. 20-45
Luting the pontic to the retainers.



Fig. 20-46
Anatomic contour wax patterns.

A



B,C

Fig. 20-47
Cut-back procedure for a three-unit anterior partial fixed dental prosthesis. **A,** Delineating the porcelain-metal junction. **B,** Wax patterns cut back for porcelain application. **C,** A ribbon saw is used to section the connector.



Fig. 20-48
Metal substructure ready for airborne particle abrasion and oxidation.



Fig. 20-49
Armamentarium for porcelain application.

- Sandpaper disks (nonveneered surfaces only)
- Rubber wheel (nonveneered surfaces only)
- Round carbide bur (No. 6 or 8)
- Airborne abrasion unit (with 25 µm aluminum oxide)

Step-by-step procedure

1. Recover the castings from the investment and prepare the surfaces to be veneered as described in Chapter 19 (Fig. 20-48).
2. Finish the gingival surface of the pontic. Do not overreduce this area.

Evaluation

Less than 1 mm of porcelain thickness is needed on the gingival surface, because once it is cemented, the restoration is seen from the facial rather than from the gingival side. Excessive gingival porcelain is a common fault in pontic framework design and may lead to fracture and poor appearance (see Fig. 20-29).

To facilitate plaque control, the metal-ceramic junction should be located lingually. Then tissue contact is on the porcelain and not on metal, which retains plaque more tenaciously.[43]

Porcelain application

Many of the steps for porcelain application are identical to those in individual crown fabrication (see Chapter 24). There are some features peculiar to pontic fabrication, however, and these are emphasized.

Armamentarium (Fig. 20-49)

- Paper napkin
- Glass slab
- Tissues or gauze squares
- Distilled water
- Glass spatula
- Serrated instrument
- Porcelain tweezers or hemostat
- Ceramist's brushes (No. 2, 4, or 6)
- Whipping brush
- Razor blade
- Cyanoacrylate resin
- Colored pencil
- Articulating tape
- Ceramic-bound stones
- Diamond stones
- Diamond disk

Step-by-step procedure

1. Prepare the metal and apply opaque as described in Chapter 24 (Fig. 20-50).
2. Apply cervical porcelain to the gingival surface of the pontic, and seat the castings on the definitive cast. A small piece of tissue paper adapted to the residual ridge on the cast by moistening with a brush prevents porcelain powder from sticking to the stone. (Cyanoacrylate resin or special separating agents can be used for the same purpose.)
3. Build up the porcelain (as described in Chapter 24) with the appropriate distribution of cervical, body, and incisal shades. The tissue paper acts as a matrix for the gingival surface of the pontic.
4. When the porcelain has been condensed, section between the units with a thin razor blade. This prevents the porcelain from pulling away from the framework as a result of firing shrinkage. A second application of porcelain is needed to correct any deficiencies caused by firing shrinkage. Such additions usually are needed proximally and gingivally on the pontic.
5. Apply a porcelain separating liquid (e.g., VITA Modisol*) to the stone ridge so that the additional

*Vident, Brea, California.



Fig. 20-50
Porcelain application. **A,** Substructure ready for opaquing. **B,** Opaque application. **C,** Body porcelain application. **D,** The porcelain after the first firing.

gingival porcelain can be lifted directly from the cast as in the fabrication of a porcelain labial margin (see Chapter 24).

6. Mark the desired tissue contact and contour the gingival surface to provide as convex a surface as possible. The pontic is now ready for clinical evaluation and soldering procedures, characterization, glazing, finishing, and polishing (see Chapters 28 to 30).

Evaluation

The porcelain on the tissue surface of the pontic should be as smooth as possible (Fig. 20-51). Pits and defects make plaque control difficult and promote calculus formation. The metal framework must be highly polished, with special care directed to the gingival embrasures (where access for plaque removal is more difficult).



Fig. 20-51
Metal-ceramic pontic replacing a lateral incisor.

All-Metal Pontics

Pontics made from metal (Fig. 20-52) require fewer laboratory steps and are therefore sometimes used for posterior FDPs. However, they have some disadvantages (e.g., their appearance). In addition, investing and casting must be done carefully because the mass of metal in the pontic is prone to porosity as the bulk increases. A porous pontic retains plaque and tarnishes and corrodes rapidly.

SUMMARY

Designs that allow easy plaque control are especially important to a pontic's long-term success. Minimizing tissue contact by maximizing the convexity of the pontic's gingival surface is essential. Special consideration is also needed to create a design that com-

STUDY QUESTIONS

1. Outline and discuss a logical classification of pontics.
2. How does pontic design change as a function of location in the dental arch?
3. What are the materials available for pontic fabrication? What are their respective advantages, disadvantages, indications, and contraindications?
4. Discuss the factors that govern the shaping of the facial and lingual surfaces of a modified ridge lap pontic.
5. What common clinical problems might be encountered if a pontic is improperly shaped or fabricated?
6. Discuss the various techniques for soft tissue augmentation and the residual ridge defects they are designed to resolve.
7. What factors should be considered in selecting the pontic material that will be in contact with the residual ridge?

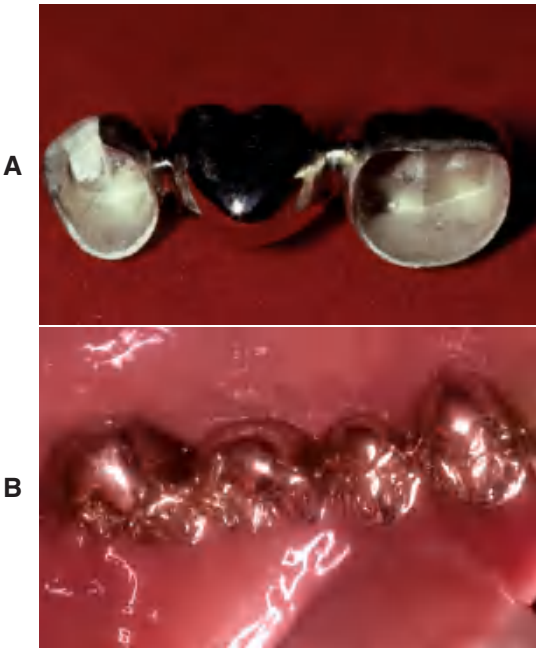


Fig. 20-52
All-metal partial fixed dental prostheses.

bines easy maintenance with natural appearance and adequate mechanical strength. When the appropriate design has been selected, it must be accurately conveyed to the dental technician.

There are subtle differences between metal-ceramic pontic fabrication and the fabrication of other types of pontics. Under most circumstances, the metal-ceramic technique is used because it is straightforward and practical. However, it requires careful execution for maximum strength, appearance, and effective plaque control. Alternative procedures are sometimes helpful, particularly when gold alloys are used for the retainers. Resin-veneered pontics should be restricted to use as longer-term interim restorations, and all-metal pontics may be the restoration of choice in nonesthetic situations, particularly those in which forces are high.

GLOSSARY*

aug·men·ta·tion \ôg′mĕn-tā′shun\ *n* (14c): to increase in size beyond the existing size. In alveolar ridge augmentation, bone grafts or alloplastic materials are used to increase the size of an atrophic alveolar ridge

back·ing \băk′ĭng\ *n* (1793): a metal support that attaches a facing to a prosthesis

center of the ridge \sĕn′ter ŭv thē rĭj\: the faciolingual or buccolingual mid-line of the residual ridge

clinical crown \klĭn′ĭ-kel kroun\: the portion of a tooth that extends from the occlusal table or incisal edge to the free gingival margin

connective tissue \ka-nĕk′tĭv tĭsh′ōō\: a tissue of mesodermal origin rich in interlacing processes that supports or binds together other tissues

crest \krĕst\ *n* (14c): a ridge or prominence on a part of a body; in dentistry, the most coronal portion of the alveolar process

crest of the ridge \krĕst ŭv tha rĭj\: the highest continuous surface of the residual ridge—not necessarily coincident with the center of the ridge

emergence profile \ĭ-mûr′jens prō′fīl\: the contour of a tooth or restoration, such as a crown on a natural tooth or dental implant abutment, as it relates to the adjacent tissues

hygienic pontic \hī′jē-ĕn′ĭk, hī-jĕn′-pōn′tĭk\: a pontic that is easier to clean because it has a domed or bullet shaped cervical form and does not overlap the edentulous ridge

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modified ridge lap \mŏd′a-fīd′ rĭj lăp\: a ridge lap surface of a pontic that is adapted to only the facial or buccal aspect of the residual ridge

ovate pontic: a pontic that is shaped on its tissue surface like an egg in two dimensions, typically partially submerged in a surgically-prepared soft-tissue depression to enhance the illusion that a natural tooth is emerging from the gingival tissues

pon·tic \pŏn′tĭk\ *n*: an artificial tooth on a fixed dental prosthesis that replaces a missing natural tooth, restores its function, and usually fills the space previously occupied by the clinical crown

residual ridge \rĭ-zĭj′ōō-al rĭj\: the portion of the residual bone and its soft tissue covering that remains after the removal of teeth

residual ridge crest \rĭ-zĭj′ōō-al rĭj krĕst\: the most coronal portion of the residual ridge

residual ridge resorption \rĭ-zĭj′ōō-al rĭj rē-sôrb′ shun, -zôrb′-\: a term used for the diminishing quantity and quality of the residual ridge after teeth are removed

(Ortman HR. Factors of bone resorption of the residual ridge. J PROSTHET DENT 1962;12:429-40.

Atwood DA. Some clinical factors related to rate of resorption of residual ridges. J PROSTHET DENT 1962;12:441-50.)

ridge augmentation \rĭj ôg′mĕn-tā′shun\: any procedure designed to enlarge or increase the size, extent, or quality of deformed residual ridge

ridge crest \rĭj krĕst\: the highest continuous surface of the residual ridge not necessarily coincident with the center of the ridge

ridge lap \rĭj lăp\: the surface of an artificial tooth that has been shaped to accommodate the residual ridge. The tissue surface of a ridge lap design is concave and envelops both the buccal and lingual surfaces of the residual ridge

sanitary pontic *obs*: a trade name originally designed as a manufactured convex blank with a slotted back. The name was used occasionaly as a synonym for a *hygienic pontic*, wherein the pontic does not contact the residual ridge

REFERENCES

1. Stein RS: Pontic-residual ridge relationship: a research report. J Prosthet Dent 16:251, 1966.
2. Siebert JS: Reconstruction of deformed, partially edentulous ridges, using full thickness onlay grafts. I. Technique and wound healing. Compend Contin Educ Dent 4:437, 1983.
3. Abrams H, et al: Incidence of anterior ridge deformities in partially edentulous patients. J Prosthet Dent 57:191, 1987.
4. Hawkins CH, et al: Ridge contour related to esthetics and function. J Prosthet Dent 66:165, 1991.
5. Abrams L: Augmentation of the deformed residual edentulous ridge for fixed prosthesis. Compend Contin Educ Dent 1:205, 1980.
6. Garber DA, Rosenberg ES: The edentulous ridge in fixed prosthodontics. Compend Contin Educ Dent 2:212, 1981.
7. Langer B, Calagna L: The subepithelial connective tissue graft. J Prosthet Dent 44:363, 1980.
8. Smidt A, Goldstein M: Augmentation of a deformed residual ridge for the replacement of a missing maxillary central incisor. Pract Periodont Aesthet Dent 11:229, 1999.
9. Kaldahl WB, et al: Achieving an esthetic appearance with a fixed prosthesis by submucosal grafts. J Am Dent Assoc 104:449, 1982.
10. Meltzer JA: Edentulous area tissue graft correction of an esthetic defect: a case report. J Periodontol 50:320, 1979.
11. McHenry K, et al: Reconstructing the topography of the mandibular ridge with gingival autografts. J Am Dent Assoc 104:478, 1982.
12. Studer SP, et al: Soft tissue correction of a single-tooth pontic space: a comparative quantitative volume assessment. J Prosthet Dent 83:402, 2000.
13. Nemcovsky CE, Vidal S: Alveolar ridge preservation following extraction of maxillary anterior teeth. Report on 23 consecutive cases. J Periodontol 67:390, 1996.
14. Bahat O, et al: Preservation of ridges utilizing hydroxylapatite. Int J Periodontol Res Dent 6:35, 1987.
15. Lekovic V, et al: A bone regenerative approach to alveolar ridge maintenance following tooth extraction. Report of 10 cases. J Periodontol 68:563, 1997.
16. Spear FM: Maintenance of the interdental papilla following anterior tooth removal. Pract Periodont Aesthet Dent 11:21, 1999.
17. Ingber JS: Forced eruption. II. A method of treating nonrestorable teeth–periodontal and restorative considerations. J Periodontol 47:203, 1976.
18. Perel ML: A modified sanitary pontic. J Prosthet Dent 28:589, 1972.
19. Hood JA, et al: Stress and deflection of three different pontic designs. J Prosthet Dent 33:54, 1975.
20. Shillingburg HT, et al: Fundamentals of Fixed Prosthodontics, 2nd ed, p 387. Chicago, Quintessence Publishing, 1981.

21. Eissmann HF, et al: Physiologic design criteria for fixed dental restorations. Dent Clin North Am 15:543, 1971.
22. Tripodakis AR, Constandinides A: Tissue response under hyperpressure from convex pontics. Int J Periodont Restorative Dent 10:409, 1990.
23. Cavazos E: Tissue response to fixed partial denture pontics. J Prosthet Dent 20:143, 1968.
24. Henry PJ, et al: Tissue changes beneath fixed partial dentures. J Prosthet Dent 16:937, 1966.
25. Jacques LB, et al: Tissue sculpturing: an alternative method for improving esthetics of anterior fixed prosthodontics. J Prosthet Dent 81:630, 1999.
26. Zitzmann NU, et al: The ovate pontic design: a histologic observation in humans. J Prosthet Dent 88:375, 2002.
27. Hirshberg SM: The relationship of oral hygiene to embrasure and pontic design: a preliminary study. J Prosthet Dent 27:26, 1972.
28. McLean JW: The Science and Art of Dental Ceramics, vol 2, p 339. Chicago, Quintessence Publishing, 1980.
29. Harmon CB: Pontic design. J Prosthet Dent 8:496, 1958.
30. Henry PJ: Pontic form in fixed partial dentures. Aust Dent J 16:1, 1971.
31. Allison JR, Bhatia HL: Tissue changes under acrylic and porcelain pontics [Abstract No. 168]. J Dent Res 37:66, 1958.
32. Silness J, et al: The relationship between pontic hygiene and mucosal inflammation in fixed bridge recipients. J Periodont Res 17:434, 1982.
33. Gildenhuys RR, Stallard RE: Comparison of plaque accumulation on metal restorative surfaces. Dent Surv 51(1):56, 1975.
34. Keenan MP, et al: Effects of cast gold surface finishing on plaque retention. J Prosthet Dent 43:168, 1980.
35. Ørstavik D, et al: Bacterial growth on dental restorative materials in mucosal contact. Acta Odontol Scand 39:267, 1981.
36. Clayton JA, Green E: Roughness of pontic materials and dental plaque. J Prosthet Dent 23:407, 1970.
37. Tolboe H, et al: Influence of pontic material on alveolar mucosal conditions. Scand J Dent Res 96:442, 1988.
38. Smith DE: The pontic in fixed bridgework. Pacific Dent Gaz 36:741, 1928.
39. Ante IH: Construction of pontics. J Can Dent Assoc 2:482, 1936.
40. Beke AL: The biomechanics of pontic width reduction for fixed partial dentures. J Acad Gen Dent 22(6):28, 1974.
41. Ferracane JL, Condon JR: Post-cure heat treatments for composites: properties and fractography. Dent Mater 8:290, 1992.
42. Rothfuss LG, et al: Resin to metal bond strengths using two commercial systems. J Prosthet Dent 79:270, 1998.
43. Wise MD, Dykema RW: The plaque-retaining capacity of four dental materials. J Prosthet Dent 33:178, 1975.
44. Kitaoka A, Ashida H: Phenomenal characteristics of peripheral drift illusion. Vision 15:261, 2003.
45. Ortman HR: Factors of bone resorption of the residual ridge. J Prosthet Dent 12:429, 1962.
46. Atwood DA: Some clinical factors related to rate of resorption of residual ridges. J Prosthet Dent 12:441, 1962.

21



RETAINERS FOR PARTIAL REMOVABLE DENTAL PROSTHESES

KEY TERMS

base
clasp
clip
guide plane
intracoronal rest
minor connector
occlusal rest
partial removable dental prosthesis
passive
precision attachment
reciprocal clasp
reciprocation
rest seat
survey line
surveyor
undercut
wrought retention clasp

There exist different philosophies regarding the need for fabrication of cast restorations for abutment teeth before fabrication of a **partial removable dental prosthesis** (partial RDP). Some authors advocate making such removable prostheses with a minimum of mouth preparation. They do not suggest the routine use of cast restorations for abutment teeth but prefer to modify the remaining natural dentition through enamoplasty and/or addition of composite resin. This has the advantage of reducing both treatment time and expense. Other authors, however, point to the advantages of using cast restorations on abutment teeth, suggesting that through precise shaping of the axial contours of such restorations, the masticatory and retentive forces can be directed more favorably through appropriate use of occlusal rest seats and **guide planes.** In addition, cast retainers permit incorporation of intracoronal rest seats or **precision attachments,** which can offer significant esthetic advantages over clasp retained partial RDPs. Use of cast crowns also allows splinting of abutment teeth with resultant reduction of mobility.[1]

The correct choice of treatment for any patient depends on a thorough history and examination and an accurate diagnosis and prognosis (see Chapter 1). Decisions concerning the restoration of abutment teeth involve many factors—caries, existing restorations, tooth vitality, shape and angulation, oral hygiene, and cost and experience—that must be

assessed and evaluated. Only then is the selected treatment likely to achieve the planned outcome that is based on the functional requirements of the patient.

TREATMENT PLANNING

The fabrication of a precisely fitting partial RDP is one of the more challenging tasks in restorative dentistry. Without a careful all-inclusive diagnosis and well-designed treatment plan, the chances of success are minimal. Patients who require a removable prosthesis usually have sustained extensive damage as a consequence of caries, periodontal disease, or trauma and may have extensive fixed and removable prosthodontic treatment needs (Fig. 21-1) They also may exhibit acquired or congenital intraoral defects. As a result of prolonged loss of arch integrity, there may be drifting or tipping, and the occlusion is often less than ideal.

Treatment plans that include a removable prosthesis may require additional diagnostic procedures besides those described in Chapters 1 and 2. Accurate diagnostic casts mounted in centric relation are extremely important. If all posterior teeth are absent, it is much more difficult to relate opposing diagnostic casts, and stable record bases must be made under these circumstances (Fig. 21-2). The necessary degree of stability can be obtained only if such record bases are fabricated on the cast that is to be articulated.

The use of a dental **surveyor** (Fig. 21-3) is essential during treatment planning for the following reasons:

1. To help assess the relative alignment of the long axes of teeth that support a partial RDP.
2. To help determine the optimum path of placement and removal.
3. To help evaluate tissue **undercuts** and their influence on partial RDP design.

The most appropriate anteroposterior and mediolateral tilt of the cast must be selected. Careful analysis is essential because a compromise between the requirements of an ideal tooth preparation (see



Fig. 21-1
A to **F,** The patient presented with extensive periodontal disease; several posterior teeth were removed. A combination of fixed and removable prostheses was used.



Fig. 21-2
Where multiple teeth are missing, a clasp-retained record base with wax rims (used here with zinc oxide–eugenol paste) should be used to ensure accurate articulation (**A** and **B**). This minimizes the risk of tipping of the casts in relation to one another.



Fig. 21-3
A dental surveyor is essential during treatment planning and in designing retainers for partial removable dental prostheses.

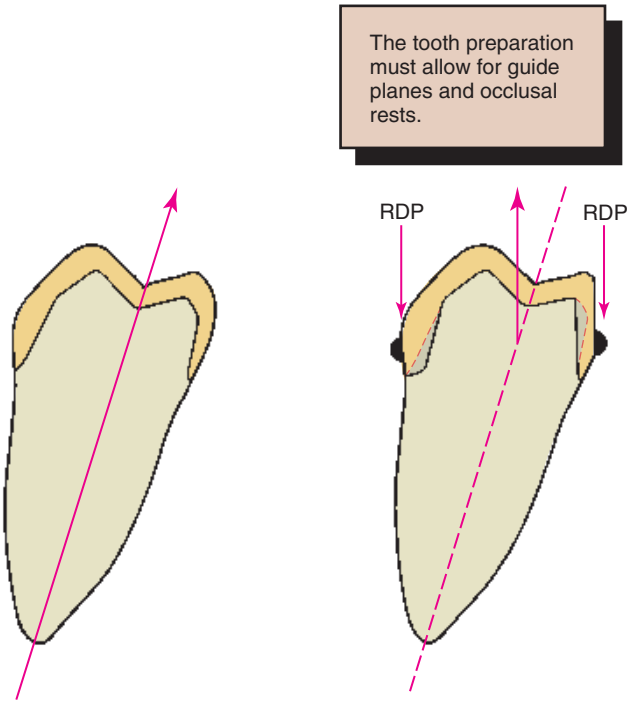


Fig. 21-4
A, Normal tooth preparation for a complete cast crown. The path of placement is in the long axis of the tooth. **B,** Modified tooth preparation for a partial removable dental prosthesis (RDP) retainer with lingual guide planes. This preparation has a more buccal path of placement.

Chapter 7) and the requirements for a particular tooth to be used as an abutment to support and retain an RDP is often necessary. The path of placement of the RDP is the most important factor in determining how much tooth reduction is needed to meet mechanical and esthetic requirements simultaneously (Fig. 21-4).

When the diagnostic cast is surveyed, the anteroposterior tilt should be established first. The lateral inclination is then determined. The operator should focus on the relative alignment of selected abutment teeth, any tissue undercuts, and the available occlusocervical dimension for anticipated proximal and reciprocal guide planes. The feasibility of recontouring axial walls and the possible consequences of such recontouring must also be considered. For instance, it may be necessary to treat a malposed tooth orthodontically or endodontically if recontouring is not feasible. Similarly, removal of a tooth

that unnecessarily complicates partial RDP design should be considered and carefully weighed against the effect of that decision on the stability of the prosthesis. If future loss of an already compromised tooth would render the partial RDP useless, it may be better to remove that tooth before initiating any prosthetic treatment.

When a patient has lost anterior teeth, the path of placement of a partial RDP should be parallel to the proximal surfaces of the abutment teeth adjacent to the space (Fig. 21-5). This results in superior esthetics because it minimizes the space between the artificial and natural teeth. Sometimes esthetics can be improved by use of a rotational placement path.[2]

Apparently complex decisions as to the best combination of tooth preparation and path of placement can be greatly simplified through diagnostic tooth preparation, waxing, and denture tooth setting (Figs. 21-6 and 21-7). These trial procedures on diagnostic casts help determine how to achieve the best mechanical and esthetic result without deviating from the principles of occlusion or making excessively bulky restorations that inevitably cause periodontal complications. The concept is to determine the precise end point in regard to occlusion and appearance with interchangeably articulator-mounted casts of the pretreatment and posttreatment condition, before treatment is initiated. The use of such cross-mounted casts (see also Chapter 3) also enables the treatment sequence to be simplified by allowing one arch to be treated at a time. The restorations on the first arch to be restored are fabricated against the diagnostically waxed opposing cast (Fig. 21-8; see also Fig. 3-34).



Fig. 21-5
The appearance of an anterior partial removable dental prosthesis is improved by careful selection of the path of placement.

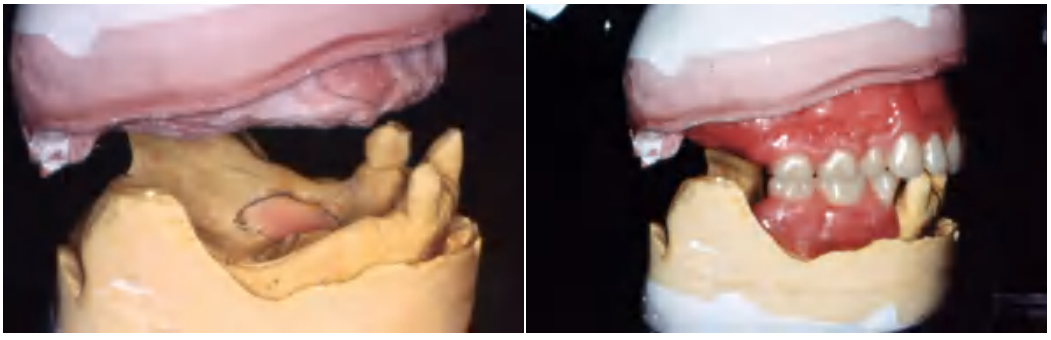
Prerequisites for Success

The clinician and laboratory technician must have a good understanding of partial RDP design (Fig. 21-9). An in-depth discussion of the approaches to framework design is beyond the scope of this text. Instead, the modifications that must be incorporated in the cast restoration to accommodate a partial RDP are considered.

Design

Many concepts of partial RDP design have been advocated. Regardless of the concept selected, the operator needs a keen understanding of the requirements placed on fixed retainers. The design should allow the forces developed during placement, removal, and function to be so directed as to cause the least harm to the remaining dentition. The proposed design (Fig. 21-10) should be carefully sketched at the initial treatment planning stage. In general, this reveals any existing problems. Each fixed restoration should be designed to be fully compatible with the removable prosthesis while concurrently meeting all criteria to properly fulfill the functional requirements of mastication and facilitating the performance of oral hygiene. Often, decisions made about the path of place-ment of the partial RDP necessitate removal of additional tooth structure in order to maintain the minimally required material thickness for the fixed prosthesis.

A



B

Fig. 21-6
Diagnostic mounted casts and waxing are essential prerequisites for extensive prosthodontic care. **A,** Diagnostically mounted casts. **B,** Diagnostic tooth arrangement. *(Courtesy of Dr. N. L. Clelland.)*

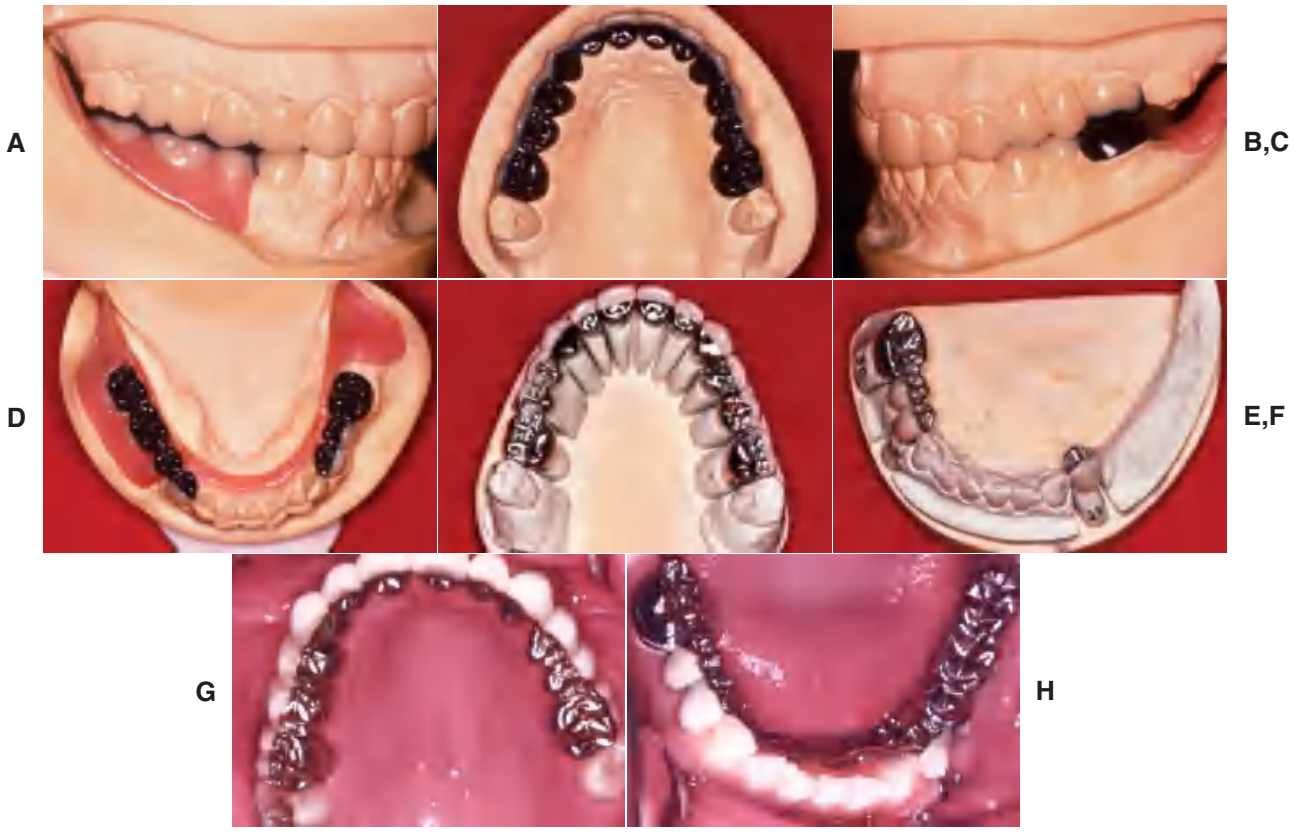


Fig. 21-7
Diagnostic tooth preparation and waxing are especially valuable in treating patients who require a combination of fixed and removable prosthodontics. **A** to **D,** Diagnostic waxing. **E** and **F,** Fixed prostheses. **G** and **H,** Completed restorations. Mandibular partial removable dental prosthesis has cast metal occlusal surfaces. *(Courtesy of Dr. J. H. Bailey.)*

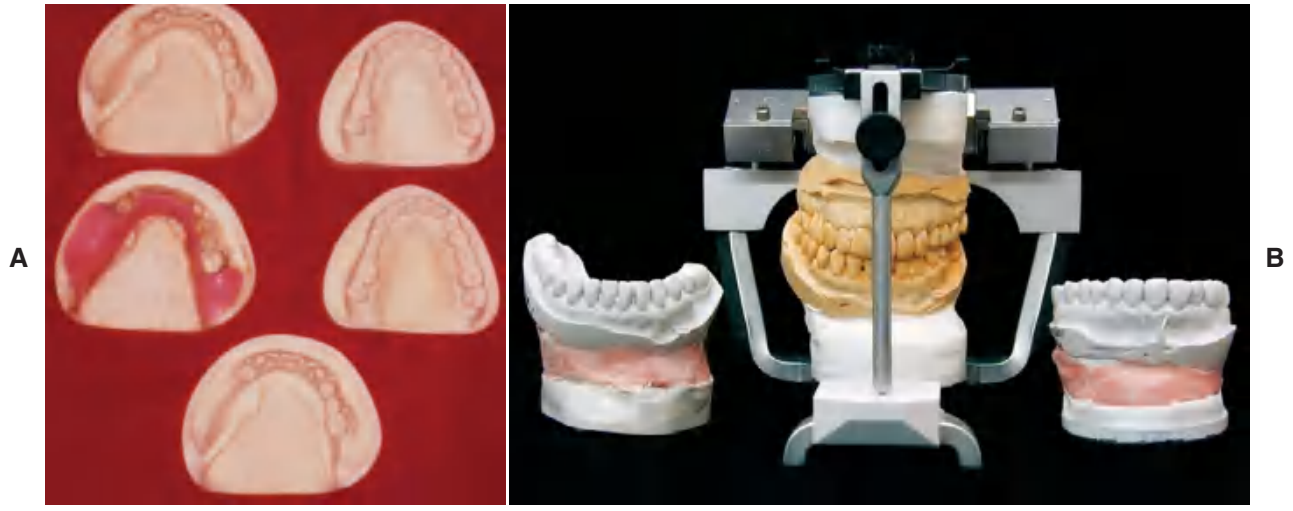


Fig. 21-8
Cross-mounted casts are used to simplify complex prosthodontic treatments. One set of casts is waxed to the end point of treatment, whereas the other set is left unaltered to enable the definitive casts to be mounted. An additional cast is needed for surveying a removable prosthesis. **A,** Casts needed for treating a patient who required a maxillary fixed prosthesis opposed by mandibular fixed and removable prostheses (see Fig. 21-7). **B,** The duplicated casts are mounted in the identical relationship on an articulator. Treatment can now be undertaken in phases. First the mandibular teeth are prepared, and a definitive cast is obtained. This is mounted against the maxillary unaltered cast, which is then replaced by the identically oriented, diagnostically waxed cast for the laboratory fabrication of the mandibular fixed prosthesis. (See also Fig. 3-34.) *(**A,** Courtesy of Dr. J. H. Bailey.)*

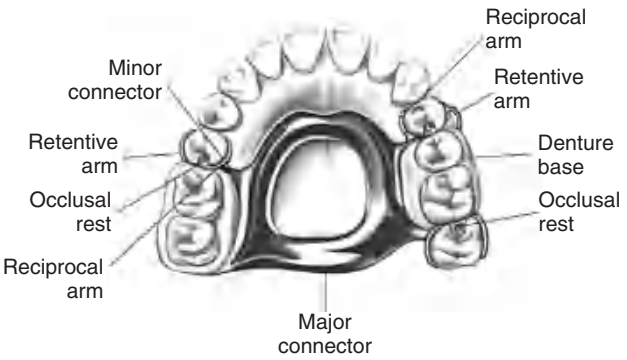


Fig. 21-9
Design of a partial removable dental prosthesis. The component parts are labeled.

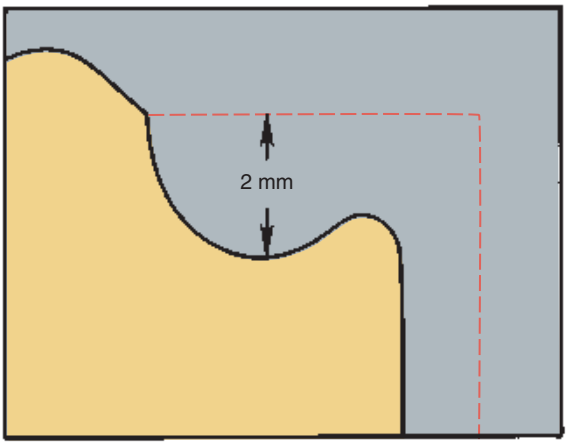


Fig. 21-11
Cross-section through an occlusal rest seat.



Fig. 21-10
Initial partial removable dental prosthesis design sketched on the diagnostic cast. *(Courtesy of Dr. N. L. Clelland.)*



Fig. 21-12
Distal rest seat on a mandibular second premolar.

Denture bases

The denture **base** areas are shaped to avoid interference with the abutment retainer during placement and removal. Therefore, the fixed prosthesis determines the denture base configuration, rather than vice versa.

Occlusal rest seat

The **rest seat** (Fig. 21-11) is the prepared recess in a tooth or restoration created to receive the occlusal, incisal, cingulum, or lingual rest. The **occlusal rest** of the partial RDP is the rigid extension that contacts the occlusal surface of a tooth or restoration. The occlusal rest of a partial RDP should fit precisely into the corresponding rest seats on the retainers. To reduce laterally directed forces, the rest seats should be spoon-shaped. The junction between the internal aspect of the rest seat and the proximal guide plane should be rounded to minimize stress on the framework and thereby reduce the chance of partial RDP fracture at the occlusal rest-**minor connector** interface.

Occlusal rest seats are most predictably placed in healthy enamel or cast metal. If they are placed in weaker materials such as amalgam, composite resin, or dental porcelain, fracture or distortion is likely to result. The size of the rest seat has been a matter of controversy. Ordinarily, if crowns are made, a No. 8 round bur produces an ideally sized rest in the wax pattern. On small teeth under normal loading, a No. 6 round bur can provide adequate space (Fig. 21-12). On anterior teeth, a cingulum rest seat should be created to support the removable prosthesis. Rests that are convex mesiodistally and resemble a V-shaped groove labiolingually (Fig. 21-13) have proven successful in clinical practice. This configuration prevents displacement of the abutment while simultaneously assisting in directing forces more parallel to its long axis. Unfortunately, a distinct cingulum rest of adequate size can rarely be placed in the cingulum of an unrestored tooth without pene-



Fig. 21-13
V-shaped cingulum rest seat.



Fig. 21-14
Incisal rest on a mandibular canine. *(Courtesy of Dr. M. T. Padilla.)*

trating through the enamel.[3] Sometimes a pin-retained or resin-bonded restoration[4] is used to provide a cingulum rest.* An incisal rest may be used on unrestored mandibular canines (Fig. 21-14). This provides good support for the partial RDP but may be unacceptable esthetically. When a rest is placed on a metal-ceramic restoration, adequate thickness of metal must remain between the lateral walls of the occlusal rest seat and the porcelain-metal junction. About 1 mm is sufficient. Similarly, a minimal metal thickness of 1 mm between the rest seat and the occlusal aspect of the prepared tooth is advisable. To minimize the risk of fracture, an occlusal rest seat should not be placed directly on porcelain.

Minor connectors

The minor connectors of a partial RDP (Fig. 21-15) are the connecting link between the major connector or base of a partial RDP and the other units of the prosthesis, such as the clasp assembly, indirect retainers, occlusal rests, and cingulum rests. They join the rest seats and the clasps to the major connector and should fit intimately against the proximal guide plane on the cast restoration. The guide plane should be as long as possible occlusocervically and

*Porcelain labial veneers (see Chapter 25) or composite resin has also been used to provide undercuts for RDP retention.[5,6]



Fig. 21-15
Minor connector of a cast partial removable dental prosthesis (*arrow*) closely adapted to the proximal guide plane.

should follow the normal configuration of the tooth buccolingually. All proximal guide planes should parallel each other.

Clasp retention

The **clasp** engages a portion of the tooth surface and either enters an undercut for retention or remains entirely above the height of contour to act as a reciprocating element. In general, it is used to stabilize and retain an RDP. The amount of retention is related to, among other things, the configuration of the retentive arm, the material from which the clasp is made, and the extent of the undercut into which it is placed and from which it is dislodged when the partial RDP is taken out of the mouth.

Partial RDP frameworks are usually fabricated from base metal alloys, although some dentists prefer titanium or even an American Dental Association type IV gold alloy. In addition to conventional cast clasps, **wrought retention clasp** arms can be made of a platinum-gold-palladium or nickel-chromium alloy wires.

The modulus of elasticity of the base metals is considerably higher than that of a type IV gold alloy. Hence, shallower retentive undercuts, on the order of 0.12 to 0.25 mm (0.005 to 0.010 inch), can be used with the former. Undercuts of 0.25 to 0.50 mm (0.010 to 0.020 inch) can routinely be used with clasps made of either type IV gold or wire.

When a clasp is in its normal position with the partial RDP fully seated, it should fit in a **passive** manner against the retainer; simultaneously, it should be at least 2 mm occlusal to the crest of the free gingiva so that it does not interfere with maintenance of periodontal health. This means that the **survey line,** a line produced on a cast by a surveyor marking the greatest prominence of contour in relation to the planned path of placement of a restoration, must not be placed too far cervically.

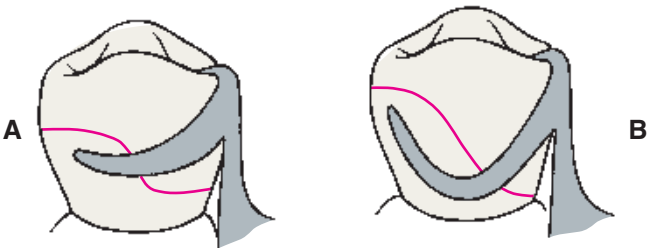


Fig. 21-16
The shape of the survey line is influenced by the material selected for the clasp. **A,** Cast clasp. Only the terminal third engages the undercut. **B,** Wrought clasp. The terminal half is retentive.

Likewise, the height of contour must not be placed too far occlusally, or binding of the retentive arm may occur during RDP placement. Ideally, it should be within the middle third of the retentive surface of the retainer. A properly contoured surface enables the retentive arm to flex gradually along the path of placement. Only the terminal third of the retentive arm should be placed gingival to the survey line (Fig. 21-16). If more than the terminal third of the retentive arm is placed cervical to the height of contour, this may impede placement and removal of the RDP.

A typical survey line for occlusally approaching clasps has an undulating configuration somewhat reminiscent of the letter *S*, with its most gingival portion adjacent to the minor connector. If a gingivally approaching clasp is used, the undercut may be immediately adjacent to the proximal guide plane, although with the popular rest, proximal plate, and I-bar (RPI) design it is placed at or mesial to the midline of the tooth.[7] Several factors—rest seat location, origin of the clasp, tissue undercuts, and degree of clasp encirclement—influence the actual configuration of the survey line for individual retainers.

Reciprocation

Reciprocation is the mechanism by which lateral forces generated by a retentive clasp passing over a height of contour are counterbalanced (Fig 21-17). This is usually done by a **reciprocal clasp** that passes along a reciprocal guiding plane. The reciprocal clasps have two functions: They guide the prosthesis into place upon insertion, and they support the abutments against horizontal forces exerted by the flexing retentive arms. The retentive arms should flex rather than displace the abutments laterally. Guide planes are needed on the crowns to allow for successful reciprocation. These should extend from the proximal guide plane to an area directly opposite the terminal position of the retentive clasp. Reciprocal clasps must contact the guide plane before the retentive arms start to flex, so that the periodontium is protected against excessive lateral loading.

To minimize lateral loading, the reciprocal arm should engage before the retentive arm starts to flex.

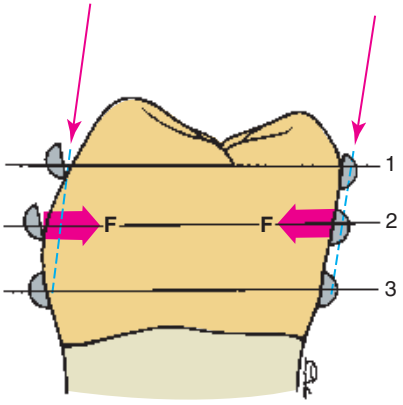


Fig. 21-17
Reciprocal arms prevent harmful lateral forces from being generated by the retentive arms during placement of a partial removable dental prosthesis (RDP). *1,* Initial contact of the retentive arm; the reciprocal arm is in passive contact. *2,* Maximum flexure of the retentive arm; the forces exerted (*F*) are resisted by the reciprocal clasp. *3,* The partial RDP fully seated; both the retentive and the reciprocal clasps should be in passive contact.

TOOTH PREPARATION

After the proposed path of placement for the partial RDP has been determined and any necessary enamel modifications made, the teeth requiring abutment crowns can be prepared (Fig. 21-18). Making complete crowns is often necessary, but when facial contour does not require modification, partial coverage may sometimes be used.

Path of Placement

Careful planning is required when the path of placement of tooth preparations for RDP retainers is selected. Although conventional crowns generally have a path in the long axis of the tooth, partial RDP retainers may not. Surfaces where both guide planes and reciprocal planes are planned, as well as areas that require survey lines in the gingival third, typically need to be "overprepared" in relation to the ideal conservative technique used on individual teeth. Because of the lingual inclination of mandibu-



Fig. 21-18

Integration of fixed and removable prosthodontic treatment involving intracoronal rest seats. **A** and **B,** A patient with extensive previous restorative treatment required replacement with a combination of fixed and removable prostheses. **C** and **D,** After mouth preparation, the teeth have been prepared for fixed retainers. **E** and **F,** Definitive casts. **G** and **H,** A diagnostic setup is used to develop the correct occlusal plane as all restorations are waxed simultaneously. **I** to **K,** After fabrication and adjustment of the fixed prostheses, the maxillary restorations are cemented. **L,** The mandibular restorations are provisionally stabilized, and the partial removable dental prosthesis (RDP) impression is made.



Fig. 21-18, cont'd

M, The mandibular restorations are provisionally stabilized, and the partial removable dental prosthesis (RDP) impression is made. **N** and **O,** The castings are retrieved, and the RDP framework is fabricated with two stabilizing arms on the lateral incisors to provide stability before the attachments are soldered onto the frame. **P** and **Q,** Autopolymerizing resin is used to relate the cast intracoronal rest seats to the RDP framework. **R** and **S,** The RDP frame is invested, with the attachments, and soldered, after which it is fitted back onto the master cast. **T** and **U,** After clinical verification of the fit, a wash impression is used to generate an altered cast, and the denture teeth are set. **V** to **X,** All retainers are now cemented.



Fig. 21-18, cont'd
Y and **Z,** Occlusal and frontal views with the partial RDP in place. **AA** and **BB,** Left and right lateral views of the completed treatment.

lar molars, reducing them slightly more in the occlusal two thirds of the lingual axial surface is often necessary to allow the development of lingual guide planes that parallel each other across the dental arch.

Similarly, the axial reduction of surfaces adjacent to an edentulous ridge often involves removal of additional tooth structure. Care must be taken that these modifications do not lessen the retention form excessively, because during denture removal, the retainers are usually subjected to forces parallel to their path of placement, and retention becomes even more important. Additional features (e.g., grooves, boxes, pinholes) are frequently needed. It is certainly not mandatory that all retainers for a partial RDP have identical paths of placement.

Rest Seats

An adequate amount of tooth structure must be removed to allow for a minimum metal thickness of 1 mm in the area of an occlusal rest seat. To achieve adequate reduction, some dentists prepare a rest seat in the tooth before starting the retainer preparation. They then use 1-mm reduction grooves to ensure adequate thickness. Although this approach can work well, problems may occur if it becomes necessary to alter the position of the rest seat during the laboratory phase. Preference therefore should be given to the slightly less conservative approach seen in Figure 21-19 because being able to move the rest seat during the laboratory phase can be extremely helpful. Often esthetic needs, such as the interproximal extent of a cut-back for a metal-ceramic restoration, can be assessed only on the laboratory bench during waxing procedures.

Axial Contours

When a crown is to serve as a partial RDP abutment, modifications may be necessary in the normal axial reduction. The extent of additional axial reduction depends on the RDP design (see Fig. 21-9).

Additional tooth reduction is necessary if a retainer must be undercontoured with regard to the original tooth form to accommodate proximal or reciprocal guide planes and to allow the nonretentive part of an occlusally approaching clasp to be positioned as far gingivally as possible. (Again, diagnostic preparations and diagnostic waxing procedures often prove very helpful in assessing the need for additional axial reduction.)

Another possible advantage of providing an abutment crown is the opportunity to shape the axial contours to accommodate the partial RDP clasps within the normal crown contours (Fig. 21-20). Although this allows for a less bulky removable pros-



Fig. 21-19
Retainer preparations. **A** and **B,** The rest seat preparation (*arrows*) allows some adjustment of rest seat location during the waxing phase.



Fig 21-20
Abutment crowns contoured to precisely receive the partial removable dental prosthesis (RDP) clasp. **A,** The cast crowns have received milled-in shelves that permit the partial RDP clasp to recess into the coronal form of the restored tooth. **B,** Partial RDP in place. *(Courtesy of Drs. K. Seckler and J. Janaowski.)*

thesis contour, it requires additional axial reduction. The use of a precision machine-tool milling device (see Fig. 21-27) is essential for these restorations.

IMPRESSION MAKING

Because of the relative interdependence of partial RDP abutment preparations, a diagnostic irreversible hydrocolloid impression should be made after the preparations have been completed. This is poured in accelerated-setting stone or plaster. The resulting cast is then surveyed and the need for any further modifications is determined; such modifications can then be incorporated with minimum loss of chair time. The same cast can also be used for fabricating the interim restorations (see Chapter 15). A definitive impression is obtained with either an elastomeric or a reversible hydrocolloid technique, as described for conventional restorations (see Chapter 14).

Occlusal Records

A record base with wax rims is needed to articulate the casts unless an adequate number of posterior teeth are present to relate the opposing casts with a conventional centric relation record.

Because a record base is stable only on the cast from which it was made, it should not be fabricated in advance. Therefore, an additional patient visit must be planned to obtain an interocclusal record. The maxillary cast orientation is transferred by means of a facebow to the articulator, and the mandibular cast is articulated in the usual manner.

WAX PATTERN FABRICATION

Waxing partial denture abutments to optimally meet all requirements can be difficult, even for experienced operators. The need for good occlusion, anatomic form, and proper contours for plaque control often appears to conflict with the need for guide planes and retentive undercuts. Careful analysis is essential at the treatment planning stages, when a diagnostic waxing procedure can prove helpful. An organized approach to waxing partial RDP retainers must be maintained. The wax patterns are made in the usual way (see Chapter 18), creating normal axial form and embrasures and allowing for optimum dis-

tribution of the forces of occlusion. This is followed by adjustment of the axial walls to accommodate the survey line and guide planes. The resulting occlusal table typically has a reduced size in comparison with a pattern that is shaped to optimal anatomic form, which affects resulting occlusal form. The rest seats are placed as the final step in this process, immediately before reflowing in the margins and investing (see Chapter 22).

Survey Line

When normal coronal contour has been established in wax, the cast is removed from the articulator and placed on the surveyor (Fig. 21-21). The preliminary path of placement that was established during the treatment planning and tooth preparation phases may require slight modification. However, a minor alteration is all that should be necessary, and it often compensates for small, previously unrecognized errors that may have occurred at the tooth preparation stage.

A survey line can be relocated by tilting the cast (e.g., a mesial undercut enlarged by increasing the mesial tilt, a buccal survey line moved further occlusally by increasing the tilt toward the buccal surface). When the cast tilt for the final path of placement has been selected, the cast is marked at three points (some technicians also mark the side of the cast). This "tripodizing" allows the selected path to be reestablished with minimum inconvenience. More wax is added until the pattern is slightly overcontoured in the area of the desired survey line and proximal and reciprocating guide planes.

The surveyor carving attachment is then used. Some dental surveyors have a movable arm, which makes wax carving easier. Identical results can usually be obtained with the rigid-arm type, but more care is necessary to prevent fracture of the wax pattern or tilting of the surveyor table. With the carving attachment, a parallel band is scraped on the surface of the pattern, and this is inspected for the possible need for additional wax. The desired survey line is then marked, after which excess wax occlusal and cervical to the line is removed with a wax carver to obtain the correct contour.

The final evaluation of the survey contour consists of dusting the pattern with zinc stearate or waxing powder, marking the height of contour with the analyzing rod, and measuring with the undercut gauge.

Guide Planes

The proximal and reciprocal guide planes (Fig. 21-22) are formed by trimming all excess wax from the patterns. Cervico-occlusally, the typical guide plane should remain within normal contours. Cervical to the guide plane, the form of the wax pattern should follow the configuration of the remaining tooth structure at the margin.

The minimum cervico-occlusal length for guide planes allows the **reciprocal arms** of the clasps to make initial contact and remain in contact during seating of the partial RDP (see Fig. 21-17).

Occlusal Rest Seats

Occlusal rest seats (Fig. 21-23) are most commonly located in the interproximal marginal ridge area and can easily be cut into the wax patterns with a handheld round bur (see Fig. 21-21). When metal-ceramic restorations are the retainers, the rest seat should be located in metal at least 1 mm from the metal-ceramic junction (Fig. 21-24). When a rest is placed in a wax pattern for a metal-ceramic restoration, this is best done after the pattern has been cut back for the metal-ceramic veneer.

Cingulum rest seats (Fig. 21-25; see also Fig. 21-13) are placed with a carver. Buccolingually, they have a V configuration in cross-section; mesiodistally, they are slightly curved, with the highest point in the center of the tooth.

SPECIAL FINISHING PROCEDURES

After the wax patterns have been invested and eliminated and the retainers have been cast, the restoration is carefully seated on the die. When the individual fit is satisfactory, it is transferred on a tripodized cast to the surveyor for milling. The survey table is adjusted so the cast is oriented at the correct angulation, and cylindrical rotary instruments are used to refine the guide planes and to make any needed corrections.

Milling

Many precision parallel milling devices are available commercially. The simplest consists of a clamp that holds a conventional straight handpiece parallel to the shaft of the surveyor (Fig. 21-26). This works satisfactorily when used carefully. There are also expensive machine-tool milling devices that can be controlled with great precision and are particularly useful for extensive attachment prostheses (Fig. 21-27).

Cylindrical carbide burs without crosscuts are recommended for refining the proximal and reciprocal guide planes. Light pressure should be used

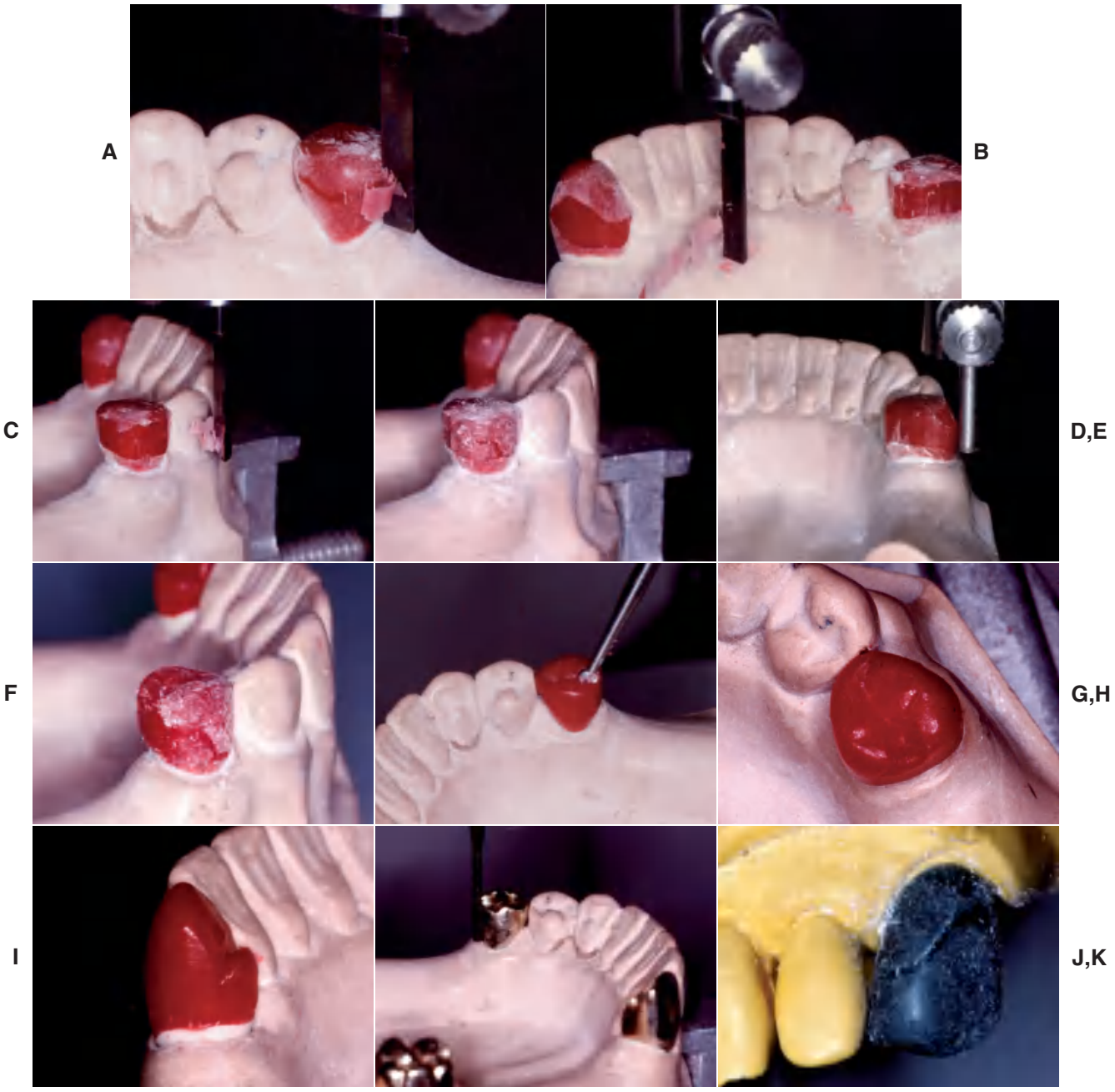


Fig. 21-21

Waxing partial removable dental prosthesis retainers. **A,** After the path of placement has been established, the carving attachment of the surveyor is used to make a 2- to 4-mm-wide band on the pattern. **B,** Note that the band includes the proximal and lingual walls of the pattern where the proximal and reciprocal guide planes, respectively, will be established. **C,** The band is carried onto the facial surface, where the retentive clasp is to be placed. Viewed from the occlusal aspect when complete, the band remains within the normal anatomic contour. **D,** The pattern is dusted with zinc stearate or powdered wax, and the desired survey line is scribed. **E,** After excess wax has been carved away occlusally and gingivally to create the desired contour, the undercut gauge is used to verify that the proper amount of wax has been removed. **F,** After smoothing and blending of the various surfaces, the pattern is again dusted with powder, and the configuration of the final survey line is verified. **G,** Then a round bur is used to place the occlusal rest seat. On premolars, a No. 6 bur is adequate; on molars, a No. 8 may be used. **H,** At least 1 mm of wax is maintained around the perimeter of the rest seat. **I,** A cingulum rest seat on a canine pattern can be carved with conventional waxing instruments. The lingual aspect of the rest seat must withstand lingual displacement. Mesiodistally, the rest seat is slightly curved, with the highest point in the middle of the pattern. **J,** After casting, the crowns are evaluated, and any adjustments are made to refine the height of contour, guide planes, and occlusal rest seats. **K,** Typical survey line for a wrought clasp. Note that the distal half of the clasp can easily be placed above the height of contour. The terminal half engages the undercut. A sufficiently long trajectory must remain incisal to the height of contour to allow gradual flexing of the clasp.



Fig. 21-22
A, A proximal guide plane and the correct axial survey lines are incorporated in the anatomic contour wax pattern. **B,** The contours are duplicated in porcelain. **C,** The fixed prostheses have been cemented. **D,** An accurately contoured retainer provides proper support for the partial removable dental prosthesis.

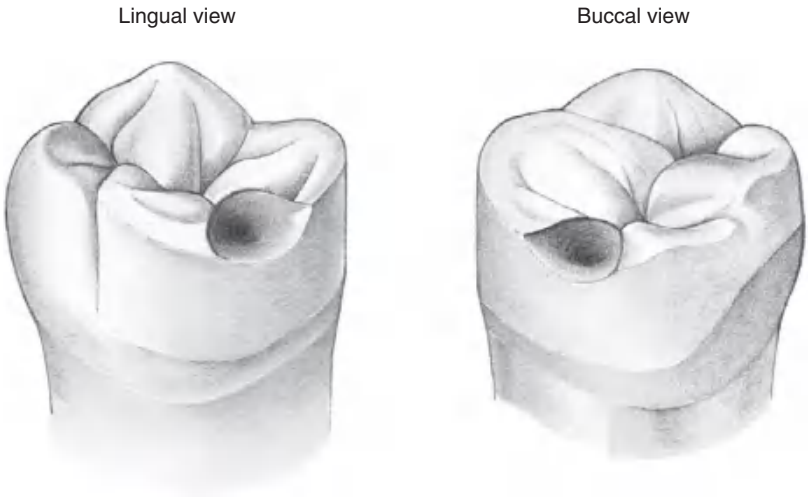


Fig. 21-23
Completed wax pattern for a partial removable dental prosthesis retainer with occlusal rest seat, distobuccal retention, and proximal and lingual guide planes.

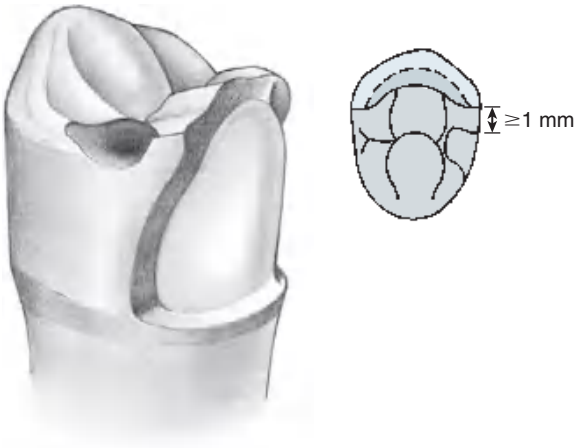


Fig. 21-24
Maxillary premolar wax pattern after cutting back for the porcelain application. The rest seat should be at least 1 mm from the metal-ceramic junction. The guide plane continues in the porcelain.



Fig. 21-25
Cingulum rest seat on a mandibular canine. Note its mesiodistal curvature (compare with Fig. 21-21*I*). *(Courtesy of Dr. X. Lepe.)*

throughout the milling procedure. Once an acceptable contour has been obtained, only minimum finishing with paper disks or rubber wheels is necessary. A complete- or partial-coverage crown is finished through the normal sequence of abrasives until a high polish has been attained. If the retainer is a metal-ceramic crown, the veneering surface is prepared after completion of the milling procedure. Then the desired survey line and retentive undercuts are established in porcelain. The porcelain can then either be glazed or polished while care is taken to maintain the desired heights of contour.

Caution is needed when survey lines are scribed on a bisque bake of porcelain. Red or green pigments must be used because they do not cause contamination after firing. Graphite from a soft lead pencil produces discoloration in the fired porcelain, and the use of such pencils must therefore be avoided (see Fig. 21-22*B*).



Fig. 21-26
Handpiece holder for milling guide planes. The holder attaches a conventional straight handpiece parallel to the shaft of a dental surveyor.



Fig. 21-27
Machine-tool milling device allows precise control of the milling process.

EVALUATION AND CEMENTATION

The clinical evaluation of the prosthesis proceeds as for any restoration. It should have good marginal integrity and proper axial contour, and it should be stable with accurate occlusal and proximal contact.

When these criteria have been met, a precementation irreversible hydrocolloid impression is poured in fast-setting stone, and the cast is analyzed on the surveyor. Any change in contour that may have occurred during finishing is easily detected at this time, when corrective action is still possible. For a metal-ceramic restoration, recontouring, repolishing, and/or reglazing may be necessary.

Cementation procedures for survey crowns are identical to those for conventional restorations (see Chapter 31). When multiple restorations involving prefabricated attachments are to be cemented, postponing cementation of the retainers until after the completion of the RDP is sometimes advantageous.

FABRICATION OF A CROWN FOR AN EXISTING PARTIAL RDP

Occasionally patients have a defective abutment crown under an otherwise satisfactory partial RDP. Although a new RDP is often the more appropriate choice, at least 14 different methods have been described for making a crown fit an existing partial RDP.[8,9] These can be classified as direct, direct-indirect, or indirect procedures.

When a direct-indirect procedure is used, a pattern is fabricated from autopolymerizing acrylic resin and wax. The resin is applied onto the tooth preparation, and resin is added until it contacts the internal aspect of the RDP clasps, thus duplicating the axial contours of the original abutment crown. This resin pattern is repositioned on a die on which the margins are refined by adding wax and shaping the restoration. The combined resin-wax pattern is invested, and after wax and resin elimination, the crown is cast.

The indirect procedure consists of a "pickup" impression of the prepared tooth and seated partial RDP. This is poured in the conventional way after any undercuts in the denture have been waxed out. The crown is fabricated in the conventional way, the RDP being removed and replaced on the cast to establish appropriate contours. Additional wax (or porcelain for a metal-ceramic crown) is added where the retentive undercut is needed (Fig. 21-28). A disadvantage of this technique in comparison with the direct approach is that the partial RDP is required in the laboratory throughout the crown fabrication.

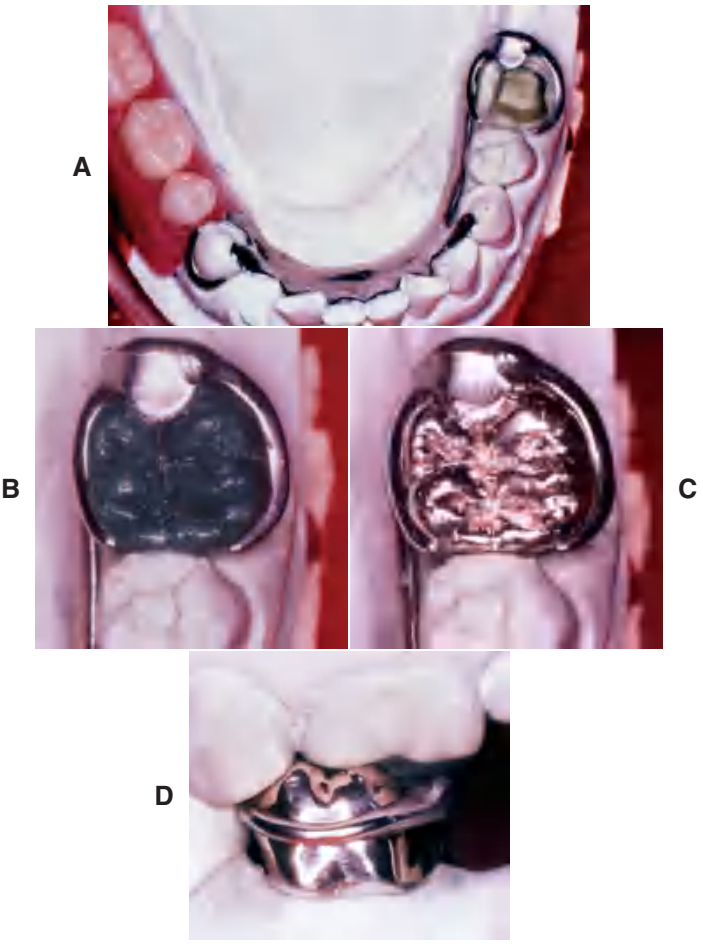


Fig. 21-28
Crown fabricated to fit an existing partial removable dental prosthesis (RDP) through the indirect procedure. **A,** After a pickup impression, the partial RDP is fitted to the definitive cast. **B,** Wax pattern. **C** and **D,** Completed crown. *(Courtesy of Dr. M. T. Padilla.)*

This may not be acceptable to the patient, particularly if the patient's appearance is affected.

With all these techniques, extra care is necessary in finishing the areas of the crown where contact with the RDP occurs. Small clasp adaptation imperfections often result, but with some practice, it is possible to routinely fabricate quite acceptable restorations that prevent the need to fabricate a new RDP.

ATTACHMENTS

A wide range of prefabricated attachments are available for use with partial RDPs.[10,11] Most of these consist of two components: one is incorporated in the crown, and the other becomes part of the RDP.



Fig. 21-29
An intracoronal and an extracoronal attachment were used in this anterior fixed dental prosthesis. *(Courtesy of Dr. F.-F. Hsu.)*

Both extracoronal and intracoronal designs are available (Fig 21-29).

In general, the use of attachments, whether extracoronal or intracoronal, should be limited. Attachments add to the complexity and cost of the restorative service and often necessitate remaking the fixed retainers when the attachments wear out. In one study, only 22 of 57 prostheses were free of complications during the first 2 years.[12] When used with distal extensions, attachments lead to higher stresses in the abutment teeth.[13] Nevertheless, their use can be justified, particularly to enhance appearance.

Extracoronal Attachments

Any prefabricated attachment for support and retention of an RDP in which the "male" and "female" components are positioned outside the normal contour of the abutment tooth is considered an extracoronal attachment (Fig. 21-30). Careful judgment is needed in deciding when to use such attachments (e.g., ERA,* Ceka,† Dalbo,‡ or Dawson§) because they place unfavorable stresses on the abutment teeth, similar to the stresses exerted by a cantilever. In addition, they make oral hygiene more difficult. In some instances, however, extracoronal attachments offer esthetic advantages that may outweigh their biologic and mechanical disadvantages (Fig. 21-31). Resin bonding has been used for the retention of extracoronal attachments through the same principles as resin-bonded prostheses.[14] It is doubtful that the retention obtained in that manner is adequate to prevent eventual dislodgment of the attachment.

*Sterngold Dental, LLC, Attleboro, Massachusetts.
†AlphaDent NV, Antwerp, Belgium.
‡Cendres & Métaux SA, Biel-Bienne, Switzerland.
§Comdent, Clearwater, Florida.

Intracoronal Attachments

Intracoronal attachments have male and female components that are positioned within the normal contour of the abutment tooth. These can be prefabricated or made in the dental laboratory.

Prefabricated types

The more commonly used prefabricated intracoronal attachments (e.g., Stern* or Ney-Cheyes No. 9†) typically consist of a precision-milled male-female assembly (Fig. 21-32) similar to the dovetail configuration described for nonrigid connectors (see Chapter 28).

The tolerance between accurately fitting components of an intracoronal precision attachment is so fine that retention results from their frictional fit. An intracoronal precision attachment partial RDP is not readily dislodged, because it can be removed only in one direction, which may become a liability in patients with limited dexterity. However, retention can be significantly reduced after wear of the retentive surfaces. Most precision attachments are made of platinum-palladium alloys, which withstand the high temperature associated with casting of metal-ceramic alloys.

The female attachment is incorporated in the retainer wax pattern, and the assembly is invested. After wax elimination, the restoration is cast directly onto the attachment. Although multiple parallel attachments can be fabricated in this manner, most technicians prefer to solder a second or third attachment to the respective retainers. This allows for verification of alignment with the attachment in the first retainer.

A tray may be incorporated in the secondary retainer for added flexibility during positioning of the second attachment parallel to the first attachment. The secondary retainer is luted into place, invested, and soldered. Male components can then be inserted. After the partial RDP framework has been made, the male attachments are either soldered to the frame or attached to the

*Sterngold Dental, LLC, Attleboro, Massachusetts.
†Ney Dental International, Bloomfield, Connecticut.

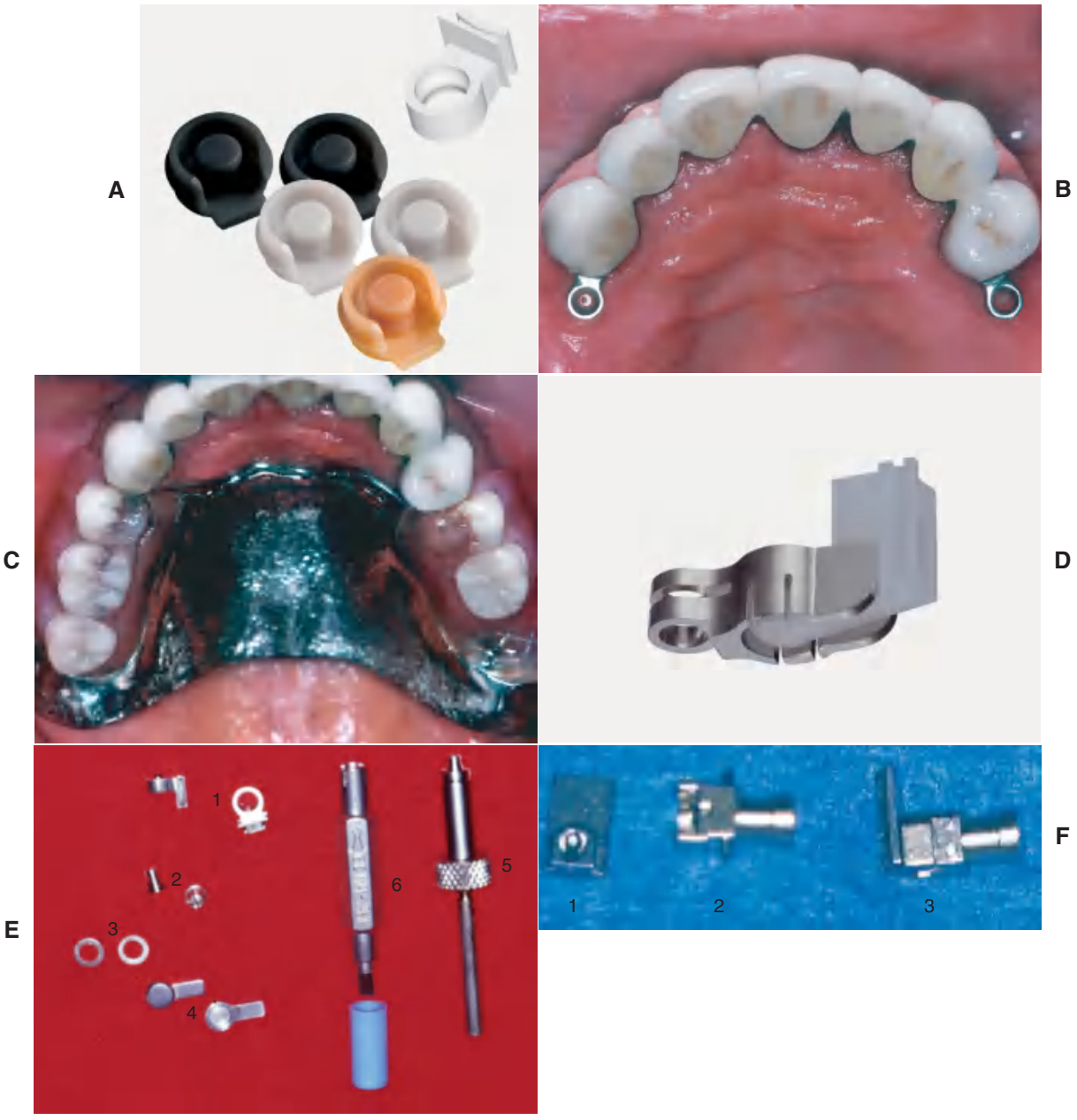


Fig. 21-30

Prefabricated extracoronal attachments. **A,** The ERA. These attachments are designed to be resilient and direct stress to both the abutment teeth and edentulous ridges when supporting distal extension partial removable dental prostheses (RDPs). The color-coded male components are processed directly into the acrylic denture base and have different levels of retention. **B,** Abutment crowns incorporating ERA attachments. **C,** Completed prostheses. **D,** The Dalbo Mini. This attachment provides some movement between male and female components. **E,** The Ceka: *1*, female component; *2*, male component; *3*, spacer; *4*, male partial RDP connector; *5*, positioning mandrel; *6*, adjustment tool. **F,** The 2.7 Dawson: *1*, male component; *2*, female component, which has a built-in replaceable plunger for retention; *3*, the 2.7 Dawson attachment assembled. (***A*** *and* ***D****, Courtesy of Sterngold Dental, LLC, Attleboro, Massachusetts;* ***B****,* ***C****, and* ***F****, courtesy of Dr. W. V. Campagni.)*

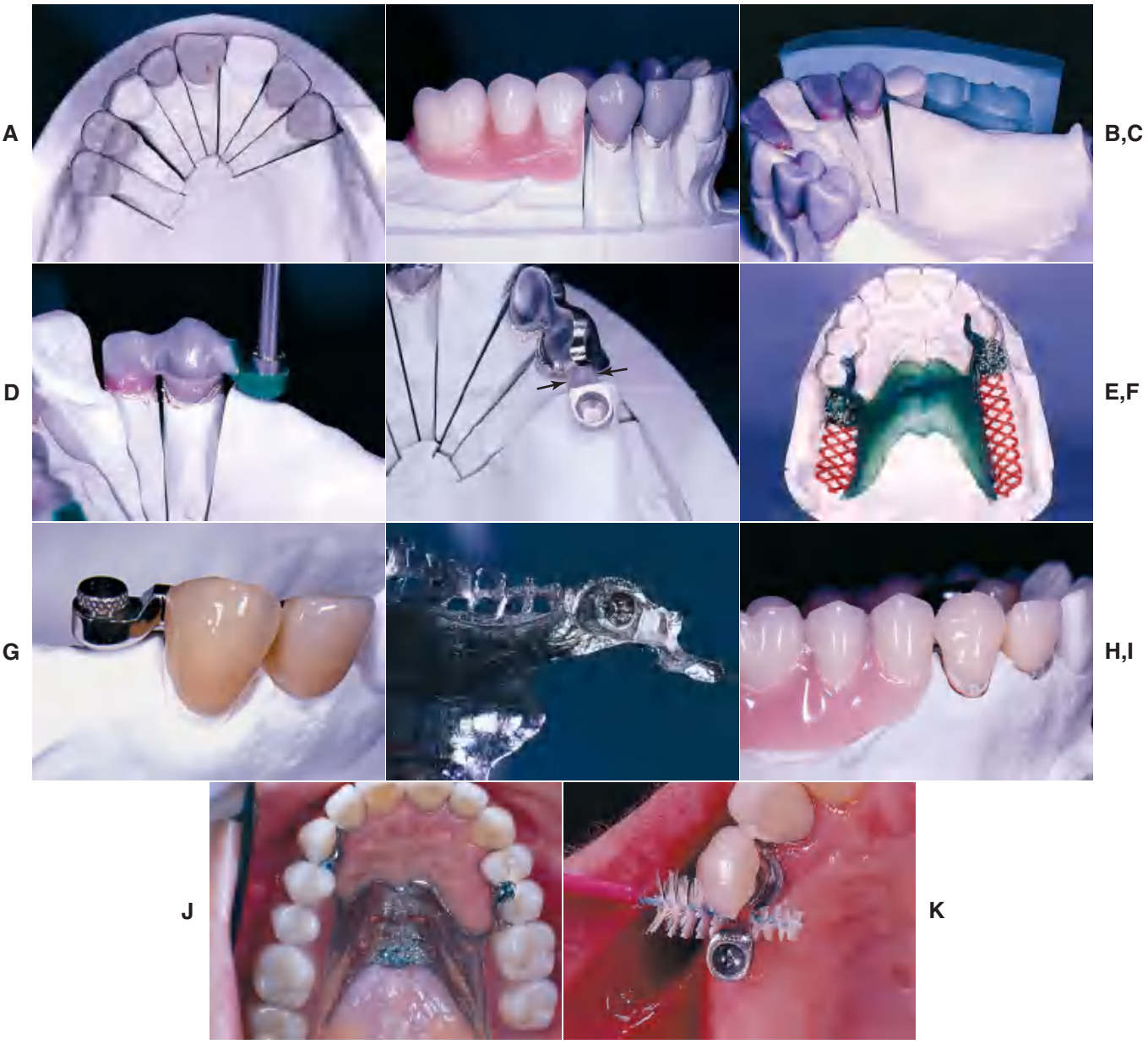


Fig. 21-31

Use of Ceka extracoronal attachments to retain a distal extension partial removable dental prosthesis (RDP). **A** and **B,** Anatomic contour waxing and occlusal plane development. **C,** A buccal index is used to allow repositioning of the denture teeth to help identify correct attachment placement. **D,** The female attachment pattern is positioned in relation to the wax pattern by means of a special mandrel in the dental surveyor. **E,** The substructures have been cast. Adequate strength is present where the extracoronal female attachment joins the retainer (*arrows*). **F,** Refractory cast with RDP wax pattern. **G,** Male component positioned in the female attachment. **H,** Attachment picked up. **I,** The completed prosthesis hides the attachment from sight. **J,** The RDP in place. **K,** Proxy brush enables appropriate plaque control around the attachment. *(Courtesy of Dr. Freijich and Mr. Behaeghel.)*

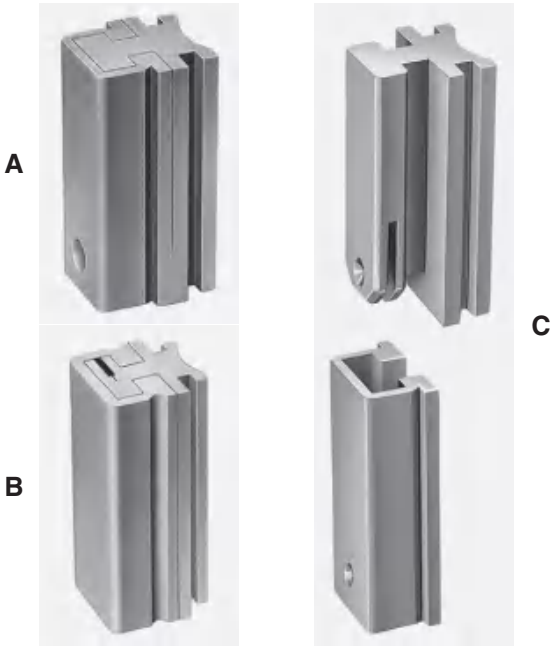


Fig. 21-32
Prefabricated intracoronal attachments. A and B, The Stern Latch (see Fig. 21-33). C, The C&M McCollum. *(A to C, Courtesy of Sterngold Dental, LLC, Attleboro, Massachusetts.)*

acrylic resin denture base with autopolymerizing resin (Figs. 21-33 and 21-34).

The preceding paragraph condenses an intricate sequence of technically highly demanding steps. The less experienced operator is strongly cautioned not to underestimate the high level of skill and meticulous attention to detail that are required.

The biggest advantage of intracoronal attachments is that they eliminate the need for an often unesthetic facial clasp. Simultaneously, however, the size of most intracoronal precision attachments limits their application, especially on vital teeth. To facilitate maintaining the health of supporting tissues, the proximal surface of the restoration should not be overcontoured. Therefore, the optimum placement of attachments is within the normal contours of the tooth and thus the restoration. However, this is usually possible only on large teeth. On small teeth, few intracoronal precision attachments can be kept within the confines of normal tooth contour without endodontic treatment. In addition, sufficient clinical crown height must exist for adequate cervico-occlusal length to allow a positive friction fit (a minimum attachment height of 4 mm or more is recommended).

Laboratory-made types

Many laboratory-made (semiprecision) attachments are in use today. Often they are referred to as *dovetails* because of the shape of their interlocking components. They can be made by incorporating a prefabricated plastic insert in the wax pattern, which is then invested and eliminated, and the pattern is cast (Fig. 21-35). The female dovetail can also be milled, after which the male component is waxed and cast.

An alternative method of fabrication is to use a tapered metal mandrel (e.g., Ticon*) that is heated and inserted in the wax pattern. When the wax is eliminated after investing, the exposed portion of the mandrel in the mold oxidizes. The crown is then cast directly onto the mandrel, which is later removed (Fig. 21-35). A male attachment can be waxed and cast separately. After seating, the attachment is soldered to the partial RDP.

Because of the inaccuracies inherent in their fabrication, most laboratory-made attachments have a limited amount of frictional retention in comparison with the commercially available precision attachments. The majority are tapered for ease of fabrication and therefore require the use of lingual clasps for positive retention.

When attachments are used with a metal-ceramic restoration, adequate metal must remain between the female component and the facial veneer of dental porcelain. A minimum material thickness of 1 mm is recommended between any intracoronal attachment and the metal-ceramic interface (Fig. 21-36).

Bars, Studs, and Magnets

Stud attachments[15] and magnets[16] (Fig. 21-37) are sometimes used to retain overdentures. They are incorporated in post-retained castings or implant abutments and offer the advantage of allowing increased occlusal force[17] (Fig. 21-38). In order to have adequate room for all attachment components, the denture resin, and a hollowed-out shell of a denture tooth (see Fig. 21-38*B*), a minimal vertical space of 7 to 9 mm is recommended, to enable successful use of these types of attachments.

A bar-retained partial RDP or overdenture can be very stable while it braces individual abutment teeth. The bar should attach to the retainer without interfering with oral hygiene.

In general, this means that considerable coronal length is necessary for the bar to produce an acceptable result. The bar should not be placed in contact with an edentulous ridge (Fig. 21-39).

*Ticonium, Albany, New York.

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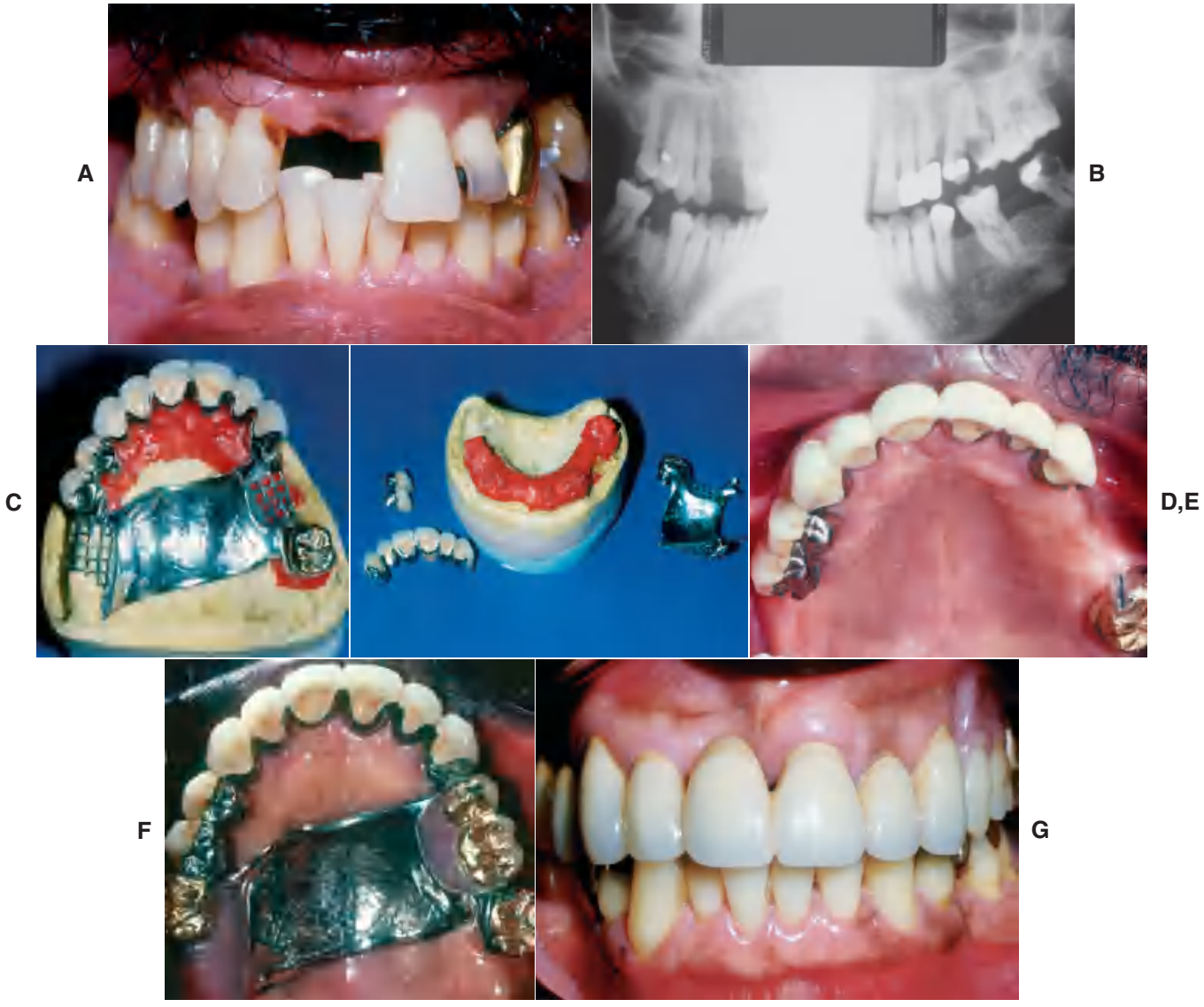


Fig. 21-33

Use of Stern Latch intracoronal attachments to support and retain a maxillary partial removable dental prosthesis (RDP). The Stern Latch attachment has frictional retention augmented by an internal gingival spring latch. The matrix may be waxed and cast-to. The male may be soldered to the framework or embedded in the resin of the finished partial RDP. A and B, This patient had extensive periodontal disease and caries, which necessitated the loss of several teeth with a hopeless prognosis. C, The resin-reinforced definitive cast with the finished fixed prostheses and partial RDP framework. D, Restorations and framework removed from the cast. E, Cemented fixed restorations without the partial RDP. F, Intraoral view of finished prostheses. G, Anterior, intraoral view of finished treatment. *(Courtesy of Dr. W. V. Campagni.)*



Fig. 21-34

Use of the Dawson 2.7 extracoronal attachment to support and retain a maxillary partial removable dental prosthesis (RDP). This precision attachment comprises an extracoronal patrix, which is waxed into the fixed abutment prosthesis and cast-to. The matrix comprises a housing with a spring-loaded plunger for retention. The plunger engages a dimple on the distal of the patrix. The plunger and spring can be removed from the housing for replacement with a special U-shaped pin. **A,** Definitive cast with finished crowns on resin replica dies for fabrication of partial RDP framework. **B,** Framework on definitive cast. Matrix will be luted to frame with resin for try-in. **C,** View of finished partial RDP, showing matrix processed in place. **D,** Occlusal view of partial RDP intraorally. **E,** Anterior view of finished treatment. *(Courtesy of Dr. W. V. Campagni.)*

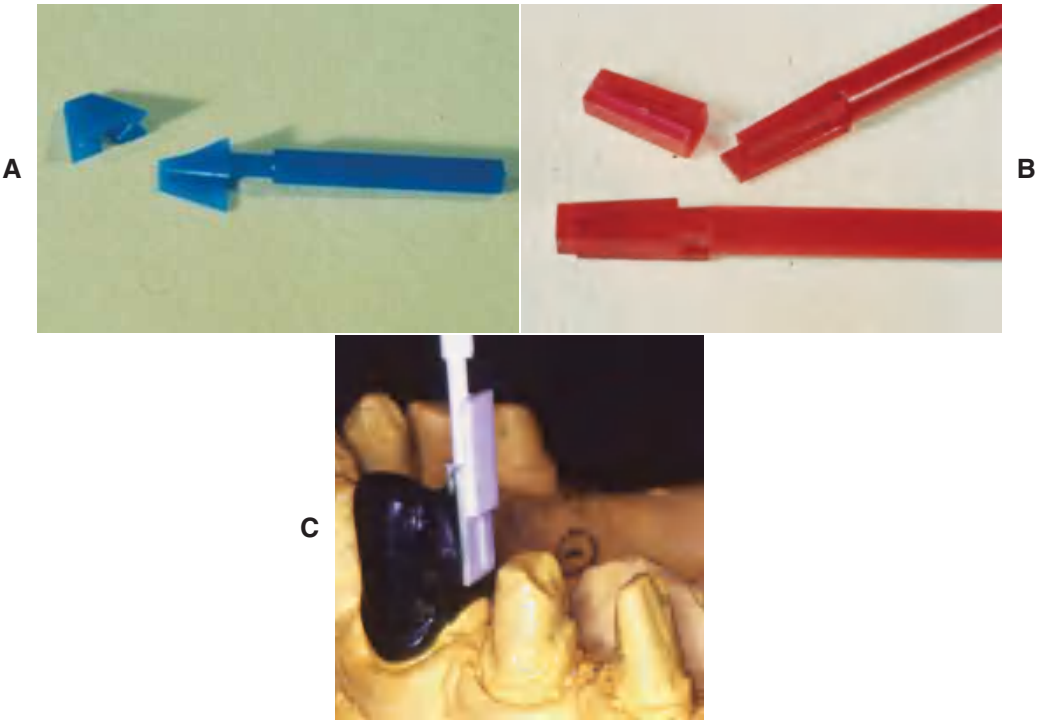


Fig. 21-35

A to **C,** Plastic preformed patterns for an intracoronal rest. *(**C,** Courtesy of Dr. F.-F. Hsu.)*

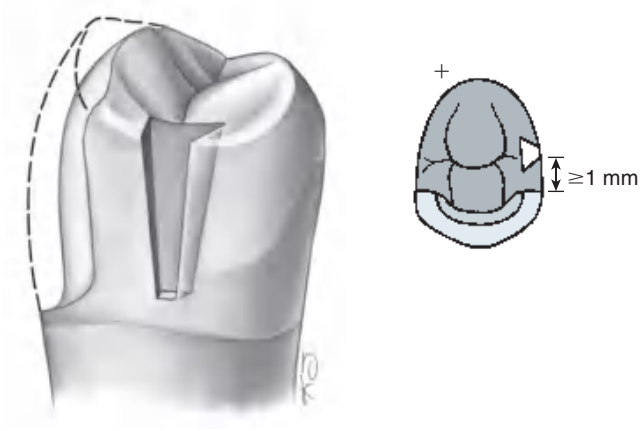


Fig. 21-36
Female intracoronal rest incorporated in a metal-ceramic restoration. The attachment should be at least 1 mm from the metal-ceramic junction. Retention is provided by a lingual undercut into which a clasp engages. Reciprocation is provided internally by the rest seat.



Fig. 21-37
A and **B,** The ERA stud attachment. Like the ERA extracoronal attachment (see Fig. 21-30*A* to *C*), this resilient attachment is available in different sizes (Stern ERA and Micro ERA) and color-coded retention levels. **C** and **D,** The Stern Root Anchor. This stud attachment comprises an intraradicular ball-and-socket joint. The nylon male (**C**) is processed into the denture acrylic. The titanium female (**D**) is cemented directly into the prepared root. **E,** The Dalla Bona Spherical. A gold alloy stud attachment with adjustable frictional resistance. **F** and **G,** The Hader bar. This bar system uses a plastic bar that is incorporated into the fixed prostheses before casting. Color-coded nylon rider clips are incorporated into the denture and are available with varying retention. Alternatively, a gold rider can be used for greater strength. **H,** The Dolder bar. This gold alloy bar is available in rigid (*1*) and resilient or hinging (*2*) configurations. **I,** *1,* Sleeve; *2,* spacer; *3,* bar. (***A*** *to* ***H,*** *Courtesy of Sterngold Dental, LLC, Attleboro, Massachusetts.)*

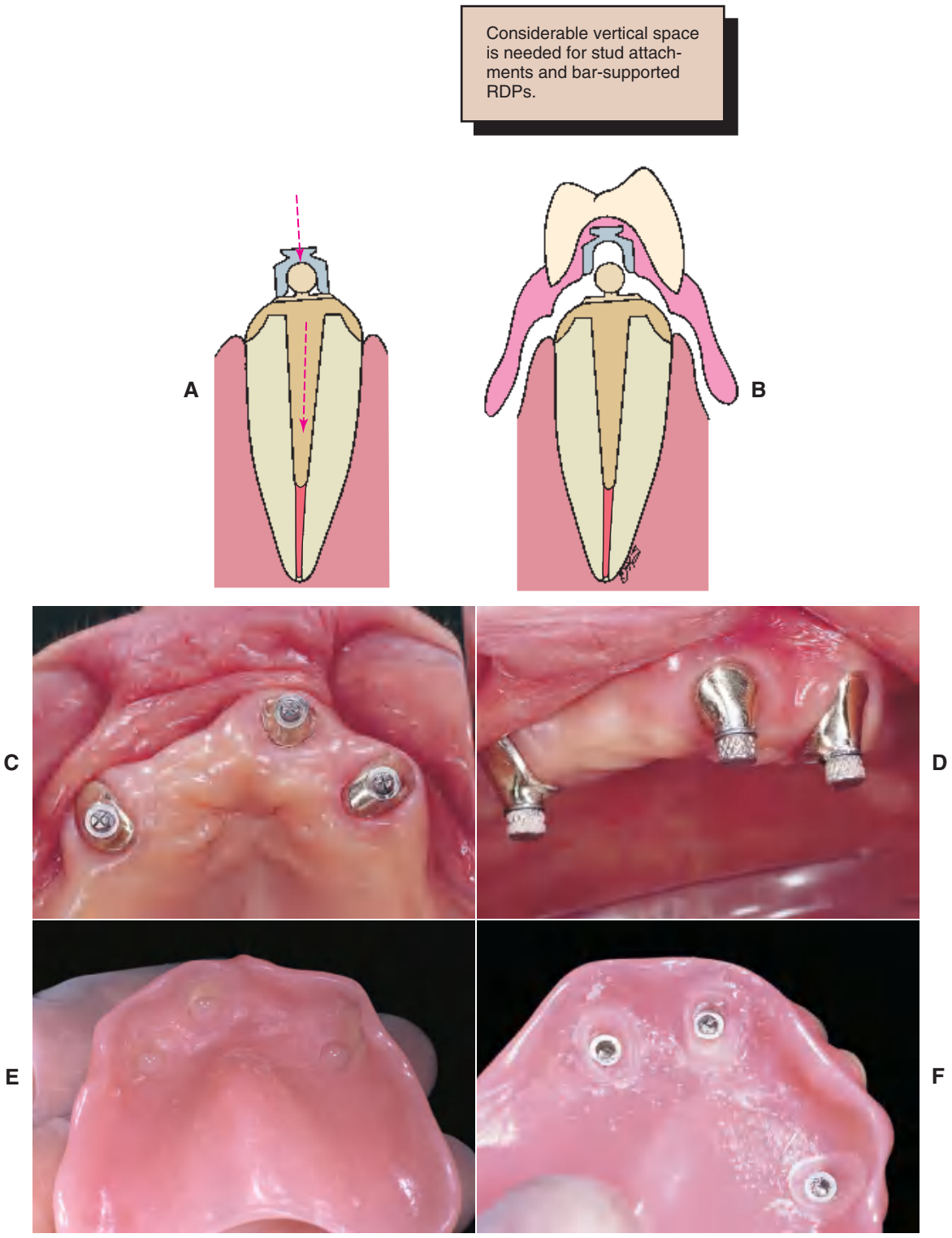


Fig. 21-38

A, Illustration of post-retained casting incorporating the male component of a stud attachment. The design allows for slightly different paths of insertion (*arrows*) of the post and overdenture. **B,** The female component is attached to the overdenture with acrylic resin. RDP, removable dental prosthesis. **C,** Occlusal view of three cemented copings with the male components in place. **D,** Female attachments have been positioned over the male attachments. **E,** Resin is applied to the internal surface of the prosthesis immediately before the denture is inserted. **F,** Denture immediately after relief of excess resin around the female components, which are now mechanically retained in the prosthesis. *(Courtesy of Dr. Freijich and Mr. Behaeghel.)*

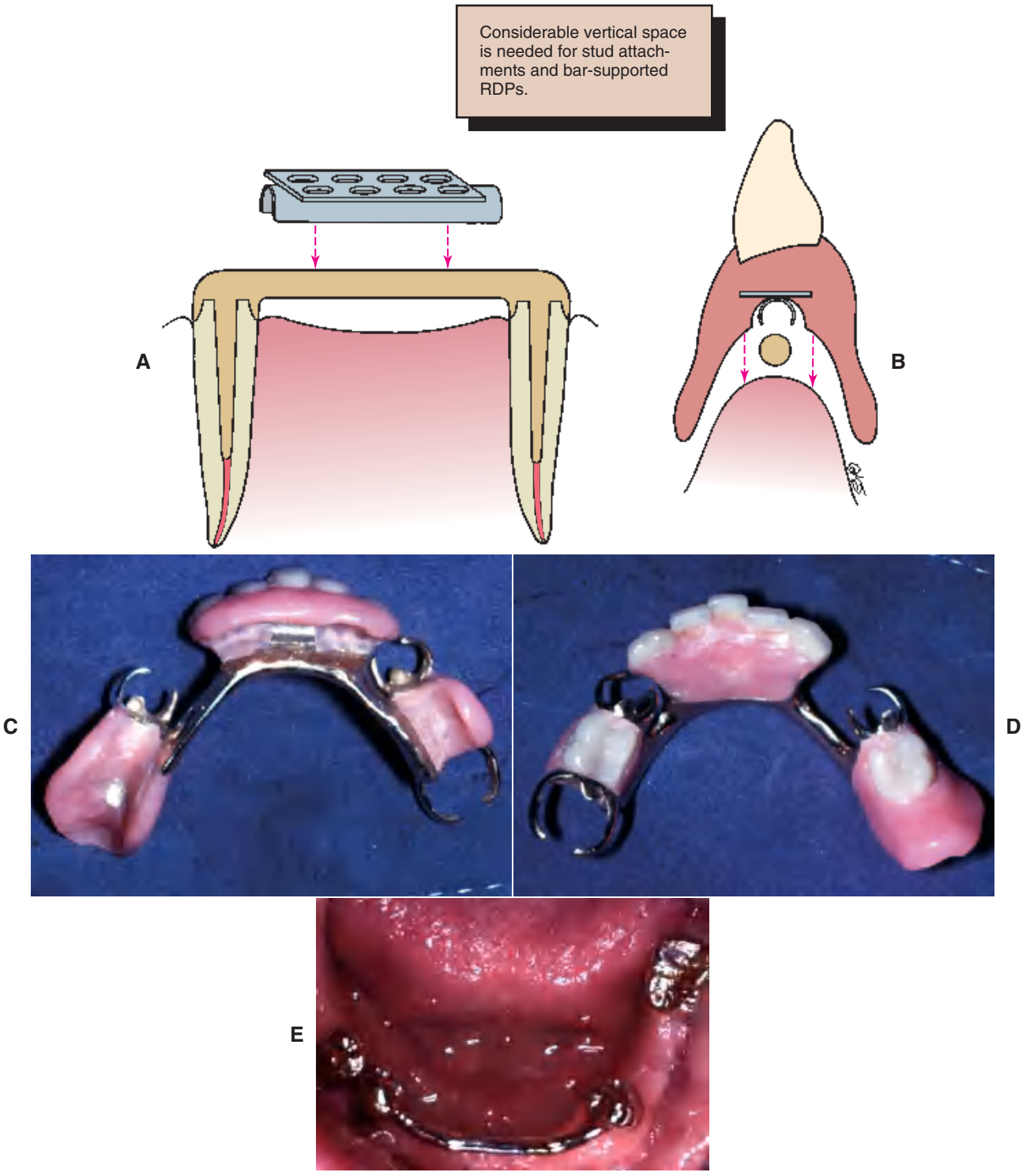


Fig. 21-39

Bar attachment. **A,** The bar is retained by posts on conventional fixed restorations. The clip provides support and retention for the partial removable dental prosthesis (RDP). **B,** Sufficient incisogingival height is needed to accommodate a bar prosthesis. **C,** Internal view of the bar-retained partial RDP. **D,** Occlusal view. **E,** Cemented fixed prosthesis with a bar to accommodate an RDP.

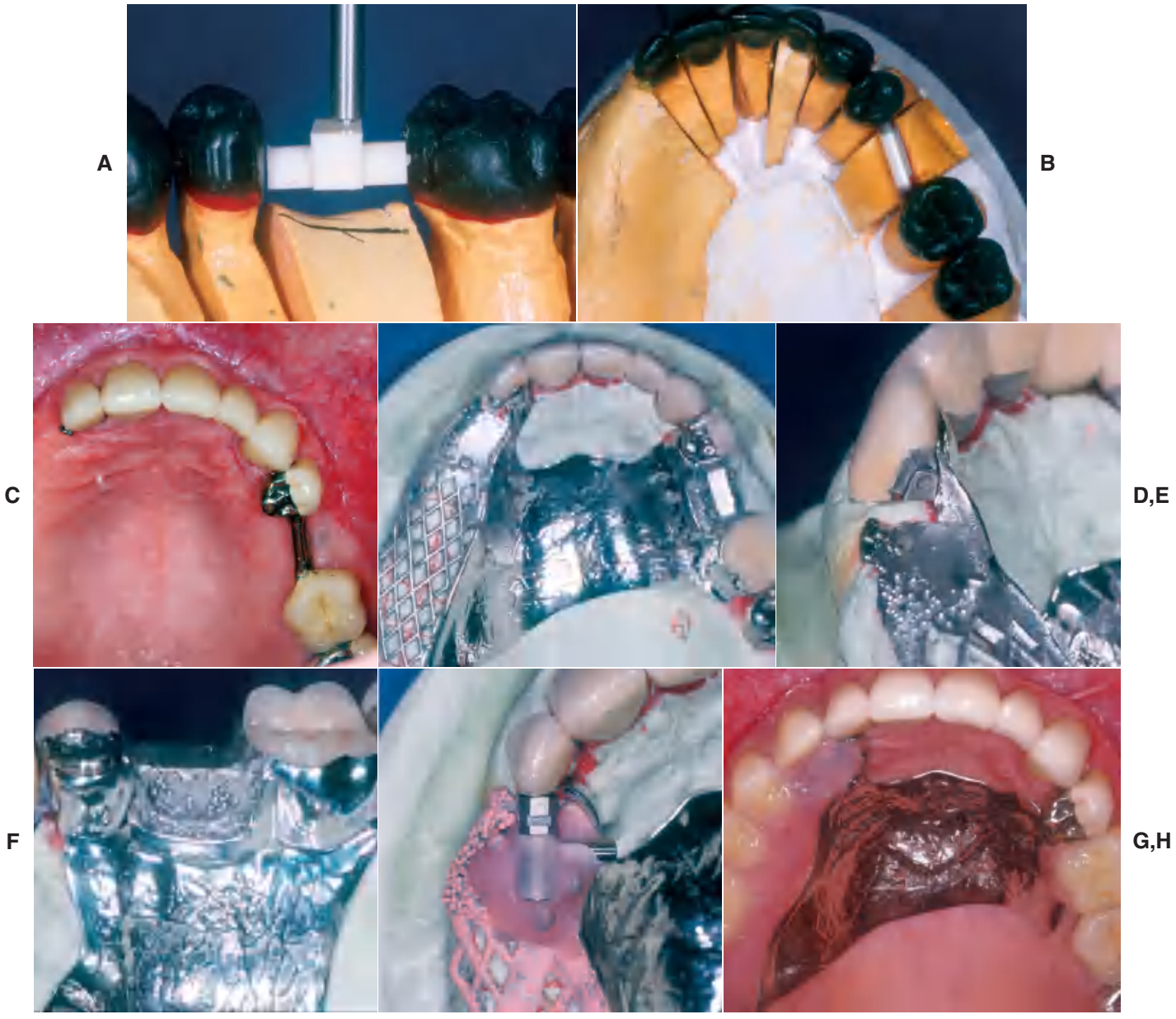


Fig. 21-40

Use of a combination of bar and extracoronal attachments for support and retention of a maxillary partial removable dental prosthesis (RDP) according to the rotational path concept. The COMPAS attachment system was chosen as the extracoronal attachment. This system was designed by Dr. Peter Dawson and is an evolution of the D 2.7 attachment (*see* Fig. 21-34), which was also designed by Dr. Dawson. It includes preformed plastic parts that are placed by mandrels and waxed into the crown forms for cut-back and casting. It also includes a spring-loaded plunger that is incorporated into the matrix, which is luted to the partial RDP framework by embedding into the resin. Preformed plastic bar and matrix forms were used and were incorporated into the fixed prostheses wax patterns. **A,** Curved bar is positioned and waxed to place. **B,** Anatomic contour waxing with bar on left and extracoronal attachment on right abutment. **C,** Completed crowns evaluated. The fixed restorations were picked up in an impression that was used to fabricate the definitive cast for the RDP framework. **D,** Framework and restorations on definitive cast. **E,** Attachment on distal side of abutment. **F,** Framework cast to fit over curved bar. **G,** Plunger assembly luted to framework for evaluation. **H,** Intraoral view of completed prostheses. *(Courtesy of Drs. W. V. Campagni and F. Munguia.)*

STUDY QUESTIONS

1. Explain the principles underlying reciprocation and their effect on the coronal contour of individual retainers.
2. Discuss the principles that govern the determination of the location of height of contour and the survey line on the retentive surface of a retainer that is to support a partial RDP.
3. How does tooth preparation for a retainer for a partial RDP differ from a conventional tooth preparation for the same tooth? What are the various factors that must be considered, and how do they influence the result?
4. What is the recommended fabrication sequence of a wax pattern for a retainer for a partial RDP?
5. Discuss the classification of attachments and the respective indications, contraindications, advantages, and disadvantages.

SUMMARY

Along with conventional diagnostic procedures, an in-depth survey analysis of the diagnostic cast must be performed for any patient who requires a partial RDP. The coronal surfaces of the abutment teeth should be shaped to allow for optimum retention and stability of the RDP during function. Simultaneously, proximal and reciprocal guide planes should be established to guide and stabilize the prosthesis during placement and to minimize horizontal forces on the abutment teeth.

To achieve harmony with the necessary RDP design, making cast restorations on otherwise intact and caries-free teeth is sometimes necessary. Unaltered crowns of natural teeth may not have suitable contours or axial configuration for the best clasp design.

The amount of tooth reduction needed to fabricate restorations with the desired survey contours is often slightly greater than that needed if the respective abutment teeth are prepared for conventional restorations. Allowances must be made for occlusal rest seats and guide planes. Precision and semiprecision attachments can offer esthetic and retentive advantages (Fig. 21-40).

Intracoronal attachments are often more esthetic than conventional clasps. They work well if kept within the normal contours of the teeth.

Extracoronal attachments should be used sparingly because of their unfavorable loading of abutment teeth and the associated problems in maintaining oral hygiene.

Attachments and occlusal rest seats in metal-ceramic restorations should be placed at least 1 mm from the metal-ceramic interface.

Survey crowns require finishing procedures for which special milling equipment is needed.

A precementation impression should be obtained for verifying that the best coronal contours have been created in harmony with the partial RDP.

GLOSSARY*

Akers clasp \Ā′kerz klăsp\ [Polk E. Akers, Chicago, III, dentist]**:** *eponym* for a one piece cast partial denture with cast clasps. He is said to have improved and standardized the one piece casting method for fabricating gold partial dentures in the early 1920s—see SUPRABULGE CLASP

Akers PE Partial dentures. J Amer Dent Assoc 1928;15:717-22.

angle of gingival convergence \ăng′gl ŭv jĭn′ji-val, -jĭn-jĭ′-kun-vûr′jens\ **1:** according to Schneider, the angle of gingival convergence is located apical to the height of contour on the abutment tooth. It can be identified by viewing the angle formed by the tooth surface gingival to the survey line and the analyzing rod or undercut gauge in a surveyor as it contacts the height of contour **2:** the angle formed by any surface of the tooth below the survey line of the height of contour, with the selected path of insertion of a prosthesis **3:** the angle formed by the tooth surface below the height of contour with the vertical plane, when the occlusal surface of the tooth is oriented parallel to the horizontal plane

Schneider RL. J Prosthet Dent 1987;58:194-6.

attachment \a-tăch′ment\ *n* (15c) **1:** a mechanical device for the fixation, retention, and stabilization of a prosthesis **2:** a retainer consisting of a metal receptacle and a closely fitting part; the former (the female [matrix] component) is usually contained within the normal or expanded contours of the crown of the abutment tooth and the latter (the male [patrix] component) is attached to a pontic or the denture framework—see FRICTIONAL A., INTERNAL A., KEY and KEYWAY A., PARALLEL A., PRECISION A., RESILIENT A., SLOTTED A.

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bar clasp \bär klăsp**:** a clasp retainer whose body extends from a major connector or denture base, passing adjacent to the soft tissues and approaching the tooth from a gingivo-occlusal direction

[3]**base** \bās\ *n* (19c)**:** the portion of a denture that supports the artificial dentition and replaces the alveolar structures and gingival tissues—see DENTURE B.

buccal vestibule \bŭk′al vĕs′ti-byōōl**:** the portion of the oral cavity that is bounded on one side by the teeth, gingiva, and alveolar ridge (in the edentulous mouth, the residual ridge) and on the lateral side by the cheek posterior to the buccal frenula

cingulum rest \sĭng′gya-lum rĕst**:** a portion of a removable dental prosthesis that contacts the prepared or natural cingulum of the tooth, termed the cingulum rest seat

clasp \klăsp\ *n* (14c)**:** the component of the clasp assembly that engages a portion of the tooth surface and either enters an undercut for retention or remains entirely above the height of contour to act as a reciprocating element. Generally it is used to stabilize and retain a removable dental prosthesis—see BAR C., CIRCUMFERENTIAL C., COMBINATION C., CONTINUOUS C.

clasp assembly \klăsp a-sĕm′blē**:** the part of a removable partial denture that acts as a direct retainer and/or stabilizer for a prosthesis by partially encompassing or contacting an abutment tooth—*usage:* components of the clasp assembly include the *clasp,* the *reciprocal clasp,* the *cingulum, incisal* or *occlusal rest,* and the *minor connector*

clip \klĭp\ *n* (15c) *slang* **1:** any of numerous devices used to grip, clasp, or hook **2:** a device used to retain a removable prosthesis intraorally to a fixed abutment; i.e., a bar, crown, or other retainer

cor·rode \ka-rōd\ *vt* (15c) **1:** deterioration of a metal due to an electrochemical reaction within its environment **2:** to eat away by degrees as if by gnawing **3:** to wear away gradually usually by chemical action

cor·ro·sion \ka-rō′zhen\ *n* (15c)**:** the action, process, or effect of corroding; a product of corroding; the loss of elemental constituents to the adjacent environment

direct retainer \dĭ-rĕkt, dī- rĭ-tā′ner**:** that component of a partial removable dental prosthesis used to retain and prevent dislodgment, consisting of a clasp assembly or precision attachment

Dolder bar [Eugene J. Dolder, Zurich, Switzerland prosthodontist]**:** *eponym* for one of many bar attachments that splint teeth or roots together while acting as an abutment for a partial removable dental prosthesis. The bar is straight with parallel sides and a round top. The sleeve or clip that fits over the bar gains retention by friction only. The bar may be of variable size and is pear shaped in cross section, as is its accompanying sleeve. This clip allows for some measure of rotational movement about the bar

Dolder EJ. The bar joint mandibular denture. J PROSTHET DENT 1961;11:689-707.

dove·tail \dŭv′tāl′\ *n* (1565)**:** a widened portion of a prepared cavity used to increase retention and/or resistance

fulcrum line \fŏŏl′krum līn\ **1:** a theoretical line passing through the point around which a lever functions and at right angles to its path of movement **2:** an imaginary line, connecting occlusal rests, around which a partial removable dental prosthesis tends to rotate under masticatory forces. The determinants for the fulcrum line are usually the cross arch occlusal rests located adjacent to the tissue borne components—see F.L. OF A REMOVABLE PARTIAL DENTURE, RETENTIVE F.L.

guiding planes \gī′dĭng plānz**:** vertically parallel surfaces on abutment teeth or/and dental implant abutments oriented so as to contribute to the direction of the path of placement and removal of a removable partial denture

Hader bar [after the Swiss tool and die technician, Helmut Hader]**:** *eponym* for a rigid bar connecting two or more abutments, which, when viewed in cross section, resembles a keyhole, consisting of a rectangular bar with a rounded superior (occlusal) ridge that creates a retentive undercut for the female clip within the removable prosthesis

Breim SL., Renner RP. An overview of tissue bars. Gen Dent 1982: 406-15.

height of contour \hīt ŭv kŏn′tŏŏr′**:** a line encircling a tooth and designating its greatest circumference at a selected axial position determined by a dental surveyor; a line encircling a body designating its greatest circumference in a specified plane

indirect retention \ĭn′dĭ-rĕkt′, -dī- rĭ-tĕn′shun**:** the effect achieved by one or more indirect retainers of a partial removable denture that reduces the tendency for a denture base to move in an occlusal direction or rotate about the fulcrum line

infrabulge clasp \ĭn′fra-bŭlj klăsp**:** a removable partial denture retentive clasp that approaches the retentive undercut from a cervical or infrabulge direction

internal attachment: see PRECISION ATTACHMENT

keep·er \kē′par\ *n* (14c)**:** any one of various devices used for keeping something in position—*usage:* in dentistry, this is usually construed to mean a magnetized alloy attached to one element of a restoration to which a magnet may adhere

Kennedy classification of removable partial dentures [Edward Kennedy, U.S. dental surgeon, variably dated 1923, 1925, and 1928]: a classification of partially edentulous arches divisible into four classes. Class 1: a bilateral edentulous areas located posterior to the remaining natural teeth. Class II: a unilateral edentulous area located posterior to the remaining natural teeth. Class III: a unilateral edentulous area with natural teeth located both anterior and posterior to it. Class IV: a single bilateral edentulous area located anterior to the remaining natural teeth. Edentulous areas, in addition to those determining the main types, were designated as *modification spaces*. O. C. Applegate's Rules govern application of the Kennedy system

Kennedy E. Partial denture construction. Brooklyn: Dental Items of Interest, 1928.

key·way \kē′wā′\ *n*: an interlock using a matrix and patrix between the units of a fixed dental prosthesis. It may serve two functions: 1) to hold the pontic in the proper relationship to the edentulous ridge and the opposing teeth during occlusal adjustment on the working cast (during application of any veneering material) and 2) to reinforce the connector after soldering

labial vestibule \lā′bē-al vĕs′ta-byōōl\: the portion of the oral cavity that is bounded on one side by the teeth, gingiva, and alveolar ridge (in the edentulous mouth, the residual ridge) and on the other by the lips anterior to the buccal frenula

lingual plate \lĭng′gwal plāt\: the portion of the major connector of a removable partial denture contacting the lingual surfaces of the natural teeth—also spelled *linguoplate*

lingual rest seat \lĭng′gwal rĕst sēt\: the depression prepared on the lingual surface of an abutment tooth to accept the metal rest of a partial denture (the lingual rest)

mill in \mĭl ĭn\ *v* **1:** the procedure of refining occluding surfaces through the use of abrasive materials—see SELECTIVE GRINDING **2:** the machining of boxes or other forms in cast restorations to be used as retainers for fixed or removable prostheses

mill·ing \mĭl′ĭng\ *v*: the machining of proximal boxes, recesses, or other forms on cast restorations to be used as retainers for fixed or removable prostheses

minor connector \mī′nar ka-nĕk′tor\: the connecting link between the major connector or base of a removable dental prosthesis and the other units of the prosthesis, such as the clasp assembly, indirect retainers, occlusal rests, or cingulum rests

occlusal rest \a-klōō′zal, -sal rĕst\: a rigid extension of a partial removable dental prosthesis that contacts the occlusal surface of a tooth or restoration, the occlusal surface of which may have been prepared to receive it—see REST SEAT

o·ver·clo·sure \ō′var-klō′zhar\ *n*: an occluding vertical dimension at a reduced interarch distance; an occluding vertical dimension that results in excessive interocclusal distance when the mandible is in the rest position; it results in a reduced interridge distance when the teeth are in contact

parallel attachment: see PRECISION ATTACHMENT

partial denture \pär′shal dĕn′chur\: a removable dental prosthesis or a fixed dental prosthesis that restores one or more but not all of the natural teeth and/or associated parts and may be supported in part or whole by natural teeth, dental implant supported crowns, dental implant abutment(s), or other fixed dental prostheses and/or the oral mucosa; *usage:* a partial denture can be described as a *fixed dental prosthesis* or *removable dental prosthesis* based on the patient's capability to remove or not remove the prosthesis. If the prosthesis is a fixed dental prosthesis that can only be removed by a clinician, i.e., a fixed dental prosthesis (FDP) supported by dental implants that has been retained by means of a mechanical system [i.e., screw(s)], this prosthesis is also termed a *fixed dental prosthesis*. Adjectives (modifiers) may be added to the clinical description of the dental prosthesis, if needed, to designate the means of mechanical retention, i.e., a *screw retained fixed dental prosthesis*. Any such prosthesis luted to dental implants (in the same manner as luting a fixed dental prosthesis to natural teeth) needs no additional designation as to its means of retention—see BILATERAL DISTAL EXTENSION REMOVABLE D.P., FIXED D.P., REMOVABLE D.P., UNILATERAL REMOVABLE D.P.

partial denture rest \pär′shal dĕn′chur rĕst\: a rigid extension of a fixed or removable partial denture that prevents movement toward the mucosa and transmits functional forces to the teeth

partial denture retention \pär′shal dĕn′chur rĭ-tĕn′shun\: the ability of a removable dental prosthesis to resist movement away from its foundation area and/or abutments

pas·sive \păs′ĭv\ *adj* (14c): **1:** not active or in operation; inert; latent **2:** resistant to corrosion **3:** existing or occurring without being active, direct, or open

precision attachment \prĭ-sĭzh′un a-tăch′mant\ **1:** a retainer consisting of a metal receptacle (matrix) and a closely fitting part (patrix); the matrix is usually contained within the normal or expanded contours of the crown on the abutment tooth/dental implant and the patrix is attached to a pontic or the removable partial denture

prosthesis framework **2:** an interlocking device, one component of which is fixed to an abutment or abutments, and the other is integrated into a removable prosthesis in order to stabilize and/or retain it

re·cip·ro·cal \rĭ-sĭp′ra-kal\ *adj, obs*: the manner in which one part of a prosthesis is made to counter the effect created by another part (GPT-1)

reciprocal arm: see RECIPROCAL CLASP

reciprocal clasp \rĭ-sĭp′ra-kal klăsp\: a component of the clasp assembly specifically designed to provide reciprocation by engaging a reciprocal guiding plane; it contacts the action of the clasp during removal and insertion of a removable partial denture

re·cip·ro·ca·tion \rĭ-sĭp′ra-kā′shun\ *n* (1561) **1:** the mechanism by which lateral forces generated by a retentive clasp passing over a height of contour are counterbalanced by a reciprocal clasp passing along a reciprocal guiding plane **2:** a mutual exchange **3:** an alternating motion—re·cip·ro·ca·tive \rĭ-sĭp′ra-kā′tĭv\ *adj*

resilient attachment \rĭ-zl′yant a-tăch′mant\ (1998): an attachment designed to give a tooth borne/soft tissue borne removable dental prosthesis sufficient mechanical flexion to withstand the variations in seating of the prosthesis due to deformations of the mucosa and underlying tissues without placing excessive stress on the abutments

rest seat \rĕst sēt\: the prepared recess in a tooth or restoration created to receive the occlusal, incisal, cingulum, or lingual rest

retentive clasp \rĭ-tĕn′tĭv klăsp\ **1:** a clasp specifically designed to provide retention by engaging an undercut **2:** a flexible segment of a partial removable dental prosthesis that engages an undercut on an abutment and that is designed to retain the prosthesis

RPD: *acronym* for *Removable Partial Denture (now termed a Removable Dental Prosthesis)*

RPI: *acronym* for *Rest, Proximal* Plate, and *I-BAR;* the clasp components of one type of removable partial denture clasp assembly

semiprecision rest \sĕm′ē-prĭ-sĭzh′an rĕst\: a rigid metallic extension of a fixed or removable dental prosthesis that fits into an intracoronal preparation in a cast restoration

stress director \strĕs dĭ-rĕk′tar, dī-\: a device or system that relieves specific dental structures of part or all of the occlusal forces and redirects those forces to other bearing structures or regions

su·pra·bulge \sōō′pra-bŭlj\ *adj*: that portion of a tooth crown that converges toward the occlusal surface, i.e., above the height of contour

suprabulge clasp \sōō′pra-bŭlj klăsp\: a removable partial denture retentive clasp that approaches the retentive undercut from an occlusal or suprabulge direction

survey line \sûr′vā′ līn\: a line produced on a cast by a surveyor marking the greatest prominence of contour in relation to the planned path of placement of a restoration

sur·vey·or \sur-vā′or\ *n* (15c): a paralleling instrument used in construction of a prosthesis to locate and delineate the contours and relative positions of abutment teeth and associated structures

tooth-supported base \tōōth-sa-pôr′tĭd bās\: a dental prosthesis base that restores an edentulous region that has abutment teeth at each end for support. The tissue that it covers is not used for support

tripod marking \trĭg′ur mär′kĭng\: those marks or lines drawn on a cast in a single plane perpendicular to the survey rod to assist with repositioning the cast on a dental surveyor in a previously defined orientation

[1]un·der·cut \ŭn′dur-kŭt\ *n* (1859) **1:** the portion of the surface of an object that is below the height of contour in relationship to the path of placement **2:** the contour of a cross-sectional portion of a residual ridge or dental arch that prevents the insertion of a dental prosthesis **3:** any irregularity in the wall of a prepared tooth that prevents the withdrawal or seating of a wax pattern or casting

[2]un·der·cut \ŭn′dur-kŭt\ *v* (ca. 1598): to create areas that provide mechanical retention for materials placement

wrought \rôt\ *adj* (13c) **1:** worked into shape; formed **2:** worked into shape by tools; hammered

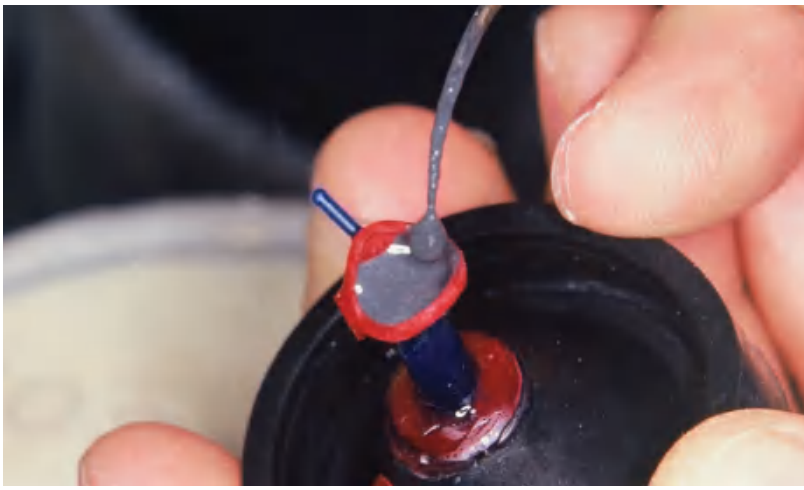
REFERENCES

1. Altay OT, et al: Abutment teeth with extracoronal attachments: the effects of splinting on tooth movement. Int J Prosthodont 3:441, 1990.
2. Krol AJ, Finzen FC: Rotational path removable partial dentures. II. Replacement of anterior teeth. Int J Prosthodont 1:135, 1988.
3. Jones RM, et al: Dentin exposure and decay incidence when removable partial denture rest seats are prepared in tooth structure. Int J Prosthodont 5:227, 1992.
4. Seto BG, et al: Resin bonded etched cast cingulum rest retainers for removable partial dentures. Quintessence Int 16:757, 1985.
5. Dixon DL, et al: Use of a partial coverage porcelain laminate to enhance clasp retention. J Prosthet Dent 63:55, 1990.

6. Davenport JC, et al: Clasp retention and composites: an abrasion study. J Dent 18:198, 1990.
7. Berg T: I-bar: myth and countermyth. Dent Clin North Am 28:371, 1984.
8. Tran CD, et al: A review of techniques of crown fabrication for existing removable partial dentures. J Prosthet Dent 55:671, 1986.
9. Elledge DA, Schorr BL: A provisional and new crown to fit into a clasp of an existing removable partial denture. J Prosthet Dent 63:541, 1990.
10. Becerra G, MacEntee M: A classification of precision attachments. J Prosthet Dent 58:322, 1987.
11. Burns DR, Ward JE: Review of attachments for removable partial denture design. I. Classification and selection. Int J Prosthodont 3:98, 1990.
12. Owall B, Jonsson L: Precision attachment-retained removable partial dentures. III. General practitioner results up to 2 years. Int J Prosthodont 11:574, 1998.
13. Chou TM, et al: Photoelastic analysis and comparison of force-transmission characteristics of intracoronal attachments with clasp distal-extension removable partial dentures. J Prosthet Dent 62:313, 1989.
14. Doherty NM: In vitro evaluation of resin-retained extracoronal precision attachments. Int J Prosthodont 4:63, 1991.
15. Mensor MC: Removable partial overdentures with mechanical (precision) attachments. Dent Clin North Am 34:669, 1990.
16. Gillings BR, Samant A: Overdentures with magnetic attachments. Dent Clin North Am 34:683, 1990.
17. Sposetti VJ, et al: Bite force and muscle activity in overdenture wearers before and after attachment placement. J Prosthet Dent 55:265, 1986.
18. Akers PE: Partial dentures. J Am Dent Assoc 15:717, 1928.
19. Schneider RL: Significance of abutment tooth angle of gingival convergence on removable partial denture retention. J Prosthet Dent 58:194, 1987.
20. Dolder EJ: The bar joint mandibular denture. J Prosthet Dent 11:689, 1961.
21. Ladenheim SL, Renner RP: An overview of tissue bars. Gen Dent 30:406, 1982.
22. Kennedy E. Partial Denture Construction. Brooklyn, NY, Dental Items of Interest, 1928.

22

INVESTING AND CASTING



KEY TERMS

alloy
back pressure porosity
carat
casting
casting machine
casting ring
casting torch
cristobalite
crucible
crucible former
flux
gypsum-bonded
heat sink
hygroscopic expansion
investing
investment
noble metal
phosphate-bonded
polishing
porosity
quartz
refractory
refractory mold
runner bar
setting expansion
shrink spot porosity
silica
sprue
thermal expansion
vacuum mixing
wax elimination
wax pattern

The lost-wax **casting** technique has been used since ancient times to convert **wax patterns** to cast metal. It was first described[1,2] at the end of the 19th century as a means of making dental castings.

The process consists of surrounding the wax pattern with a mold made of heat-resistant **investment** material, eliminating the wax by heating, and then introducing molten metal into the mold through a channel called the **sprue.** In dentistry, the resulting casting must be a highly accurate reproduction of the wax pattern in both surface details and overall dimension. Small variations in **investing** or casting can significantly affect the quality of the final restoration. Successful castings depend on attention to detail and consistency of technique.

An understanding of the exact influence of each variable in the technique is important for making rational decisions to modify the technique as needed for a given procedure.

PREREQUISITES

When the wax pattern has been completed and its margin has been reflowed (see p. 578), it is carefully evaluated for smoothness, finish, and contour (see Chapter 18). The pattern is inspected under magnification, and any residual flash (wax that extends beyond the preparation margin) is removed. A sprue is attached to the pattern, then removed from the die, and attached to a **crucible former** (Fig. 22-1). The wax pattern must be invested immediately because any delay leads to distortion of the pattern as a result of stress relief of the wax.[3]

Sprue

Sprue design (Fig. 22-2) varies depending on the type of restoration being cast, the **alloy** used, and the

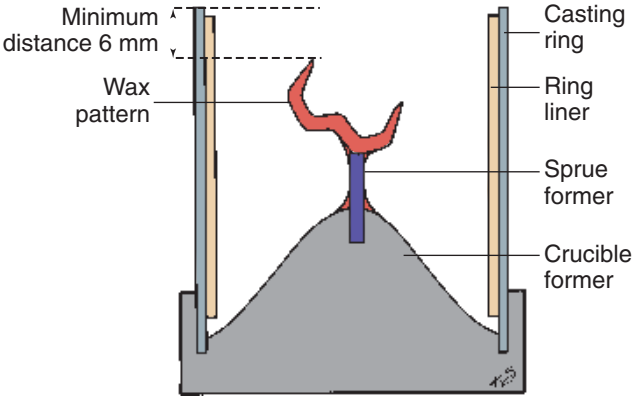


Fig. 22-1
Wax pattern attached to the crucible former with a sprue ready for investing. A ring liner is in place.

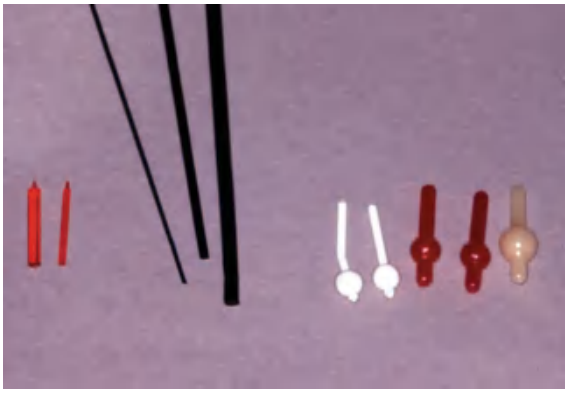


Fig. 22-2
Prefabricated plastic and wax sprues are preferred over metal sprues because the material is eliminated during the heating cycle.

casting machine. There are three basic requirements, as follows:

1. The sprue must allow the molten wax to escape from the mold.
2. The sprue must enable the molten metal to flow into the mold with as little turbulence as possible.
3. The metal within it must remain molten slightly longer than the alloy that has filled the mold. This provides a reservoir to compensate for the shrinkage that occurs during solidification of the casting alloy.

The shape of the channel in the **refractory mold** is determined by the sprue that connects the wax pattern to the crucible former. The sprue can be made from wax, plastic, or metal. Wax sprues are preferred for most castings because they melt at the same rate as the pattern and thus allow easy escape of the molten wax. Solid plastic sprues soften at a higher temperature than the wax pattern and may block the escape of wax, which results in increased casting roughness. However, plastic sprues can be useful when casting fixed dental prostheses in one piece because their added rigidity minimizes distortion. Also, hollow plastic sprues that allow the escape of wax are available.

If a metal sprue is used, it should be made of noncorroding metal to avoid possible contamination of the casting. Metal sprues are often hollow to increase contact surface area and strengthen the attachment between the sprue and pattern. They are usually separated from the investment at the same time the crucible former is. Special care must then be taken to examine the orifice for small particles of investment that may break off when such a sprue is removed, because these can cause an incomplete casting if undetected (see p. 701).

Diameter

In general, a relatively large-diameter sprue is recommended because this improves the flow of molten metal into the mold and ensures a reservoir during solidification.[4,5]

A 2.5-mm (10-gauge) sprue is recommended for molar and metal-ceramic patterns. A smaller 2.0-mm (12-gauge) sprue is adequate for premolar castings and most partial-coverage restorations.

In some casting techniques other than the commonly used centrifugal technique, a narrow sprue, or a sprue design that narrows at the point of attachment to the wax pattern, is essential. For instance, with air-pressure machines, the melt is made directly in the depression created by the crucible former and then forced into the mold by the sudden change in air pressure. With this technique, a narrow sprue prevents the molten metal from flowing into the mold prematurely.

Location

The sprue should be attached to the bulkiest noncritical part of the pattern, away from margins and occlusal contacts. Normally, the largest nonfunctional cusp is used (Fig. 22-3). The point of attachment should allow a stream of metal to be directed to all parts of the mold without having to flow in an opposite direction to the casting force (Fig. 22-4).

The sprue must also allow for proper positioning of the pattern in the ring. This can be crucial because expansion within the mold is not uniform.[6,7] For example, spruing on the cusp tip can give good results, but spruing on the proximal contact may produce a casting that is too wide mesiodistally and too short occlusocervically.

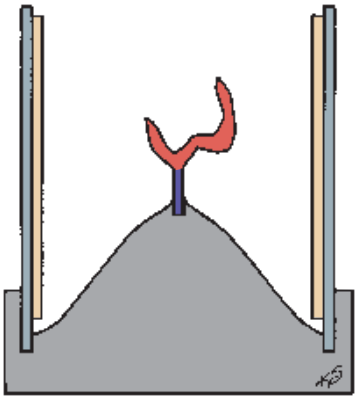


Fig. 22-3
Correct sprue placement on the bulkiest nonfunctional cusp allows molten alloy to flow to all parts of the mold.

Incorrect sprue placement. The gold needs to change direction at an angle of almost 90 degrees after entering the mold. Better placement is at a 45-degree angle on the thickest portion of the pattern.

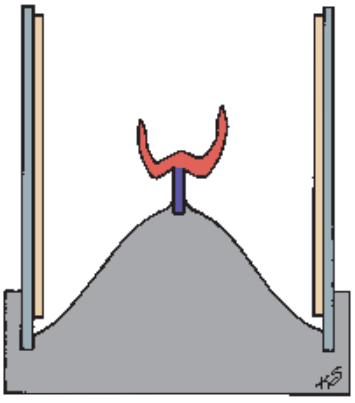
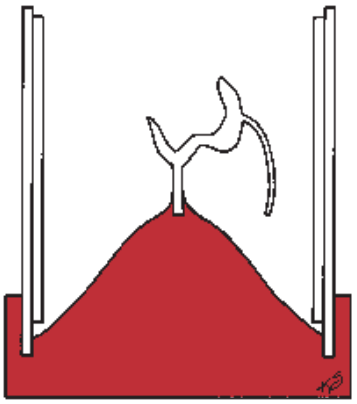


Fig. 22-4
Incorrect sprue placement in the central fossa obliterates occlusal anatomy and may result in poor mold filling because the molten metal is not pushed into the cusp tips by centrifugal force.

Attachment

The sprue's point of attachment to the pattern should be carefully smoothed to minimize turbulence. For the centrifugal casting technique, the attachment area should not be restricted because necking increases casting **porosity** and reduces mold filling.[8] Similarly, excessively widening the attachment can cause this part of the cooling melt to solidify last, causing a void on the internal aspect of the casting, known as **shrink-spot porosity.**



A



B

Fig. 22-5
A and **B,** Thin auxiliary sprues may help gases escape and ensure that casting solidifies in a critical area.

Venting

Small auxiliary sprues or vents have been recommended to improve casting of thin patterns. Their action may help gases escape during casting[9] or ensure that solidification begins in critical areas by acting as a **heat sink**[10] (Fig. 22-5).

Crucible Former

The sprue is attached to a crucible former* (Fig. 22-6), usually made of rubber, which serves as a base for the **casting ring** during investing. The exact shape of the crucible former depends on the type of ring and casting machine used. With most modern machines, the crucible former is tall, to allow use of a short sprue and also to enable the pattern to be positioned near the end of the casting ring.

*Sometimes also referred to as a *sprue former.*



Fig. 22-6
Rubber crucible formers. *(Courtesy of Whip Mix Corporation, Louisville, Kentucky.)*

Various methods to influence the amount of *setting expansion* of the investment.

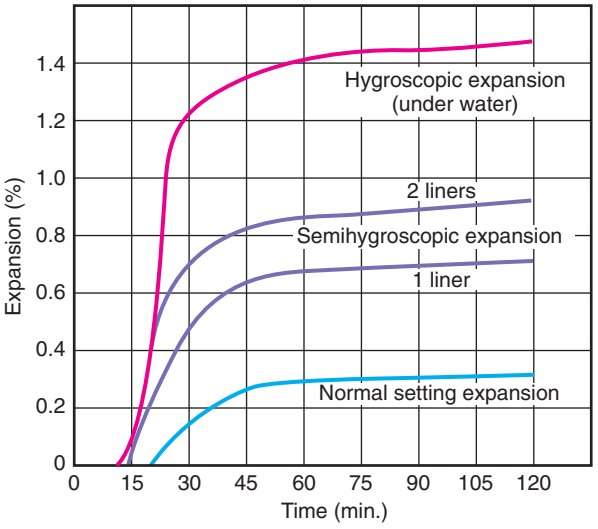


Fig. 22-7
Setting expansions of dental casting investments. Note that expansion can be increased by a hygroscopic technique, as well as by the particular type of ring liner used. *(Courtesy of Whip Mix Corporation, Louisville, Kentucky.)*

Casting Ring and Liner

The casting ring serves as a container for the investment while it sets and restricts the **setting expansion** of the mold. Normally a liner is placed inside the ring to allow for more expansion, because the liner is somewhat compressible. Use of two liners allows for additional compression and enables increased setting expansion of the investment material. At one time, asbestos was used as the liner, but this has been replaced by other materials to avoid the health risks associated with asbestos fibers. Like many other factors that come into play in achieving consistent casting with the proper quality of fit, changes in the liner are important. Wetting the liner increases the **hygroscopic expansion** of the mold and should be carefully controlled. An absorbent dry liner removes water from the investment and makes a thicker mix, which leads to increase in the total expansion.[11,12] To prevent expansion restriction, care must be taken not to squeeze the liner against the ring. Increased expansion can be obtained by placing the mold in a water bath. This is because of hygroscopic expansion (Fig. 22-7). The position of the pattern in the casting ring also affects expansion. For consistent results, a single crown should be centered in the ring, equidistant from its walls. When fixed prostheses are cast as one piece, greater accuracy is achieved if the pattern is placed near the center of a large or special oval ring, rather than if a portion of a multiunit wax pattern is only partially centered and partially near the edge of a smaller ring.[6]

Ringless Investment Technique

With the use of higher strength, phosphate-bonded investments, the ringless technique has become quite popular (Fig. 22-8).[13] The method entails the use of a paper or plastic casting ring and is designed to allow unrestricted expansion.[14] This can be useful with higher melting alloys that shrink more because of a larger cooling trajectory.



Fig. 22-8
Ringless investment technique. Crucible formers and cone-shaped plastic rings for a ringless casting system. The crucible former and plastic ring are removed before wax elimination, leaving the invested wax pattern. The systems are designed to achieve expansion that is unrestricted by a metal ring. *(Courtesy of Whip Mix Corporation, Louisville, Kentucky.)*

Spruing Technique

Armamentarium (Fig. 22-9)

- Sprue (A)
- Sticky wax (B)
- Rubber crucible former (C)
- Casting ring (D)
- Ring liner (E)
- Bunsen burner (F)
- Pattern cleaner (G)
- Scalpel blade (H)
- Forceps (I)

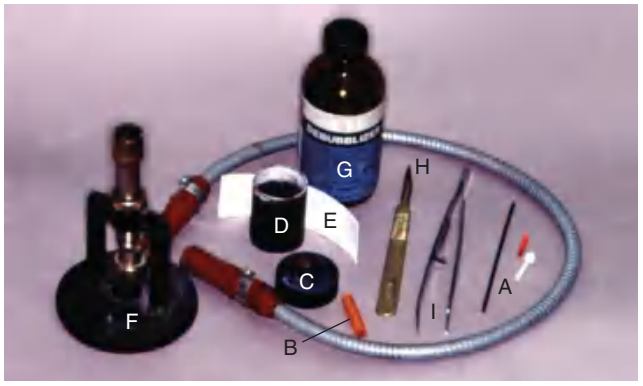


Fig. 22-9
Armamentarium for spruing the wax pattern.

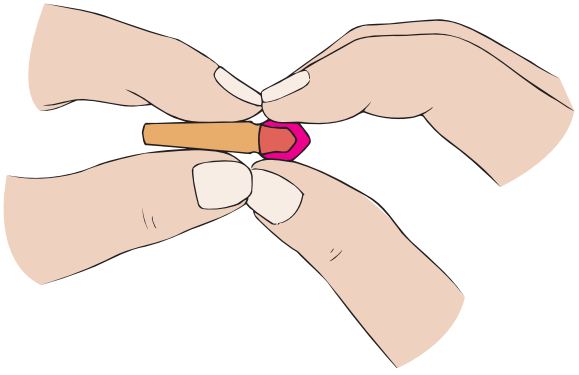
Step-by-step procedure for a single casting

A 2.5-mm (10-gauge) sprue form is recommended for molar crowns or metal-ceramic castings, and a 2-mm (12-gauge) sprue for premolar and partial-coverage restorations. The procedure is as follows:

1. Attach a 12-mm wax sprue to the bulkiest nonfunctional cusp of the wax pattern, and angle it so that it is obtuse to the adjacent axial walls and occlusal surface (Fig. 22-10*A*). This angle is usually about 135 degrees to the axial walls, and it facilitates filling of the mold.
2. Add wax to the point of attachment and smooth it to prevent turbulence during casting.
3. Remove the pattern from the die, using extreme caution not to distort it (Fig. 22-10*B*).
4. Holding the sprue with forceps, insert it into the hole in the crucible former (Fig. 22-10*C*). It should now be luted into place with wax, and the junction between sprue and **crucible** should be

A





B

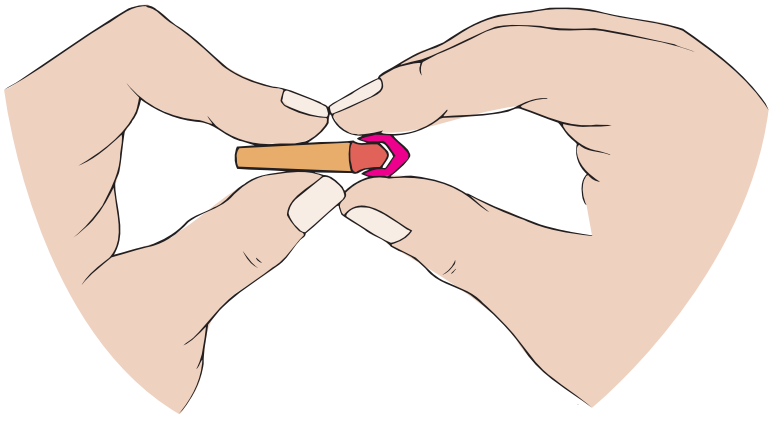


Fig. 22-10
Spruing technique for a single casting. **A,** Attaching the sprue to the pattern. **B,** Removing the pattern from the die (see p. 566 for a description of this technique).



Positioning the pattern closer to the end of the ring increases the risk of the casting alloy breaking through the end of the investment.

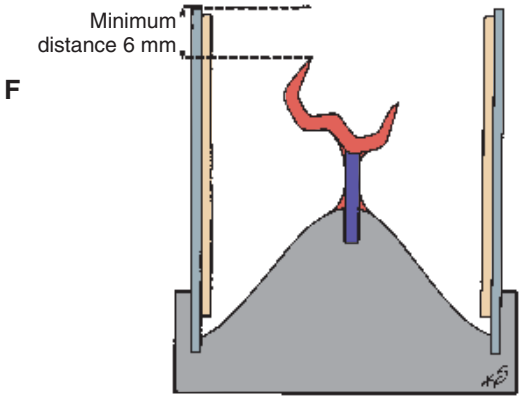


Fig. 22-10, cont'd

C, Positioning the pattern on the crucible former. **D,** Application of surfactant. **E,** A ring liner increases the setting expansion. **F,** The pattern must be positioned sufficiently away from the end of the ring.

smoothed. Use of a surfactant enhances wetting of the pattern during investing (Fig. 22-10*D*).

5. Line the casting ring, keeping it flush with the open end, and moisten the liner (Fig. 22-10*E*).
6. Place the ring over the pattern to ensure that it is long enough to cover the pattern with about 6 mm of investment (Fig. 22-10*F*). If necessary, the sprue may be shortened, or a longer ring may be chosen as an alternative.

Procedure for multiple castings

When more than two units are being cast together, each is joined to a **runner bar** (Fig. 22-11). A single sprue is used to feed the runner bar. Two units may be cast with a runner bar, or each unit may be fed from a separate sprue.

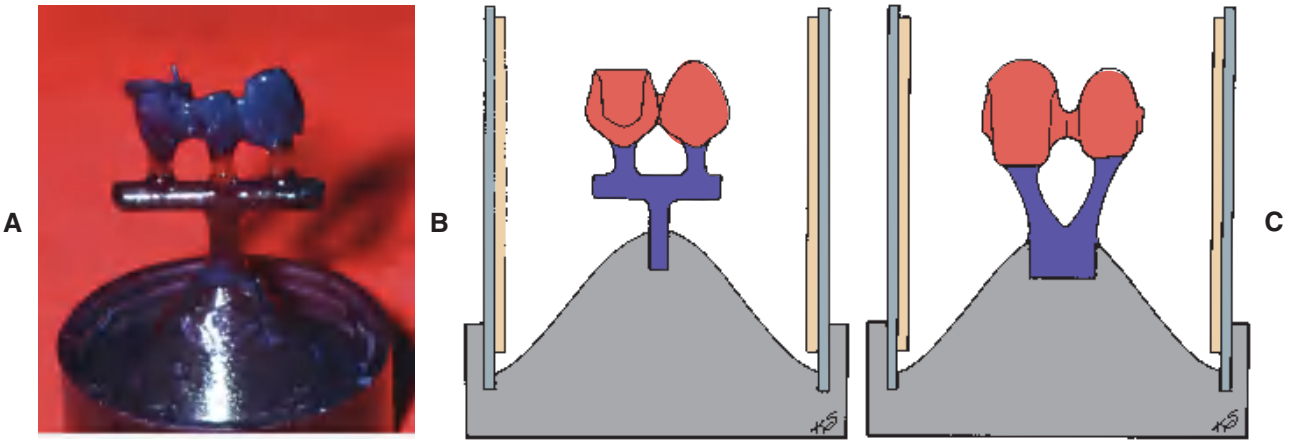


Fig. 22-11
Spruing multiple units. **A,** For more than two castings, a runner bar is used. **B,** For two castings, a runner bar may be used, or each casting may be fed through separate sprues (**C**).

MATERIALS SCIENCE

M. H. Reisbick

Several investment materials are available for fabricating a dental casting mold. These typically consist of a **refractory** material (usually **silica**) and a binder material, which provides strength. Additives are used by the manufacturer to improve handling characteristics.

When investments are classified by binder, three groups are recognized: **gypsum-bonded, phosphate-bonded**, and silica-bonded investments. Each has specific applications. The gypsum-bonded investments are used for castings made from American Dental Association (ADA) type II, type III, and type IV gold alloys. The phosphate-bonded materials are recommended for metal-ceramic frameworks. The silica-bonded investments are for high-melting base metal alloys used in casting partial removable dental prostheses. However, because of their limited application in fixed prosthodontics, silica-bonded investments are not included in the following discussion.

Gypsum-Bonded Investments

Gypsum is used as a binder, along with **cristobalite** or **quartz** as the refractory material, to form the mold. The cristobalite and quartz are responsible for the **thermal expansion** of the mold during **wax elimination.** Because gypsum is not chemically stable at temperatures exceeding 650°C (1200°F), these investments are typically restricted to castings of conventional types II, III, and IV gold alloys.

Expansion

Three types of expansion can be manipulated to obtain the desired size of casting: setting, hygroscopic, and thermal.

Setting expansion

As the gypsum investment sets after mixing, it expands and slightly enlarges the mold. The pattern, metal casting ring, and compressibility of the ring liner all influence this expansion.

The water/powder ratio can be altered to reduce or increase the amount of setting expansion. The use of less water increases the setting expansion and results in a slightly larger casting. Use of an additional ring liner increases the setting expansion, as does a slight increase in mixing time. If a smaller casting is desired, more water can be used or the liner can be eliminated, both of which curtail the amount of expansion. When attempting to alter setting expansion, the clinician should not deviate more than minimally from the manufacturer's recommendations, to ensure that there are no changes in the essential properties of the investment.

Hygroscopic expansion

Hygroscopic expansion occurs when water is added to the setting gypsum investment immediately after the ring has been filled. Usually this is accomplished by submerging the ring in a water bath at 37°C (100°F) for up to 1 hour immediately after investing. A significant amount of additional setting expansion results, enabling the use of a slightly lower wax elimination temperature. A wet ring liner also con-

tributes hygroscopic expansion to the portion of the mold with which it is in contact (see Fig. 22-7).

Thermal expansion

As the mold is heated to eliminate the wax, thermal expansion occurs (Fig. 22-12). The silica refractory material is principally responsible for this because of solid-state phase transformations. Cristobalite changes from the α to the β (high-temperature) form between 200°C (392°F) and 270°C (518°F); quartz transforms at 575°C (1067°F). These transitions involve a change in crystal form, an accompanying change in bond angles and axis dimension, and a decreased density, producing a volume increase in the refractory components.

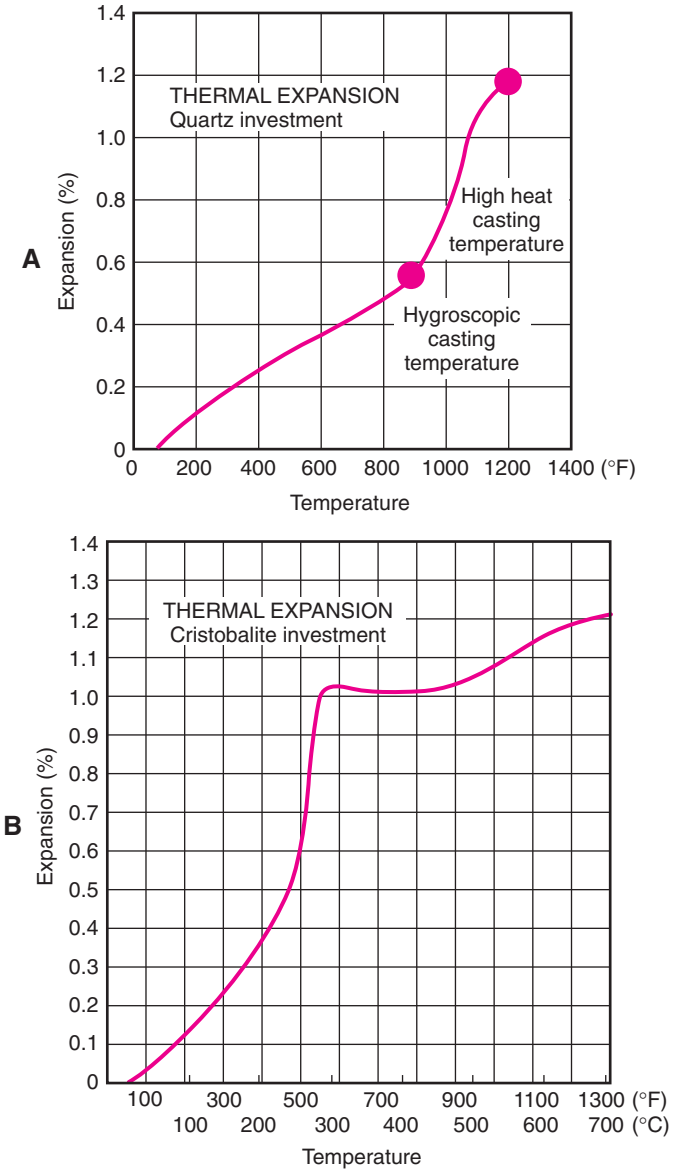


Fig. 22-12
Thermal expansions of quartz-based (A) and cristobalite-based (B) investments. *(Courtesy of Whip Mix Corporation, Louisville, Kentucky.)*

Phosphate-Bonded Investments

Because most metal-ceramic alloys fuse at approximately 1400°C (2550°F) (as opposed to conventional gold alloys at 925°C [1700°F]), additional shrinkage occurs when the casting cools to room temperature. To compensate for this, a larger mold is necessary. The added expansion can be obtained with phosphate-bonded investments.

The principal difference between gypsum-bonded and phosphate-bonded investments is the composition of the binder and the relatively high concentration of silica refractory material in the latter. The binder consists of magnesium oxide and an ammonium phosphate compound. In contrast to gypsum-bonded products, this material is stable at burnout temperatures above 650°C (1200°F) (Fig. 22-13), which allows for additional thermal expansion. Most phosphate-bonded investments are mixed with a specially prepared suspension of colloidal silica in water. (Some, however, can be mixed with water alone.)

Some phosphate-bonded investments contain carbon and therefore are gray in color. Carbon-containing materials should not be used for casting base metals because the carbon residue affects the final alloy composition. They may be used for casting high-gold or palladium content alloys.

Expansion

Compared to gypsum-bonded investments, phosphate-bonded investments offer greater flexibility in controlling the amount of expansion. The liquid/powder ratio needs only slight modification to effect a significant change in setting expansion. Increasing the proportion of special liquid (colloidal silica) also increases expansion.

Working time

Phosphate-bonded investments have a relatively short working time in comparison with gypsum materials. Their exothermic setting reaction accelerates as the temperature of the mix rises during manipulation. The filled ring feels warm to the touch even shortly after it has been filled. A longer mixing time significantly accelerates the setting reaction and temperature and thus reduces the working time even further. The addition of water to the colloidal silica suspension increases the working time, with

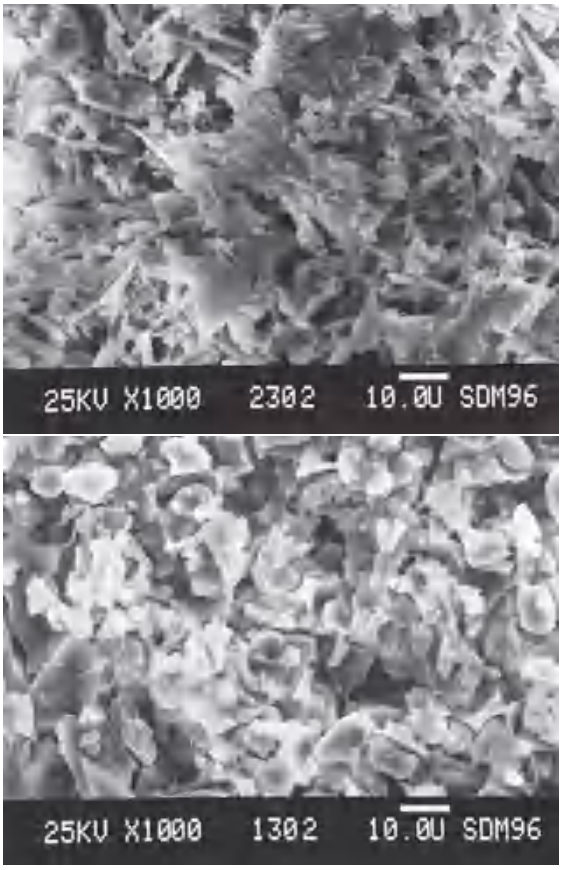


Fig. 22-13
Scanning electron micrographs of a gypsum-bonded investment (**A**) and a phosphate-bonded investment (**B**), each heated to 700°C (1292°F).

some loss of setting expansion. Many technicians therefore vary the quantity of special liquid and water between batches and make trial mixes for each new shipment. This has been a reliable means of adjusting expansion.[15]

Gas is formed during the reaction and must be removed for a sufficiently long period to minimize nodules on the casting.[16] Maintaining a vacuum for about 60 seconds appears to be adequate.

• • •

SELECTION OF MATERIALS

Selecting a Casting Alloy

The choice of casting alloy largely determines the selection of investment and casting techniques and therefore is discussed first.

The number and variety of alloys suitable for casting have expanded dramatically, largely because of changes in the price of gold. Many alloys are available, especially for metal-ceramic restorations (see Chapter 19). The dentist must be able to make a rational choice on the basis of current information.

Factors to be considered

Intended use

Alloys for casting were traditionally classified on the basis of their intended use, as follows:

Type I: simple inlays
Type II: complex inlays
Type III: crowns and fixed dental prostheses
Type IV: partial removable dental prostheses and pinledges
Porcelain: metal-ceramic alloys

Physical properties

In 1965, the ADA adopted the specifications of the Fédération Dentaire Internationale (FDI), which classified casting alloys according to their physical properties (specifically their hardness), as follows:

Type I: soft
Type II: medium
Type III: hard
Type IV: extra hard

Porcelain-type alloys with a high **noble metal** content were found to have hardness similar to that of type III alloys, and base metal alloys were found to be harder than type IV alloys (see Chapter 19).

Color

Manufacturers place considerable emphasis on the color of their alloys, and color preference is often given to gold over silver. The patient's views on the subject should be sought if the metal will be visible in the mouth; otherwise, the color of the dental alloy is irrelevant.

Color is not a good guide to gold content: 9-**carat** jewelry alloy with only 37.5% gold looks considerably more yellow than does a metal-ceramic dental alloy with 85% gold but no copper.

Composition

To be accepted by the ADA as an alloy suitable for dental restorations,[17] the manufacturer must list the percentage composition by weight of the three main ingredients and any noble metal percentage. The functional characteristics of corrosion resistance and tarnish resistance were traditionally predicted on the basis of gold content. In general, if at least half the atoms in the alloy are gold (which would be 75% by weight), good resistance to corrosion and tarnish can be predicted. Nevertheless, clinical evaluations have failed to show statistically significant differences in the tarnish resistance of high-gold (77%) and low-gold (59.5% to 27.6%) alloys.[18] However, a poorly for-

mulated alloy, even of high gold content, can rapidly tarnish intraorally.

Cost

Treatment plans are often modified to suit the financial capabilities of the patient or a third party. Base metal alloys have found favor principally because of their low cost. Similarly, alloys containing approximately 50% gold have been found to offer some economic advantage (although the savings are not proportional to the reduced gold content of the alloy). Alloys containing primarily palladium and only a small percentage of gold are an alternative for use in the metal-ceramic technique, although soldering procedures may be less predictable.

When the intrinsic metal cost of a restoration is calculated, the volume of the casting, rather than its weight, should be determined. Dental casting alloys can vary considerably in density from below 8 g/mL to over 18 g/mL (see Table 19-1). An "average" restoration has a volume of 0.08 mL; an all-metal pontic may have a volume reaching 0.25 mL.[19] Therefore, it is conceivable that the cost of a large pontic cast in a low-density alloy would be equal to or less than the cost of a complete cast crown fabricated from a high-density alloy. When noble metal prices are high, more sophisticated techniques of scrap recovery become economically attractive. These can range from installing conventional metal catchers in all areas where castings are finished to equipping all work stations with filtered suction machines.

Clinical performance

In most respects, clinical performance (biologic and mechanical) is more important than cost. Biologic properties that can be evaluated include gingival irritation, recurrent caries, plaque retention, and allergies. Mechanical properties include wear resistance and strength, marginal fit, ceramic bond failure, connector failure, and tarnish and corrosion.

A risk in choosing a new alloy is that defective clinical performance may fail to appear in laboratory testing or in short-term animal and clinical trials. For example, manufacturers introduced copper-based casting alloys with very poor corrosion resistance[20] when the price of gold was rapidly rising.* Although the clinically established alloys all have disadvantages, their performance is likely to have been well documented, and the prognosis of restorative treatment can be more accurately predicted.

*In fact, these formulations were very similar to those for aluminum-bronze alloys sold as dental gold in the 1920s.

Laboratory performance

Sound laboratory data are essential in the selection of a casting alloy. Important areas of consideration are casting accuracy, surface roughness, strength, sag resistance, and metal-ceramic bond strength. Currently available data suggest that nickel-chromium alloys have lower casting accuracy[21] and greater surface roughness[22] than do gold alloys (Fig. 22-14) but higher strength and sag resistance because of their higher melting ranges.[23]

Handling properties

The ease with which an alloy can be manipulated may influence its selection. An alloy that produces satisfactory clinical results, but only under extremely critical conditions or with expensive equipment,

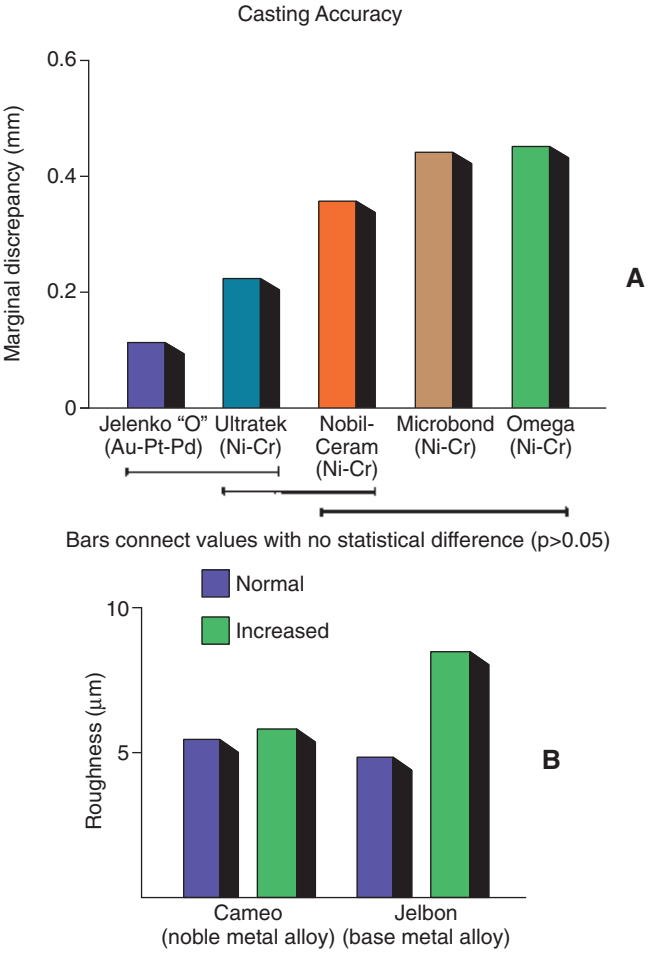


Fig. 22-14

A, Comparison of casting accuracies with different alloys. Au-Pt-Pd, gold-platinum-palladium; Ni-Cr, nickel-chromium. B, Influence of metal casting temperature and alloy selection on casting roughness. (**A,** *From Duncan JD: The casting accuracy of nickel–chromium alloys for fixed prostheses. J Prosthet Dent 47:63, 1982;* **B,** *from Ogura H, et al: Inner surface roughness of complete cast crowns made by centrifugal casting machines. J Prosthet Dent 45:529, 1981.*)

may be rejected in favor of one that produces acceptable results with less critical manipulation.

The ability to burnish an alloy to reduce marginal gap width and thus reduce the exposed thickness of the luting agent is important,[24] although the areas where marginal adaptation is clinically most important (interproximally and subgingivally) are usually not very accessible for such manipulation.

Biocompatibility

All materials for intraoral use should be biocompatible. In addition, it should be possible to handle them safely in the office or laboratory. Many hazardous materials are commonly used in dentistry, such as mercury, chloroform, silver cyanide, and hydrofluoric acid. Consequently, restrictions have been imposed on their shipping and use. For instance, asbestos in casting ring liners and uranium salts in dental porcelain are no longer used. There is also concern[25] for the possible health hazards (see Chapter 19) associated with alloys containing nickel and beryllium. Although no definite conclusions can be drawn, appropriate safety precautions are advisable when these alloys are being ground. Filtered suction units and appropriate barriers (masks) should be used. The ADA[26] requires nickel-containing alloys to carry a precautionary label stating that their use should be avoided in patients with a known nickel allergy (Fig. 22-15).



Fig. 22-15
A and **B,** Dramatic gingival reactions to nickel-containing metal-ceramic restorations. *(Courtesy of Dr. W. V. Campagni.)*

Selecting an Investment Material

After the choice of casting alloy has been made, the investment material can be selected.

Ideal properties

An ideal investment should incorporate the following features:

1. Controllable expansion to compensate precisely for shrinkage of the cast alloy during cooling.
2. The ability to produce smooth castings with accurate surface reproduction and without nodules.
3. Chemical stability at high casting temperatures.
4. Adequate strength to resist casting forces.
5. Sufficient porosity to allow for gas escape.
6. Easy recovery of the casting.

Gypsum-bonded investments

Gypsum-bonded investments satisfy most of the requirements for an ideal material, although they are not suitable for casting metal-ceramic alloys because the gypsum is unstable at the high temperatures required and sulfide contamination of the alloy can occur. In addition, with some materials, obtaining adequate expansion may be difficult. This can be critical in casting complete crowns. A casting that is slightly oversized (in a controlled manner) is advantageous for accurate seating (see Chapters 7 and 29). Factors that increase expansion[27] of gypsum-bonded investments include the following:

1. Use of a full-width ring liner.
2. Prolonged spatulation.
3. Storage at 100% humidity.
4. Lower water/powder ratio.
5. Use of a dry liner.
6. Use of two ring liners.
7. Hygroscopic technique with the pattern in the upper part of the ring.[28]

Phosphate-bonded investments

Phosphate-bonded investment materials offer certain advantages over gypsum-bonded investments. They are more stable at high temperatures and thus are the material of choice for casting metal-ceramic alloys. They expand rapidly at the temperatures used for casting alloys, and their expansion can be conveniently and precisely controlled. The increased expansion that they exhibit results from a combination of the following factors:

1. Heat from the setting reaction softens the wax and allows freer setting expansion.
2. The increased strength of the material at high temperatures restricts shrinkage of the alloy as it cools.
3. The powder mixed with colloidal silica reduces the surface roughness of the castings and also increases expansion. Thus, expansion can be con-

veniently controlled by slightly diluting the colloidal silica with distilled water.

However, castings made with phosphate-bonded investments are rougher than those made with gypsum-bonded investments[29] and are more difficult to remove from the investment.[30] Because phosphate-bonded investments have lower porosity,[31] complete mold filling is more difficult. Castings also are more likely to have surface nodules, which must be removed. (**Vacuum mixing** and a careful investing technique help reduce but do not eliminate the occurrence of nodules.)

INVESTING

Vacuum mixing of investment materials (Fig. 22-16) is highly recommended for consistent results in casting with minimal surface defects, especially when phosphate-bonded investments are used. Good results are possible with brush application of vacuum-mixed investment or when the investment is poured into the ring under vacuum. Vacuum mixing with brush application of the investment is the suggested mode. To expedite the procedure and minimize distortion, all necessary items and materials should be prepared before the wax pattern is reflowed and removed from the die.



Fig. 22-16
Vacuum investing machines. A, The Whip Mix combination unit. B, The Multivac Compact. (*A, Courtesy of Whip Mix Corporation, Louisville, Kentucky; B, courtesy of DENTSPLY Ceramco, York, Pennsylvania.*)

Armamentarium (Fig. 22-17)

- Vacuum mixer and bowl (A)
- Vibrator (B)
- Investment powder (gypsum or phosphate bonded) (C)
- Water (D) or colloidal silica (E)
- Spatula (F)
- Brush (G)
- Surfactant graduated cylinder (H)
- Crucible former (I)
- Casting ring (J) and liner (K)

Step-by-Step Procedure

Brush technique

In this technique, the pattern is first painted with surface tension reducer; the surface must be wet completely. The procedure is as follows:

1. The mixing bowl can either be wiped completely dry or shaken dry. If shaken dry, remember that the residual water adds about 1 mL to the mix. Add investment powder to the liquid in the mixing bowl, and quickly incorporate it by hand (Fig. 22-18*A*). Residual material from the spatula is wiped onto the mechanical mixing blade,

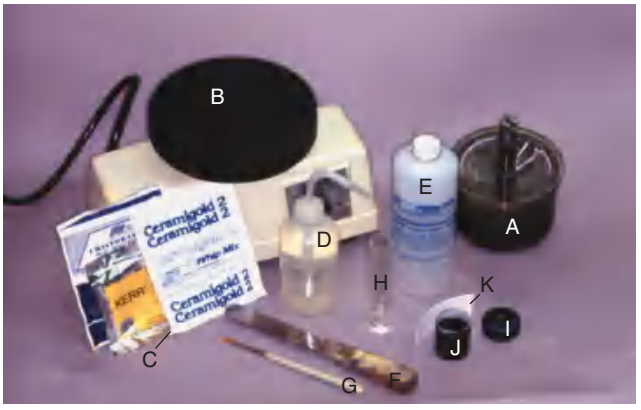


Fig. 22-17
Investing armamentarium.

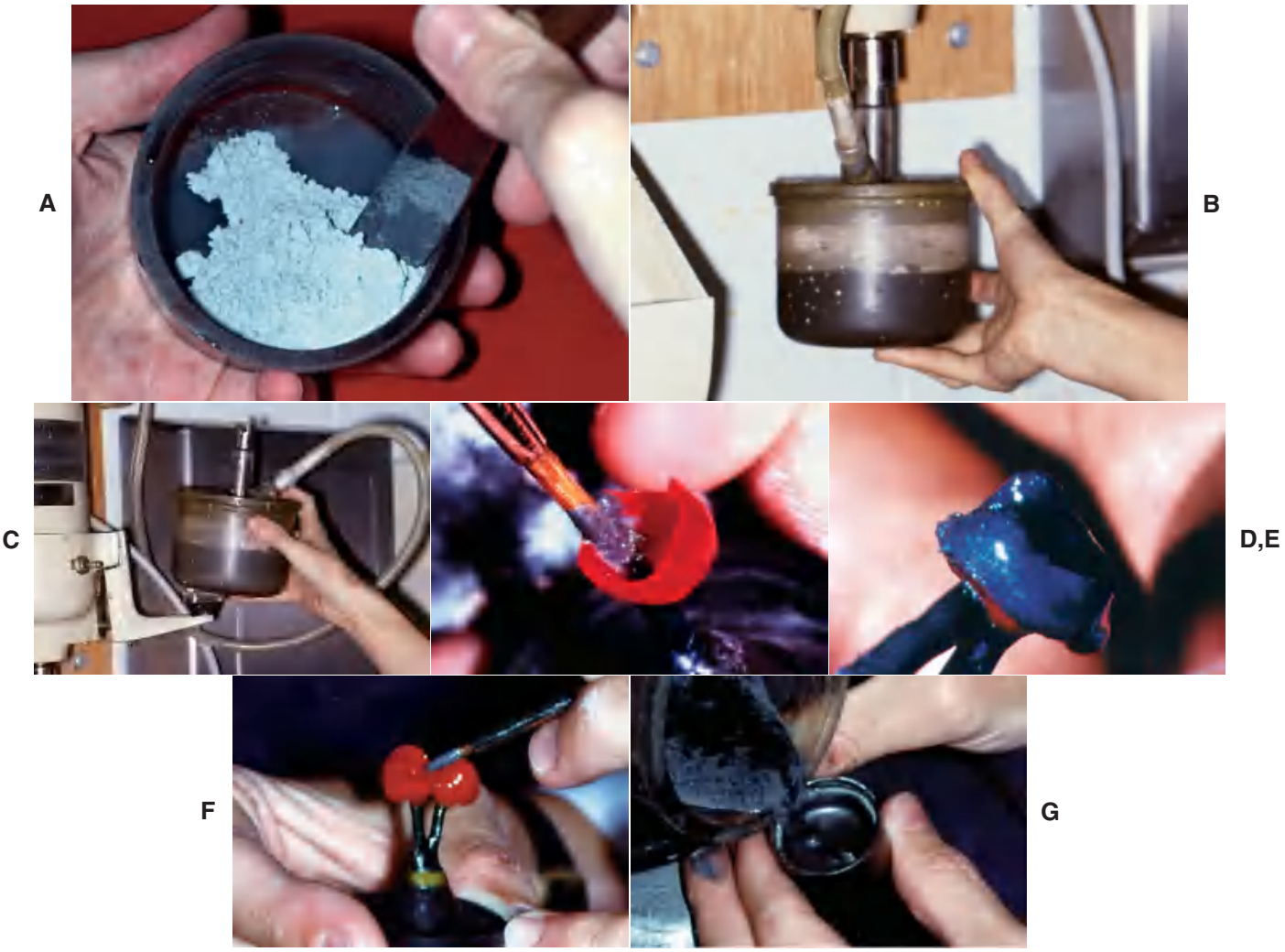


Fig. 22-18

Investing procedure: brush technique. **A,** The mix is hand-spatulated to incorporate powder quickly. **B,** The investment is vacuum-mixed according to manufacturer's recommendations. **C,** The mix is vibrated for a few seconds. **D.** The wax pattern is carefully coated, the investment teased ahead of the brush. **E,** Be sure that all surfaces of the pattern are covered. **F,** Note the finger that is interposed between the crucible former and the top of the vibrator as these patterns are being brush invested. **G,** The ring is slowly filled, with the bowl held on the vibrator to facilitate investment flow. The ring is tilted from side to side to avoid trapping air under the pattern.

which helps maintain the correct liquid/powder ratio, crucial for accurate control of expansion.

2. Attach the vacuum hose to the bowl, evacuate the bowl, and mechanically spatulate (Fig. 22-18*B*). The mixing should be carefully timed in accordance with the manufacturer's instructions and the type of mixing bowl used (high speed versus low speed). If phosphate-bonded investments are used, additional vibration under vacuum helps minimize nodules (Fig. 22-18*C*).
3. Coat the entire pattern with investment, pushing the material ahead of the brush from a single point (Fig. 22-18*D*). Gently vibrate throughout the application of investment, being especially careful to coat the internal surface and the margin of the pattern (Fig. 22-18*E*).

A finger positioned under the crucible former on the table of the vibrator minimizes the risk of excessive vibration and possible breaking of the pattern from the sprue (Fig. 22-18*F*). After the pattern has been completely coated, the ring is immediately filled by vibrating the remaining investment out of the bowl.

4. Place the lined casting ring over the pattern and, with the aid of vibration, pour the investment

down the side of the ring. Fill the ring slowly, starting from the bottom and moving up (Fig. 22-18*G*).
5. When the investment reaches the level of the pattern, tilt the ring several times to cover and uncover the pattern, thereby minimizing the possible entrapment of air. Investing must be performed quickly within the working time of the investment. If the investment begins to set too soon, rinse it off quickly with cold water. The wax pattern can then be replaced on the die, and its margins can be reflowed again.
6. After the ring is filled to the rim, allow the investment to set.
7. If the hygroscopic technique is used, place the ring in a 37°C (100°F) water bath for 1 hour.

Vacuum Technique

1. First, hand-spatulate the mix (Fig. 22-19*A*).
2. With the crucible former and pattern in place, attach the ring to the mixing bowl (Fig. 22-19*B*).
3. Attach the vacuum hose and mix according to the manufacturer's recommendations (Fig. 22-19*C* and *D*).
4. Invert the bowl and fill the ring under vibration (Fig. 22-19*E*).
5. Remove the vacuum hose before shutting off the mixer (Fig. 22-19*F*).
6. Remove the filled ring and crucible former from the bowl (Fig. 22-19*G*).
7. Immediately clean the bowl and mixing blade under running water (Fig. 22-19*H*).

Wax Elimination

Wax elimination or burnout consists of heating the investment in a thermostatically controlled furnace (Fig. 22-20) until all traces of the wax are vaporized. The temperature reached by the investment determines its thermal expansion.

All water in the investment must be driven off during wax elimination. The temperature to which the ring is heated during wax elimination must be sufficiently high. It should be maintained long enough ("heat soak") to minimize a sudden drop in temperature upon removal from the furnace. Such a drop may result in an incomplete casting because of excessively rapid solidification of the alloy as it enters the mold. Once the investment is heated during the wax-elimination procedure, heating must be continued, and casting must be completed. Cooling and reheating of the investment can cause casting inaccuracy because the refractory mold and binder do not revert to their original forms (hysteresis). Inadequate expansion and cracking of the investment are typical results.

Step-by-Step Procedure

1. Allow the investment to set for the recommended time (usually 1 hour), and then remove the rubber crucible former (Fig. 22-21). If a metal sprue is used, remove it as well. The ring should be placed in a humidor if stored overnight. The smooth "skin" that forms on the ring with phosphate-bonded investments should be removed, and any loose particles of investment should be blown off with compressed air.
2. Reexamine the ring for any residual particles and then place it with the sprue facing down in the furnace on a ribbed tray. The tray allows the molten wax to flow out freely.
3. Bring the furnace to 200°C (400°F), and hold this temperature for 30 minutes. Most of the wax is by then eliminated.
4. Increase the heat to the final burnout temperature (generally 650°C [1200°F] or 480°C [900°F] if a hygroscopic technique is used; follow the manufacturer's instructions), and hold that temperature for 45 minutes. Because the heating rate affects expansion,[32] it also should be standardized as part of the investing and casting protocol in order to routinely obtain accurately fitting castings. The mold is now ready for casting, although a large casting ring requires increased heating time. If preferred, two burnout furnaces can be set at 200°C and 650°C or 480°C, or a programmable two-stage furnace can serve equally well. However, the investment should not be overheated or kept at temperature too long. Gypsum-bonded investments are not stable above 650°C. Also, some carbon in carbon-containing investments burns off, which causes increased surface roughness of the casting.[22]

When the casting ring is transferred to the casting machine, a quick visual check of the sprue in shaded light is helpful to see whether it is properly heated. It should be a cherry-red color.

ACCELERATED CASTING METHOD

Conventional casting techniques require considerable time, typically 1 hour for bench set (generally judged as the time taken for the investment to reach its maximum exothermic setting reaction temperature) for the investment and 1 to 2 hours for the wax elimination. An accelerated casting procedure that

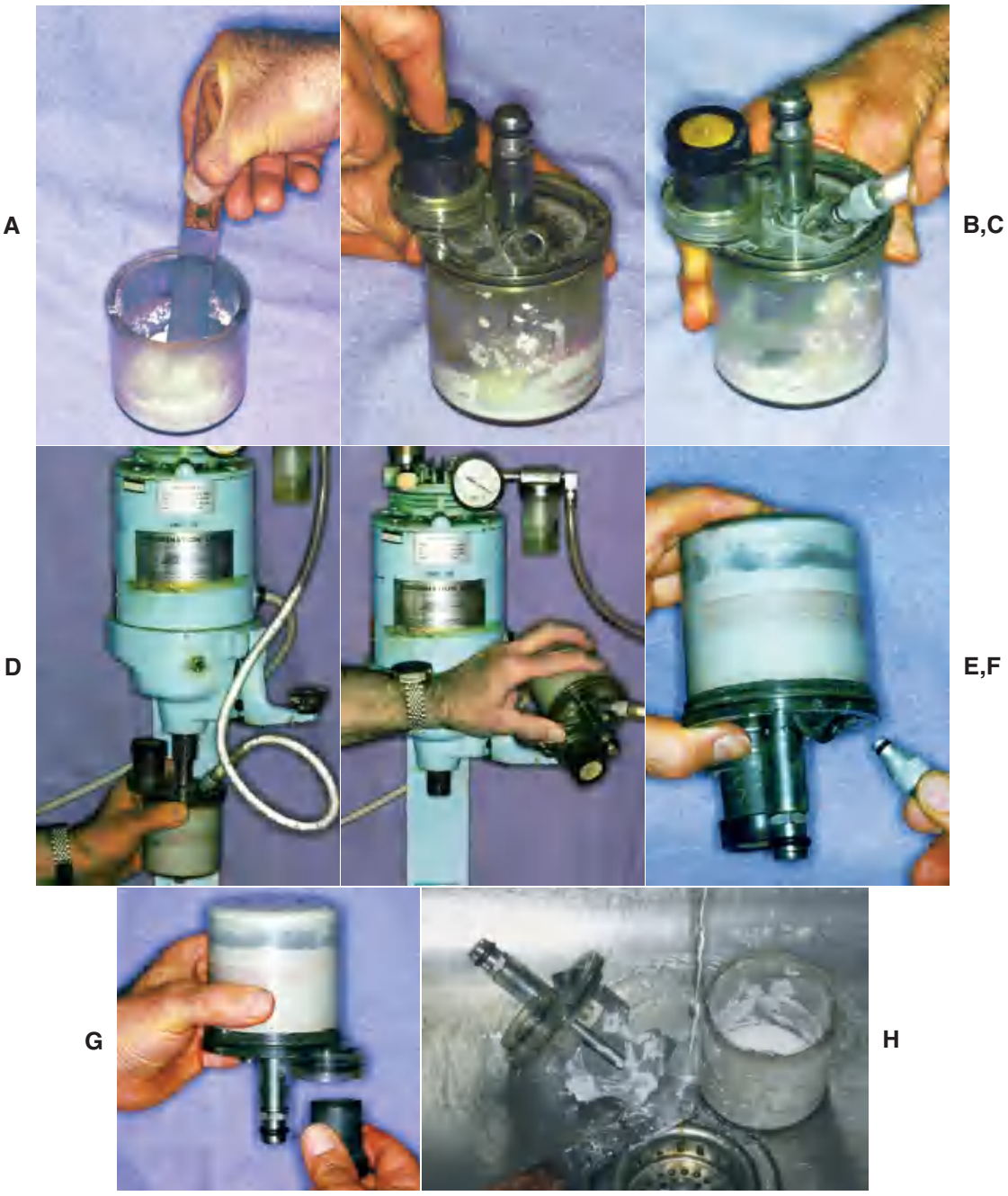


Fig. 22-19

Investing procedure: vacuum technique. **A,** The mix is hand-spatulated. **B,** With the crucible former in place, the ring is attached to the mixing bowl. **C,** The vacuum hose is attached. **D,** Mixing is performed according to manufacturer's recommendations. **E,** The bowl is inverted, and the ring is filled under vibration. **F,** The vacuum hose is removed before the mixer is shut off. **G,** The filled ring and crucible former are removed from the bowl. **H,** The bowl and mixing blade are cleaned immediately under running water.



Fig. 22-20

Burnout ovens are available with manual, semiautomatic, or fully programmable controls. A, Whip Mix Apollo II; B, Ney Vulcan. *(A, Courtesy of Whip Mix Corporation, Louisville, Kentucky; B, courtesy of DENTSPLY Ceramco, York, Pennsylvania.)*

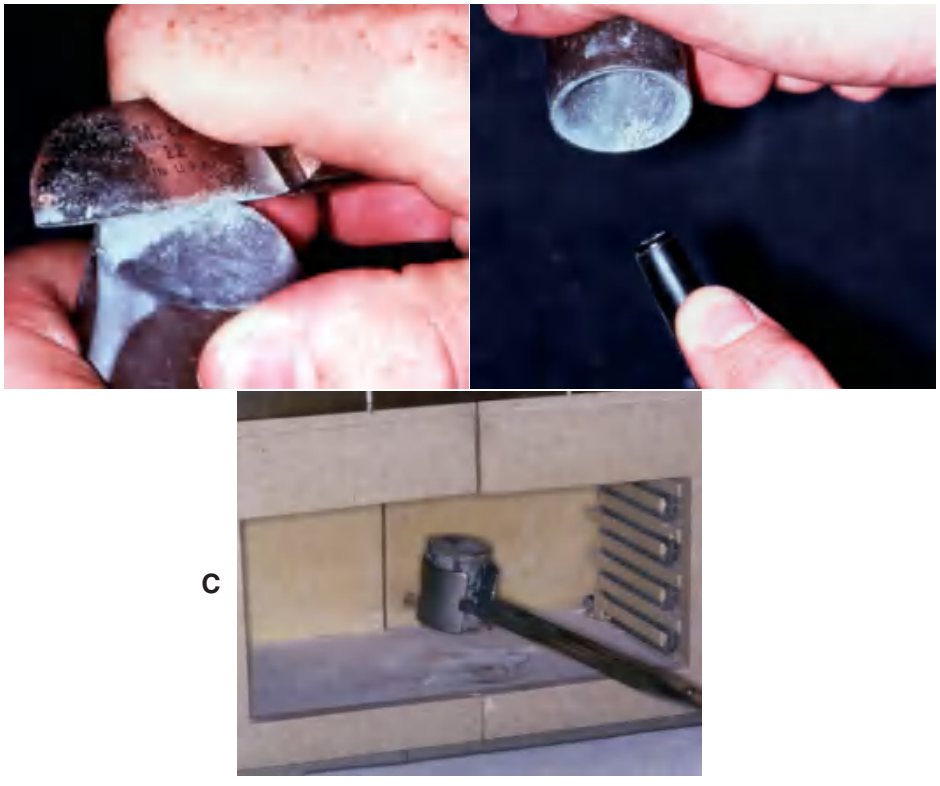


Fig. 22-21

A, When the investment has set, the "skin" at the top of the ring is trimmed off. B, The rubber crucible former is removed, and any loose particles of investment are blown off. C, The ring is then placed in the furnace for the recommended burnout schedule.



Fig. 22-22
Casting machines. A, Kerr Broken-Arm. B, Degussa Model TS-1. *(**A,** Courtesy of Kerr Corporation, Orange, California; **B,** courtesy of DENTSPLY Ceramco, York, Pennsylvania.)*

reduces this time to 30 to 40 minutes has been proposed.[33–35] Initially suggested as a way to make cast post-and-core restorations in a one-visit procedure,* the procedure has been found to produce castings with accuracy and surface roughness similar to those produced by traditional methods.[36,37] The technique entails the use of a phosphate-bonded investment that is given approximately 15 minutes for bench set and a 15-minute wax elimination by placing the ring in a furnace preheated to 815°C (1500°F).

CASTING

Casting Machines

A casting machine (Fig. 22-22) requires a heat source to melt the alloy and a casting force. For a complete casting, the casting force must be high enough to overcome the high surface tension of the molten alloy,[38] as well as the resistance of the gas within the mold.

The heat source can be either the reducing flame of a torch or electricity. Conventional alloys can be melted with a gas-air torch (Fig. 22-23*A* and *B*), but for the metal-ceramic alloys in a higher melting range, a gas-oxygen torch (Fig. 22-23*C*) is needed. For base metal alloys, a multiorifice gas-oxygen torch (Fig. 22-23*D*) or oxyacetylene torch is needed. Electric heating can occur by convection from a heating muffle or by generation of an induction current in the alloy. Advocates of the latter[39] maintain that heating can be more evenly controlled, which prevents undesirable changes in alloy composition caused by volatilization of the elements with lower melting points. In general, the electric machines are expensive and more appropriate for larger dental laboratories, whereas a torch may be the method of choice for smaller laboratories and dental offices.

In present-day casting machines, either air pressure or centrifugal force is still used to fill the mold; both were first proposed in the early days of lost-wax castings.[2,40] Some machines evacuate the mold before it is filled with metal, and vacuum has been shown to improve mold filling,[41] although it is not clear whether the difference is clinically significant.[42]

Casting Technique

The ring is not removed from the burnout furnace until the alloy has been melted and is ready to cast.

Cleaning a previously cast alloy is necessary to remove investment debris and oxides before its reuse. Noble metal alloys can be melted on a charcoal block with a gas-air torch, which provides a reducing atmosphere. Remaining impurities are removed through pickling and ultrasonic or steam cleaning. Alloys from different manufacturers should not be mixed, even if they are similar.

Similarly, a dedicated crucible should be used for each alloy. Overheated or otherwise abused alloys, as well as grindings and old restorations, should be returned to the manufacturer as scrap materials, rather than being reused.

Armamentarium (Fig. 22-24)

- Broken-arm (Kerr) centrifugal casting machine
- Crucible
- Blowtorch

*Also for castings made for dental licensure examinations.



Fig. 22-23
A, Gas-air casting torch. **B,** Gas-air tip. **C,** Gas-oxygen casting torch. **D,** Multiorifice tip.



Fig. 22-24
Casting armamentarium.

- Protective colored goggles
- Tongs
- Casting alloy
- **Flux**

Procedure

The casting machine is given three clockwise turns (four if metal-ceramic alloys are used) and locked in position with the pin. The cradle and counterbalance weights are checked for the appropriate size of the casting ring. A crucible for the alloy being cast is placed in the machine. The torch (gas-air for regular alloys, gas-oxygen for metal-ceramic) is lit and adjusted. For metal-ceramic alloys, the clinician should wear a pair of colored goggles to protect the eyes and also to enable direct viewing of the melt.

The crucible is preheated (Fig. 22-25*A*), particularly over the trajectory that will be in contact with the alloy, and the alloy is added. Preheating avoids excessive slag formation during casting. Also, when metal-ceramic alloys are cast, a crucible that is too cool can "freeze" the alloy, resulting in an incomplete casting. Sufficient mass of alloy must be present to sustain adequate casting pressure. With a high-density noble metal alloy, 6 g (4 dwt*) is typically adequate for premolar and anterior castings, 9 g (6 dwt) is adequate for molar castings, and 12 g (8 dwt) is adequate for pontics.

The alloy is heated in the reducing part of the flame until it is ready to cast. A little flux can be added to conventional gold alloys (not metal-ceramic alloys). Gold alloys ball up and have a mirror-like shiny surface that appears to be spinning. Nickel-chromium and cobalt alloys are ready to cast when the sharp edges of the ingot round over. The mold is placed in the cradle of the casting machine (Fig. 22-25*B*) and kept on the alloy with the reduc-

*Pennyweight (*d* is an abbreviation for *denarius*, a Roman silver coin).

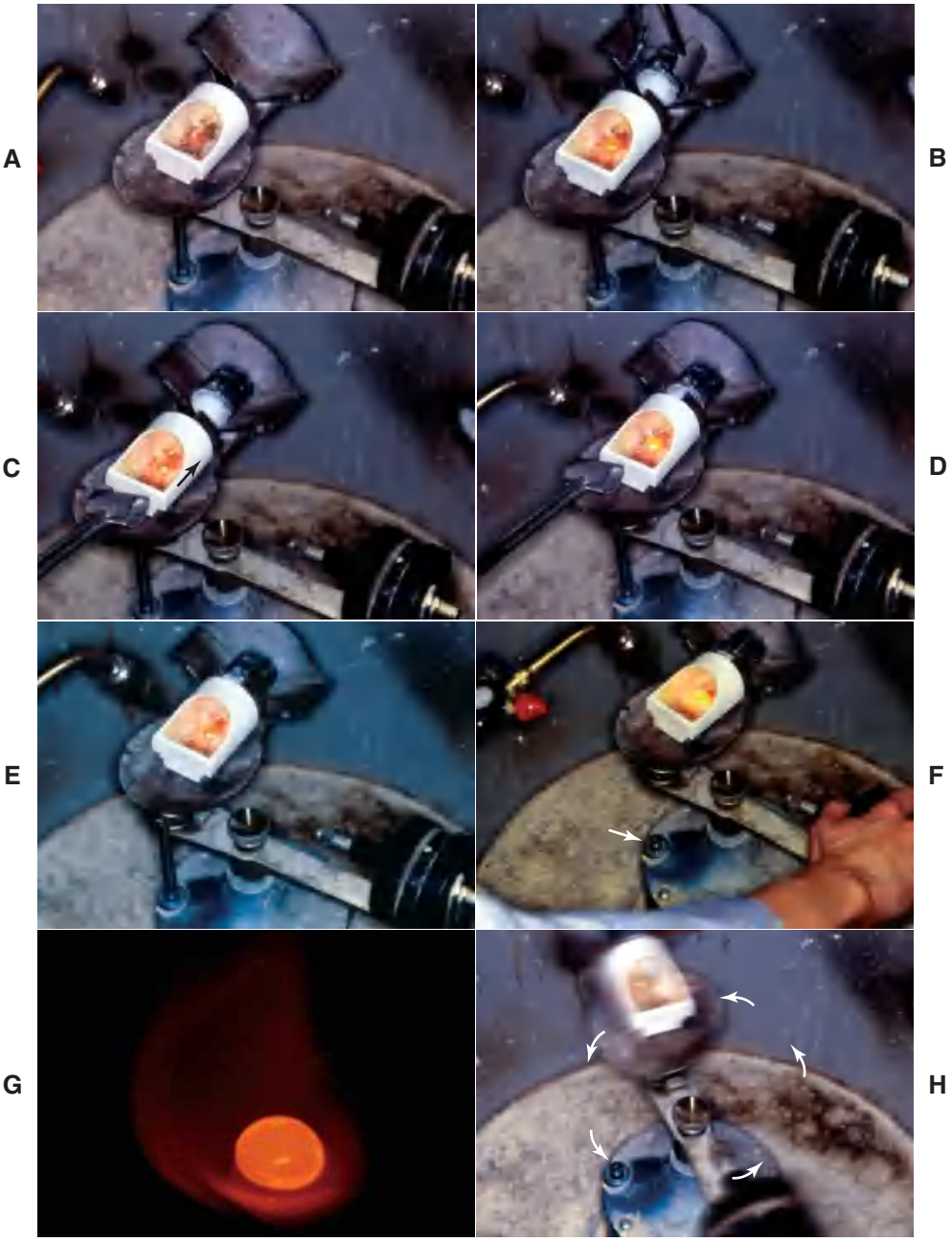


Fig. 22-25
Casting technique. **A,** Preheating the crucible. **B,** Making the melt. When the alloy is molten, the casting ring is removed from the furnace and placed in the cradle. **C,** Tongs are used to slide the crucible platform into contact with the casting ring (*arrow*). **D,** The orifice of the crucible aligns with the sprue. **E,** Heating continues for a few seconds so that the melting is complete and casting can proceed. **F,** The casting arm is pulled forward until the pin drops (*arrow*). **G,** The melt, seconds before casting. **H,** Centrifugal force carries the melt into the mold cavity (arrows show the direction of spin).

ing flame until the crucible is moved into position (Fig. 22-25*C* to *G*). The casting machine arm is then released to make the casting (Fig. 22-25*H*). The machine is allowed to spin until it has slowed enough that it can be stopped by hand, and the ring is removed with casting tongs.

Recovery of the casting

After the red glow has disappeared from the button, the casting ring is plunged under running cold water into a large rubber mixing bowl (Fig. 22-26).

Gypsum-bonded investments quickly disintegrate, and elimination of residue is easily accom-

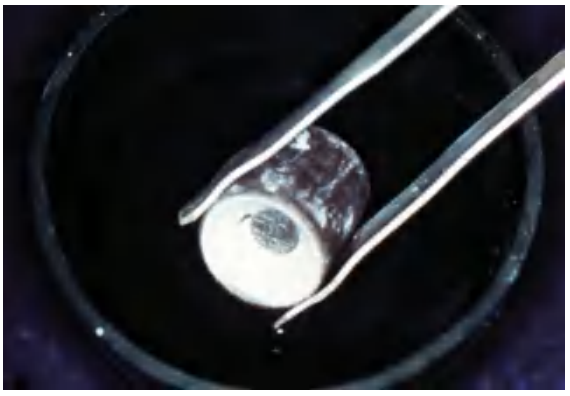


Fig. 22-26
The ring is quenched in cold water in a plaster bowl. Gypsum-bonded investments readily disintegrate; phosphate-bonded investments are much stronger and need careful devestment.



Fig. 22-27
Nonfuming pickling acid can be used in conjunction with this covered pickling unit.



Fig. 22-28
Recovery of a casting from phosphate-bonded investment. **A,** Trimming is done from the button end of the ring. **B,** Investment is being pushed out of the casting ring. **C,** The mold is broken open. **D,** Investment is removed from the casting. Care must be taken to avoid damaging the margin.

plished with a toothbrush. Final traces can be removed ultrasonically. Oxides are removed by pickling in 50% hydrochloric acid (or, preferably, a nonfuming substitute) (Fig. 22-27). Phosphate-bonded investments do not disintegrate equally well, and some must be forcibly removed from the casting ring. They can be handled as soon as they have been sufficiently cooled under running water.

A knife is used to trim the investment at the button end of the ring (Fig. 22-28*A*). The other end is not trimmed because of the risk of damaging the margin. When the ring liner is exposed, the investment can be pushed out of the ring (Fig. 22-28*B*). It is then broken apart under running water (because it is still hot [Fig. 22-28C]). The remaining investment is carefully removed with a small blunt instrument (Fig. 22-28*D*), and any traces are dissolved in hydrofluoric acid or a less caustic substitute. Care must be taken to prevent scratching of the internal surface of the casting or damage to the margins.

Evaluation

The casting is never fitted on the die until the inner surface has been carefully evaluated under magnification; even tiny imperfections can cause damage to the stone die. *A die may be rendered useless in a matter of seconds if a casting is fitted prematurely.*

Defects in the casting

Investing and casting requires meticulous attention to detail to obtain a successful, properly fitting casting. Table 22-1 summarizes and provides examples of the more common causes of various problems.

Roughness

The surface of a casting should be smooth, although finishing and **polishing** are still required (see Chapter 29). Lines or grooves in the casting are usually present but overlooked in the wax pattern. They may necessitate a remake, particularly if they were positioned near the margin or on the fitting surface. Generalized casting roughness may indicate a breakdown of the investment from excessive burnout temperature.

Nodules

Bubbles of gas trapped between the wax pattern and the investment produce nodules on the casting surface. Even minute nodules can limit the seating of the casting to a considerable degree. When they are large or situated on a margin, they usually necessitate remaking of the restoration. When small, they can often be removed with a No. ¼ or No. ½ round bur (Fig. 22-29). A binocular microscope is extremely helpful for detecting and removing nodules. A slight excess of metal should be removed to ensure that the nodule does not interfere with complete seating.

Keys to avoiding nodules include a careful investing technique, use of a surfactant, vacuum spatulation, and careful coating of the wax pattern with investment. Castings made with phosphate-bonded investment are especially prone to imperfections, and experience and care are necessary to produce castings that are routinely free of nodules.

Fins

Fins are caused by cracks in the investment that have been filled with molten metal. These cracks can result from a weak mix of investment (high water/powder ratio), excessive casting force, steam generated from too-rapid heating, reheating an invested pattern, an improperly situated pattern (too close to the periphery of the casting ring), or even premature or rough handling of the ring after investing.

Incompleteness

If an area of wax is too thin (less than 0.3 mm), which occurs occasionally on the veneering surface of a metal-ceramic restoration, an incomplete casting may result. Thickening of the wax in these areas is recommended. Incomplete casting of normal-thickness wax patterns may result from inadequate heating of the metal, incomplete wax elimination, excessive cooling ("freezing") of the mold, insufficient casting force, not enough metal, or metal spillage.

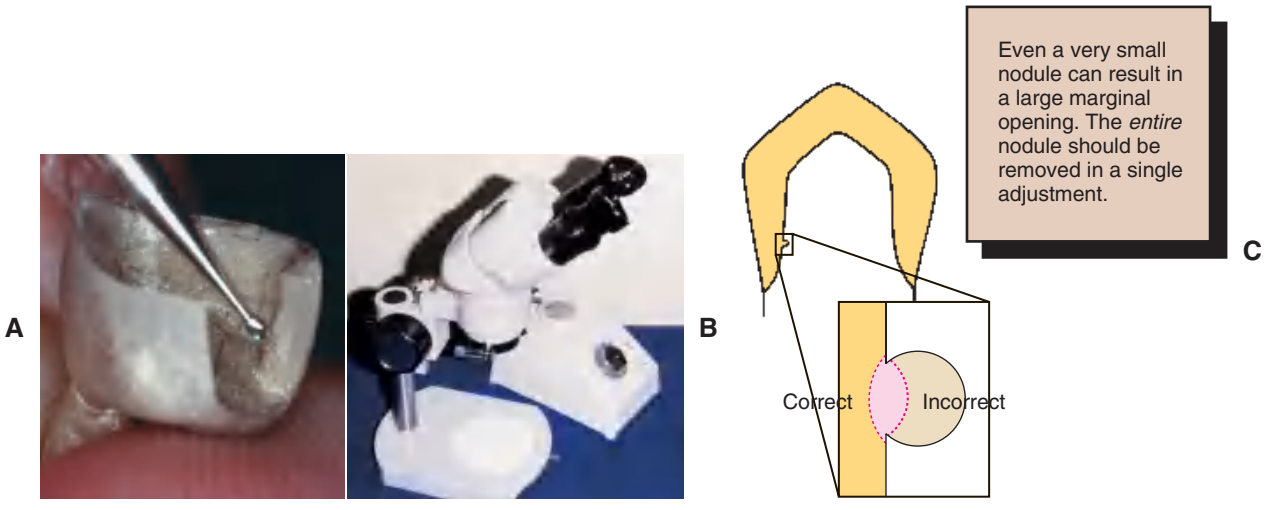


Fig. 22-29

Removing casting nodules. Small nodules are frequently present, particularly with phosphate-bonded investments. They interfere with seating and must be identified before the casting is placed on the die. **A,** Once they are identified, a small round bur can be used to remove them. **B,** Magnification is helpful for this. **C,** Remove slightly more, rather than less, metal than the size of the nodule to ensure the casting does not bind during seating.

Table **22-1 COMMON CAUSES OF CASTING FAILURE**

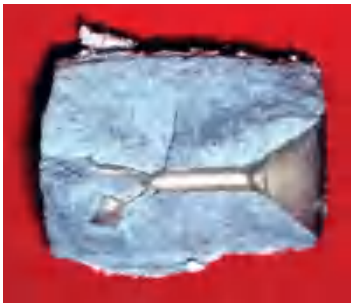
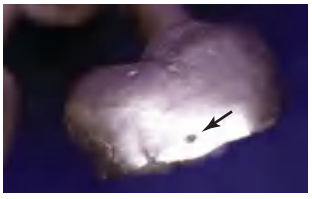
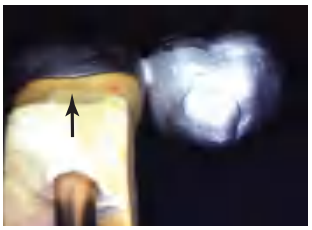
Problem	Possible causes	Appearance
Rough casting	Excess surfactant Improper water/powder ratio Excessive burnout temperature	
Large nodule	Air trapped during investing procedure	
Multiple nodules	Inadequate vacuum during investing Improper brush technique Lack of surfactant	
Nodules on occlusal surface	Excessive vibration	
Fins	Increased water/powder ratio Pattern too near edge of investment Premature heating (mold still wet) Too-rapid heating Dropped mold	
Incomplete casting	Wax pattern too thin Cool mold or melt Inadequate metal	

Table **22-1—cont'd**

Problem	Possible causes	Appearance
Incomplete casting with shiny, rounded defect	Incomplete wax elimination	
"Suck-back" porosity	Improper pattern position Narrow, long sprue	
Inclusion porosity	Particle of investment dislodged during casting	
Marginal discrepancy	Wax pattern distortion Uneven expansion	
Inadequate or excessive expansion	Improper water/powder ratio Improper mixing time Improper burnout temperature	

Voids or porosity

Voids in the casting (in particular in the margin area) may be caused by debris trapped in the mold (usually a particle of the investment undetected before wax elimination). A well-waxed smooth sprue helps prevent this. Porosity resulting from solidification shrinkage ("suck-back") occurs if the metal in the sprue solidifies before the metal in the mold, as may happen when a sprue is too narrow, too long, or incorrectly located or when a large casting is made in the absence of a chill vent. Gases may dissolve in the molten alloy during melting and leave porosity.

Back pressure porosity[43] may be caused by air pressure in the mold as the molten metal enters. Its occurrence is reduced by using a more porous investment, locating the pattern near the end of the ring (6 to 8 mm), and casting with a vacuum technique.

Marginal discrepancies

Inaccuracies of fit at the margin can be caused by distortion during removal of the wax pattern from the die. They may also result from increased setting expansion (hygroscopic technique) after uneven expansion of the mold.

Dimensional inaccuracies

The casting can be either too small or too large. Attention to detail is essential for an accurately expanded mold. A standardized procedure is needed in regard to liquid/powder ratio, spatulation, the ring liner, the amount of liquid added, and mold heating.

REVIEW OF TECHNIQUE

The following list summarizes the steps involved in investing and casting (Fig. 22-30) and should prove helpful in reviewing the material covered in this chapter:

1. A sprue 2 or 2.5 mm in diameter (10- or 12-gauge) is attached to the bulkiest nonfunctional cusp (the larger size for molar and metal-ceramic patterns, the smaller size for premolar and partial coverage). Multiple units can be sprued with a runner bar (see Fig. 22-30*A*).
2. The pattern is carefully removed from the die and attached to a crucible former (sprue length should be 6 mm or less) (see Fig. 22-30*B*).
3. The pattern is painted with surface tension reducer (see Fig. 22-30*C*) and then carefully coated with vacuum-mixed investment (see Fig. 22-30*D*).
4. The ring is filled, and the investment is allowed to bench set for a minimum of 1 hour.
5. After wax elimination, the casting machine is prepared, and the crucible is preheated. The alloy is melted, the ring is transferred, and the casting is made promptly (see Fig. 22-30*E*).
6. The casting is recovered from the investment (see Fig. 22-30*F*).
7. Defects are identified and corrected if possible (see Fig. 22-30*G*).

SUMMARY

Investing and casting, a series of highly technique-sensitive steps, converts the wax pattern into a metal casting. Accurate and smooth restorations can be obtained if the operator pays special attention to each step in the technique. When initial attempts at casting produce errors or defects, appropriate corrective measures must be taken so that they do not recur.



Fig. 22-30

Technique review. **A,** A sprue 2 or 2.5 mm in diameter (10- or 12-gauge) is attached to the bulkiest nonfunctional cusp; multiple units can be sprued with a runner bar. **B,** The pattern is carefully removed from the die and attached to a crucible former. **C,** The pattern is painted with surface tension reducer. **D,** The pattern is then carefully coated with vacuum-mixed investment. **E,** After wax elimination, the casting machine is prepared, and the crucible is preheated. The alloy is melted, the ring is transferred, and the casting is made promptly. **F,** The casting is recovered from the investment. **G,** Defects (arrow) are identified and corrected if possible.

STUDY QUESTIONS

1. Discuss in detail the requirements of a sprue and the factors and special considerations involved in selecting the sprue position.
2. Discuss gypsum-bonded and phosphate-bonded investments, and explain the various ways that investment expansion can be influenced, including pertinent materials science considerations.
3. What is the difference between gypsum- and phosphate-bonded investments?
4. What determines investment selection? What are the ideal properties of an investment material?
5. What factors can result in rough castings, nodules on castings, finning of a casting, or incomplete castings?
6. Identify the various types of casting porosity. What are the causes for each?

GLOSSARY*

al·loy \ăl′oi′, a-loi′\ *n* (14c)**:** a mixture of two or more metals or metalloids that are mutually soluble in the molten state; distinguished as binary, ternary, quaternary, etc., depending on the number of metals within the mixture. Alloying elements are added to alter the hardness, strength, and toughness of a metallic element, thus obtaining properties not found in the pure metal. Alloys may also be classified on the basis of their behavior when solidified—*usage*: see BASE METAL, NOBLE METAL

alloying element \a-loi′ĭng ĕl′a-ment\ (1998)**:** metallic or non-metallic elements added to or retained by a pure metal for the purpose of giving that metal special properties

an·neal \a-nēl′\ *vt* (1580) **1:** to heat a material, such as metal or glass, followed by controlled cooling to remove internal stresses and create a desired degree of toughness, temper, or softness to a material **2:** to heat a material, such as gold foil, to volatilize and drive off impurities from its surface, thus increasing its cohesive properties. This process is termed *degassing* **3:** to homogenize an amalgam alloy by heating in an oven

back pressure porosity \băk prĕsh′er pa-rŏs′ĭ-tē**:** porosity produced in dental castings thought to be due to the inability of gases in the mold to escape during the casting procedure

base metal \bās mĕt′l**:** any metallic element that does not resist tarnish and corrosion—see NOBLE METAL

car·at \kăr′at\ *n* (15c): a standard of gold fineness. The percentage of gold in an alloy, stated in parts per 24. Pure gold is designated 24 carat

[1]cast \kăst\ *vb* (13c)**:** to produce a shape by thrusting a molten liquid or plastic material into a mold possessing the desired shape

[1]cast·ing \kăs′tĭng\ *n* (14c)**:** something that has been cast in a mold; an object formed by the solidification of a fluid that has been poured or injected into a mold

casting ring \kăs′tĭng rĭng**:** a metal tube in which a refractory mold is made for casting dental restorations

compressive stress \kŏm-prĕs′ĭv strĕs**:** the internal induced force that opposes the shortening of a material in a direction parallel to the direction of the stresses; any induced force per unit area that resists deformation caused by a load that tends to compress or shorten a body

crist·o·bal·ite \krĭs′tō-bă′līt\ *n***:** an allotropic form of crystalline silica used in dental casting investments

cru·ci·ble \krōō′sa-bal\ *n* (15c)**:** a vessel or container made of any refractory material (frequently porcelain) used for melting or calcining any substance that requires a high degree of heat

crucible former \krōō′sa-bal fôr′mer**:** the base to which a sprue former is attached while the wax pattern is being invested in refractory investment; a convex rubber, plastic, or metal base that forms a concave depression or crucible in the refractory investment

dental casting investment \dĕn′tl kăs′tĭng ĭn-vĕst′ment**:** a material consisting principally of an allotrope of silica and a bonding agent. The bonding substance may be gypsum (for use in lower casting temperatures) or phosphates and silica (for use in higher casting temperatures)

de·vest \dĭ-vĕst\ *vb***:** the retrieval of a casting or prosthesis from an investing medium

dwt: *abbr* [*denarius* + *weight*] pennyweight; called also *pennyweight;* a measurement of weight in the troy system equal to 24 grains, or 0.05 ounce. Its metric equivalent is 1.555 grams

flux \flŭks\ *n* (14c) **1:** in physics, the rate of flow of a liquid, particles or energy **2:** in ceramics, an agent that lowers the fusion temperature of porcelain **3:** in metallurgy, a substance used to increase fluidity and to prevent or

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reduce oxidation of a molten metal **4:** any substance applied to surfaces to be joined by brazing, soldering or welding to clean and free them from oxides and promote union

gyp·sum \jĭp′sum\ *n* (14c)**:** the natural hydrated form of calcium sulfonate, $CaSO_4$ $2H_2O$ gypsum dihydrate

hygroscopic expansion \hī′gra-skŏp′ĭk ĭk-spăn′shun**:** expansion due to the absorption of moisture

in·vest·ing \ĭn-vĕs′tĭng\ *v***:** the process of covering or enveloping, wholly or in part, an object such as a denture, tooth, wax form, crown, etc. with a suitable investment material before processing, soldering, or casting

in·vest·ment *n***:** see DENTAL CASTING I., REFRACTORY I.

investment cast \ĭn-vĕst′ment kăst**:** a cast made of a material that will withstand high temperature without disintegration–*comp* REFRACTORY CAST

[1]met·al \mĕt′l\ *n* (13c)**:** any strong and relatively ductile substance that provides electropositive ions to a corrosive environment and that can be polished to a high luster. Characterized by metallic atomic bonding

muf·fle \mŭf′al\ *n***:** the portion of a furnace, usually removable or replaceable, in which material may be placed for processing without direct exposure to heating element

noble metal \nō′bal mĕt′l\: those metal elements that resist oxidation, tarnish, and corrosion during heating, casting, or soldering and when used intraorally; examples include gold and platinum–*comp* BASE METAL

occluded gas porosity \a-klōō′dĭd găs pa-rŏs′ĭ-tē**:** a porosity produced in castings due to the inability of gasses in the mold to escape

[1]pick·le \pĭk′al\ *n* (15c)**:** a solution or bath for preserving or cleaning; any of various baths used in cleaning or processing

[2]pick·le \pĭk′al\ *vt* **pick·led** \pĭk′ald\ **pick·ling** \pĭk′lĭng\ (1552)**:** to treat, preserve, or clean in or with an agent

[1]pol·ish \pŏl′ĭsh\ *vb* (14c)**:** to make smooth and glossy, usually by friction; giving luster; the act or process of making a denture or casting smooth and glossy

[2]pol·ish \pŏl′ĭsh\ *n* (1704)**:** a smooth, glossy surface; having luster

pol·ish·ing \pŏl′ĭsh-ĭng\ *v, obs* **1:** to make smooth and glossy, usually by friction; to give luster to (GPT-1) **2:** *obs:* the act or process of making a denture or casting smooth and glossy (GPT-1)

po·ros·i·ty \pa-rŏs′ĭ-tē, pô-\ *n, pl* **-ties** (14c) **1:** the presence of voids or pores within a structure **2:** the state or quality of having minute pores, openings or interstices–see BACK PRESSURE P., OCCLUDED GAS P., SHRINK-SPOT P., SOLIDIFICATION P.

proportional limit \pra-pôr′sha-nal lĭm′ĭt**:** that unit of stresses beyond which deformation is no longer proportional to the applied load

quartz \kwôrts\ *n* (ca. 1631)**:** an allotropic form of silica; the mineral SiO_2 consisting of hexagonal crystals of colorless, transparent silicon dioxide

re·frac·tory \rĭ-frăk′ta-rē\ *adj* (1606)**:** difficult to fuse or corrode; capable of enduring high temperatures

refractory investment \rĭ-frăk′ta-rē ĭn-vĕst′mant**:** an investment material that can withstand the high temperatures used in soldering or casting

refractory mold \rĭ-frăk′ta-rē mōld**:** a refractory cavity into which a substance is shaped or cast

setting expansion \sĕt′tĭng ĭk-spăn′shun**:** the dimensional increase that occurs concurrent with the hardening of various materials, such as plaster of paris, dental stone, die stone, and dental casting investment

shrink-spot porosity \shrĭngk-spŏt pa-rŏs′ĭ-tē**:** an area of porosity in cast metal that is caused by shrinkage of a portion of the metal as it solidifies from the molten state without flow of additional molten metal from surrounding areas

si·li·ca \sĭl′ĭ-ka\ *n* (ca 1301)**:** silicon dioxide occurring in crystalline, amorphous, and usually impure forms (as quartz, opal, and sand, respectively)

solidification porosity \sa-lĭd′a-fĭ-kā′shun pa-rŏs′ĭ-tē**:** a porosity that may be produced by improper spruing or improper heating of either the metal or the investment

sprue \sprōō\ *n* (1880) **1:** the channel or hole through which plastic or metal is poured or cast into a gate or reservoir and then into a mold **2:** the cast metal or plastic that connects a casting to the residual sprue button

sprue button \sprōō bŭt′n**:** the material remaining in the reservoir of the mold after a dental casting

sprue former \sprōō fôr′mar**:** a wax, plastic, or metal pattern used to form the channel or channels allowing molten metal to flow into a mold to make a casting

thermal expansion \thûr′mal ĭk-spăn′shun**:** expansion of a material caused by heat

vacuum casting \văk′yōō-um kăst′ĭng**:** the casting of a material (i.e., metal, plastic) in the presence of a partial vacuum

vacuum investing \văk′yōō-um ĭn-vĕst′ĭng**:** the process of investing a pattern within a partial vacuum

vacuum mixing \văk′yōō-um mĭks′ĭng**:** a method of mixing a material such as plaster of paris or casting investment below atmospheric pressure

wax elimination \wăks ĭ-lĭm′a-nā′shun\: the removal of wax from a mold, usually by heat

wax expansion \wăks ĭk-spăn′shun\: a method of expanding a wax pattern to compensate for the shrinkage of gold during the casting process

wax pattern \wăks păt′urn\: a wax form that is the positive likeness of an object to be fabricated

REFERENCES

1. Philbrook D: Cast fillings. Iowa State Dent Soc Trans 277, 1897.
2. Taggart WH: A new and accurate method of making gold inlays. Dent Cosmos 49:1117, 1907.
3. Anusavice KJ: Phillips' Science of Dental Materials, 10th ed. Philadelphia, WB Saunders, 1996.
4. Ryge G, et al: Porosities in dental gold castings. J Am Dent Assoc 54:746, 1957.
5. Johnson A, Winstanley RB: The evaluation of factors affecting the castability of metal ceramic alloy–investment combinations. Int J Prosthodont 9:74, 1996.
6. Mahler DB, Ady AB: The influence of various factors on the effective setting expansion of casting investments. J Prosthet Dent 13:365, 1963.
7. Takahashi J, et al: Nonuniform vertical and horizontal setting expansion of a phosphate-bonded investment. J Prosthet Dent 81:386, 1999.
8. Verrett RG, Duke ES: The effect of sprue attachment design on castability and porosity. J Prosthet Dent 61:418, 1989.
9. Strickland WD, Sturdevant CM: Porosity in the full cast crown. J Am Dent Assoc 58:69, 1959.
10. Rawson RD, et al: Photographic study of gold flow. J Dent Res 51:1331, 1972.
11. Earnshaw R: The effect of casting ring liners on the potential expansion of a gypsum-bonded investment. J Dent Res 67:1366, 1988.
12. Davis DR: Effect of wet and dry cellulose ring liners on setting expansion and compressive strength of a gypsum-bonded investment. J Prosthet Dent 76:519, 1996.
13. Engelman MA, et al: Oval ringless casting: simplicity, productivity, and accuracy without the health hazards of ring liners. Trends Tech Contemp Dent 6:38, 1989.
14. Shell JS: Setting and thermal expansion of investments. III. Effects of no asbestos liner, coating asbestos with petroleum jelly, and double asbestos liner. J Alabama Dent Assoc 53:31, 1969.
15. Ho EK, Darvell BW: A new method for casting discrepancy: some results for a phosphate-bonded investment. J Dent 26:59, 1998.
16. Lacy AM, et al: Incidence of bubbles on samples cast in a phosphate-bonded investment. J Prosthet Dent 54:367, 1985.
17. American Dental Association: Dentist's Desk Reference: Materials, Instruments and Equipment, 1st ed. Chicago, The American Dental Association, 1981.
18. Sturdevant JR, et al: The 8-year clinical performance of 15 low-gold casting alloys. Dent Mater 3:347, 1987.
19. Goldfogel MH, Nielsen JP: Dental casting alloys: an update on terminology. J Prosthet Dent 48:340, 1982.
20. Johansson BI, et al: Corrosion of copper, nickel, and gold dental casting alloys: an in vitro and in vivo study. J Biomed Mater Res 23:349, 1989.
21. Duncan JD: The casting accuracy of nickel-chromium alloys for fixed prostheses. J Prosthet Dent 47:63, 1982.
22. Ogura H, et al: Inner surface roughness of complete cast crowns made by centrifugal casting machines. J Prosthet Dent 45:529, 1981.
23. Moffa JP, et al: An evaluation of nonprecious alloys for use with porcelain veneers. I. Physical properties. J Prosthet Dent 30:424, 1973.
24. Moon PC, Modjeski PJ: The burnishability of dental casting alloys. J Prosthet Dent 36:404, 1976.
25. Moffa JP, et al: An evaluation of nonprecious alloys for use with porcelain veneers. II. Industrial safety and biocompatibility. J Prosthet Dent 30:432, 1973.
26. American Dental Association Council on Dental Materials, Instruments, and Equipment: Biological effects of nickel-containing dental alloys. J Am Dent Assoc 104:501, 1982.
27. Lacy AM, et al: Three factors affecting investment setting expansion and casting size. J Prosthet Dent 49:52, 1983.
28. Vieira DF, Carvalho JA: Hygroscopic expansion in the upper and lower parts of the casting ring. J Prosthet Dent 36:181, 1976.
29. Cooney JP, Caputo AA: Type III gold alloy complete crowns cast in a phosphate-bonded investment. J Prosthet Dent 46:414, 1981.
30. Chew CL, et al: Investment strength as a function of time and temperature. J Dent 27:297, 1999.
31. Abu Hassan MI, et al: Porosity determination of cast investment by a wax-infiltration technique. J Dent 17:195, 1989.
32. Papadopoulos T, Axelsson M: Influence of heating rate in thermal expansion of dental phosphate-bonded investment material. Scand J Dent Res 98:60, 1990.

33. Campagni WV, Majchrowicz M: An accelerated technique for casting post-and-core restorations. J Prosthet Dent 66:155, 1991.
34. Campagni WV, et al: A comparison of an accelerated technique for casting post-and-core restorations with conventional techniques. J Prosthodont 2:159, 1993.
35. Bailey JH, Sherrard DJ: Post-and-core assemblies made with an accelerated pattern elimination technique. J Prosthodont 3:47, 1994.
36. Konstantoulakis E, et al: Marginal fit and surface roughness of crowns made with an accelerated casting technique. J Prosthet Dent 80:337, 1998.
37. Schilling ER, et al: Marginal gap of crowns made with a phosphate-bonded investment and accelerated casting method. J Prosthet Dent 81:129, 1999.
38. Henning G: The casting of precious metal alloys in dentistry: a rational approach. Br Dent J 133:428, 1972.
39. Preston JD, Berger R: Some laboratory variables affecting ceramo-metal alloys. Dent Clin North Am 21:717, 1977.
40. Jameson A: British patent no. 19801, 1907.
41. Hero H, Waarli M: Effect of vacuum and supertemperature on mold filling during casting. Scand J Dent Res 99:55, 1991.
42. Eames WB, MacNamara JF: Evaluation of casting machines for ability to cast sharp margins. Operative Dent 3:137, 1978.
43. Anusavice KJ: Phillips' Science of Dental Materials, 11th ed. Philadelphia, WB Saunders, 2003.

23



DESCRIPTION OF COLOR, COLOR-REPLICATION PROCESS, AND ESTHETICS

Alvin G. Wee, Contributing Author

KEY TERMS

achromatic
chroma
CIELAB color system
color blindness
color rendering index
color temperature
cones
electromagnetic spectrum
esthetics
fluorescence
hue
metamerism
Munsell color order system
opalescence
photopic vision
reflectance
rods
saturation
scotopic vision
shade
value
visible spectrum
wavelength

An understanding of the process in which the color and translucency of fixed restorations are planned and obtained so as to replicate the color and contours of its adjacent teeth is important for achieving an esthetic restoration. Errors, especially in the color replication process, have been a problem and a source of frustration for dentists and technicians and may lead to dissatisfaction for the patient. This chapter outlines some of the principles of color, light, and human perception as it relates to the color replication process and **esthetics** of fixed restorations.

DESCRIPTION OF COLOR

Just as a solid body can be described by three dimensions of physical form (length, width, and depth), color has three primary attributes that allow it to be described with the same precision. Describing these attributes, however, depends on the color system used. Two systems are explained: the more visually descriptive **Munsell color order system** and the more quantitative **CIELAB color system**.

Munsell Color Order System[1]

This system was widely used in the dental literature and also used in the past to quantify color.[2,3] It is still a popular method of visually describing

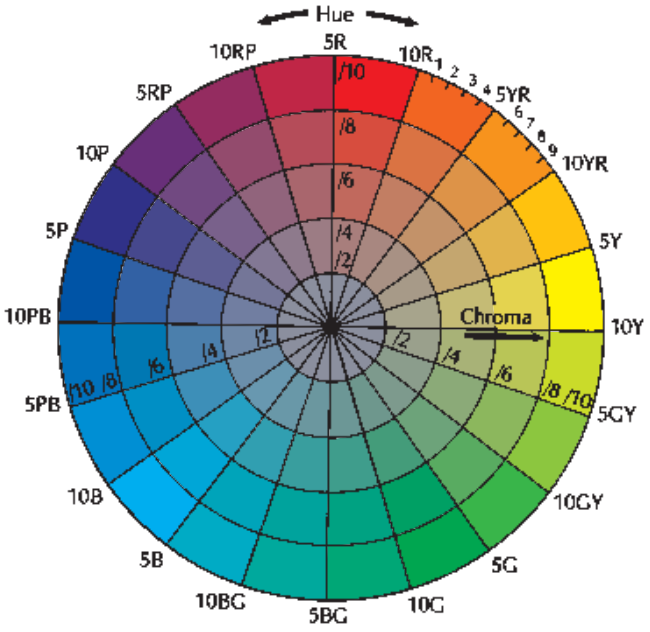


Fig. 23-1
Arrangement of Hue and Chroma in the Munsell system. *R,* red; *YR,* yellow-red; *Y,* yellow; *GY,* green-yellow; *G,* green; *BG,* blue-green; *B,* blue; *PB,* purple-blue; *P,* purple; *RP,* red-purple.

color. The three attributes of color in this system are called **Hue, Chroma,** and **Value.***

Hue

Hue is defined as the particular variety of a color. The hue of an object can be red, green, yellow, and so on, and is determined by the **wavelength** of the reflected and/or transmitted light observed. The place of that wavelength (or wavelengths) in the visible range of the spectrum determines the hue of the color. The shorter the wavelength, the closer the hue is to the violet portion of the spectrum; the longer the wavelength, the closer it is to the red portion. In the Munsell color system, Hues are arranged around the wheel (Fig. 23-1).

Chroma

Chroma is defined as the intensity of a hue. The terms ***saturation*** and *chroma* are used interchangeably in the dental literature; both mean the strength of a given hue or the concentration of pigment. A simple way to visualize differences in chroma is to imagine a bucket of water. When one drop of ink is added, a solution of low chroma results. Adding a second drop of ink increases the chroma, and so on, until a solution is obtained that is almost all ink and consequently of high chroma. In the Munsell color system, the intensity of Chroma of a particular Hue is more intense on the outer rim than near the hub of the wheel (Fig. 23-2).

*When used in reference to the Munsell coordinates, these terms are capitalized.

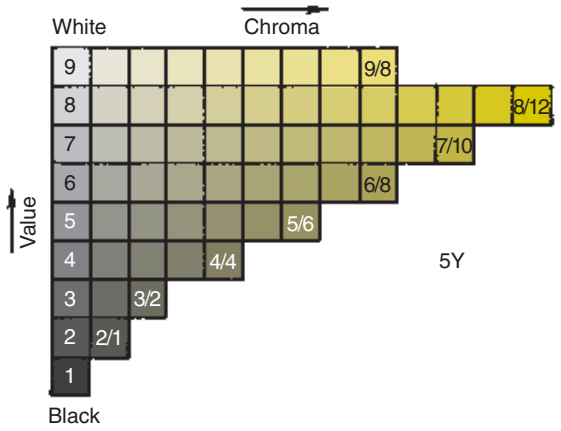


Fig. 23-2
Arrangement of Value and Chroma in the Munsell system. *Y,* yellow.

Value

Value is defined as the relative lightness or darkness of a color or the brightness of an object. The brightness of any object is a direct consequence of the amount of light energy the object reflects and/or transmits (see Fig. 23-2).

It is possible for objects of different hues to reflect the same number of photons and thus have the same brightness or value. A common example is the difficulty experienced in trying to tell a green object from a blue object in a black and white photograph. The two objects reflect the same amount of light energy and therefore appear identical in the picture.

A restoration that has too high a value (is too bright) may be easily detected by an observer and is a common esthetic problem in metal-ceramic prosthodontics.

CIELAB Color System

The CIELAB color system is used almost exclusively for color research in dentistry around the world.[4–7] It was introduced in 1976 and recommended by the International Commission on Illumination. The strength of this system, unlike that of the Munsell system, is its ability for clinical interpretation, as equal distances across the CIELAB color space (color differences or ΔE) represent approximately uniform steps in human color perception, improving the interpretation of color measurements. This means that the magnitude of perceptible and/or acceptable color difference can be defined between, for

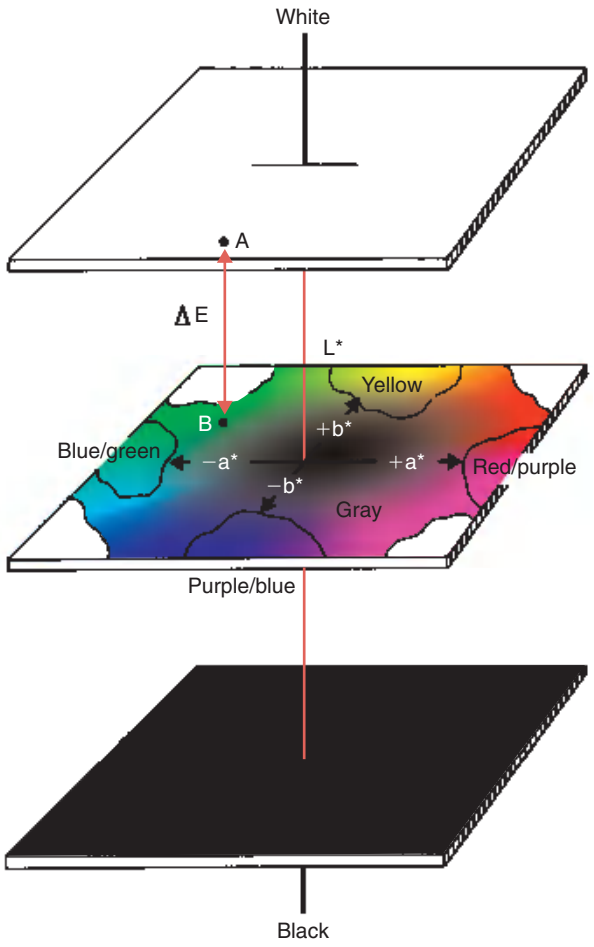


Fig. 23-3

L*a*b* color space. Any color can be defined in terms of these coordinates. L* (the vertical axis) defines the lightness or darkness of the color and corresponds to Value in the Munsell system; a* and b* define the chromatic characteristic. The color difference (ΔE) between two colors (A and B) can be calculated from the sum of the squares of the differences among the three coordinates. The system is arranged so that a color difference of 1 is perceivable by 50% of observers with normal color vision.[60] *(From Rosenstiel SF, Johnston WM: The effect of manipulative variables on the color of ceramic metal restorations. J Prosthet Dent 60:297, 1988.)*

example, a porcelain crown and the adjacent natural dentition.

The CIELAB color order system defines color space by three coordinates: L*, a*, and b*. L* is similar to the Munsell system's Value and represents the lightness, brightness, or black/white character of the color. The coordinates a* and b* describe the chromatic characteristics of the color. L* describes the **achromatic** character of the color. Colors with high value or L* (such as tooth colors) are located near the top of the color space, as depicted in Figure 23-3. The chromatic, or non-black/white, characteristics of a color are represented in the Munsell system by Hue and Chroma and in the CIELAB system by a*



Fig. 23-4

Locations in space can be defined in polar (*dashed line*) or Cartesian (*solid lines forming right angle*) coordinates.

and b*. In each system, these two coordinates define the location of color on a plane of given lightness, such as the one depicting color *B* in Figure 23-3. In the Munsell system, the color is identified by one polar coordinate (Hue) and one linear, or Cartesian,[†] coordinate (Chroma); in the CIELAB system, both coordinates (a* and b*) are Cartesian. For an analogy, consider how the location of a house in a city might be described. It could be said that someone lived a distance of 11.85 miles (linear coordinate) in the north-northwest direction (polar coordinate) from downtown. This is analogous to describing a color in the Munsell system. The identical location could also be defined as being 10.6 miles north and 5.3 miles west of downtown (two Cartesian coordinates) (Fig. 23-4). This is analogous to describing a color in CIELAB. They represent the same location in space. However, unlike the Munsell coordinates, the CIELAB coordinates define the color space in approximately uniform steps of human color perception. This means that equal distances across the CIELAB color space (color differences, or ΔE) represent approximately equally perceived **shade** gradations, an arrangement that makes interpretation of color measurements more meaningful.

L*

L* is a lightness variable proportional to Value in the Munsell system. It describes the achromatic character of the color.

a* and b*

The a* and b* coordinates describe the chromatic characteristics of the color. Although they do not

[†]From the Latin form of René Descartes, 1596-1650, the French philosopher and mathematician.

correspond directly to Munsell's Hue and Chroma, they can be converted by numerical parameters[8] (see Fig. 23-3). The a* coordinate corresponds to the red-purple/blue-green axis in the Munsell color space. A positive a* relates to a predominantly red-purple color, whereas a negative a* denotes a color that is more blue-green. Similarly, the b* coordinate corresponds to the yellow/purple-blue axis.

COLOR REPLICATION PROCESS

The process in which the color of adjacent teeth is replicated in a metal-ceramic or all-ceramic crown is termed in this chapter the *color replication process.* The color replication process for fixed restorations (Fig. 23-5) consists of the shade-matching phase followed by a shade-duplication phase. Shade matching can be accomplished through either the more common visual shade matching or the increasingly popular instrumental analysis. The shade duplication takes place in the dental laboratory, in which either the use of corresponding porcelain selected in the shade-duplication phase or the use of more sophisticated porcelain mixtures is used to fabricate the fixed restoration. If visually perceptible differences can be observed between the final restoration and the originally matched restoration, it is possible for the clinician to apply surface characterization porcelains to the restoration to adjust any color discrepancy.

SHADE-MATCHING PHASE

This phase occurs in the dentist's office, in which the information on the color and translucency of the adjacent teeth to be matched is recorded through either visual shade matching or instrumental color analysis.

Visual Shade Matching

Visual assessment of the shade and translucency is the method most frequently applied in dentistry.[9] Studies have shown that this often-used method is difficult to apply with accuracy and often yields unreliable and inconsistent results.[10,11] Fortunately, a lifelike and successful restoration does not have to be an exact duplicate of the color and translucency of the adjacent teeth. It should, however, blend with the teeth as a result of the distribution of ceramic materials in the restoration. Not only is the apparent color of an object influenced by its physical properties, the nature of the light to which the object is exposed, and the subjective assessment of the observer; the variability of two of the three factors (e.g., lighting and subjectivity of the observer) can cause the same object (e.g., tooth) to look very different. Understanding the three main factors (lighting, subjectivity of human vision, and the object) that influence the outcome of visual shade matching can improve the accuracy and reliability of this process.

Lighting

Light is necessary for color to exist. An object that is perceived as a certain color absorbs all light waves corresponding to other colors and reflects only the waves of the object's color. For example, an object that absorbs blue and green light and reflects red appears red. The quality and quantity of the light source and the environment in which the teeth/shade guides are being visually matched are important.

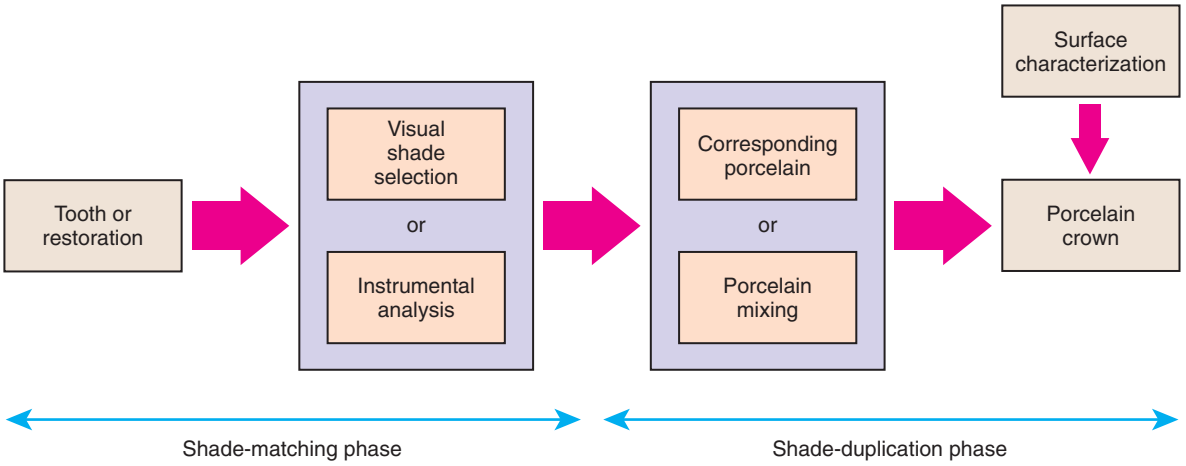


Fig. 23-5
Color replication process for fixed restorations.

Although daylight was initially thought to be the ideal light source for color matching,[10] its use is not recommended, in view of inconstant color characteristics. The color of daylight can vary from red-orange at sunset to blue when the sky is clear. The relative intensity of daylight also fluctuates during the day with cloud cover.[12] An ideal light source for visual shade matching is one that is diffuse and comfortable for the eyes, allowing observers to assess the color accurately and comfortably.[12] In one study, evaluators obtained better visual shade matching in controlled stable, constant, and standard full-spectrum lighting than in daylight.[13]

Description of light

Scientifically, light is described as visible electromagnetic energy whose wavelength is measured in nanometers (nm), or billionths of a meter. The eye is sensitive only to the visible part of the **electromagnetic spectrum,** a narrow band with wavelengths from 380 to 750 nm. At the shorter wavelengths lie ultraviolet, x, and gamma rays; at the longer wavelengths are infrared radiation, microwaves, and television and radio transmission waves (Fig. 23-6).

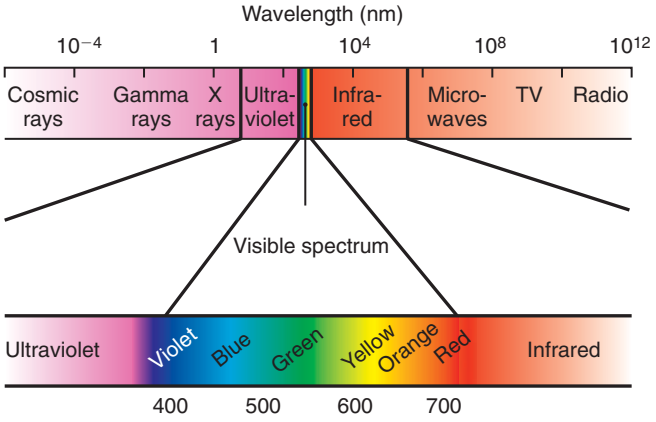


Fig. 23-6

Electromagnetic energy spectrum. A nanometer (nm) is 10^{-9} meter.

Pure white light consists of relatively equal quantities of electromagnetic energy over the visible range. When it is passed through a prism (Fig. 23-7), it is split into its component colors because the longer wavelengths are bent (refracted) less than the shorter ones.

Quality of light source

A light source of the appropriate quality should be used during visual shade matching. The appropriate **color temperature** with appropriate spectral energy distribution and **color rendering index** (CRI) must be considered when selecting a light source.

A light source with a color temperature close to 5500° K (D55) that is spectrally balanced throughout the **visible spectrum** is ideal for color matching. Color temperature is related to the color of a standard black body when heated and is reported in degrees Kelvin (K), or absolute (0° K = –273° C). Accordingly, 1000° K is red; 2000° K is yellow; 5555° K is white; 8000° K is pale blue. D65 (Fig. 23-8) is considered to be the true color temperature of white light as perceived by human observers.[14] D65 is very commonly used in dental shade matching as the standard lighting for visual shade matching. A light source with a CRI greater than 90 is recommended for shade matching.[15] The CRI, on a scale of 1 to 100, indicates how well a particular light source renders color in comparison with a specific standard source. Dental personnel's shade-matching ability on a designed color test[16] was significantly better with a full-spectrum light source of 5700° K (CRI = 91) than with the following light sources: 6000° K (CRI = 93), 4200° K (CRI = 65) and 7500° K (CRI = 94).[17]

Unfortunately, the most common light sources in dental operatories are incandescent and fluorescent, neither of which is ideal for shade matching. An ordinary incandescent light bulb emits relatively higher concentrations of yellow light waves than of

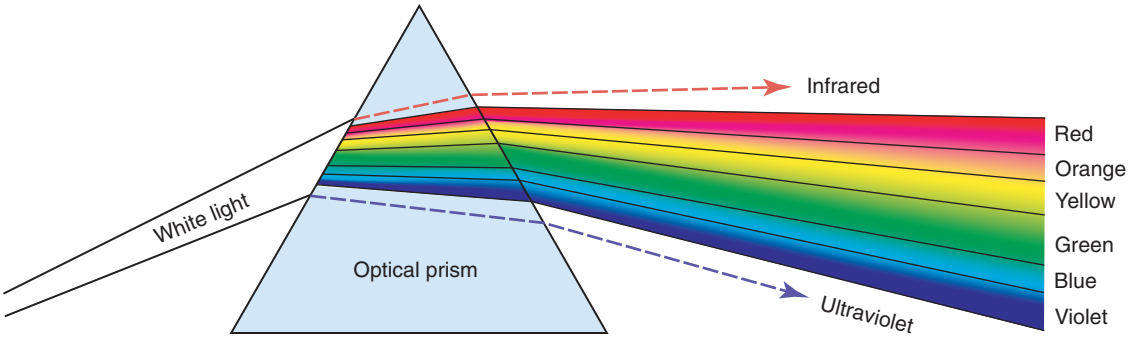


Fig. 23-7

A prism bends or refracts long wavelengths of light less than shorter wavelengths, thereby separating the colors.

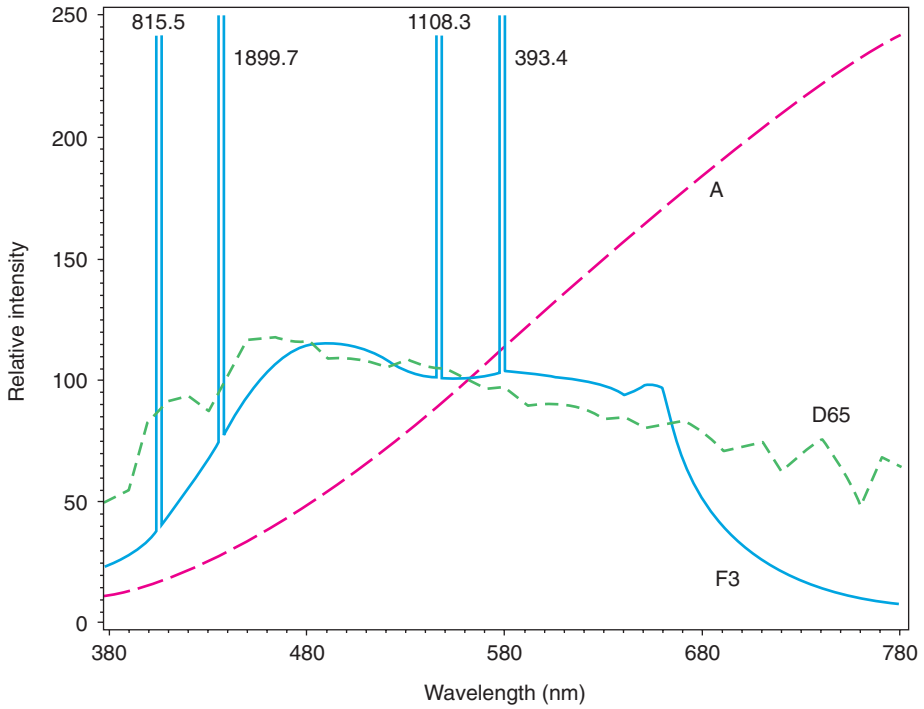


Fig. 23-8
Relative intensity versus wavelength of three light sources: D65 is relatively balanced; tungsten filament (A illuminant) is high in orange and red wavelengths; fluorescent (F3 illuminant) tube light has peaks of blue and yellow.

blue and blue-green, whereas fluorescent ceiling fixtures give off relatively high concentrations of blue waves. Color-corrected fluorescent lighting is recommended because it approaches the necessary type of balance. Recommended commercial color-corrected ambient lighting, ideal for shade matching, for the dental operatory can be found in Table 23-1.

Quantity of light source

Appropriate intensity of the ambient lighting in the dental operatory provides the dentist with visual comfort, particularly in terms of contrast. It is recommended that the light intensity for the dental operatory be between 18 to 28 lux* and 28 lux for the dental laboratory.[18] The intensity of the dental operatory lighting has not been found to be crucial for color matching when the light intensity ranged from 1.5 to 28 lux.[19]

Auxiliary light sources

If ambient lighting in the dental operatory is not ideal in terms of quality and quantity for visual shade matching, the use of auxiliary lighting is recommended. The auxiliary light source for shade matching should be intense enough to overcome the influence of the ambient light. It has been recommended that the ratio of task (shade matching) to ambient light should not exceed 3:1; too much intensity does not allow discrimination of small color differences.[18] Commercial auxiliary lighting, such as the Demetron Shade Light* (Fig. 23-9) or the Shade Wand,† is recommended for shade matching (see Table 23-1).

Shade-matching environment

The ambient and direct lighting used for shade matching scatters and reflects from surfaces before reaching the structure that it illuminates. The colors of the dental operatory, clothing of the dentist and dental assistants, the patient's clothing, and the dental drape may influence the perceived color of the patient's teeth and shade guide.[20] To maintain the necessary lighting quality for shade matching, the chroma of the environment should be carefully controlled. It is recommended that the walls, staff clothing, patient drape, and shade-matching environment have a Chroma of four Munsell units or less, which are the pastel[18] or the ideal neutral gray tones.[21] Further recommendations include that the ceiling have a Munsell Value of 9. All other major reflectors (e.g., walls, cabinets) should present at least a Munsell Value of 7 and a Chroma of no more than 4. Countertops not within the working area can

*Lux is a unit of illumination, equal to 1 lumen per square meter—originally based on the illumination provided by a household candle at a distance of 1 m.

*Kerr Corporation, Orange, California.
†Authentic Products, Inc., San Antonio, Texas.

Table **23-1 EXAMPLES OF COMMERCIAL BALANCED LIGHTING AVAILABLE**

Product Name	Company	Type	CRI	CCT (°K)	Estimated life (hours)
CRS Light	CRSLight, Cleveland, Ohio	Fluorescent tube	91	5750	20,000
Full Spectrum, Supreme	NaturalLighting.com, Houston, Texas	Compact fluorescent tube	96	5000	20,000
Lumichrome 1XX	Lumiram, White Plains, New York	48-inch fluorescent tube	98	6500	24,000
Lumichrome 1XZ	Lumiram, White Plains, New York	24-inch fluorescent tube	95	5700	24,000
Demetron Shade Light	Kerr Corporation, Orange, California	Handheld fluorescent tube (3 hours' battery life)	93	6500	20,000
Shade Wand	Authentic Products, Inc., San Antonio, Texas	Handheld fluorescent tube	–	5500	–
Hand Held	Great Lakes Lighting, Bay City, Michigan	Handheld fluorescent tube	94	–	9000
Vita-Lite	Duro-Test Lighting, Inc., Philadelphia, Pennsylvania	Handheld fluorescent tube	91	5500	10,000 to 28,000
Light-A-Lux (40-watt T-12)	American Environmental Products, Fort Collins, Colorado	Compact fluorescent	90	5900	20,000
Super Daylite (32-watt T-8)	American Environmental Products, Fort Collins, Colorado	Compact fluorescent bulb	98	6500	20,000
Super Daylite (40-watt T-12)	American Environmental Products, Fort Collins, Colorado	Compact fluorescent bulb	96	5000	20,000
Super 10,000 Lux (40-watt T-10)	American Environmental Products, Fort Collins, Colorado	Compact fluorescent	91	5000	20,000
F40/C50/RS/WM	General Electric Company, GE Lighting, Cleveland, Ohio	48-inch fluorescent tube	90	5000	20,000

CCT, correlated color temperature; CRI, color-rendering index.
Data from Wee AG: Color matching: color matching conditions. In Paravina RD, Powers JM, eds: Esthetic color training in dentistry. St. Louis, Mosby, 2004; and Paravina RD, personal communication, 2004.



Fig. 23-9
An auxiliary battery-operated balanced light source: Demetron Shade Light by Kerr Corporation. *(Courtesy of Kerr Corporation, Orange, California.)*

have a Chroma of up to 6 but a Munsell Value retained at 7 or greater.[22]

Human vision

Light from an object enters the eye and acts on receptors in the retina (**rods** and **cones**). Impulses from these are passed to the optical center of the brain, where an interpretation is made. Shade matching is therefore subjective: different individuals have different interpretations of the same stimulus.

The eye

Under low lighting conditions, only the rods are used (**scotopic vision**). These receptors allow an interpretation of the brightness (but not the color) of objects to be made. The rods are most sensitive to blue-green objects. Color vision is dependent on the cones, which are active under higher lighting conditions (**photopic vision**). The change from photopic to scotopic vision is called *dark adaptation* and takes about 40 minutes.[23]

The area with the most cones is in the center of the retina, which is free of rods. The rods begin to predominate toward the periphery. This means that the central field of vision is more color perceptive. Although the exact mechanism of color vision is not known, there are three types of cones—sensitive to red, green, and blue light[24]—that form an image in much the same way as the additive effect of the pixels in a television picture.

Color adaptation

Color vision decreases rapidly as a person stares at an object. The original color appears to become less and less saturated until it appears almost gray.

Deceptive color perception

The brain can be tricked in how it perceives color. A classic example of such a trick is the Benham disk

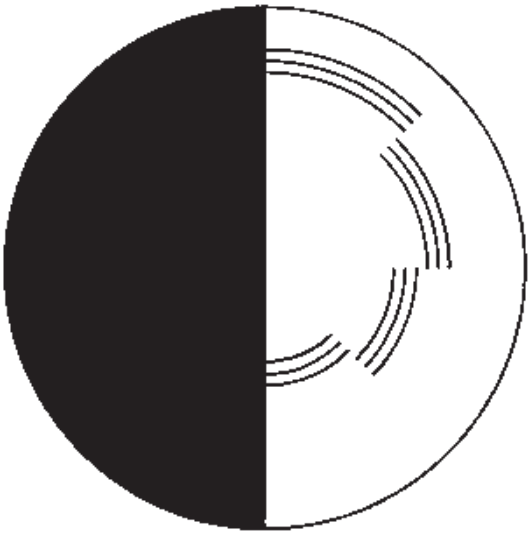


Fig. 23-10
The Benham disk. When it rotates, red, green, and blue rings are seen. The order of the colors is reversed if the disk rotates in the opposite direction. This is a purely sensory phenomenon caused by afterimages.

(Fig. 23-10). When this black and white disk is illuminated and rotated at an appropriate speed, it appears to be highly colored.

Color is also influenced by surrounding colors, particularly complementary ones (those diametrically opposed in Fig. 23-1). For example, when blue and yellow are placed side by side, their chroma may appear to be increased. The color of teeth can also look different if the patient is wearing brightly colored clothing or lipstick (Fig. 23-11).

Metamerism

Two colors that appear to be a match under a given lighting condition but have different spectral **reflectance** (Fig. 23-12) are called *metamers*, and the phenomenon is known as **metamerism.** For example, two objects that appear to be an identical shade of yellow may absorb and reflect light differently. Yellow objects normally reflect yellow light, but some may actually absorb yellow light and reflect orange and green. To an observer, the orange and green combination looks yellow, although when the lighting is changed, the metamers no longer match. This means that a sample that appears to match under the operatory light, for example, may no longer be satisfactory in daylight. The problem of metamerism can be avoided by selecting a shade and confirming it under different lighting conditions (e.g., natural daylight and fluorescent light).

Fluorescence

Fluorescent materials, such as tooth enamel, re-emit radiant energy at a lower frequency than it is absorbed.[25] For example, ultraviolet radiation is re-emitted as visible light. In theory, a mismatch can

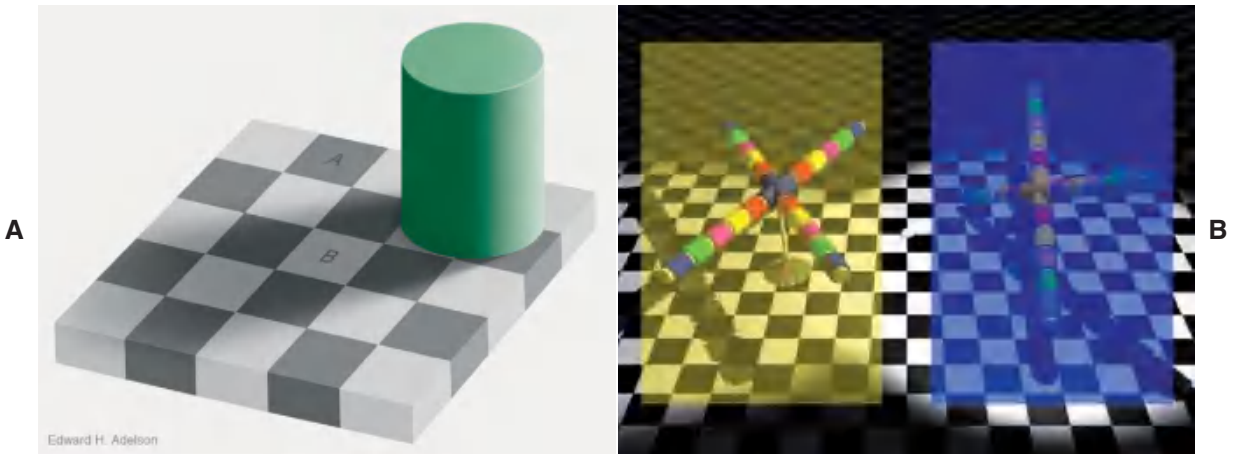


Fig. 23-11a

A, The Checker Shadow Illusion. The squares marked *A* and *B* are the same shade of gray. For proof, see Fig. 23-11b, *A*. **B,** The Colored Cross Illusion. The central element of the two X-shaped objects appear very different in color but are, in fact, exactly the same. For proof, see Fig. 23-11b, *B*. (***A,*** *Courtesy of Dr. E.H. Adelson;* ***B,*** *Courtesy of Dr. R.B. Lotto.)*

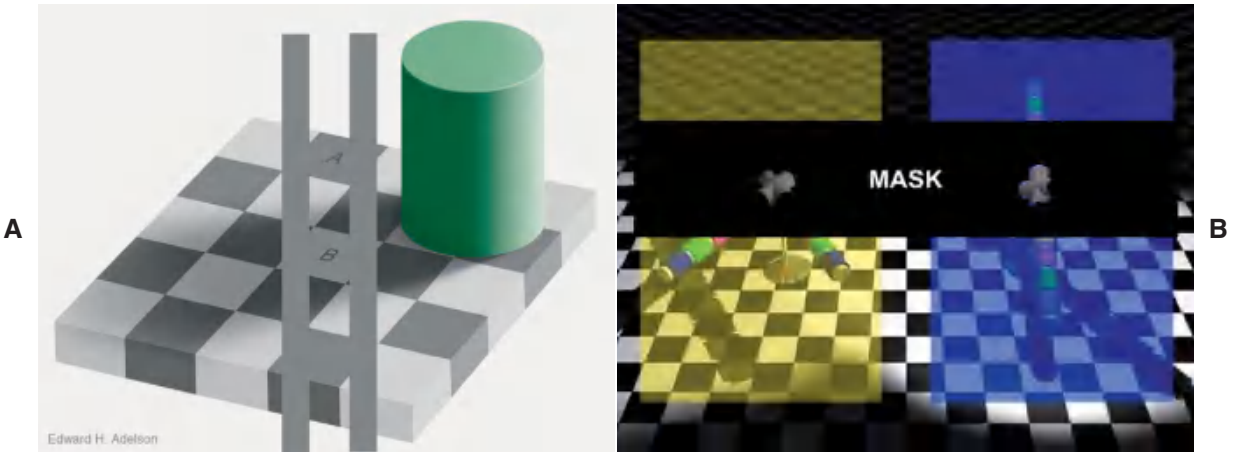


Fig. 23-11b

A, The Checker Shadow Illusion. The original image plus two stripes. By joining the squares marked *A* and *B* with two vertical stripes of the same shade of gray, it becomes apparent that both squares are the same. **B,** When a mask that isolates the central elements from the surrounding colors is placed, the illusion is revealed. As with many so-called illusions, both of these effects really demonstrate the success rather than the failure of the visual system. The visual system is not very good at being a physical light meter, but that is not its purpose. The important task is to break the image information down into meaningful components, thereby allowing the nature of the objects in view to be perceived. However, when selecting appropriate tooth shades, it is important not to be influenced by the surrrounding colors. (***A,*** *Courtesy of Dr. E. H. Adelson;* ***B,*** *Courtesy of Dr, R.B. Lotto.)*

occur if the dental restoration has different **fluorescence** than the natural tooth. In practice, fluorescence does not play a significant role in color matching dental restorations.[26]

Opalescence

Natural teeth, particularly at their incisal edges, exhibit a light-scattering effect* that creates the appearance of bluish-white colors as the teeth are seen at different angles. This is similar to the bluish-white background seen in opal gemstones (hence the term ***opalescence***). Manufacturers try to match this effect when formulating dental porcelains.[27,28]

Color blindness

Defects in color vision (**color blindness**) affect about 8% of the male population and less of the female population.[29] Different types exist, such as achromatism (complete lack of hue sensitivity), dichromatism (sensitivity to only two primary hues—usually either red or green is not perceived), and anomalous trichromatism (sensitivity to all three hues with deficiency or abnormality of one of the three primary pigments in the retinal cones). Dentists should therefore have their color perception

*Called *Mie scattering* after Gustav Mie, 1868-1957, German physicist.

tested. If any deficiency is detected, the dentist should seek assistance when selecting tooth shades.[30]

Shade selection systems

The most convenient method for selecting a shade is a commercially available porcelain shade guide (Fig. 23-13). Table 23-2 presents color measurement values made from Vita Lumin vacuum, Ivoclar Chromascop, and Vitapan 3D-Master shade guides with a spectroradiometer. Each shade tab (Fig. 23-14) has an opaque backing color, neck color, body color, and incisal color. Shade matching consists of picking the shade tab that looks the most natural and reproducing this color in a laboratory with materials and techniques recommended by the manufacturer. The procedure is easier if specimens of the same hue are grouped together in the shade guide. In the past, shade guides were produced in response to the demand for denture teeth rather than on the range of natural tooth color.[31] More recently, shade guides have covered the color space occupied by natural teeth,* such as the Vitapan 3D-Master shade guide (see Fig. 23-13*C*).

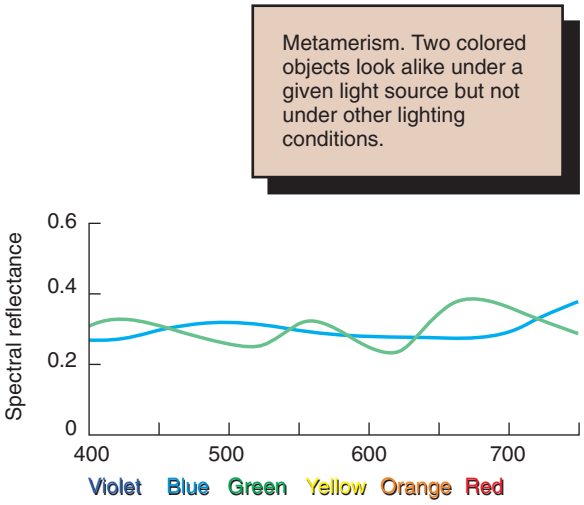


Fig. 23-12
Spectral reflectance curves of a metameric pair. The two objects represented appear to match under some lighting conditions but not under others.

Vita Lumin vacuum shade guide: Hue matching
In the popular Vita Lumin vacuum shade guide (see Fig. 23-13*A*), A1, A2, A3, A3.5, and A4 are similar in hue, as are the B, C, and D shades. Choosing the nearest hue first and then selecting the appropriate match of chroma and value from the tabs available is the recommended technique.

If its chroma or intensity is low, accurately determining a given hue may be difficult. Therefore, the region with the highest chroma (i.e., the cervical region of canines) should be used for initial hue selection (Fig. 23-15*A*).

*Shades that match artificially bleached teeth are also available.

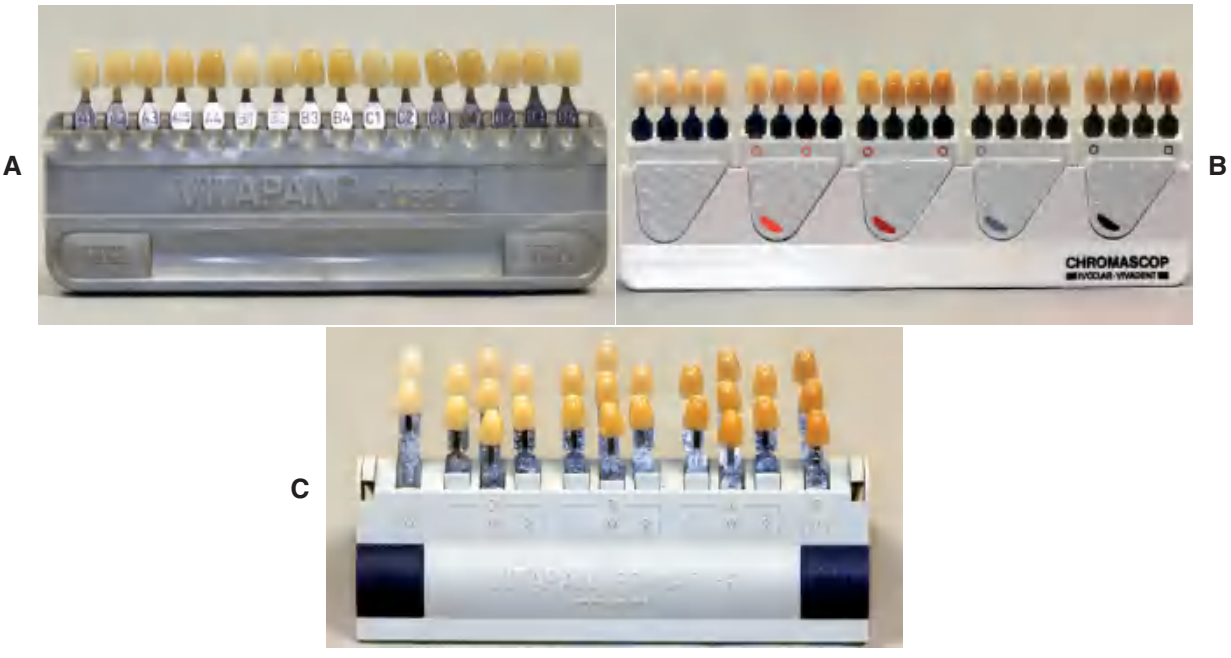


Fig. 23-13
Commercial shade guides. **A,** The Vita Lumin vacuum shade guide. **B,** Ivoclar Chromascop shade guide. **C,** Vitapan 3D-Master shade guide.

Table 23-2 **CIELAB VALUES: VITAPAN 3D-MASTER, IVOCLAR CHROMASCOP, AND VITA LUMIN VACUUM SHADE GUIDES MEASURED WITH SPECTRORADIOMETER WITH 45° ILLUMINATION AND 0° OBSERVER WITHOUT AN APERTURE**

Shade guide	Tab	L*	a*	b*
Vitapan 3D-Master	0M1	79.08	–0.55	5.36
	0M2	76.31	–0.27	6.89
	0M3	77.4	–0.61	8.35
	1M1	73.91	–0.51	10.83
	1M2	75.17	–0.43	17.32
	2L1.5	70.68	–0.26	16.5
	2L2.5	70.65	–0.05	22.01
	2M1	70.27	0.56	12.96
	2M2	70.78	0.48	18.04
	2M3	68.27	0.07	20.73
	2R1.5	70.84	1.01	15.3
	2R2.5	69.66	1.19	20.52
	3L1.5	66.1	1.01	18.62
	3L2.5	66.5	1.44	24.15
	3M1	66.19	1.48	14.44
	3M2	66.61	1.41	19.54
	3M3	66.88	1.81	24.65
	3R1.5	65.05	2.06	15.87
	3R2.5	64.88	2.22	21.38
	4L1.5	62.21	2.16	19.41
	4L2.5	61.5	3.25	26.44
	4M1	61.28	2.4	16.03
	4M2	62.58	3.36	21.93
	4M3	61.88	3.55	27.08
	4R1.5	61.45	3.45	18.84
	4R2.5	62.54	4.04	23.98
	5M1	58.36	3.27	17.72
	5M2	57.54	4.67	23.64
	5M3	58.5	5.81	30.1
Ivoclar Chromascop	110	74.24	–0.09	14.96
	120	74.04	0.32	17.04
	130	72.14	–0.31	17.68
	140	72.64	1.19	20.68
	210	70.63	1.41	22.99
	220	69.93	2.56	20.69
	230	68.5	3.14	23.39
	240	66.94	3.9	22.73
	310	67.57	0.69	22.97
	320	65.42	1.98	24.25
	330	65.9	2.45	27.93
	340	63.17	3.77	25.21
	410	67.63	1.65	17.88
	420	67	1.27	18.42
	430	65.72	0.14	18.55
	440	65.24	0.48	19.25
	510	64.33	1.28	20.28
	520	62.8	2.14	22.75
	530	62.2	2.81	24.51
	540	59.74	6.35	23.02

Table **23-2—cont'd**

Shade guide	Tab	L*	a*	b*
Vita Lumin Vacuum	A1	71.88	–1.06	13.64
	A2	69.28	0.67	16.99
	A3	67.27	1.2	19.61
	A3.5	65.12	1.82	22.07
	A4	62.35	2.17	22.68
	B1	72.09	–1.47	12.3
	B2	69.83	–1.14	18.86
	B3	67.31	0.95	22.76
	B4	66.49	1.09	24.51
	C1	67.03	–1.08	13.94
	C2	61.56	0.1	18.68
	C3	62.15	0.53	17.16
	C4	57.36	1.96	20.14
	D2	65.85	–0.42	13.65
	D3	64.25	1.14	18.41
	D4	64.86	–0.67	20.34

Data from Kuo S: Color accuracy of digital images for use in craniofacial rehabilitation. Master's thesis. The Ohio State University, 2003.

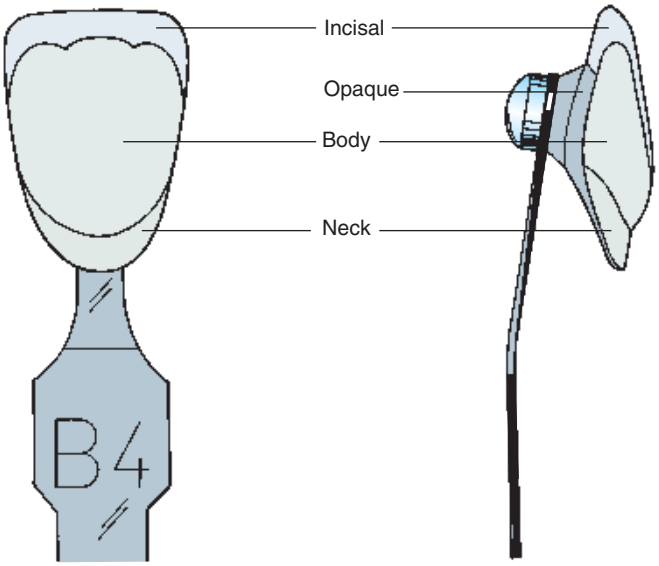


Fig. 23-14
Porcelain shade sample.

Chroma selection

Once the hue is selected, the best chroma match is chosen. For example, if a B hue is determined to be the best match for color variety, there are four available gradations (tabs) of that hue: B1, B2, B3, and B4 (Fig. 23-15*B*). Several comparisons are usually necessary for determining which sample best represents the hue and its corresponding chroma (saturation) level. Between comparisons, glancing at a gray object rests the operator's eyes and helps avoid retinal cone fatigue.

Value selection

Finally, value is determined with a second commercial guide whose samples are arranged in order of increasing lightness (Fig. 23-15*C*). (The lightness readings—L* in Table 23-2—can be used as a guide to the sample sequencing.) By holding the second shade guide close to the patient, the operator should be able to determine whether the value of the tooth is within the shade guide's range. Attention is then focused on the range of shade that best represents the value of the tooth and how that range relates to the tab matching for hue and saturation. An observer is able to assess the value most effectively by observing from a distance, standing slightly away from the chair, and squinting the eyes. By squinting, the observer can reduce the amount of light that reaches the retina. Stimulation of the cones is reduced, and a greater sensitivity to achromatic conditions may result.[32] While squinting, the observer concentrates on which disappears from sight first—the tooth or the shade tab. The one that fades first has the lower value.

When the proper value selection has been made, it is the exception rather than the rule for this to coincide with the determinations for hue and chroma. The operator must decide whether to change the previously selected shade sample. If the independent value determination is lower than the value of the sample selected for hue and chroma, a change is



Fig. 23-15
Shade matching using the Lumin Vacuum shade guide. **A,** Selecting hue by matching samples with high chroma (e.g., A4, B4, C4, or D3) to a tooth with high chroma (i.e., canine). **B,** Selecting chroma from within the hue group (e.g., B1, B2, B3, or B4). **C,** Value-ordered shade guide is used to check lightness.

usually necessary, because increasing the value of an object by adding surface stain (which always reduces brightness) is not possible. If the value determination is higher than the hue determination, the operator should decide whether this difference can be bridged through internal or surface characterization of the restoration. The final decisions about hue, chroma, and value are then communicated to the laboratory.

Vitapan 3D-Master shade guide*

The manufacturer of this shade system (Fig. 23-16*A*) claims that it covers the entire tooth color space. The shade samples are grouped in six lightness levels, each of which has chroma and hue variations in evenly spaced steps (Fig. 23-16*B*). The shade guide is spaced in steps (ΔE) of four CIELAB units in the lightness dimension and two CIELAB units in the hue and chroma dimensions. The difference between lightness and color steps seems a logical approach to reducing the number of shade samples needed in the guide because of the way the CIELAB units are visually perceived. It seems to match the color difference formula of the Colour Measurement Committee (CMC) of the Society of Dyers and Colourists.[33] Because the guide is evenly spaced, intermediate shades can be predictably formulated by combining porcelain powders.[34]

The manufacturer recommends selecting the lightness (Fig. 23-16*D*) first, then chroma (Fig. 23-16*E*), and finally the hue (Fig. 23-16*F*). A form is available to facilitate the laboratory shade prescription, which can include intermediate steps (Fig. 23-16*G*).

Extended-range shade guides

Most commercial shade systems cover a range more limited than the colors found in natural teeth, and the steps in the guide are greater than can be perceived visually.[35] Some porcelain systems are available with extended-range shade guides, and other manufacturers have extended their ranges over the years. The use of two or more shade guides is a practical way to extend the range of commercial guides.

Dentin shade guides

When a translucent all-ceramic system for a crown or veneer is used (see Chapter 25), communicating the shade of the prepared dentin to the dental laboratory is helpful. One system (IPS Empress)* provides specially colored die materials that match the dentin shade guide and enable the technician to judge restoration esthetics (Fig. 23-17).

*Vident, Brea, California.

*Ivoclar Vivadent, Amherst, New York.

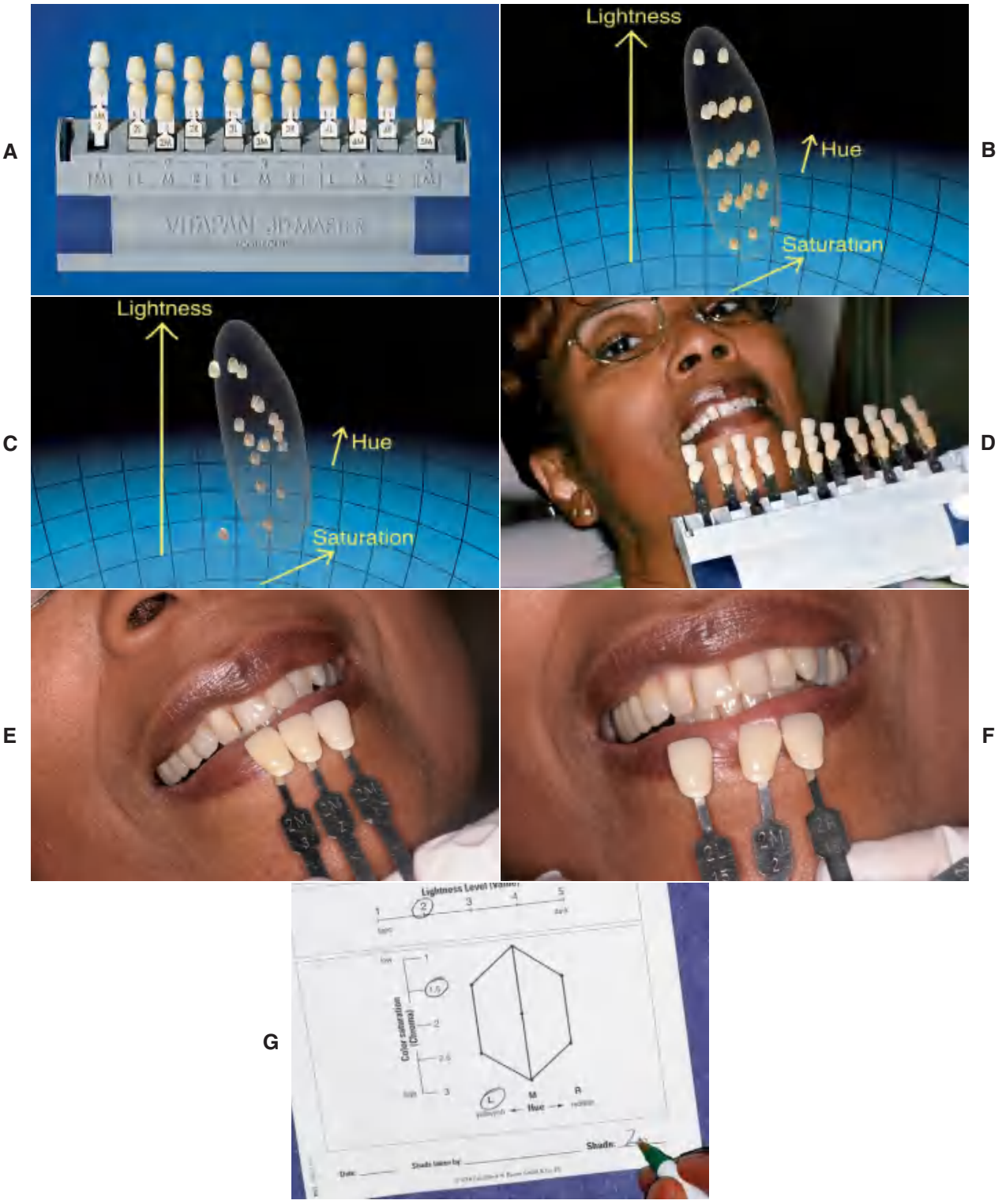


Fig. 23-16

Shade selection with the Vitapan 3D-Master shade guide. **A,** The shade guide is arranged in five lightness levels (plus an additional level for bleached teeth). **B,** Each lightness level has sufficient variations in chroma and hue to cover the natural tooth color space. **C,** This is in contrast to traditional shade guides, which are not uniformly spaced. **D,** Lightness is selected first, then chroma or saturation (**E**) and finally hue (**F**). **G,** The color communication form allows convenient laboratory shade prescription and intermediate shades if necessary. *(**A** to **C,** Courtesy of Vident, Brea, California.)*

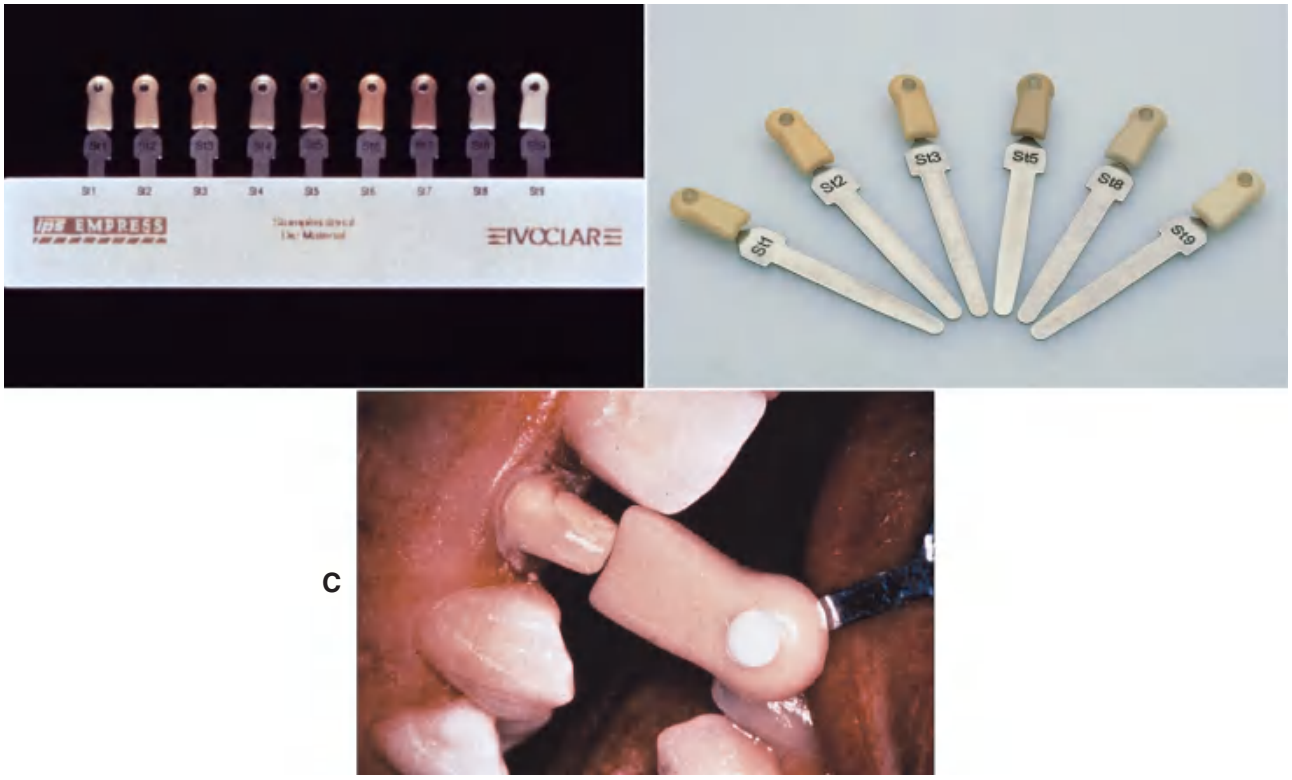


Fig. 23-17
A to C, Dentin shade guide is used to communicate the color of the prepared tooth to the technician when translucent ceramic systems are used. *(Courtesy of Ivoclar Vivadent, Amherst, New York.)*

Custom shade guide

Unfortunately, certain teeth may be impossible to match to commercial shade samples. In addition, difficulties may be encountered in reproducing the shade guides in the final restorations. The extensive use of surface characterization has severe drawbacks, because the stains increase surface reflection and prevent light from being transmitted through the porcelain.[36]

One approach to this problem is to extend the concept of a commercial shade guide by making a custom shade guide (Fig. 23-18). An almost infinite number of samples can be made by using different combinations of porcelain powders in varying distributions. However, the procedure is time consuming and is generally confined to specialty practice.

Shade distribution chart

Shade distribution charting (Fig. 23-19) is a practical approach to accurate shade matching and is recommended even when a fairly good match is available from the commercial shade sample.

The tooth is divided into three regions: cervical, middle, and incisal. Each region is matched independently, either to the corresponding area of a commercial shade sample or to a single-color porcelain chip. Because only a single color is matched, intermediate shades can usually be estimated rather easily and duplicated by mixing porcelain powders. The junctions between these areas are normally distinct and can be communicated to the laboratory in the form of a diagram. The shade distribution and thickness of the enamel porcelain are particularly important.[37] Individual characteristics are marked on such a sketch and enable the ceramist to mimic details such as hairline fractures, hypocalcification, and proximal discolorations.

Summary of guidelines for visual shade matching

Regardless of which shade guide system is used, there should be general adherence to the following principles:

1. Shade matching should be made under balanced lighting and in an appropriate shade-matching environment with gray or pastel color walls/cabinets.
2. Anything on the patient that influences the shade matching, including brightly colored clothing, should be draped, and lipstick should be removed.



Fig. 23-18
A, A custom shade guide. **B,** Commercially available tabs for fabricating custom shade samples. (**A,** *Courtesy of Dr. A. M. Peregrina.*)

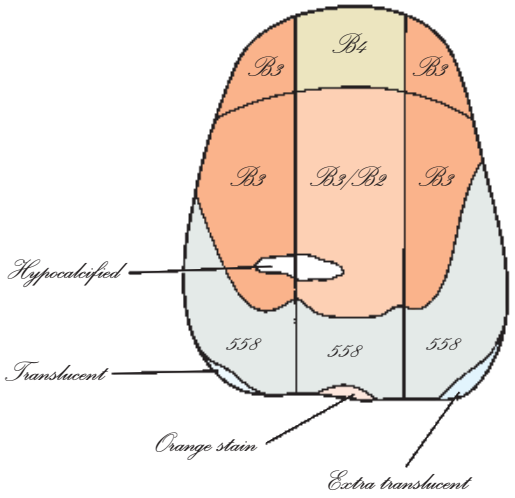


Fig. 23-19
Shade distribution chart.

3. The teeth to be matched should be clean. If necessary, stains should be removed by prophylaxis.
4. Shade matching should be made at the beginning of a patient's visit. Tooth color increases in value when the teeth are dry, particularly if a rubber dam has been used.
5. Cheek retractors should be used to provide an unhindered intraoral shade-matching area.
6. Choices of shade tab should be expanded by using several shade guides or mentally noting that the shade of the tooth could be between two shade tabs. The technician should be asked to mix the porcelain in equal amount to obtain an in-between shade.
7. The patient should be viewed at eye level so that the most color-sensitive part of the retina is used. A viewing working distance of approximately 10 inches (25 cm) should be adopted.
8. If the tooth and shade tab have different surface characteristics, wetting the surface of both helps remove the differences.
9. Shade matching should be made quickly (less than 5 seconds), with the shade tab placed directly next to the tooth being matched. This ensures that the background of the tooth and the shade sample are the same, which is essential for accurate matching. The dentist should be aware of eye fatigue, particularly if very bright fiberoptic illumination has been used.
10. The dentist should rest his or her eyes between viewings by focusing on a neutral gray surface immediately before a matching, because this balances all the color sensors of the retina. Resting eyes on a blue card was once advised, but it is not recommended because it results in blue fatigue.
11. To select the appropriate hue, the canine tooth is recommended for comparison because it has the highest chroma of the dominant hue.
12. The dentist can select an appropriate value by squinting.
13. The number of shade tabs should be reduced and separated to approximately three as quickly as possible. Then one or two of the shade tab that matches the best should be reselected.
14. Shade matching should be confirmed at one or two other visits and, if possible, confirmed with an auxiliary staff member. It is also recommended that shade selection be confirmed under several different lightings.

15. If an exact match cannot be selected, a shade tab with the lower chroma and highest value should be selected, because extrinsic characterization can be used to increase chroma and reduce the value (see Chapter 30).
16. The dentist should map the polychromatic nature of the tooth being matched—its special characteristics (e.g. cracks, hypocalcification, and translucency of the incisal enamel of the tooth)—with one of the following: (a) a shade distribution chart, (b) a digital image or 35-mm slide film with the closest shade tab beside the tooth, or (c) staining of the closest matching shade tab.

INSTRUMENTAL COLOR ANALYSIS

Color-Measuring Instruments

Color matching for dental restorative materials is generally done visually by matching a shade sample. In industry, electronic color measuring instruments, such as spectrophotometers, spectroradiometers, and colorimeters are used. Spectrophotometers and spectroradiometers measure light reflectance at wavelength intervals over the visible spectrum. Spectrophotometers differ from spectroradiometers primarily in that they have a stable light source and usually have an aperture between the detector and sample. Colorimeters provide direct color coordinate specifications without mathematical manipulation. This is accomplished by sampling light reflected from an object through three color filters that simulate the response of the color receptors in the eye.

Color-measuring instruments with an aperture between the translucent object and the illumination and sensor have been shown to exhibit "edge loss" when carrying out measurements.[38,39] Edge loss is a phenomenon that occurs when light is scattered through a translucent material that originally would be seen by the eye but is simply not measured by the instrument. This happens when the light is scattered in the translucent object away from the aperture and does not return back through the aperture to the sensor and has been shown to be wavelength dependent. Thus, color-measuring instruments measuring translucent objects with an aperture assign incorrect color coordinates.[39] The phenomenon must be avoided if accurate color measurements of translucent objects, such as teeth and porcelain, are to be obtained, which is done by using a combination of an external light source that does not cause shadowing and a spectroradiometer (Fig. 23-20). CIELAB data measured by this arrangement for three different shade guides and 360 anterior teeth from 120 human subjects[40] are shown in Figure 23-21.

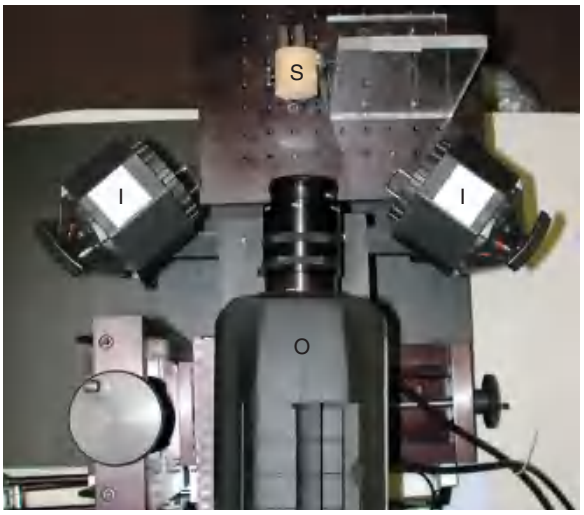


Fig. 23-20
Spectroradiometer (PR 705, PhotoResearch, Inc.) with an optical set-up of 45-degree illumination (I) and 0-degree observer (O) for measurements of a translucent material specimen (S).

Various clinical color-measuring devices are available (Fig. 23-22). They range from simple to complicated, with capabilities and prices to match. The devices are generally one of three types: colorimeters, spectrophotometers, or digital color analyzers with various measuring geometries (Table 23-3). In vitro testing of some of these devices with various shade tabs have shown them to have reliability of approximately 90%, whereas their accuracy is approximately 70% to 80%.[41,42] Initial clinical testing of some of these instruments shows similar clinical outcomes for visual matching.[43,44]

SHADE-DUPLICATION PHASE

Errors associated with the duplication of the selected shade with dental porcelain are well documented. These errors are related to the underlying metal used,[45,46] the batch of porcelain powder,[47] the brand of porcelain,[6,48] and the number of times glazing was performed.[49] Visually detectable differences between the color of the shade tab and the fired porcelain are not uncommon.[48,50] Surface corrections of these errors include surface characterization, as discussed in Chapter 30. Another strategy that has been used is to include custom shade guides (see Fig. 23-18) in the shade-matching process. The custom shade guide should be from the same metal and porcelain type that will be used when the metal-ceramic crown is fabricated.

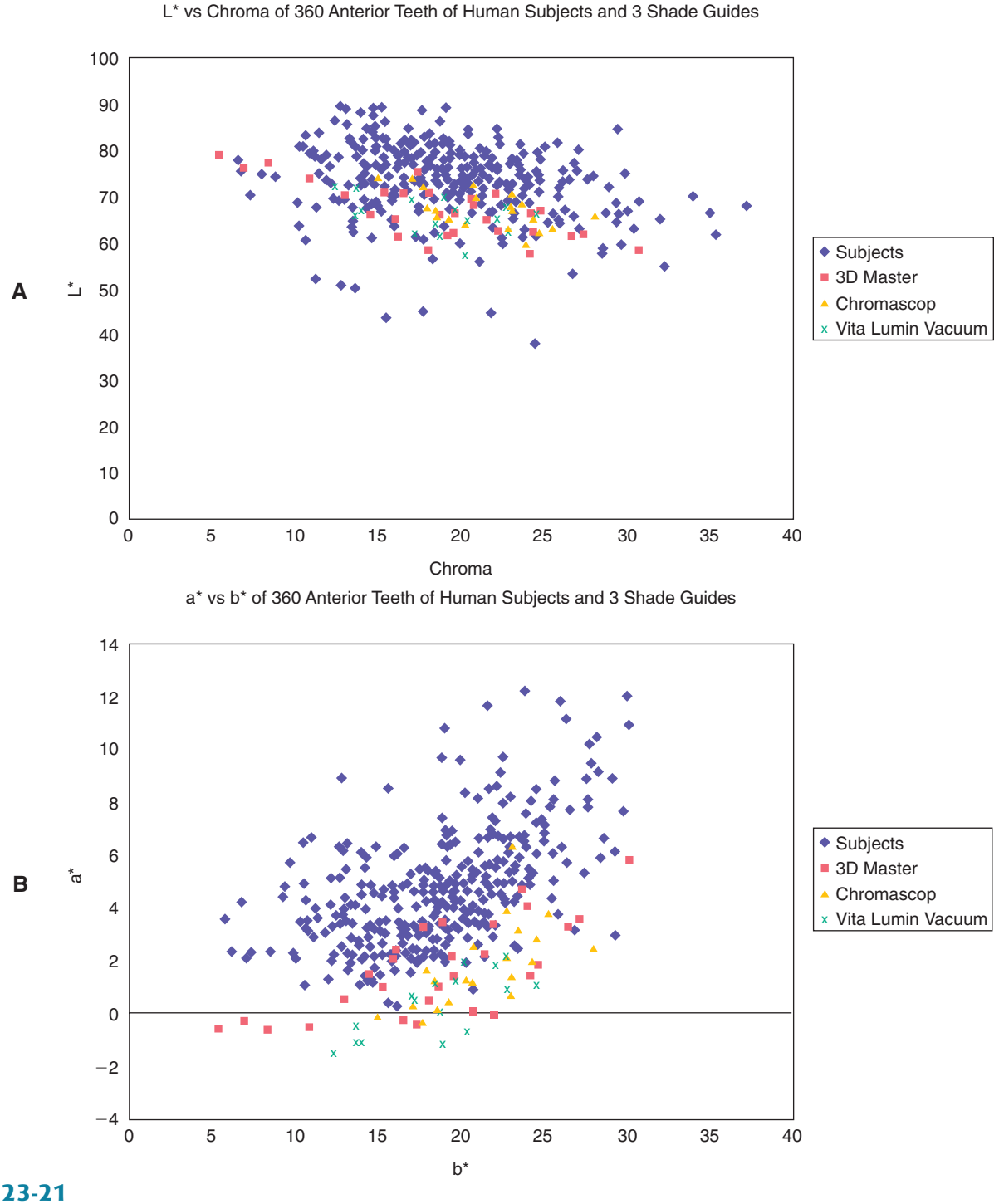


Fig. 23-21
A and **B**, Color of 360 anterior teeth of human subjects and 3 shade guides. **A**, L* versus chroma. **B**, a* versus b*.

ESTHETICS

Esthetics is the study of beauty. Knowledge of esthetics helps the dentist achieve a pleasing appearance or effect. A successful prosthodontic restoration provides the patient with excellent long-term function. It should also produce an attractive smile; esthetics is often the primary motivating factor for patients to seek dental care.[51] In fact, correction of esthetic problems has a positive effect on self-esteem.[52]

Anatomy of a Smile

Most people believe they can recognize an attractive smile, but individual opinion varies, particularly

Table 23-3 CURRENT SHADE-MEASURING DEVICES*

System	Manufacturer	Type	Approximate cost as of February 2006
ShadeEye NCC	Shofu Dental Corporation, San Marcos, California	Colorimeter	$5500
EasyShade	Vident, Brea, California	Spectrophotometer	$3000
ShadeScan	Cynovad, Inc., Montreal, Quebec, Canada	Digital color imaging/ colorimeter	$3500
ShadeVision	X-Rite, Inc., Grand Rapids, Michigan	Digital color imaging/ colorimeter	$5500
SpectroShade	MHT, Niederhasli, Switzerland	Digital color imaging/ spectrophotometer	$10,000
ClearMatch	Smart Technology, Hood River, Oregon	Software only (to be used with digital camera)	$3000

*Data from Brewer JD, et al: Advances in color matching. Dent Clin North Am 48:341, 2004.

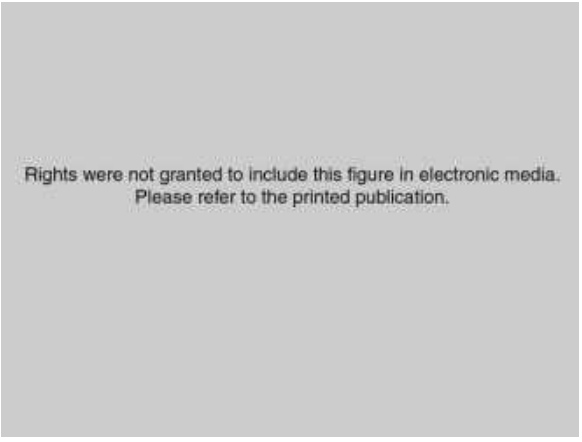


Fig. 23-22
Use of the ShadeScan (Cynovad, Inc.) to record the color map of a patient's anterior incisor. *(Courtesy of Cynovad, Inc., Montreal, Quebec, Canada.)*

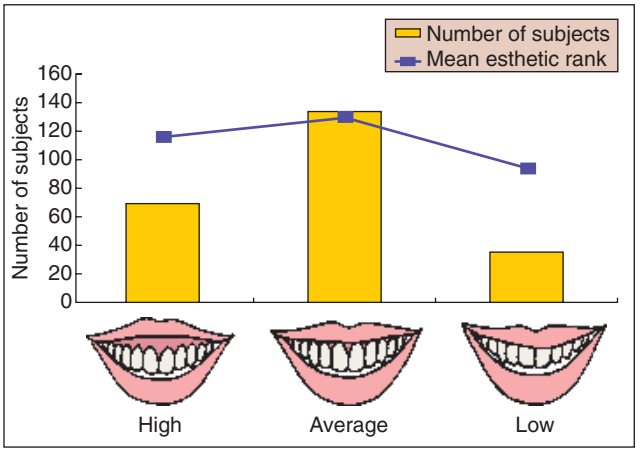


Fig. 23-23
Number of subjects and mean esthetic rank for three upper lip positions. *(From Dong JK, et al: The esthetics of the smile: a review of some recent studies. Int J Prosthodont 12:9, 1999.)*

when cultural factors are considered. Research is conducted by showing test subjects photographs or computer-manipulated images of various smiles and having subjects grade the images for attractiveness[53,54] (Fig. 23-23).* Such research is quantified in the standard dental (a)esthetic index (DAI), an orthodontic treatment need index based on perceptions of dental esthetics in the United States.[55] In general, an extensive smile that showed the complete outline of the maxillary anterior teeth and teeth posterior to the first molar was considered the most attractive and youthful (Fig. 23-24). (A smile in an aging individual shows less of the maxillary incisors and more of the mandibular incisors.)

*See also www.dent.ohio-state.edu/restsurvey/appearance/.

The "buccal corridor" refers to the amount of space between the cheeks and teeth in a smile and is related to the width of the dentition and the width of the mouth during a smile[56] (Fig. 23-25). The "smile arc" refers to the relative curvature of incisal edges of the maxillary teeth and the curvature of the lower lip. In smiles that were considered the most attractive, these curvatures were very similar,[57] a factor that should be considered when restorations are shaped.

Proportion

Esthetics depends largely on proportion. An object is considered beautiful if it is properly proportioned and unattractive if it is top-heavy, squat, or out of proportion. Concepts of proportion are probably based on what is found in nature. Leaves, flowers, shells,



Fig. 23-24

A to G, Computer image manipulation was used to determine the attractiveness of various smiles. Light colors and oval-shaped teeth in women and rectangular teeth in men were considered the most attractive. *(From Carlsson GE, et al: An international comparative multicenter study of assessment of dental appearance using computer-aided image manipulation. Int J Prosthodont 11:246, 1998.)*



Fig. 23-25

Computer imaging illustrating variations in buccal corridor and smile arc. Acc, Accentuated. *(Courtesy of Dr. Jay Parekh.)*

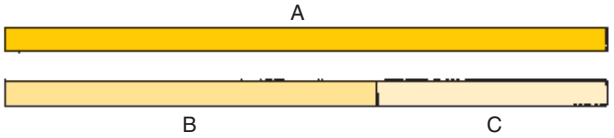


Fig. 23-26
The golden proportion. The ratio of *A* to *B* (1.618 to 1) is the same as that of *B* to *C*.



Fig. 23-27
The calipers always extend to the golden proportion.



Fig. 23-28
Computer-simulated smiles. **A,** The anterior teeth are manipulated to give average proportion values. The lateral incisors are 66% the width of the centrals and the canines are 84% the width of the lateral incisors. **B,** These anterior teeth have been manipulated to the golden proportion. The lateral incisors are 62% the width of the central incisors, and the canines are 62% the width of the lateral incisors. Only 8% of general public respondents preferred or much preferred the golden proportion image in an internet survey. *(From Rosenstiel SF, Rashid RG: Public preferences for anterior tooth variations: a web-based study. J Esthet Restor Dent 14:97, 2002.)*

and pine cones normally develop in proportion. Their growth is closely related to a mathematical progression (called the *Fibonacci* series*) in which each number is the sum of the two immediately preceding it (i.e., 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, and so on). The ratio between succeeding terms converges on approximately 1.618 to 1, known as *the golden proportion.* When a line is bisected in the golden proportion, the ratio of the smaller section to the larger section is the same as the ratio of the larger section to the whole line (Fig. 23-26). The golden proportion was used extensively in ancient Greek architecture and is exemplified in the Parthenon.

Claims have been made[58] that the golden proportion exists in natural dentitions in the ratio of the widths of incisors and canines as seen from the front. Waxing guides, grids, or special calipers† that always extend to the golden proportion can be used, which may be helpful in designing a well-proportioned prosthesis (Fig. 23-27). However, studies of simulated smiles (Fig. 23-28) have revealed that designing prostheses to match the golden proportion is by no means optimal, except for patients in whom incisor length may be increased after periodontal disease.[59,60] Other investigators have attempted to apply mathematical concepts to dental esthetics.[61]

*After Leonardo Fibonacci, c. 1170–c. 1250, Italian mathematician, who devised it in the 13th century.
†Panadent Corporation, Grand Terrace, California.

Of particular importance to anterior tooth esthetics appears to be the height/width ratio of the maxillary incisors. When dentists were asked to select the most attractive smile, they consistently chose the image with maxillary incisor height/width ratio closest to a 75% to 78% range (Fig. 23-29).[59,62]

Balance

Balance, including the location of the midline (Fig. 23-30), is an important prosthodontic concept.[63] The observer expects the left and right sides of the mouth to balance out, if not to match precisely. An obvious restoration on one side may be balanced if there is a diastema or a large tooth on the other side. If something is out of balance, the brain infers that there is an unreciprocated force and the



Fig. 23-29
Computer-simulated smiles with different central incisor height/width ratios. A, 89%; B, 85%; C, 77%; D, 73%. C was chosen as best by 65% of dentists responding, followed in popularity by B, D, and A. *(From Rosenstiel SF, et al: Dentists' perception of anterior esthetics: a web-based survey [Abstract no. 1481]. J Dent Res 83 [Special Issue A], 2004.)*



Fig. 23-30
Poor esthetics resulting from a lack of balance. The differences in central incisor and canine heights and misaligned midline contribute to lack of symmetry.

arrangement is unstable; a balanced arrangement implies stability and permanence.

Midline

Coincidence of facial and incisal midlines is stressed when orthodontic treatment planning is assessed and should be carefully evaluated in the planning of prosthodontic treatment. Studies have shown that the mean threshold for acceptable dental midline deviation is 2.2+/–1.5 mm[64] and that there was no difference in the perception of midline discrepancies between orthodontists and young laypeople; differences in this perception increased with the size of the discrepancy but not by gender.[60,65]

Incisal Embrasure Form

The shape of incisal embrasures can have a dramatic effect on dental esthetics (Fig. 23-31). Increased embrasure form is seen in the young dentition, and a restoration with unnaturally reduced embrasures can appear unattractive. However, some patients demand reduced embrasures, seeking "perfectly" even incisal edges, although this appearance was "preferred" or "strongly preferred" by fewer than 30% of respondents to an internet survey.[60] As with all aspects of personal esthetics, the patient's opinion is paramount; the dentist provides expert knowledge. A sensible approach to achieving optimal incisal embrasure form when restoring with multiple ceramic restorations is to designate that the restorations be returned from the dental laboratory with reduced embrasure form. During the evaluation procedure, the embrasures can be carefully increased intraorally according to the patient's wishes.

Incisor Angulation

The mesial or distal angulation of the maxillary incisor teeth can have a dramatic effect on esthetics (Fig. 23-32). In general, slight mesial angulation

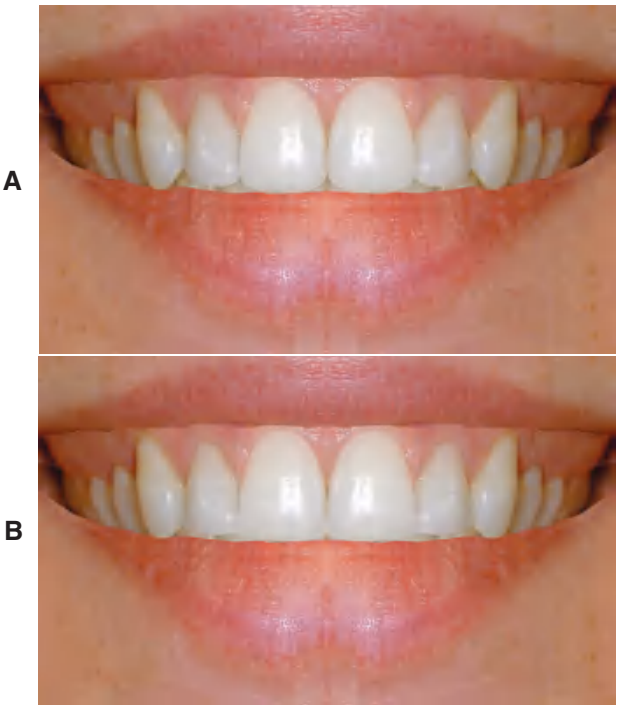


Fig. 23-31
Computer-simulated smiles used to evaluate the response to incisal embrasure form. A, Natural embrasures. B, Reduced embrasures. In an internet survey with 1934 responses, A was much preferred by 25% and preferred by 36%, and B was much preferred by 9% and preferred by 19%. Ten percent expressed no preference. *(From Rosenstiel SF, Rashid RG Public preferences for anterior tooth variations: a web-based study. J Esthet Restor Dent 14:97, 2002.)*



Fig. 23-32
Computer-simulated images used to evaluate the effect of incisor angulation on anterior esthetics. Three-degree distal inclination of the central incisor (A) is preferred to 3-degree mesial inclination (B). Three-degree distal inclination of the lateral incisor (C) is preferred to 3-degree mesial inclination (D). *(From Rosenstiel SF, et al: Dentists' perception of anterior esthetics: a web-based survey [Abstract no. 1481]. J Dent Res 83 [Special Issue A], 2004.)*

STUDY QUESTIONS

1. Discuss the relationship of the visible spectrum to the electromagnetic energy spectrum, color, and invisible waves.
2. What is the Munsell color order system? Define the individual measures used.
3. What is the CIELAB color system? Define the individual measures used.
4. How does the human eye function? How does it recognize color, light, and dark?
5. What is metamerism? How can it be avoided or minimized? What is color adaptation? Color blindness? Fluorescence? The Benham disk is an example of which phenomenon?
6. How should a shade be selected?
7. Explain the differences between the Vita Lumin vacuum and the Vita 3D Master shade guides.

is acceptable, but distal angulation should be avoided.[62] Knowledge of these principles and attention to detail in designing anterior restorations is the key to highly esthetic restorations.

SUMMARY

An understanding of the science of color and color perception is crucial for success in the ever-expanding field of esthetic restorative dentistry. Although limitations in materials and techniques may make a perfect color match impossible, a harmonious restoration can almost always be achieved. Shade matching should be approached in a methodical and organized manner. This enables the practitioner to make the best choice and communicate it accurately to the laboratory. Newly developed shade systems and instruments may help the practitioner achieve a reliable restoration match. The size and shape of restorations are equally important when a highly esthetic result is sought. Knowledge of the optimal proportion and the relative position of the teeth to each other and the soft tissues is essential.

GLOSSARY*

ach·ro·mat·ic \ăk′ra-măt′ĭk\ *adj* (1766) **1:** lacking in hue and saturation, therefore falling into a series of colors that varies only in lightness or brightness **2:** possessing no hue; being or involving black, gray or white

achromatopsia \ā-krō′ma-tŏp′zhē-a\ *n* **1:** monochromatism **2:** a type of monochromatism in which all colors are perceived as achromatic, called also *achromatism, total color perception deficiency*

additive color mixture \ăd′ ĭ-tĭv kŭl′ur mĭks′chur**:** the perceived color that results when the same area of the retina of the eye is illuminated by lights of different spectral distribution such as by two colored lights–*comp* SUBTRACTIVE COLOR SYSTEM

af·ter·im·age \ăf′ter ĭm′ĭj\ *n* (1874)**:** in visual acuity, a prolongation or renewal of a visual sensory experience, ascribable to residual excitation after external stimuli have ceased to operate

angle of incidence \ăng′gl ŭv ĭn′sĭ-dens**:** the angle formed between the axis of a light beam and a perpendicular to the object's surface

angle of reflection \ăng′gl ŭv rĭ-flĕk′shun**:** the angle formed between the axis of a reflected light beam and a perpendicular to the object's surface

anomalous trichromatic vision \a-nŏm′a-lus trī′krō-măt′ĭk vĭzh′un**:** a form of defective color vision in which three stimuli are required for color matching, but the proportions in which they are matched differ significantly from those required by the normal trichromat. There are three forms of anomalous trichromatic vision: protanomalous, deuteranomalous, and tritanomalous

Bezold-Brucke effect [Helmholtz, 1867]**:** the apparent change in hue that accompanies a change in luminance

can·dle \kăn′dl\ *n* (12c)**:** a unit of luminous intensity, equal to 1/60 of the luminous intensity of a square centimeter of a black body heated to the temperature of the solidification of platinum (1773° C)

candle power \kăn′dl pou′er**:** luminous intensity expressed in candles

[1]ce·ram·ic \sa-răm′ik\ *adj* (1850)**:** of or relating to the manufacture of any product made essentially from a nonmetallic mineral (as clay) by firing at a high temperature

chroma \krō′ma\ *n* (1889) **1:** the purity of a color, or its departure from white or gray **2:** the intensity of a distinctive hue; saturation of a hue **3:** chrome describes the strength or saturation of the hue (color)–see also SATURATION

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Munsell AH. A color notation. Baltimore: Munsell Color Co. Inc. 1975:14–7.

chromatic stimulus \krō-măt′ik stĭm′ya-lus\: a stimulus that under prevailing conditions of adaptation gives rise to a perceived chromatic color

chromaticity coordinates \krō′ma-tĭs′ĭ-tē kō-ôr′dĭ-nĭtz\: the two dimensions of any color order system that exclude the lightness dimension and describe the chromaticity. Unless otherwise specified, the term refers to the CIE coordinates x, y, and z for Illuminant C and 2 degrees (1931) Standard Observer—called also *color coordinates*

chromaticity diagram \krō′ma-tĭs′ĭ-tē dī′a-grăm\: a plane diagram in which each point represents a different combination of dominant wavelength and purity and which is usually constructed in some form of a triangle with calorimetric primaries represented at the corners. The CIE standard chromaticity diagram is essentially a right angle triangle representing hypothetical primaries and the complete chromaticity gamut of the CIE standard observer

chro·mat·ic·ness \krō′măt′ĭk-nĕs\ *n*: the intensity of hue as expressed in the Natural Color System

chro·ma·top·sia \krō′ma-tŏp′zha\ *n*: an abnormal state of vision in which colorless objects appear colored; a visual defect in which colored objects appear unnaturally colored and colorless objects appear color tinged

CIE LAB system \C I E Lăb sĭs′tem\: CIE LAB relates the tristimulus values to a color space. This scale accounts for the illuminant and the observer. By establishing a uniform color scale, color measurements can be compared and movements in color space defined

CIE standard illuminant \C I E stăn′dard ĭ-lōō′ma-nent\: the illuminants A, B. C, D_{65} and other illuminants, defined by the CIE in terms of relative spectral power distributions; A = Planckion radiation (a theoretical body that absorbs all incident optical radiant energy) a temperature of about 2856° K; B = Direct solar radiation 48,000° K; C = Average daylight; D_{65} = Daylight including the ultraviolet region: 6500° K

collarless metal ceramic restoration \kŏl′er-lĕs mĕ′l sa-răm′ĭk rĕs′ta-rā′shun\: a metal ceramic restoration whose cervical metal portion has been eliminated. Porcelain is placed directly in contact with the prepared finish line

col·or \kŭl′or\ *n* (13c) **1:** a phenomenon of light or visual perception that enables one to differentiate otherwise identical objects **2:** the quality of an object or substance with respect to light reflected or transmitted by it. Color is usually determined visually by measurement of hue, saturation, and luminous reflectance of the reflected light **3:** a visual response to light consisting of the three dimensions of hue, value, and saturation—see PERCEIVED C., PSYCHOPHYSICAL C.

color blindness \kŭl′or blīnd′nĭs\: abnormal color vision or the inability to discriminate certain colors, most commonly along the red-green axis

color constancy \kŭl′or kŏn′stan-sē\: relative independence of perceived color to changes in color of the light source

color deficiency \kŭl′or dĭ-fĭsh′en-sē\: a general term for all forms of color vision that yield chromaticity discrimination below normal limits, such as monochromatism, dichromatism, and anomalous trichromatism

color difference \kŭl′or dĭf′er-ens\: magnitude and character of the difference between two colors under specified conditions; referred to as delta E

color rendering index \kŭl′or rĕn′der-ing ĭn′dĕks\: a number from 1 to 100 given to a light source to indicate its relative equivalence to pure white light which has a color rendering index (CRI) of 100. The closer the number is to 100, the more it resembles pure white light

color standard \kŭl′or stăn′dard\: a color whose psychophysical dimensions have been accurately measured and specified

color stimulus \kŭl′or stĭm′yu-lus\: visible radiation entering the eye and producing a sensation of color, either chromatic or achromatic

color temperature \kŭl′or tĕm′per-a-chōōr′, tĕm′pra-\: the temperature in degrees Kelvin (Celsius plus 273°) of a totally absorbing or black body (object) that produces colors as the temperature changes. The range is from a dull red to yellow to white to blue. This term is sometimes used incorrectly to describe the color of "white" light sources. The correct term to describe the color of light sources is correlated color temperature

col·or·im·e·ter \kŭl′a-rĭm′ĭ-ter\ *n* (ca. 1863): a device that analyzes color by measuring it in terms of a standard color, scale of colors, or certain primary colors; an instrument used to measure light reflected or transmitted by a specimen

complementary colors \kom′pla-mĕn′ta-rē, -trē kŭl′orz\: **1:** two colors that, when mixed together in proper proportions, result in a neutral color. Colored lights that are complementary when mixed in an additive manner form white light and follow the laws of additive color mixture. Colorants that are complementary when mixed together form black or gray and follow the laws of subtractive colorant mixture **2:** colors located in directly opposite positions on the color wheel. Colorants that are

complementary when mixed together form black or gray and follow the laws of subtractive color

cone \kōn\ *n* (1562)**:** one of the receptors of color vision found in the retinal layer of the eye and concentrated in the macula lutea

continuous spectrum \kon-tĭn′yōō-us spĕk′trum**:** a spectrum or section of the spectrum in which radiations of all wavelengths are present; opposed to line spectra or band spectra

correlated color temperature \kôr′a-lā′tid kŭl′er tĕm′per-a-chōōr**:** the term describing the color of white light sources. Specifically, it is the temperature of the Planckion (black body) radiator that produces the chromaticity most similar to that produced by the light source expressed in degrees Kelvin or in mired; it is measured in degrees Kelvin, to which a black body must be raised to provide the closest match, in chromaticity, to a particular light source

delta E \dĕl′ta Ē**:** total color difference computed by use of a color difference equation. It is generally calculated as the square root of the sums of the squares of the chromaticity difference and the lightness difference. It signifies the difference between sample and standard

deuteranomalous vision \dōō′ter-a-nŏm′a-lus, dyōō′-ter-a-nŏm′a-lus vĭzh′on**:** a form of anomalous trichromatism in which the viewer requires more green in a mixture of red and green to match spectral yellow than does a normal trichromat. The relative spectral visual sensitivity does not differ noticeably from normal. Hue discrimination is poor in the red to green region of the spectrum

dichromatic vision \dī′krō-măt′ĭk vĭzh′en**:** defective color vision characterized by the interpretation of wavelengths from the red portion of the spectrum matching a given green. There are two known sub classifications. One requires red light to be approximately 10 times brighter than the red selected by the other to achieve a similar color mismatch

dimensions of color \dĭ-mĕn′shunz ŭv kŭl′er**:** terms used to describe the three dimensional nature of color. In the Munsell Color Order System, the dimensions are named hue, value, and chroma. These are used to describe the color family (hue), the lightness/darkness (value), and the purity or strength (chroma)

electromagnetic spectrum \ĭ-lĕk′trō-măg-nĕt′ĭk spĕk′trŭm**:** the range of energy waves that extend from gamma rays to radio waves. The eye is sensitive to a very narrow band of wavelengths between about 380 and 760 nm

esthetic reshaping \ĕs-thĕt′ĭk rē-shāp′ĭng**:** the physical modification of the surfaces of teeth to improve appearance

es·thet·ics \ĕs-thĕt′ĭks\ *adj* (1798) **1:** the branch of philosophy dealing with beauty **2:** in dentistry, the theory and philosophy that deal with beauty and the beautiful, especially with respect to the appearance of a dental restoration, as achieved through its form and/or color. Those subjective and objective elements and principles underlying the beauty and attractiveness of an object, design or principle—see DENTAL E., DENTURE E.—**aes·thet·i·cal·ly** *adj*

flu·o·res·cence \flŏŏ-rĕs′ens\ *n* (1852)**:** a process by which a material absorbs radiant energy and emits it in the form of radiant energy of a different wavelength band, all or most of whose wavelengths exceed that of the absorbed energy. Fluorescence, as distinguished from phosphorescence, does not persist for an appreciable time after the termination of the excitation process

hue \hyōō\ *n* (bef. 12c)**:** often referred to as the basic color, hue is the quality of sensation according to which an observer is aware of the varying wavelengths of radiant energy. The dimension of color dictated by the wavelength of the stimulus that is used to distinguish one family of color from another—as red, green, blue, etc. The attribute of color by means of which a color is perceived to be red, yellow, green, blue, purple, etc. White, black, and grays possess no hue

Munsell AH. A color notation. Baltimore**:** Munsell Color Co. Inc, 1975:14-6.

il·lum·inant \ĭ-lōō′ma-nant\ *adj* (15c)**:** mathematical description of the relative spectral power distribution of a real or imaginary light source, that is, the relative energy emitted by a source at each wave length in its emission spectrum—see CIE STANDARD ILLUMINANT

invariant color match \ĭn-vâr′ē-ant kŭl′ar măch**:** a perfect color match under all light conditions

ir·i·des·cent \ĭr′ĭ-dĕs′ant\ *adj* (1796)**:** colors produced by interference, refraction, or diffraction

Kelvin temperature [Thomson W. (Lord Kelvin), Scottish mathematician and physicist (1824-1907)]**:** absolute temperature indicated by the symbol K. Zero Kelvin = 273° C

light \līt\ *n* (bef. 12c)**:** the aspect of electromagnetic radiation of which the human observer is aware through the visual sensations that arise from the stimulation of the retina of the eye

light source \līt sors**:** an object that emits light or radiant energy to which the human eye is sensitive. The emission of a light source can be described by the relative amount of energy, emitted at each wavelength in the visible spectrum; the emission may be described in terms of its correlated color temperature

light·ness \līt′nĭs\ *n* (bef. 12c) **1:** achromatic dimension necessary to describe the three-dimensional nature of color, the others being hue and saturation. The lightness dimension may also be called brightness. In the Munsell Color Order System, the lightness dimension is called value **2:** perception by which white objects are distinguished from gray and light objects from dark ones; equivalent to shading in grays

lim·bus \lĭm′bas**:** a border or interface especially if marked by a difference in color or structure between adjoining parts

met·a·mer \mĕt′a-mer′\ *n***:** one of a pair of objects whose colors match when viewed in a described way but do not match under all viewing conditions

metameric pair \mĕt′a-mer′ik pâr**:** a pair of objects whose colors match when viewed in a described way, but which do not match if the viewing conditions are changed. Thus a metameric pair of samples exhibit the same tri-stimulus values for a described set of viewing conditions (observer, light source, geometry of the illumination and viewing arrangement) but have different spectral distributions. Hence, they exhibit a match that is conditional

me·tam·er·ism \ma-tăm′a-rĭz′um\ *n.* (1877)**:** pairs of objects that have different spectral curves but appear to match when viewed in a given hue exhibit metamerism. Metamerism should not be confused with the term's *flair* or *color constancy,* which apply to apparent color change exhibited by a single color when the spectral distribution of the light source is changed or when the angle of illumination or viewing is changed

monochromatic vision \mŏn′a-krō-măt′ĭk vĭsh′an**:** vision in which there is no color discrimination

Munsell chrome [Alfred H. Munsell, Massachusetts, U.S. artist and teacher, 1858-1918]**:** *eponym* for the Munsell color system chrome, which is that quality by which a strong color is distinguished from one that is weak. The departure of a color sensation from that of white or gray; the intensity of a distinctive hue color intensity—see also SATURATION

Munsell color order system [Alfred H. Munsell, Massachusetts, U.S. artist and teacher, 1858-1918]**:** *eponym* for a color order system; developed in 1905, it places colors in an orderly arrangement encompassing the three attributes of hue, value, and chrome

Munsell AH. A color notation. Baltimore: Munsell Color Co., 1975:14-6.

Munsell hue [Alfred H. Munsell, Massachusetts, U.S. artist and teacher, 1858-1918]**:** *eponym* for that quality by which one color family is distinguished from another, as red from yellow, and green from blue or purple. The dimension of color determined by wavelength

Munsell value [Alfred H. Munsell, Massachusetts, U.S. artist and teacher, 1858-1918]**:** *eponym* for the relative brightness of a color. The quality of grayness in comparison to white (high value) and black, (low value); in the Munsell color system, the value of a color is determined by which gray on the value scale it matches in lightness/darkness (black is assigned a value of zero; white a value of 10)

natural color system \năch′ar-al, năch′ral kul′ar sĭs′tam**:** a color order system derived by Anders Hard that defines six color perceptions using the concept of percentage for localizing nuances within the three part system. The six perceptions are white, black, red, green, yellow, and blue. The dimensions of hue, blackness or whiteness, and chrome are used to relate colors within this system

partitive color mixing \pär′tĭ-tĭv**:** color mixing in which both additive and subtractive principles are involved. The eye interprets tiny dots of subtractive color too small to be individually resolved at the viewing distance. The resultant color will be the average of the colors used

perceived color \par-sēvd′ kŭl′ar**:** attribute of visual perception that can be described by color names: white, gray, black, yellow, orange, brown, red, green, blue, purple, etc., or by a combination of names

phos·phor·es·cence \fŏs′fa-rĕs′ans\ *n* (1796)**:** a form of photoluminescence based on the properties of certain molecules to absorb energy (either near ultra violet or visible), and emit it in the form of visible radiation at a higher wavelength. Distinguished from fluorescence in that light continues to be emitted for some time after the exciting energy has ceased—see FLUORESCENCE, LUMINANCE

pho·tom·et·er \fō-tŏm′ĭ-ter\ *n* (1884)**:** an instrument for the measurement of emitted, reflected, or transmitted light. For the measurement of luminous intensity, a visual receptor element (the eye) may be used in the measuring device or a physical receptor element may be used that can be related to the calculated response of a standard observer—see PHYSICAL P., VISUAL P.

pho·ton \fō′tŏn\ *n* (ca. 1922)**:** a massless particle, the quantum of the electromagnetic field, carrying energy, momentum, and angular momentum—called also *light quantum*

photopic vision \fō-tŏp′ĭk vĭzh′an**:** vision as it occurs under illumination sufficient to permit the full discrimination of colors. It is the function of the retinal cones and is not dependent on the retinal rods—called also daylight vision as contrasted with twilight or scotopic vision

photoreceptor process \fō′tō-rĭ-sĕp′tar prŏs′ĕs′, prō′sĕs′\: that specific process that is set in motion in a visual sensory end organ or other photic receptor by the incidence of its adequate stimulus, i.e., light

primary colors \prī′mĕr′ē, -ma-rē kŭl′erz\: three basic colors used to make most other colors by mixture, either additive mixture of lights or subtractive mixture of colorants

primary colors additive \prī′mĕr′ē, -ma-rē kŭl′erz ăd′ĭ-tĭv\: three colored lights from which all other colors can be matched by additive mixture. The three must be selected so that no one of them can be matched by mixture of the other two. Generally, red, green, and blue are used. Additive primaries are the complements of the subtractive primaries

protonomalous vision \prō′ta-nŏm′a-lŭs vĭzh′un\: a form of color deficient vision in which the ability to perceive blue and yellow is retained. Hue discrimination is poor in the red to green region of the spectrum

pseudoisochromatic color tests \sōō′dō-ī′sa-krō-măt′ĭk kŭ′lar tĕsts\: tests for detecting color vision deficiency. The charts are made up of colored spots that yield a legible pattern (number, letter, figure, etc.,) for a normal observer but yield no legible pattern for observers with anomalous types of color vision

psychophysical color \sī′kō-fĭz′ĭ-kal kŭ′lar\: a specification of color stimulus in terms of operationally defined values, such as three tri-stimulus values

re·flec·tance \rĭ-flĕk′tans\ *n* (1926): the ratio of the intensity of reflected radiant flux to that of the incident flux. In popular usage, it is considered as the ratio of the intensity of reflected radiant flux to that reflected from a defined reference standard. Specular reflection is the angle of reflection equal to the angle of incidence. Surface reflection is associated with objects having optically smooth surfaces. These objects are usually termed *glossy*

re·frac·tion \rĭ-frăk′shun\ *n* (1603): the deflection of light or energy waves from a straight path that occurs when passing obliquely from one medium into another in which its velocity is different

re·frac·tory \rĭ-frăk′ta-rē\ *adj* (1606): difficult to fuse or corrode; capable of enduring high temperatures

rod \rŏd\ *n* (bef. 12th cent.): the photoreceptor in the retina that contains a light-sensitive pigment capable of initiating the process of scotopic vision, i.e., low intensity for achromatic sensations only

sat·u·ra·tion \săch′a-rā′shun\ *n* (1554): the attribute of color perception that expresses the degree of departure from gray of the same lightness. All grays have zero saturation

scotopic vision \ska-tō′pĭk vĭ′shun\: vision that occurs in faint light or dark adaptation and is attributable to the retinal rods. The maximum of the relative spectral visual sensitivity is shifted to 510 nm and the spectrum is seen uncolored

shade \shād\ *n* **1:** a term used to describe a particular hue, or variation of a primary hue, such as a greenish shade of yellow **2:** a term used to describe a mixture with black (or gray) as opposed to a tint that is a mixture with white—see TOOTH COLOR SELECTION

spectral reflection \spĕk′tral rĭ-flĕk′shun\: reflection in which the angle of reflection is equal to the angle of incidence. Associated with objects having optically smooth (glossy) surfaces—called also *mirrored reflection*

spec·tro·pho·tom·e·ter \spĕk′trō-fō-tŏm′ĭ-tar\ *n*: photometry device for the measurement of spectral transmissions, reflectance, or relative emissions. Spectrophotometers are normally equipped with dispersion optics (prism or grating) to give a continuous spectral curve

spec·trum \spĕk′trum\ *n* **1:** band of colors produced when sunlight is passed through a prism **2:** spatial arrangements of components of radiant energy in order of their wavelengths, wave numbers, or frequency—**spec·tral** *adj*

standard illuminant \stăn′dard ĭ-lōō′ma-nant\: the illuminants A, B. C, D (and others) defined by the CIE in terms of their relative power distribution curves. “A” is an illuminant with a Planckion temperature of approximately 2854°K. It is intended to represent a common tungsten filament source. “B” approximates solar radiation—4870°K—and is obsolete. “C” is average daylight, 6740°K. “D” is daylight with the near ultraviolet source included

standard light source \stăn′dard līt sôrs, sōrs\: a reference light source whose spectral power distribution is known

standard of care: the level of care that reasonably prudent healthcare providers in the same or a similar locality would provide under similar circumstances

subtractive color system \sub-trăk′tĭv kŭ′lar sĭs′tum\: the system whereby light is removed by filtration or absorption from a white source. The primary colors of the subtractive system are magenta, cyan, and yellow—called also *pigment mixture color system*

subtractive primary colors \sub-trăk′tĭv prī′mĕr′ē, -ma-rē\: the primary colorant substances for pigment and filtering mixtures typically evoking responses of cyan (blue-green), magenta (red-blue), and yellow (red-green). The complementary colors of the subtractive primary colors are red, green, and blue. Magenta is a mixture of red and blue and is the complement of green. Cyan is a

mixture of blue and green and is the complement of red. Yellow is a mixture of red and green and is the complement of blue

trichromatic system \trī-krō-măt′ĭk sĭs′tam\: a system for specifying color stimuli in terms of the tri-stimulus value based on matching colors by additive mixtures of three primary colored lights

tri·chro·ma·tism \trī-krō′ma-tĭz′um\ *n*: a type of vision in which the colors seen require, in general, three independently adjustable primaries (such as red, green, and blue) for their duplication by mixture; trichromatism may be either anomalous trichromatism or normal vision

tri-stimulus value \trī-stĭm′ya-lus văl′yōō\: (R, G, B: X, Y, Z, etc.) Amounts of the three reference color stimuli, in a given trichromatic system, required to match the color of the stimulus considered

tri·ta·no·pia \trī-tă′nō-pē′a\ *n*: form of dichromatism in which reddish blue and greenish yellow stimuli are confused. Tritanopia is a common result of retinal disease but may be inherited—called also *blue blindness, hence tritanope*

ul·tra·vi·o·let \ŭl′tra-vī′a-lĭt\: radiant energy of wavelengths shorter than extreme violet and lying beyond the ordinarily visible spectrum. Usually assigned to wavelengths shorter than 380 nm

uniform color space \yōō′na-fôrm kŭl′ar spās\: color space in which equal distances are intended to represent threshold or above threshold perceived color differences of equal size

val·ue \văl′yōō\ *n* (14c): the quality by which a light color is distinguished from a dark color, the dimension of a color that denotes relative blackness or whiteness (grayness, brightness). Value is the only dimension of color that may exist alone—see MUNSELL VALUE

Munsell, AH. A color notation. Baltimore: Munsell Color Co., 1975:14–7.

visible spectrum \vĭz′a-bal spĕk′trum\: the section of the electromagnetic spectrum that is visible to the human eye. It ranges from 380 nm to 760 nm

visual adaptation \vĭzh′ōō-al ăd′ăp-tā′shun\: adjustive change in visual sensitivity due to continued visual stimulation or lack of stimulation. Three recognized types are: 1) *scotopic* or dark adaptation 2) *photopic* or light adaptation 3) *chromatic* or color adaptation

wave length \wāv lĕngkth\: the distance at any instant between two adjacent crests (or identical phases) of two series of waves that are advancing through a uniform medium. The wavelength varies inversely with the vibration rate or number of waves passing any given point per unit period of time

REFERENCES

1. Munsell AH: A Color Notation, 11th ed. Baltimore, Munsell Color Co., 1961.
2. Sproull RC: Color matching in dentistry, II. Practical applications of the organization of color. J Prosthet Dent 29:556, 1973.
3. Hammad IA, Stein RS: A qualitative study for the bond and color of ceramometals. II. J Prosthet Dent 65:169, 1991
4. Rinke S, et al: Colorimetric analysis as a means of quality control for dental ceramic materials. Eur J Prosthodont Restor Dent 4:105, 1996.
5. Seghi RR, et al: Spectrophotometric analysis of color difference between porcelain systems. J Prosthet Dent 56:35, 1986.
6. Rosenstiel SF, Johnston WM: The effect of manipulative variables on the color of ceramic metal restorations. J Prosthet Dent 60:297, 1988.
7. Okubo SR, et al: Evaluation of visual and instrument shade matching. J Prosthet Dent 80:642, 1998.
8. Wyszecki G, Stiles WS: Color Science: Concepts and Methods, Quantitative Data and Formulae, 2nd ed, p 840. New York, Wiley & Sons, 1982.
9. van der Burgt TP, et al: A comparison of new and conventional methods for quantification of tooth color. J Prosthet Dent 63:155, 1990.
10. Culpepper WD: A comparative study of shade-matching procedures. J Prosthet Dent 24:166, 1970.
11. Geary JL, Kinirons MJ: Colour perception of laboratory-fired samples of body-coloured ceramic. J Dent 27:145, 1999.
12. Saleski CG: Color, light and shade matching. J Prosthet Dent 27:263, 1972.
13. Paravina RD, et al: Color comparison of two shade guides. Int J Prosthodont 15:73, 2002.
14. Romney AK, Indow T: Estimating physical reflectance spectra from human color-matching experiment. Proc Natl Acad Sci U S A 99:14607, 2002.
15. Sproull RC, Preston JD: Understanding color. In Goldstein RE, ed: Esthetics in Dentistry, vol 1, p 207, London, BC Decker, 1998.
16. Bergen SF: Color Education in the Dental Profession. Master's thesis, New York University, 1975.
17. Bergen SF, McCasland J: Dental operatory lighting and tooth color discrimination. J Am Dent Assoc 94:130, 1977.
18. Preston JD, et al: Light and lighting in the dental office. Dent Clin North Am 22:431, 1978.
19. Barna GJ, et al: The influence of selected light intensities on color perception within the color

range of natural teeth. J Prosthet Dent 46:450, 1981.
20. Preston JD, Bergen SF: Color Science and Dental Art. St. Louis, Mosby, 1980.
21. Lemire PA, Burk B: Color in Dentistry. Hartford, CT, JM Ney Co, 1975.
22. Hall GL, Bobrick M: Improved illumination of the dental treatment rooms. SAM-TR-68-103. Tech Rep SAM-TR December:1, 1968.
23. Wyszecki G, Stiles WS: Color Science: Concepts and Methods, Quantitative Data and Formulae, 2nd ed, p. 519. New York, Wiley & Sons, 1982.
24. Land EH: The retinex theory of color vision. Sci Am 237:108, 1977.
25. Wyszecki G, Stiles WS: Color Science: Concepts and Methods, Quantitative Data and Formulae, 2nd ed, p. 236. New York, Wiley & Sons, 1982.
26. Seghi RR, Johnston WM: Estimate of colorimetric measurement errors associated with natural tooth fluorescence [Abstract no. 1578]. J Dent Res 71:303, 1992.
27. Yamamoto M: Newly developed opal ceramic and its clinical use with respect to relative breaking indices. I. Significance of opalescence and development of opal ceramic. Quintessenz Zahntech 1989;15:523.
28. Hegenbarth EA: Opalescence effect in low melting ceramic. Quintessenz Zahntech 17:1415, 1991.
29. Rushton WAH: Visual pigments and color blindness. Sci Am 232:64, 1975.
30. Davidson SP: Shade selection by color vision defective dental personnel. J Prosthet Dent 63:97, 1990.
31. Hall NR: Tooth colour selection: the application of colour science to dental colour matching. Aust Prosthodont J 5:41, 1991.
32. McPhee ER: Light and color in dentistry. I. Nature and perception. J Mich Dent Assoc 60:565, 1978.
33. Ragain JC, Johnston WM: Color acceptance of direct dental restorative materials by human observers. Color Res Appl 25:278, 2000.
34. Wee AG, et al: Color formulation and reproduction of opaque dental ceramic. Dent Mater 21:665, 2005.
35. O'Brien JW, et al: Coverage errors of two shade guides. Int J Prosthodont 4:45, 1991.
36. McLean JW: The Science and Art of Dental Ceramics, vol 2, p 308. Chicago, Quintessence Publishing, 1980.
37. Blackman RB: Ceramic shade prescriptions for work authorizations. J Prosthet Dent 47:28, 1982.
38. Johnston WM, et al: Analysis of edge-losses in reflectance measurements of pigmented maxillofacial elastomer. J Dent Res 75:752, 1996.
39. Bolt RA, et al: Influence of window size in small-window color measurement, particularly of teeth. Phys Med Biol 39:1133, 1994.
40. Gozalo-Diaz DJ: Relationship between the color of teeth, gingiva, lips and skin. Master's thesis, The Ohio State University, 2004.
41. Wee AG: Reliability of the shadescan for three different shade guides [Abstract no. 395]. J Dent Res 83(Special Issue A), 2004.
42. Kim S, et al: Reliablity and accuracy of electronic shade matching instruments [Abstract no. 408]. J Dent Res 84(Special Issue A), 2005.
43. Wee AG, et al: Evaluating porcelain color match of different porcelain shade-matching systems. J Esthet Dent 12:271, 2000.
44. Raigrodski AJ, Chiche GJ: Computerized shade selection in matching anterior metal-ceramic crowns [Abstract no. 395]. J Dent Res 83(Special Issue A), 2004.
45. Brewer JD, et al: Spectrometric analysis of the influence of metal substrates on the color of metal-ceramic restorations. J Dent Res 64:74, 1985.
46. Stavridakis MM, et al: Effect of different high-palladium metal ceramic alloys on the color of opaque porcelain. J Prosthodont 9:71, 2000.
47. O'Brien WJ, et al: Sources of color variation on firing porcelain. Dent Mater 7:170, 1991.
48. Groh CL, et al: Differences in color between fired porcelain and shade guides. Int J Prosthodont 5:510, 1992.
49. Jorgenson MW, Goodkind RJ: Spectrophotometric study of five porcelain shades relative to the dimensions of color, porcelain thickness, and repeated firings. J Prosthet Dent 42:96, 1979.
50. Douglas RD, Przybylska M: Predicting porcelain thickness required for dental shade matches. J Prosthet Dent 82:143, 1999.
51. Elias AC, Sheiham A: The relationship between satisfaction with mouth and number and position of teeth. J Oral Rehabil 25:649, 1998.
52. Davis LG, et al: Psychological effects of aesthetic dental treatment. J Dent 26:547, 1998.
53. Dong JK, et al: The esthetics of the smile: a review of some recent studies. Int J Prosthodont 12:9, 1999.
54. Carlsson GE, et al: An international comparative multicenter study of assessment of dental appearance using computer-aided image manipulation. Int J Prosthodont 11:246, 1998.
55. Proffit WR, Fields HW: Contemporary Orthodontics, 3rd ed. St. Louis, Mosby, 2000.
56. Johnson DK, Smith RJ: Smile esthetics after orthodontic treatment with and without extraction of

four first premolars. Am J Orthod Dentofacial Orthop 108:162, 1995.
57. Sarver DM: The importance of incisor positioning in the esthetic smile: the smile arc. Am J Orthod Dentofacial Orthop 120:98, 2001.
58. Levin EI: Dental esthetics and the golden proportion. J Prosthet Dent 40:244, 1978.
59. Rosenstiel SF, et al: Dentists' preferences of anterior tooth proportion–a web-based study. J Prosthodont 9:123, 2000.
60. Rosenstiel SF, Rashid RG Public preferences for anterior tooth variations: a web-based study. J Esthet Restor Dent 14:97, 2002.
61. Ahmad I: Geometric considerations in anterior dental aesthetics: restorative principles. Pract Periodont Aesthet Dent 10:813, 1998.
62. Rosenstiel SF, et al: Dentists' perception of anterior esthetics. A web-based survey [Abstract no.1481]. J Dent Res 83(Special Issue A), 2004.
63. Lombardi RE: The principles of visual perception and their clinical application to denture esthetics. J Prosthet Dent 29:358, 1973.
64. Beyer JW, Lindauer SJ: Evaluation of dental midline position. Semin Orthodont 4:146, 1998.
65. Johnston CD, et al: The influence of dental to facial midline discrepancies on dental attractiveness ratings. Eur J Orthod 21:517, 1999.

24

METAL-CERAMIC RESTORATIONS



KEY TERMS

bisque bake
ceramic
devitrification
feldspar
firing
frit
glaze
opacity
opaque
pigment
porcelain
quartz
silica
stain
substructure
thermal expansion
translucency
vitrification

HISTORICAL PERSPECTIVE

Ceramic objects have been fabricated for thousands of years. The earliest techniques usually consisted of shaping the item in clay or soil and then baking it to fuse the particles together. The initial attempts resulted primarily in coarse and somewhat porous products, such as goblets and other forms of pottery. Later developments led to very detailed stoneware items. The Egyptian faiences are the first known effort to enamel a **substructure** with a ceramic veneer (Fig. 24-1). Their typical blue-green hues result from metal oxides created during the **firing** process.

More recently, although still in antiquity, Chinese ceramists developed **porcelain,** which was characterized by **vitrification, translucency,** hardness, and impermeability. European attempts at developing porcelain of similar quality were conducted in the 17th century. These efforts spread the knowledge of porcelain's basic components: kaolin and **feldspar.**

As early as the second half of the 18th century, Pierre Fauchard and others attempted to use porcelain in dentistry. Their efforts were largely unsuccessful. However, porcelain was successfully used for dental prostheses by the end of the 1800s, when the technique to fire all-porcelain jacket crowns on a platinum matrix was first developed.[1] It was not until the mid-1950s that a dental porcelain was developed with a coefficient of **thermal expansion** similar to that of dental casting alloys. The metal-ceramic restoration first became available commercially during the later 1950s.[2] Today this technique is considered a routine procedure with high predictability.

OVERVIEW

The metal-ceramic restoration (Fig. 24-2) consists of a metal substructure (see Chapter 19) supporting a ceramic veneer that is mechanically and chemically bonded to it. The chemical component of the bond is achieved through firing (baking).

Porcelain powders of varying composition and color are applied and fired to produce the desired appearance. The first ceramic layer, the **opaque,** masks the dark metal oxide and is the primary



Fig. 24-1
Glazed Egyptian faience tile from the Western Doorway or Gate of the Mortuary Temple of Ramses III, with a "Rekhyet" bird worshipping the cartouche of Ramses III, "Lord of the Two Lands" (ca. 1182-1151 BCE), Dynasty XX, excavated at Medinet Habu by the Oriental Institute. *(Courtesy of the Oriental Institute, The University of Chicago.)*

source of color for the completed restoration. The opaque is covered with slightly translucent body porcelain, which is then veneered with a more translucent enamel overlay that contains only a few **pigments.** Achieving an accurate appearance match may warrant incorporating either translucent or highly pigmented powders into selected areas of the buildup. The shiny, lifelike appearance of the completed metal-ceramic restoration results from a surface **glaze** formed during an additional firing after the restoration has been shaped.

Historically, the metal-ceramic restoration was fabricated with metal margins, and the veneer was limited to visible areas. More recently, however, the use of porcelain on occlusal and lingual surfaces has become common.[3] Several techniques[4,5] have been developed to obtain porcelain margins on the facial aspect of the restoration. The latter technique is common for anterior teeth, whereas the metal collar is commonly used in posterior areas with a lesser esthetic demand.

METAL PREPARATION

Shape

Sharp angles or pits on the veneering surface of a metal-ceramic restoration should be avoided because they can contribute to internal stress in the final porcelain.[6] Convex surfaces and rounded contours should be created so that the porcelain is supported without development of stress concentrations

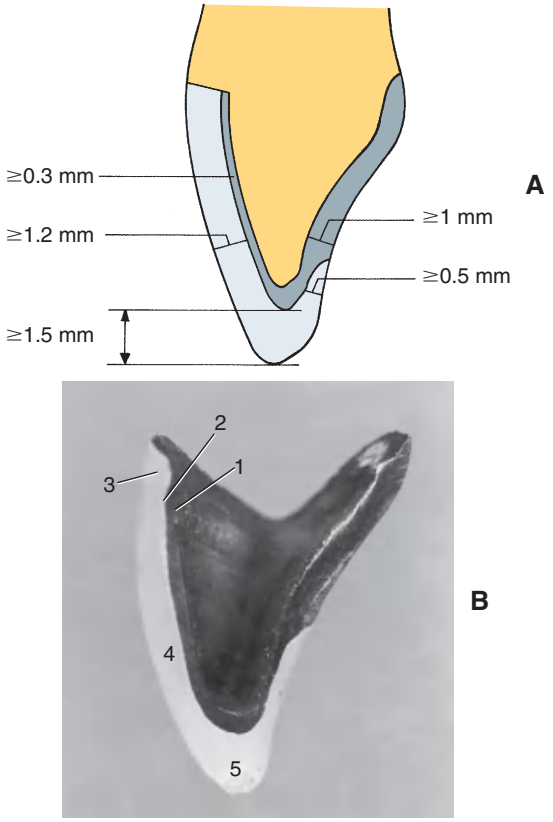


Fig. 24-2
A, Longitudinal section through a metal-ceramic crown. Note the minimum dimensions. **B,** Sectioned metal-ceramic restoration. *1,* Metal substructure; *2,* opaque porcelain; *3,* gingival porcelain; *4,* body porcelain; *5,* incisal porcelain.

(Fig. 24-3). In addition, a smooth surface facilitates wetting of the framework by the porcelain slurry.

The intended metal-ceramic junction should be as definite (90-degree angle) and as smooth as possible to make finishing easier during all fabrication stages (Fig. 24-4). The metal framework must be sufficiently thick to prevent distortion during firing. A minimum of 0.3 mm is advocated for the noble metal alloys; 0.2 mm is sufficient for base metal alloys, which can be finished thinner and still withstand distortion because of their higher fusing ranges, moduli of elasticity, and yield strengths (see Chapter 19).

The mechanical properties of a metal-ceramic restoration depend largely on the design of the substructure that supports the ceramic veneer. The metal-ceramic interface must be at least 1.5 mm from all centric occlusal contacts and must be distinct to facilitate the removal of excess porcelain. The veneering surface must be finished to a smooth texture with rounded internal angles to allow proper wetting by the opaque porcelain.

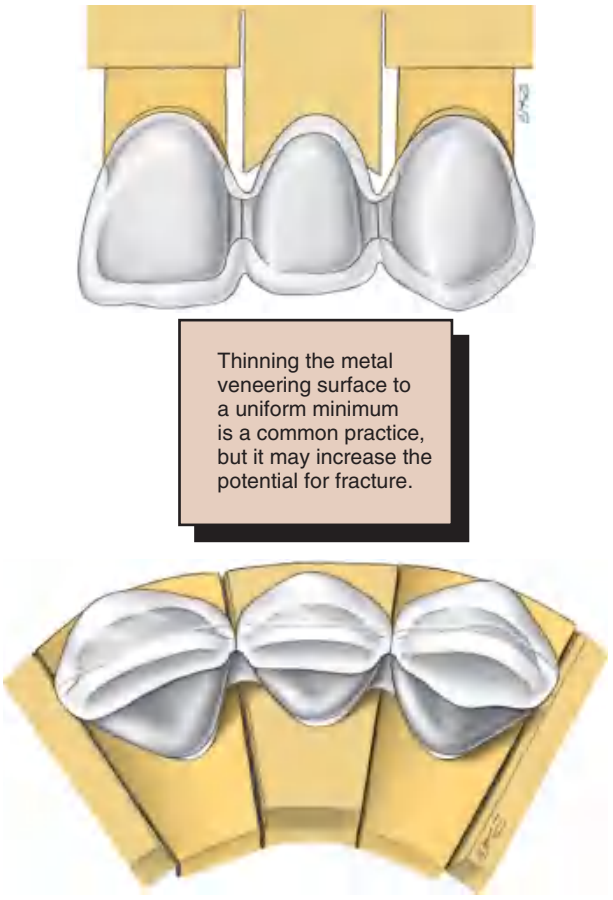


Fig. 24-3
Substructure design for an anterior partial fixed dental prosthesis. The metal should be shaped to support an even thickness of porcelain.

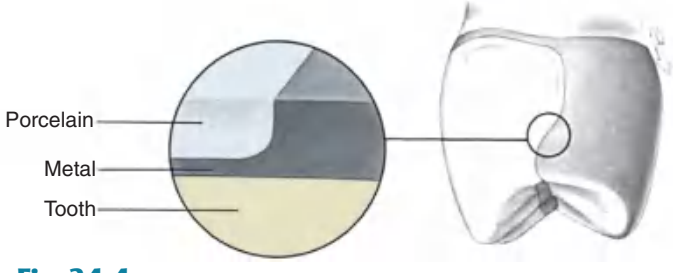


Fig. 24-4
The metal substructure should have a distinct margin for finishing the veneer.

Investment Removal

After the framework has been cast, all investment should be removed ultrasonically with airborne particle abrasion or with steam (according to the alloy manufacturer's directions). The phosphate-bonded investments, which must be used with the high-fusing metal-ceramic alloys, are more difficult to remove from the metal surface than are conventional gypsum-bonded investments. Hydrofluoric acid dissolves the refractory **silica** component of the investment. However, this acid is extremely dangerous and must be handled very cautiously.[7] A small spill on the skin results in painful acid burns, and slight exposure to the fumes may produce severe corneal damage. Less dangerous substitute solutions (e.g., Stripit*) are available.

Careful examination of the internal aspect of the framework may reveal small investment particles. Several cycles of ultrasonic cleaning may be necessary to eliminate all residual investment. If air abrasion is used for investment removal, the margins of the framework must be protected to prevent damage by the abrasive particles.[8]

Oxide Removal

The oxide layer that has been formed on the metal surface during casting must be partially removed with either acid or air abrasion. For optimal metal-porcelain bonding, the alloy manufacturer's directions should be followed precisely, because achieving a successful bond depends on a controlled thickness of the metal-oxide layer.

Metal Finishing

Care is needed when the veneering surfaces are ground, to avoid dragging the metal over itself, which could entrap air and grinding debris (which later results in bubbling or contamination of the porcelain). Finishing the surface in one direction with light pressure helps avoid trapping debris between folds of the metal, which is a problem when high-gold content alloys with high elongation values are used (Fig. 24-5).

Surface finishing should be performed with ceramic-bound stones, because the organic binders used in conventional rotary instruments are a potential source of contamination. Carbide burs also may be used safely. After the surface has been smoothed, it should be air abraded with aluminum oxide according to the manufacturer's instructions. This creates a satin finish on the veneering surface that is easily wettable by the porcelain slurry (Fig. 24-6).

Thickness

A dial (or metric) caliper is invaluable for verifying that the metal substructure conforms to all specified minimum dimensions (Fig. 24-7). Metal thickness of less than 0.3 mm may lead to distortion during

*National Keystone, Cherry Hill, New Jersey.

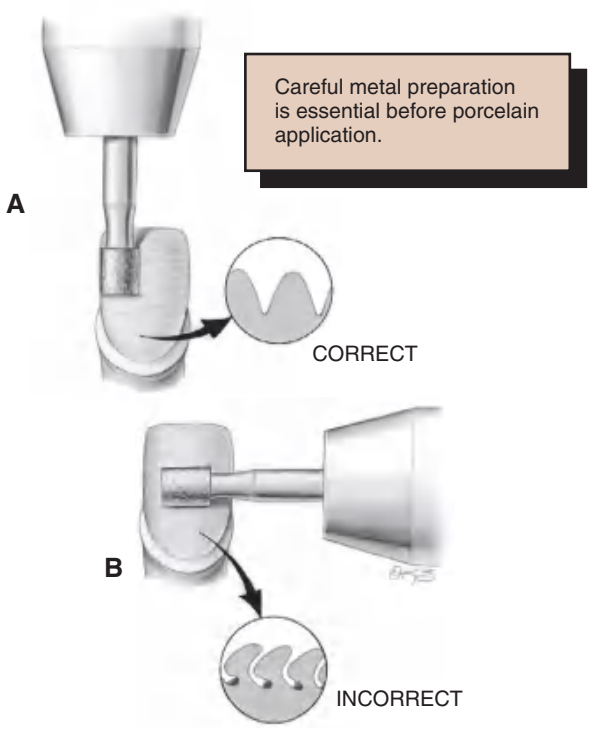


Fig. 24-5
A, Correct way to prepare the veneer area. The metal should be ground in the same direction. **B,** Incorrect multidirectional grinding can trap debris in the high-noble alloys.

firing. Sometimes the margin is thinned to a knife edge so that a metal line is not visible. There is no evidence that thinning the margin adversely affects the fit of restorations cast in contemporary alloys.[9,10] The all-porcelain labial margin design can provide a better appearance, particularly when a high smile line and thin gingival tissue necessitate good esthetics at the labial margin.

Finishing

Finishing of the metal-ceramic interface is a difficult laboratory procedure and requires attention to detail. The axial surfaces and visible portion of the metal collar should be contoured and finished to a rubber wheel stage before preparation of the veneering surface is attempted (Fig. 24-8*A* and *B*). At this time, the margin itself is left untouched. Round stones and carbides can be used to finish the veneering surface at the metal-ceramic interface (Fig. 24-8*C*), and the desired right-angle configuration is then easily obtained. Any remaining irregularities can be blended easily with barrel-shaped stones (Fig. 24-8*D*).

When the grinding phase is completed, a satin finish is obtained by air abrading the veneering surface with a fine-grit alumina (Fig. 24-8*E*).

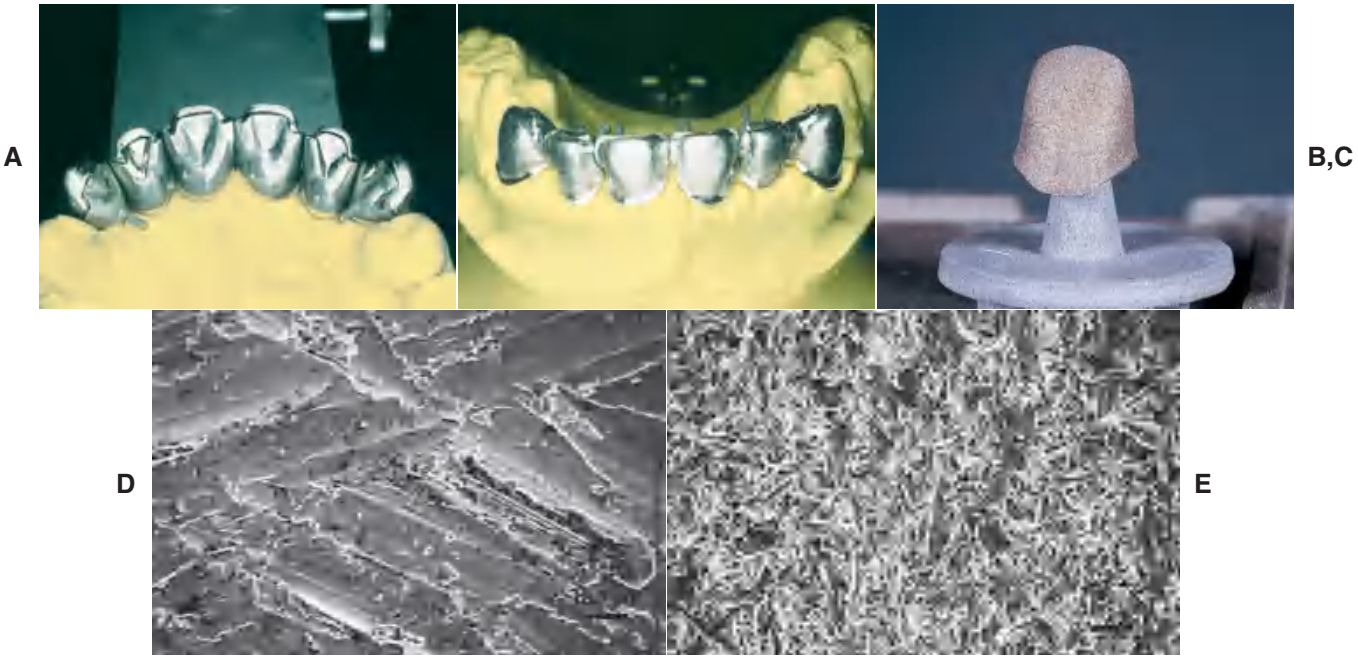


Fig. 24-6
Metal preparation. **A** and **B,** Castings prepared by grinding. **C,** Satin finish obtained by air-abrasion. **D** and **E,** Scanning electron micrographs of metal after grinding with a stone (**D**) and with air-abrasion (**E**). (***D*** *and* ***E,*** *Courtesy of Dr. J. L. Sandrik.*)

Cleaning

Although a properly prepared framework appears smooth to the naked eye, its appearance is still quite rough when viewed with a microscope. Small particles, grinding debris, oil, and finger grease must be removed because they interfere with the wetting process, which is crucial for a good metal-to-ceramic bond.

The substructure can be cleaned by immersion in a general-purpose cleaning solution in an ultrasonic unit. The duration of the cleaning cycle depends on the unit, but 5 minutes is adequate in most cases.



Fig. 24-7
Dimensions should be verified with calipers.

Residual soap can be removed by rinsing the substructure in distilled water. Some manufacturers recommend following this with a rinse in 92% alcohol (conventional 70% isopropyl alcohol should not be used because it contains aromatic and mineral oils, which could cause contamination). Steam cleaning is an excellent and time-saving alternative to ultrasonic cleaning. To prevent further contamination, the veneering surface should not be touched once the cleaning procedures have been completed.

Oxidizing

To establish the chemical bond between metal and porcelain, a controlled oxide layer must be created on the metal surface (Fig. 24-9). In noble-metal alloys, iron, tin, indium, and gallium are the base elements used for oxide formation (see p. 748).

The oxide layer is typically obtained by placing the substructure on a firing tray, inserting it into the muffle of a porcelain furnace, and raising the temperature to a specified level that sufficiently exceeds the firing temperature of the porcelain. A vacuum is created in the firing chamber, which, although insufficient to remove adherent gases, reduces the thickness of the oxide layer. The incorrect term *degassing* often is used interchangeably with *oxidizing* (see p. 750).

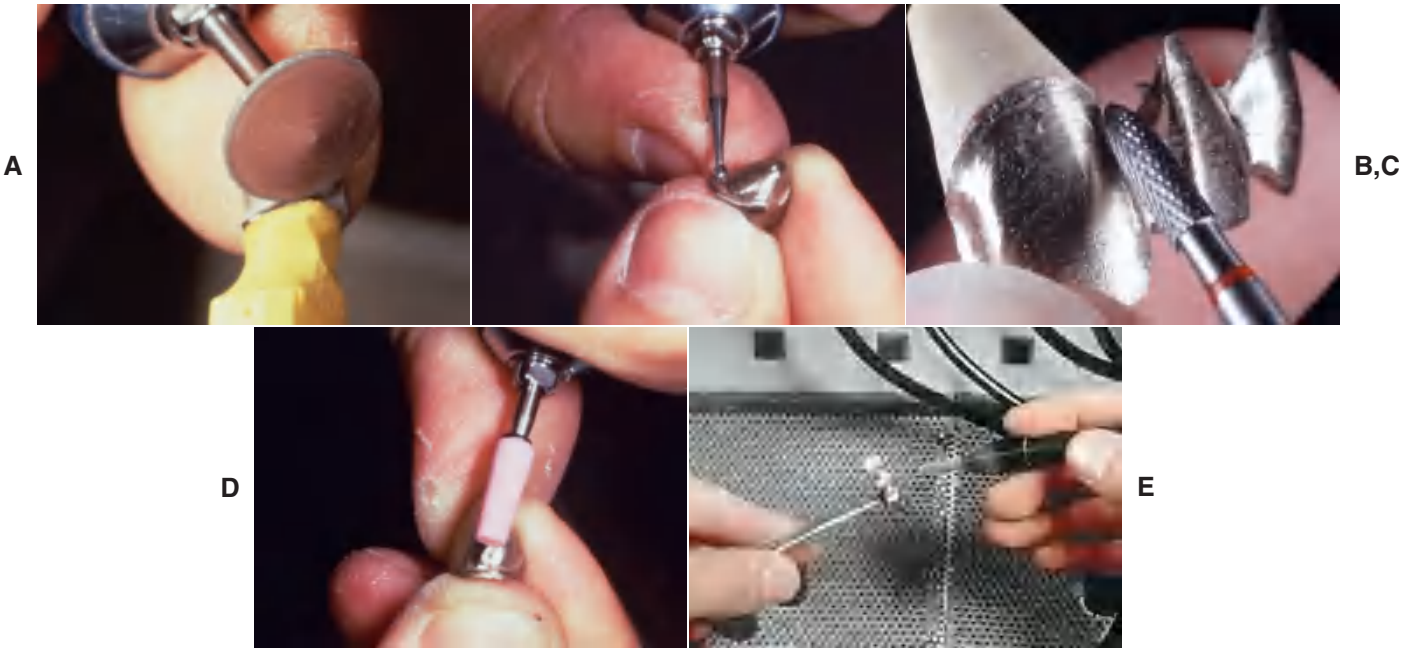


Fig. 24-8
Preparing the substructure. **A,** Nonveneering surface finished to the rubber wheel stage. **B** and **C,** Metal-ceramic junction delineated with a tungsten carbide bur. **D,** Veneering surface dressed with a ceramic-bound stone. (Note: To avoid perforation, check the metal thickness regularly with calipers.) **E,** Air abrasion of the veneering area. The margins have been protected by soft wax.

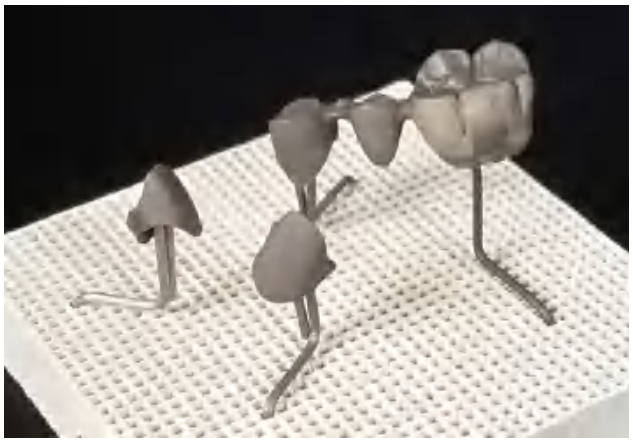


Fig. 24-9
Metal-ceramic substructure after cleaning and before oxidizing in the porcelain furnace.

The specific procedure may vary slightly, depending on the alloy used. High-gold content ceramic alloys usually are held at the oxidizing temperature for several minutes. The first porcelain application can be performed as soon as the casting has cooled to room temperature after it is removed from the furnace.

Many of the lower gold content alloys contain more base elements, which can result in a thicker oxide layer. Some of these systems therefore do not require the work to be held at the oxidizing temperature for any length of time. To reduce excessive surface oxides, some manufacturers recommend briefly air abrading the casting with alumina or placing it in hydrofluoric acid after firing.

Because of lower costs, the use of nonnoble or base metal alloys for metal-ceramic restorations is now widespread. These alloy systems undergo continuous oxide formation. Although the techniques for different systems vary, most manufacturers prefer not to oxidize substructures made of base metal alloys. Instead, they recommend performing the first porcelain application immediately after cleaning. Because the extent of oxide formation cannot be easily controlled, there is a potential for failure through the thick and brittle oxide layer with these alloy systems. However, it may be of no significance with other alloy systems.

MATERIALS SCIENCE

Isabelle L. Denry
Leon W. Laub

Dental ceramics are generally classified into three groups according to their maturation or fusion range: high-fusing (1290° to 1370° C [2350° to 2500° F]), medium-fusing (1090° to 1260° C [2000° to 2300° F]), and low-fusing (870° to 1070° C [1600° to 1950° F]). In contrast to denture teeth and the original porcelain jacket crowns, which are fired in the medium- and high-fusing ranges, metal-ceramic veneer restorations are fired in the range of 950° to 1020° C (1750° to 1860° F). This discussion is limited to these low-fusing porcelains.

Porcelain Manufacture

Dental porcelain is produced from a blend of **quartz** (SiO_2), feldspar (potassium aluminum silicate orthoclase, sodium aluminum silicate albite), and other oxides. During manufacture, the materials are heated to high temperature to form a glassy mass and then rapidly cooled by quenching them in water, which causes the glassy mass to fracture into many small fragments. The resulting product is called a ***frit.*** This process may be repeated several times, after which the frit is ball-milled until the desired particle size distribution is obtained. Because fritting takes place at temperatures much higher than those used in the fabrication of a dental restoration, most of the chemical reactions between raw materials occur before they are used in the dental laboratory. Typical compositions are provided in Table 24-1, although the actual compositions vary according to the proposed use of the end product. Most formulations designed for metal-ceramic use are similar to that described by Weinstein and colleagues.[11,12] They consist of a mixture of two frits: a low-fusing glass frit and a high-expansion frit consisting of crystalline leucite ($KAlSi_2O_6$) (Fig. 24-10) with tetragonal symmetry (Fig. 24-11). This combination overcomes the two principal difficulties in veneering metal with ceramic: having a porcelain firing temperature well below the melting range of the metal and having a sufficiently high thermal expansion compatible with the metal. After firing in the laboratory, dental ceramics consist of about 20% volume tetragonal leucite crystals dispersed in a glassy matrix.[13] The structure of this glassy matrix is a random Si-O network. The silicon atom combines with four oxygen atoms in a tetrahedral configuration (Fig. 24-12). These tetrahedra may be linked into a chain with both covalent and ionic bonds, which leads to a metastable structure. However, such a Si-O network would have a very high melting point. Usually, potassium and sodium are added to the glass composition to help break down the Si-O network and are therefore known as *glass* modifiers. In dental ceramics, potassium and sodium are initially provided by the feldspars. Two desirable consequences result: (1) The softening temperature of

Table **24-1** **COMPOSITION OF HIGH-, MEDIUM-, AND LOW-FUSING BODY PORCELAINS (WEIGHT PERCENTAGE)**

	High-fusing	Medium-fusing	Low-fusing (vacuum fired)	Metal-ceramic
SiO_2	72.9	63.1	66.5	59.2
Al_2O_3	15.9	19.8	13.5	18.5
Na_2O	1.68	2.0	4.2	4.8
K_2O	9.8	7.9	7.1	11.8
B_2O_3	–	6.8	6.6	4.6
ZnO	–	0.25	–	0.58
ZrO_2	–	–	–	0.39

Modified from Yamada HN, Grenoble PB: Dental Porcelain: The State of the Art–1977. Los Angeles, University of Southern California School of Dentistry, 1977.

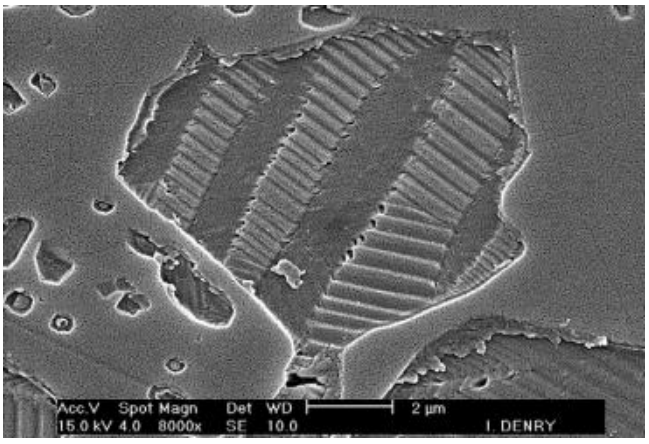


Fig. 24-10
Scanning electron micrograph of polished and etched leucite-containing dental ceramic, showing a tetragonal leucite crystal.

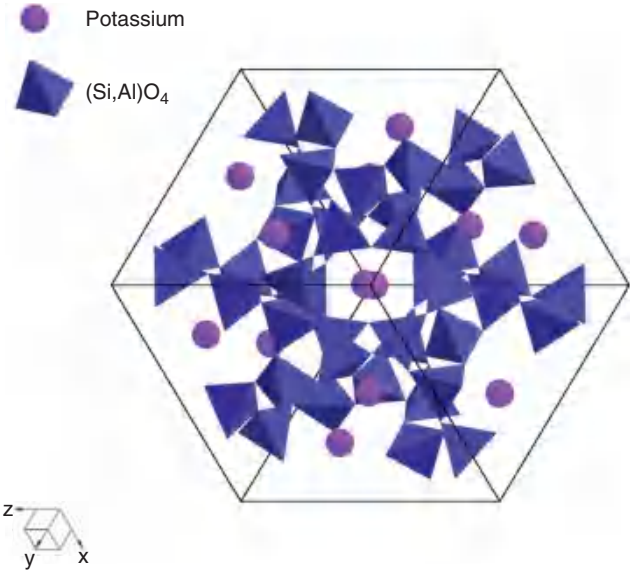


Fig. 24-11
Crystalline structure of low-temperature (tetragonal) leucite.

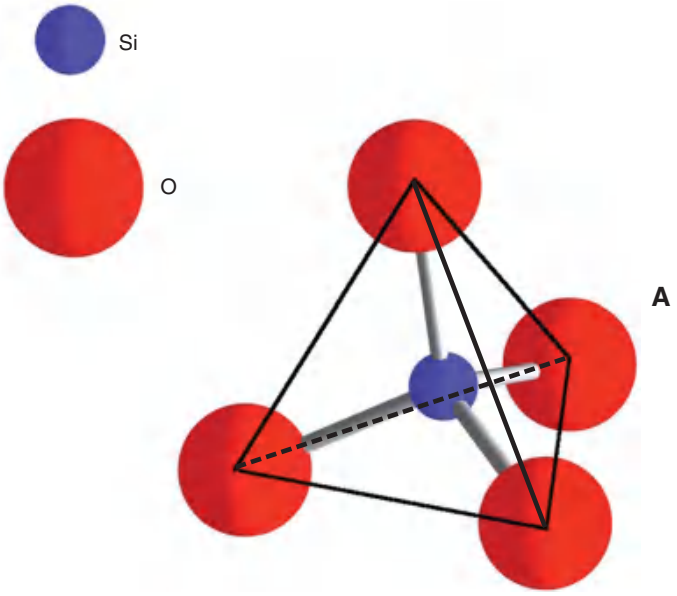




Fig. 24-12
A and **B,** The Si-O tetrahedral configuration.

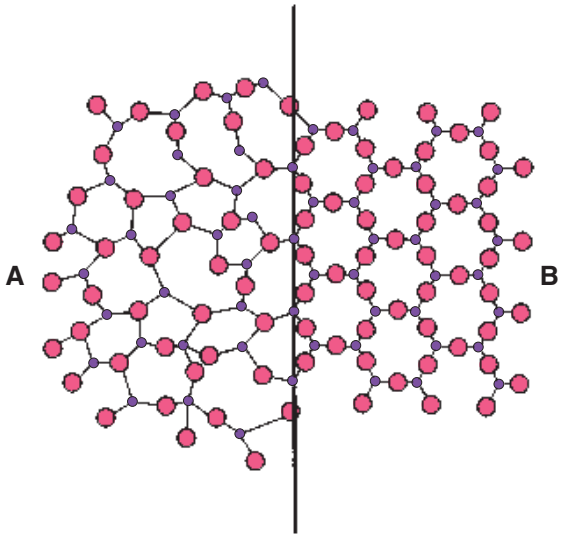


Fig. 24-13
Change in the Si-O network structure from a glassy (A) to a crystalline (B) form. *(Modified from Kingery WD, et al: Introduction to Ceramics, 2nd ed. New York, Wiley & Sons, 1976.)*

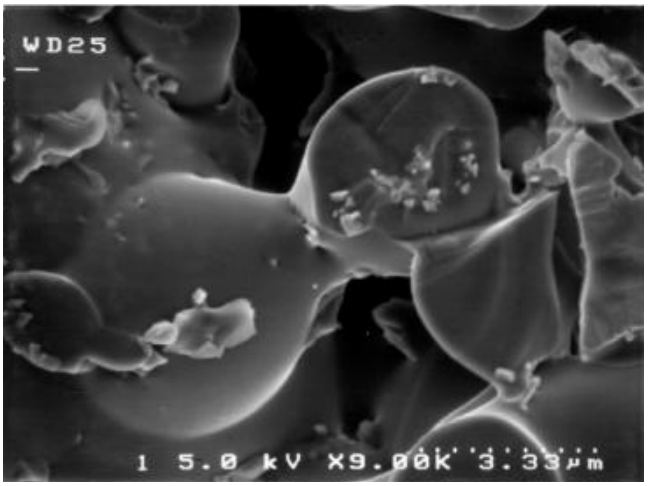


Fig. 24-14
Vitreous sintering. Partial melting of the unfused particles leads to their bonding. Observe the necking caused by the glass flow. *(Modified from Van Vlack LH: Elements of materials science, ed 2, Reading, Mass, 1964, Addison-Wesley.)*

the glass is reduced, and (2) the coefficient of thermal expansion is increased. The manufacturer adjusts the oxide content so that the dental ceramic's coefficient of thermal expansion is close to the corresponding value for the alloys used to make the substructure. If the composition of the glass is not properly adjusted, extensive breakdown and reorganization of the Si-O network may occur, leading to a crystallization of the glass (also called ***devitrification***). The change in lattice structure from a vitreous to a crystalline form (devitrification) is shown schematically in Figure 24-13. This phenomenon may occur partially in dental ceramics if a ceramic restoration is fired too often, and it is typically associated with an increase in the coefficient of thermal expansion and **opacity.**

Feldspar also contains alumina (Al_2O_3), which acts as an intermediate oxide to increase the viscosity and hardness of the glass. As a result, dental porcelain has a good resistance to slump or pyroplastic flow; this resistance is necessary for obtaining the desired configuration of the restoration.

Porcelain Technique

Dental porcelain is usually received from the manufacturer in powder form, which is mixed with either water or a water-based glycerin-containing liquid to form a paste of workable consistency. This mixture is then used to make a restoration with the required configuration. Several condensation techniques (e.g., vibration and blotting) are used to remove as much excess water as possible. The porcelain particles are drawn together during condensation by capillary action. Proper condensation minimizes steam generation during the drying phase of firing. When the mass is heated, individual porcelain particles conglomerate by sintering. The viscous flow of unfused particles results in wetting and bridging between such particles (Fig. 24-14). Consequently, a loss of interstitial space occurs, accompanied by as much as a 27% to 45% volumetric shrinkage after firing.[14]

Types of Porcelain

The following porcelain blends are produced for the different roles they play in the fabrication of metal-ceramic restorations: opaque, body, and incisal porcelains.

Opaque porcelain

This is applied as a first ceramic coat and performs two major functions: it masks the color of the alloy, and it is responsible for the metal-ceramic bond.

Opacifying oxides are added to the original porcelain blend. The density of these oxides is greater than that of the glass matrix. Consequently, the oxides of tin, titanium, and zirconium have a higher refractive index than do the components of the glass matrix (feldspar and quartz): 2.01 to 2.61 and 1.52 to 1.54, respectively. When a specific range of oxide particle sizes is used, most of the incident light is scattered and reflected rather than transmitted through the porcelain, effectively masking the color of the alloy substrate.

A scanning electron microscope (SEM) view of the alloy-porcelain interface[15] for a high noble metal alloy

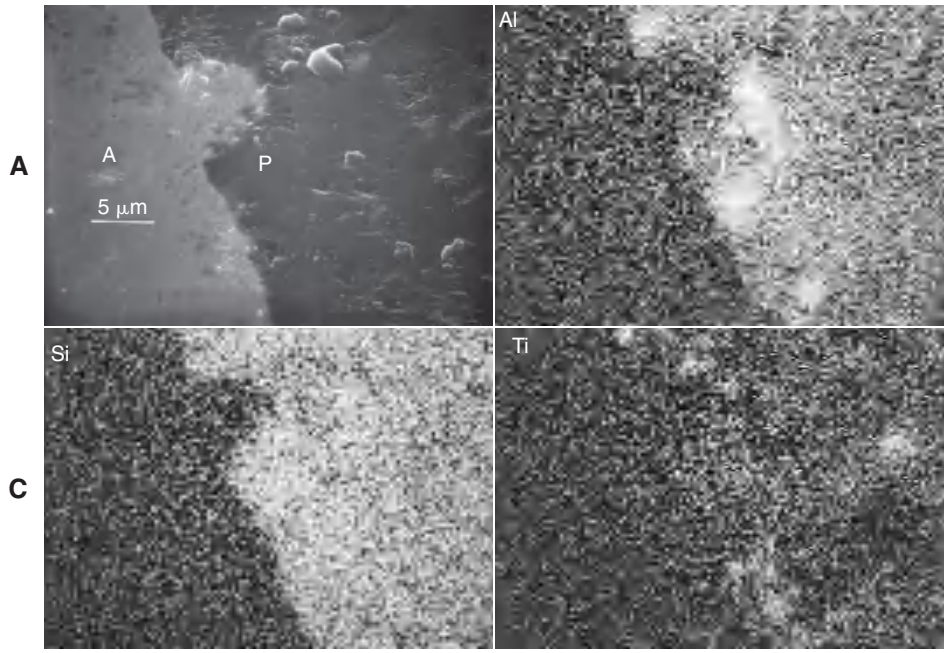


Fig. 24-15
Alloy-porcelain interface for a high noble metal alloy system: Degudent U (Degussa) and Vita normal (Vident). A, Scanning electron microscopic view of the interface. B to D, Elemental maps of aluminum (B), silicon (C), and titanium (D). *(From Laub LW, et al: The metal-porcelain interface of gold crowns [abstract no. 874]. J Dent Res 57:A293, 1978.)*

is shown in Figure 24-15. When the region around the interface is examined for specific elements (a technique known as *elemental mapping*), the concentrations of aluminum and titanium can be identified. These appear as dense regions in the figure, which indicates that discrete oxide particles of aluminum and titanium are in the opaque porcelain, probably just beneath the surface. By comparing the elemental map with the photomicrograph of the interface, it is possible to identify the distribution and size of the subsurface opacifying oxide particles. Silicon examined in this way also demonstrates a uniform porcelain distribution, which is to be expected.

Body porcelain

Body porcelain is fired onto the opaque layer, usually in conjunction with the incisal porcelain. It provides some translucency and contains metallic oxides that aid in shade matching. Body porcelains are available in a wide selection of shades to match adjacent natural teeth. Most porcelain manufacturers provide an opaque shade for each body shade. Although porcelains of different manufacturers are given the same nominal shade (e.g., the popular VITA Classical shade guide*), there is significant color variation among manufacturers,[16,17] and a dentist should know which system the technician uses.

*Vident, Brea, California.

Incisal porcelain

Incisal porcelain is usually translucent. As a result, the perceived color of the restoration is significantly influenced by the color of the underlying body porcelain.

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Porcelain-Alloy Bonding

William A. Brantley
Leon W. Laub

The formation of a strong bond between the opaque porcelain layer and the cast alloy is essential for the longevity of the metal-ceramic restoration. Extensive research since the 1970s has provided insight into the important factors for achieving metal-ceramic bonding. Early work[18] established the importance of wetting the alloy surface by the porcelain at the firing temperature. Although similar measurements of contact angles have not been reported for current dental porcelains and casting alloys, good wetting is essential for minimizing porosity at the metal-ceramic interface. A detailed relationship between the elevated-temperature contact angle and metal-ceramic bonding has not been established, but the research by O'Brien and Ryge[18] indicates that perfect wetting (a contact angle of 0 degrees) does not occur.

In the model by Borom and Pask,[19] an idealized continuous lattice structure is considered across the metal-ceramic interface for chemical bonding. This would be achieved in principle by incorporating certain oxidizable elements in the porcelain composition that can diffuse into the casting alloy at the elevated temperatures of the porcelain firing cycles and have the same equilibrium chemical potentials in both the metal and ceramic. However, in reality the situation at the dental metal-ceramic interface does not fit this idealized model. Research on gold[20] and high-palladium[21,22] alloys used for ceramic veneering has shown that the structure of the oxidized regions is highly complex, and similar results would be anticipated for detailed studies of other types of oxidized dental casting alloys. The existence of multiple phases in the oxidized region of the alloy indicates that the proposed continuity[19] of atomic bonds cannot generally be achieved across the metal-ceramic interface, except possibly at sites where the glass matrix of the porcelain is in contact with the solid solution matrix of the alloy.

Manufacturers incorporate in the casting alloy composition small amounts of certain base metals that form oxides[23,24] and contribute chemical bonding to the metal-ceramic adherence. Investigators using the electron microprobe and SEM[15,25-30] have shown that these elements accumulate at the metal-ceramic interface and form an interfacial oxide layer. For noble metal alloys, elements having a major role for porcelain adherence are iron (high-gold alloys), tin and indium (lower gold content, palladium-silver, silver-palladium, and high-palladium alloys), and gallium (high-palladium alloys). For base metal alloys in which the principal elements are nickel and cobalt, chromium oxidation provides chemical bonding for porcelain adherence, whereas titanium oxidation fulfills this role for the titanium casting alloys.

Figure 24-16*A* is an SEM photomicrograph of the interface for a high-palladium alloy bonded to dental porcelain. This alloy undergoes complex external and internal oxidation during the porcelain firing cycles. The internal oxide particles in the palladium solid solution grains are too small (less than 1 to 2 μm in diameter) for accurate compositional determinations by x-ray energy-dispersive spectroscopic analysis with the SEM. X-ray diffraction[21] has shown that $CuGa_2O_3$ and SnO_2 are present in the oxidation region when the alloy surface receives standard airborne particle abrasion with 50 μm of aluminum oxide before oxidation. Figure 24-16*B* shows line scans obtained with the SEM for major elements in the metal and ceramic near the interface. Variations in the x-ray counts occurred when the line scan crossed a region of internal oxidation.

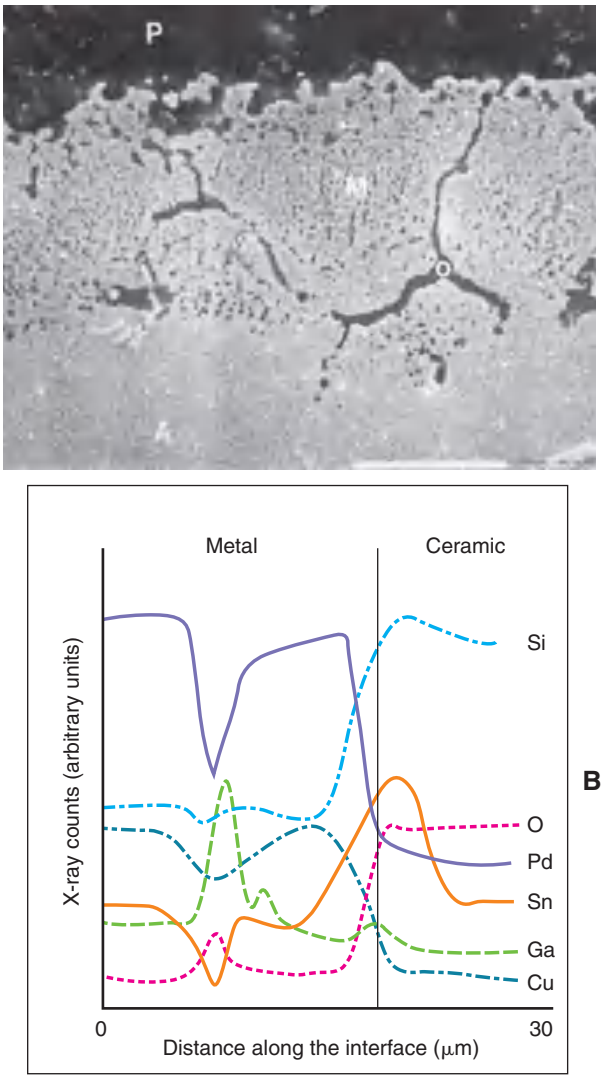


Fig. 24-16

A, Secondary electron (scanning electron microscopic [SEM]) photomicrograph of the metal-ceramic interface for Liberty (Heraeus Kulzer) palladium-copper-gallium (Pd-Cu-Ga) high-palladium alloy (*A*) bonded to VITA VMK 68 (Vident) dental porcelain (*P*). The grain boundaries of the alloy (*M*) have been widened by the formation of oxide (*O*) deposits, and there are numerous very small oxide particles within the grains. Scale bar = 10 μm. **B,** Elemental line scans perpendicular to the metal-ceramic interface obtained by x-ray energy-dispersive spectroscopic analyses for the Liberty alloy. Because the raw SEM data have not undergone matrix corrections, the relative elemental concentrations (x-ray counts) are qualitative, but the indicated trends are appropriate. O, oxygen; Si, silica; Sn, tin. *(From Papazoglou E, et al: New high-palladium casting alloys. Studies of the interface with porcelain. Int J Prosthodont 9:315, 1996.)*

Factors Affecting the Bond

Most metal-ceramic systems require that the cast alloy be subjected to an initial oxidation step before the several layers of dental porcelain are fired. (A notable exception is the palladium-copper-gallium [Pd-Cu-Ga] high-palladium alloy Freedom Plus,* in which the oxidation step does not need to be performed before firing the opaque porcelain layer.) This step has also been called a *conditioning bake* or *degassing*. The latter term, which is frequently used in the dental laboratory industry, is inaccurate, because this procedure's purpose is to oxidize the metal surface for subsequent adherence to the fired porcelain. Historically, some clinicians thought that the heating cycle might result in loss of gases incorporated in the alloy during melting. However, this occurs during solidification because of the much greater solubility of atmospheric gases in the molten alloy than in the solidified alloy; it results in the formation of microscopic porosity[31] in the casting.

The oxide layer between the metal and ceramic should have an optimum thickness for a strong metal-ceramic interfacial bond. This was demonstrated in the 1970s for selected noble and base metal alloys.[32] Research has shown that particular care is required with the base metal casting alloys to avoid excessively thick oxide layers.[33] Beryllium is added to some nickel-chromium (Ni-Cr) alloy compositions to lower the melting range; beryllium also has an effect on the thickness of the oxide layer.[34] Some systems require the application of a bonding agent before firing of the opaque porcelain. Certain formulations consist of colloidal gold suspensions that are fired on silver-colored, gold-based ceramic alloys for esthetic purposes. SEM examination of the interfaces has shown that in Ni-Cr alloys, the bonding agents may increase or decrease the width of the interaction zone between the metal and ceramic.[29] An analysis of bonding agents for several Ni-Cr alloys indicates that they contain elements found in porcelain (e.g., aluminum, tin, and silicon).[34] For certain specific brands of Ni-Cr alloys, the bonding agent appears to increase the adherence between the alloy and the opaque porcelain. The manufacturer indicates whether a bonding agent is necessary or beneficial.

Airborne particle abrasion with aluminum oxide (alumina) is routinely performed on the alloy castings to create surface irregularities and to provide mechanical interlocking with the opaque dental porcelain, which has sufficiently low viscosity in the firing temperature range to flow into these microscopic openings. Early studies found no effect of such surface roughening in the interfacial resistance of gold-platinum-palladium (Au-Pt-Pd),[35] gold-palladium-silver (Au-Pd-Ag), and Ni-Cr[36] systems to shear loading. More recent research with a Pd-Cu-Ga high-palladium alloy showed that controlled amounts of mechanical surface roughening that yielded greater notch depth for the irregularities increased the metal-ceramic bond strength, with greater improvements from coarse roughening.[37]

The linear coefficients of thermal expansion for the metal (α_M) and ceramic (α_C) must closely match to achieve a strong interfacial bond. Typically, α_M values range from 13.5 to 14.5 $\times$ 10^{-6}/degree Celsius; α_C values range from 13.0 to 14.0 $\times$ 10^{-6}/degree Celsius.[38] The slightly higher coefficient for the metal causes the ceramic to be in a beneficial state of residual compressive stress at room temperature (Fig. 24-17). (The thermal contraction and expansion coefficients are assumed to be equal, and residual stress is developed in the ceramic only below its glass transition temperature, at which time viscous flow is no longer possible.) Porcelain is much stronger in compression than tension, and residual tensile stress in the porcelain must be avoided, to prevent fracture of the restoration.

Adherence between the alloy casting and porcelain is very important in fixed prosthodontics, and investigators have used a variety of test configurations with shear, tensile, flexural, and torsional loading to determine the metal-ceramic bond strength. Ideally, the interfacial bond is strong enough so that fracture of the test specimen occurs entirely within the porcelain (cohesive failure). In

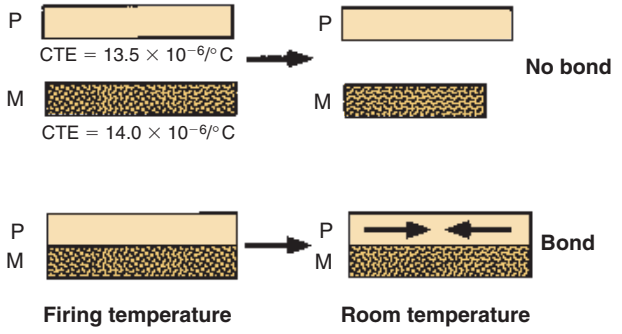


Fig. 24-17

The ceramic-metal bond at the firing temperature and at room temperature when the thermal coefficient of expansion of the metal is 0.5 $\times$ 10^{-6}/degree Celsius greater than that of the ceramic, which thus places the ceramic in compression at room temperature. *(Adapted from Craig RG, et al: Dental Materials: Properties and Manipulation, 7th ed. St. Louis, Mosby, 2000.)*

*Heraeus Kulzer, Armonk, New York.

one early study,[39] no significant difference was found in the diametral tensile strength of commercial dental porcelains for air firing and vacuum firing. Lower tensile strength values of 28 MPa (4100 psi) for opaque porcelain, in comparison with 42 MPa (6100 psi) for gingival porcelain, were attributed to greater porosity and the inclusion of opacifying oxides in the latter. In addition, vacuum firing appeared to have little effect on the porosity of the opaque porcelain. On the basis of this research, the tensile strength of the metal-ceramic bond should exceed 28 MPa to have cohesive failure through the porcelain rather than failure at the interface. Measurement of the shear strength of dental porcelain[40] allows a similar prediction for the minimum interfacial shear strength required for cohesive shear failure through the ceramic. Results from several studies[34,41,42] in which researchers measured the tensile bond strength of metal-ceramic systems were consistent with these concepts. Cohesive failure within the porcelain occurred at 15 to 39 MPa (2200 to 5700 psi), whereas shear bond strengths ranged from 55 to 103 MPa (8000 to 15,000 psi). For many of the shear bond strength determinations, a mixed mode of failure was observed, in which adhesive failure at the metal-ceramic interface extended into the porcelain, which fractured cohesively.

Subsequently, the focus for evaluating the metal-ceramic interfacial bond was directed toward measurement of porcelain adherence rather than determination of bond strength. Anusavice and associates[43] reported a finite element analysis of the tests that had been used to measure metal-ceramic bond strength (e.g., pull-shear, three-point bending, and four-point bending). Two major problems were revealed for all the bond strength tests: The stress varied with position along the metal-ceramic interface (particularly near porcelain termination sites), and there was a lack of the pure shear stress conditions that were considered necessary to simulate the loading generally expected to cause clinical failure. Furthermore, the small mismatch between the thermal contraction coefficients of the metal (α_M) and ceramic (α_C) results in an unknown amount of residual stress at the interface, and an idealized value of metal-ceramic bond strength assumes the presence of a residual stress-free interface.

To avoid these problems, O'Brien proposed a completely different approach,[44,45] focusing on the mode of failure of metal-ceramic specimens or restorations rather than measurement of bond strength. The adhesive and/or cohesive failure can occur at six possible sites or combinations of those sites (Fig. 24-18). Adhesive failure can occur (1) at the porcelain-metal interface if no oxide layer is present, (2) at the metal oxide-metal interface, and (3) at the porcelain-metal oxide interface. Cohesive failure can occur (4) through the porcelain, which is the desirable mode; (5) through the metal oxide layer; and (6) through the metal.* This approach for evaluating the metal-ceramic bond by determining the area fraction of adherent porcelain on fractured test specimens was adopted in the American National Standards Institute/American Dental Association (ANSI/ADA) specification no. 38 for metal-ceramic systems,[46] although the method of microscopic measurement was not specified.

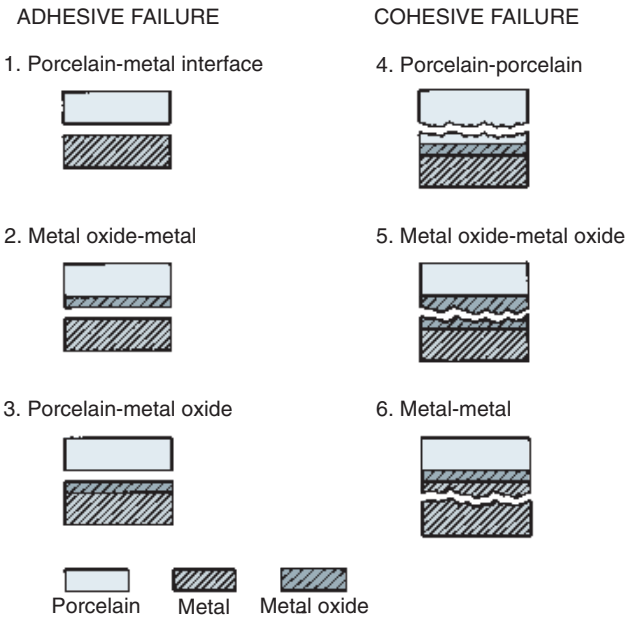


Fig. 24-18

Possible modes of failure of alloy-porcelain restorations. *(Modified from O'Brien WJ: Evolution of dental casting. In Valega TM Sr, ed: Alternatives to Gold Alloys in Dentistry [DHEW Publication No. (NIH) 77-1227, p 5]. Washington, DC, U.S. Government Printing Office, 1977.)*

A quantitative x-ray spectrometric method was developed by Ringle and coworkers[47] to measure porcelain adherence. The fracture surfaces of metal-ceramic specimens loaded to failure in biaxial flexure are examined with the SEM, with x-ray energy-dispersive spectroscopic analysis. This method is based on the principle that silicon is a major element in dental porcelain but is largely absent in dental alloys (except as contaminants from investments or polishing abrasives used to prepare specimens). The amount of dental porcelain remain-

*Metal fracture is highly unlikely but is included in this model for completeness.

ing on the metal surface of the fractured specimen is readily determined by measuring the silicon Kα signal, with necessary calibration measurements on the oxidized alloy surface before porcelain application and on the porcelain surface before testing the specimen. This technique has been used to measure the oxide adherence to a variety of ceramic alloys[48] and the porcelain adherence to high-palladium alloys[49,50] and to titanium and an alloy of titanium-aluminum-vanadium (Ti-6Al-4V).[51-54] Another philosophical change in the recommended method for evaluating the metal-ceramic bond has occurred with the introduction of International Organization for Standardization (ISO) standard no. 9693 for dental porcelain fused to metal restorations,[55] which contains a three-point bending test. Lenz and colleagues[56] performed a finite element analysis for this test, considering the stress concentrations that arise at the porcelain termination sites, although the effect of unknown residual stresses arising from the mismatch between α_M and α_C could not be included.[57] Investigators using several Pd-Ga high-palladium alloys with identical values of elastic modulus found no correlation between the porcelain adherence measured by the x-ray spectrometric method[49,50] and the force to failure by the three-point bending test in ISO standard no. 9693[55] and Lenz and colleagues' analysis.[56] These experimental results cast doubt on the effectiveness of x-ray spectrometric technique[48,49] in measuring porcelain adherence. In future experimental research in this area, investigators may use a fracture-mechanics approach to evaluate the metal-ceramic interfacial bond.

Other important factors that affect the metal-ceramic bond are the surface treatment of the alloy before the porcelain is fired and the atmosphere of the porcelain furnace during firing. As previously mentioned, air abrasion of the cast alloy is typically performed before the oxidation step to help remove surface contaminants that remain from devesting and to help clean the casting and provide microscopic surface irregularities for mechanical retention of the ceramic. The oxidation step for the alloy can be performed in air or by using the reduced atmospheric pressure (approximately 0.1 atm) available in dental porcelain furnaces. A much thinner oxide layer is formed if the alloy is oxidized at this reduced atmospheric pressure, in comparison with the thickness for oxidation in air. One manufacturer (Heraeus Kulzer, Armonk, New York) recommends performing the oxidation step in air and then carefully reducing the thickness of the oxide layer before firing the opaque porcelain. Manufacturer's recommendations for the oxidation of the alloy and the porcelain firing cycles must be followed. An early study[58] showed that the shear bond strength of porcelain-gold alloy specimens was 60% greater when air firing was employed; another study at that time[59] revealed that the tensile bond strength varied according to the furnace atmosphere used. The shear bond strength of porcelain-nickel–based alloy specimens was greater when firing was performed in oxidizing atmospheres than in non-oxidizing or reducing atmospheres.[60] More recently, Wagner and associates[37] found that the use of a reducing atmosphere severely reduced the bond strength of a Pd-Cu-Ga high-palladium alloy, which confirmed the role of alloy oxidation during the standard porcelain firing cycles. Areas of current research activity are surface modification of cast titanium with chemical solutions,[52] control of interfacial variables (different porcelain firing environments and sputtered gold film),[53] and use of special gold[54] and silicon nitride[61] coatings to improve the porcelain adherence.

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SELECTION CRITERIA

Most manufacturers of modern dental porcelains specify the alloy systems with which a material is compatible. Usually that compatibility refers to the relative coefficients of thermal expansion. The shade selected clinically determines which powders to combine. Depending on the characteristics of the color to be matched, several powders can be combined for the desired esthetic result. Commercially available porcelains can be divided into fine-grain and coarse-grain types. The typical particle size of a fine-grain porcelain ranges from 5 to 110 μm; the particle size for a coarse-grain porcelain can be as large as 200 μm.

Opaque Porcelain

For a proper mechanical bond and chemical interaction at the interface, opaque porcelain must wet the surface easily. It becomes the primary source of color of the restoration and must mask the color of the metal, even in thin layers. Opaque thickness generally should not exceed 0.1 mm; otherwise, achieving an esthetic result without overcontouring the restoration becomes impossible, although a greater thickness may be needed to mask the darker oxide of some alloys.[62] Small amounts of zirconium oxide and titanium oxide, in conjunction with alumina, act as the opacifying agents to block the darker color of the oxidized metal. Some of these oxides are also present in the body porcelain. Manufacturers supply opaque porcelains in paste and powder form (Fig. 24-19).



Fig. 24-19
Metal-ceramic porcelain. Opaque porcelains are available as powders or pastes. *(Courtesy of Ivoclar Vivadent, Amherst, New York.)*

Body and Incisal Porcelains

As with opaque porcelain, the selection of body and incisal porcelains is based largely on their esthetic properties. However, the amount of shrinkage that occurs when these powders are fired must also be considered. The volume of body and incisal porcelains usually shrinks as much as 27% to 45% during a first firing[14]; opaque porcelain, on the other hand, may exhibit some cracking during an initial bake, but it remains relatively stable dimensionally. Lower-fusing metal-ceramic porcelains* have become popular.[63] These materials should be considered when opposing enamel wear is likely to be a problem, because in vitro they tend to exhibit lower abrasiveness than do conventional formulations.[64]

FABRICATION

For optimum esthetics, custom-mixing body and enamel powders to achieve desired color variations is recommended.

Porcelain Application

Armamentarium (Fig. 24-20)

- Porcelain modeling liquid
- Paper napkin
- Glass slab or palette
- Tissues or gauze squares
- Two cups of distilled water
- Glass spatula
- Serrated instrument
- Porcelain tweezers or hemostat
- Ceramist's sable brushes (Nos. 2, 4, and 6) and whipping brush
- Razor blade or modeling knife
- Cyanoacrylate resin
- Colored pencil or felt-tip marker
- Articulating tape
- Ceramic-bound stones
- Flexible thin diamond disk (about 20 mm in diameter)

Step-by-step procedure

After the metal substructure has been oxidized, it must be inspected carefully. An uninterrupted oxide layer should cover the entire surface to be veneered.

Opaque porcelain (Fig. 24-21)

1. After selecting the opaque bottle, shake it to mix the powder thoroughly. Then place it on the bench to allow the smaller pigment particles to settle. Over time, all porcelain powders segregate into layers of different particle size if left undisturbed.
2. Dispense a small amount of powder on a glass slab or palette. Add some modeling liquid and mix it with the spatula. Metal instruments should not be used in mixing, because metal particles could rub off and act as contaminants. The proper opaque consistency should "hold an edge" for a few seconds.
3. Moisten the substructure with some of the liquid, and pick up a small bead of opaque with the tip of the brush or spatula. Apply it to the coping, which should be held with the porcelain tweezers.
4. Use light vibration to spread the material thinly and evenly. Moving the serrated instrument back and forth over the handle of the tweezers creates the necessary disturbance. Excess moisture that comes to the surface can be blotted off with a clean tissue. Vibration may not be as necessary with the so-called paint opaques.
5. Apply a second bead on top of the first, and spread it in a similar manner. To minimize the entrapment of air when the two masses meet, do not apply opaque porcelain adjacent to the initial mass. If the moisture content is properly controlled, condensing poses little difficulty. A mix that is too wet will slump and produce too thick a layer on the substructure, especially in the concave areas near the porcelain-metal junction.
6. Once the veneering surface is covered, add more material to a dry base. Wetting the initial application before adding more porcelain may be necessary. If not, the moisture will be absorbed

*Finesse, DENTSPLY Ceramco, York, Pennsylvania; Omega 900, Vident, Brea, California.



Fig. 24-20
A, Armamentarium for porcelain application. **B,** Whip Mix Pro Press 100 *(left)* and Pro 100 *(right)* porcelain furnaces. **C,** DENTSPLY Centurion porcelain furnace. *(**B** courtesy Whip Mix Corporation, Louisville, Kentucky; **C** courtesy DENTSPLY International, York, Pennsylvania.)*

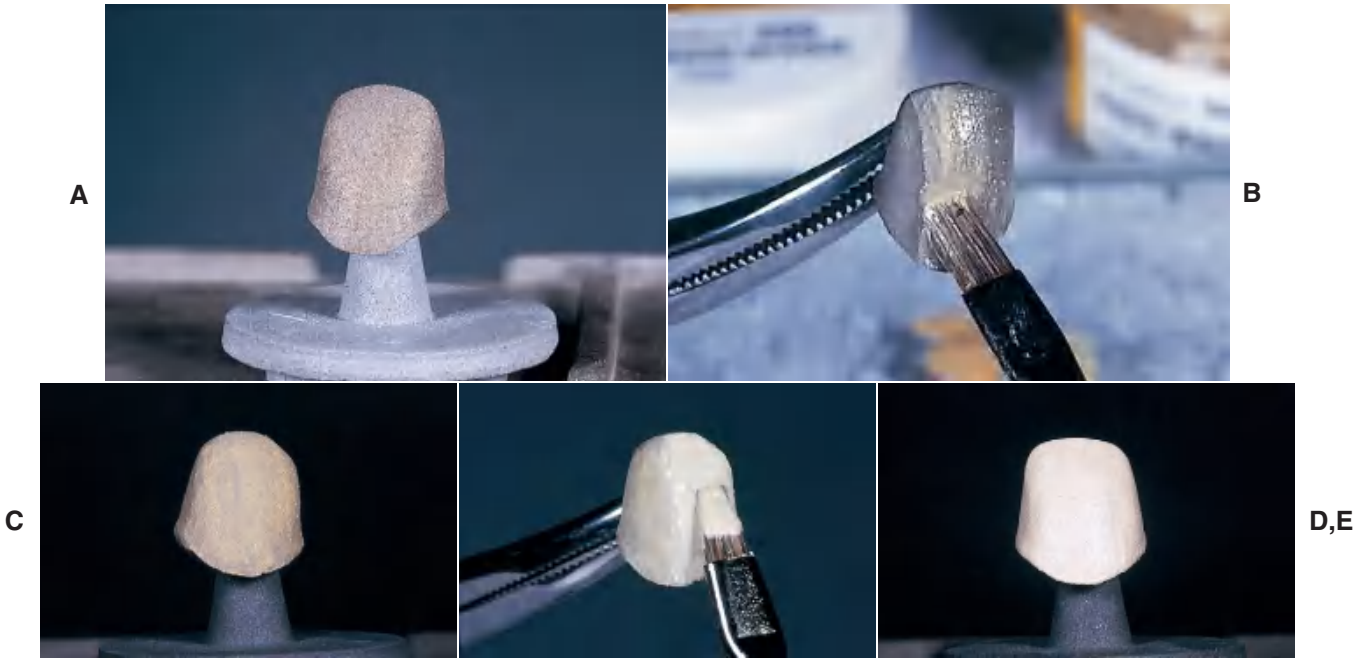


Fig. 24-21
Opaque porcelain application. **A,** Substructure is oxidized. **B,** Porcelain is applied. Vibration can be used to help spread the opaque into an even, thin film (**C**). **D,** Application of additional opaque. **E,** After drying in front of the furnace, the opaque powder should have a uniform matte-white appearance. Excess must be removed before firing.

immediately by the dry base layer before a new material can be properly condensed and distributed, which results in a porous and weakened application (similar to constructing a sand castle with wet sand on a dry beach). The addition of more liquid and further vibration will resolve the problem.

7. When the entire veneering surface has been covered, remove any excess material from other surfaces with the side of a slightly moistened brush. If the metal immediately adjacent to the veneer has been properly prepared and smoothed, it is not difficult to remove the excess porcelain. However, this crucial task is often overlooked, and its omission can make metal polishing much more difficult.
8. After removing any excess porcelain, carefully inspect the inside of the restoration for porcelain particles. A stiff, dry, short-bristle brush can be used to remove the particles.
9. Before firing, inspect the opaque application to see that it satisfies the following criteria:
   - The entire veneering surface is evenly covered with a smooth layer that masks the color of the metal.
   - There is no excess anywhere on the veneering surface.
   - There is no opaque on any external surface adjacent to the veneer.
   - There is no opaque on the internal aspect of the substructure.

   If these criteria have been met, the coping is transferred to a sagger tray and placed near the open muffle of the porcelain furnace for several minutes. This allows moisture to evaporate. When drying is completed (this varies according to specific manufacturer's recommendations), reinspect the work for any residual excess opaque powder. Material that was previously overlooked is clearly visible, because the chalky white porcelain contrasts with the darker oxidized metal. A stiff, short-bristle brush can again be used to remove any remaining porcelain. The opaque is then fired according to manufacturer's recommendations.
10. After the first firing, remove the work from the muffle and set it aside to cool to room temperature.
11. At this time, inspect the opaque veneer for cracks, thin spots, and general adequacy of coverage. When the veneer is removed from the furnace, it appears yellow; however, when it has cooled, the more representative matte-white color is apparent. Fired opaque should have an eggshell appearance. If necessary, a second application of opaque can be made. Small cracks and fissures are common after the first firing. This problem can be resolved by applying moisture, followed by a thin mix of opaque carefully condensed into the fissures. When correcting a thin area where the color of the metal has not been masked completely, moisten the surface before applying a second coat (to facilitate wetting).
12. After firing, check that the opaque application (Fig. 24-22) meets the following criteria:
    - Relatively smooth, even layer masking the color of the framework.
    - Eggshell appearance.
    - No excess on any external or internal surface of the restoration (which would prevent it from seating fully on the die).



Fig. 24-22
Evaluation of the opaque porcelain.

Body and incisal porcelains

When a satisfactory opaque layer has been fired, the body and incisal porcelains (Fig. 24-23) can be applied. The use of several porcelains in one restoration is common. Body porcelains with increased opacity* may be used where less translucency is required (e.g., the gingival area of the pontic, incisal mamelons) to mimic existing anatomic features of adjacent natural teeth. Special neck powders can be applied on the cervical third, and incisal powders on the incisal edge, to simulate natural enamel. In general, the restoration is built to anatomic contour; when it is acceptable, a cut-back similar to that made during the waxing stage allows for a veneer of the more translucent incisal porcelain.

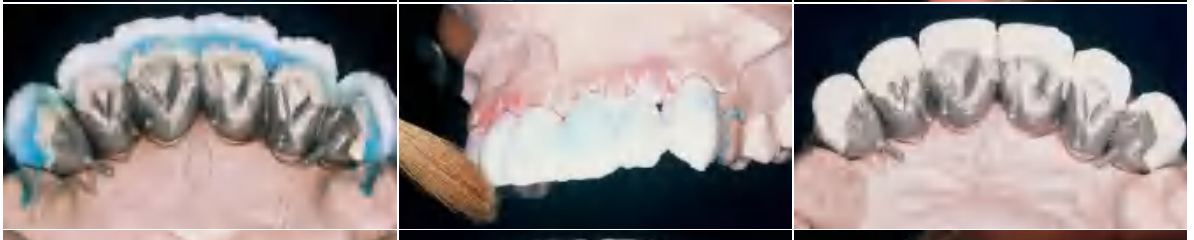
1. Dispense the neck, body, incisal, and other powders on a glass slab or palette. If the same slab was used for the opaque porcelain, any opaque residue must be removed.
2. Mix the powders with the recommended liquid or distilled water. The moisture content for

*Often called *opacious dentins.*


A B

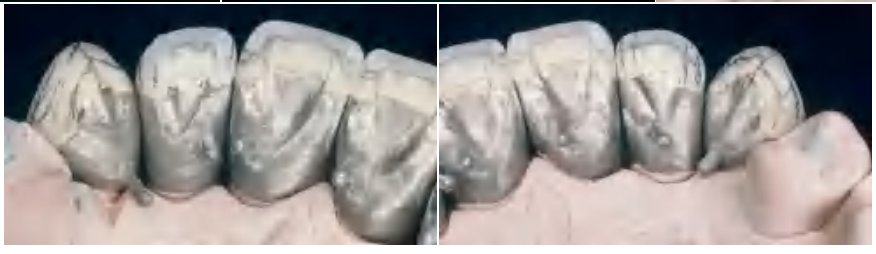

C D,E


F G,H


I J,K


L M,N


O P,Q


R S

these powders should be the same as for opaque porcelain. Specially formulated liquids that allow longer manipulation than is possible with conventional glycerin-containing liquids are available.

3. Wet the previously fired opaque layer with a small amount of the liquid, and place a bead of neck powder on the cervical portion of the veneering surface. Gentle patting with a brush and light tapping on the cast produces adequate vibration during the preliminary stage of condensation. A tissue is held close for removal of excess surface moisture. During the entire buildup procedure, the facial surface should not be blotted with tissue, because the smaller pigment particles might be removed. Blotting consistently from the lingual aspect is recommended and results in superior esthetics.
4. After placing the neck powder and sculpting it, build the veneer to anatomic contour with body porcelain. Use the adjacent and opposing teeth as a guide. Where contact is anticipated between the wet buildup and stone cast, the cast can be coated with a small amount of cyanoacrylate resin, immediately blown into a thin layer. This seals the surface and prevents the absorption of moisture from the buildup.
5. To compensate for the firing shrinkage that results when the particles fuse, slightly overbuild the porcelain. A typical metal-ceramic anterior crown shrinks 0.6 mm at the incisal edge and 0.5 mm midfacially[65] (Fig. 24-24).
6. When the body buildup is completed, assess it for proper mesiodistal, faciolingual, and incisogingival contour.
7. Depending on the desired appearance, make a cut-back for the more translucent incisal powder. Some manufacturers recommend carrying the incisal veneer all the way to the cervical portion of the restoration; others suggest limiting it to the incisal third. An almost infinite variety of possibilities exists, and only with experience can the dentist predict the finished product's appearance. Whether the cut-back is made with a razor blade, scalpel, or modeling instrument, condensing the body buildup well before cutting back is necessary. This minimizes the risk of fracture during the process. Furthermore, to minimize the chance of damaging the unsupported incisal portion of the buildup, the cut-back should be made from incisal to cervical aspects. Adequate space must exist for the incisal veneer in the interproximal area.
8. Apply the incisal powder in the same manner, and overbuild the restoration as described for body porcelain. The remaining body powder must be wet before application of the incisal powder, and, again, intermittent light vibration helps achieve an acceptable level of condensation. Prolonged condensation should be avoided. It does not reduce porosity[66] or

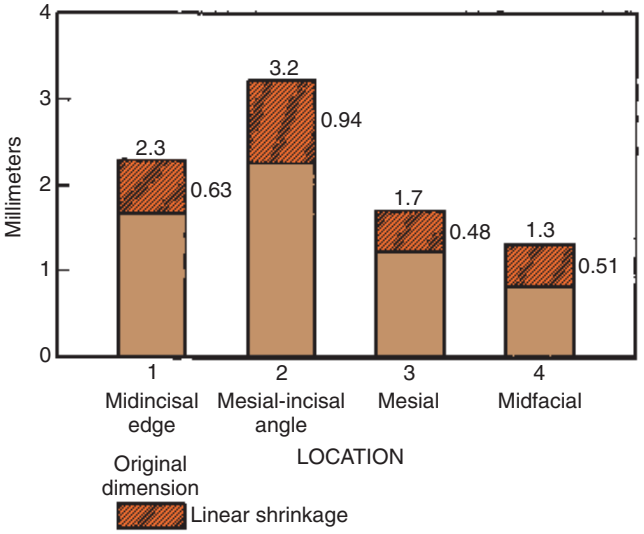


Fig. 24-24
Mean shrinkage values from firing of a typical maxillary central incisor metal-ceramic crown. *(From Rosenstiel SF: Linear firing shrinkage of metal-ceramic restorations. Br Dent J 162:390, 1987.)*

Fig. 24-23
Body and incisal porcelain application. **A** to **E,** Development of incisal mamelons with opacious dentin. The incisal plaster or silicone putty index is made from the anatomic contour wax patterns (see Chapter 18) and serves as a guide to developing proper incisal edge position. **F** and **G,** Cervical and body powders are added to the contour. **H,** Alternatively, the incisal index can be used to establish incisal edge position. This is especially helpful for extensive restorations. **I,** Restorations are slightly overbuilt. **J,** The buildup is smoothed with a whipping brush. **K,** Restorations are separated with a razor blade before firing. Additional porcelain is added to the proximal contacts. **L** and **M,** Restorations after firing of the first body bake. **N,** Porcelain is added in areas of deficient contour. **O,** After firing, the proximal contacts are carefully adjusted, and the restorations are seated on the cast. **P** to **S,** Restorations are contoured by grinding. Careful attention is paid to the shape and position of line angles and incisal edges. When completed, the restorations are ready for clinical evaluation and final contouring intraorally (see Chapter 30).

increase fracture toughness[67] and may lead to unwanted redistribution of the pigmented particles.

9. Mark the opposing teeth on the stone cast with a red or green felt-tip marker. These markings are not absorbed if the cast first has been coated with cyanoacrylate resin. The articulator can then be closed to allow the antagonists to contact the wet porcelain. If this is done carefully, the markings are transferred onto the buildup without fracturing, and the buildup can be modified to the necessary occlusal scheme. Only red or green dyes, which burn off without leaving a residue, should be used for these markings. Blue or black pigments usually contain metal oxides or carbon, which after firing can discolor the porcelain.
10. Moisten the proximal contact areas immediately before removing the completed buildup from the cast. This reduces the risk of fracturing that portion of the buildup.
11. After the restoration has been removed from the cast, fill in the proximal contact areas. At this time, the work should be reinspected for any excess material beyond the veneering area (which, as before, must be removed before firing). The internal aspect of the coping should be reinspected even more carefully, because enamel powders are quite transparent in thin layers and are not easily detected after firing.
12. Place the restoration on a sagger tray close to the open muffle at the drying temperature recommended by the manufacturer. A drying time of 6 to 10 minutes is usually sufficient. If a restoration is fired prematurely, the residual moisture in the buildup may generate steam, and the accompanying vapor pressure causes the buildup to explode. After the drying process, once it has been determined that no undesired excess material remains, proceed with firing. When the firing is completed, the work should cool to room temperature before further handling. Follow the manufacturer's recommendations concerning the cooling rate after firing. Incorrect cooling rates may lead to residual stresses that eventually result in porcelain fracture during function. Thermal expansion increases after slow cooling, because additional (high-expansion) leucite crystallizes.[68] In general, alloys with high thermal expansion coefficients require more rapid cooling than do alloys with low coefficients.[69]
13. Be especially critical when evaluating the first (or low bisque) bake. If the surface is fissured, grind the porcelain before adding any more (Fig. 24-25). The shape of the restoration

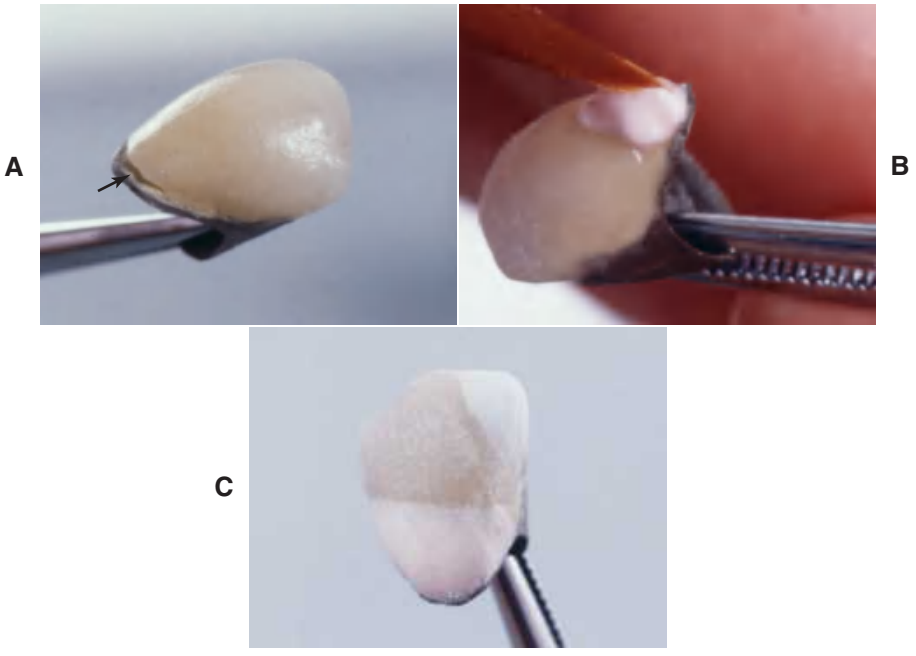


Fig. 24-25

A, This restoration had a defect *(arrow)* at the gingival margin after the first firing. Access for repair is made by grinding out such cracks. **B,** Additional porcelain is applied after the area is moistened. **C,** The porcelain has been added, and the restoration is ready for a second firing.

should conform to the standards set by dental anatomy and the predetermined occlusal scheme for the patient.

14. Remove all excess material with ceramic-bound stones. A flexible diamond disk is imperative for proper shaping of the embrasure spaces. To extend its usefulness, the disk should be kept moist.
15. When the restoration has been contoured and all the necessary areas reduced, certain portions probably require a second application of porcelain.
16. Before a second corrective bake (also referred to as a *patch bake*), clean the restoration ultrasonically to remove any grinding debris.
17. Place the second body and incisal layers directly on the slightly moistened low **bisque bake.** Evaluate the color at this time, keeping the restoration moist. Sometimes another bake is needed, particularly for an extensive prosthesis. However, multiple firings lead to devitrification of the porcelain, with a loss of translucency and a decrease in the restoration's fracture resistance.[70]

Internal Characterization

Internal or intrinsic characterization or staining may be accomplished by incorporating colored pigments in the opaque, body, or incisal powder. These pigments are ceramic in nature and have physical properties similar to those of the porcelain powders.

Most commercially available porcelains have colored opaque modifiers that can be selectively mixed with the opaque to increase the saturation of the desired pigment. A variation of this approach is to use opacified dentin powders that produce a finished restoration with a slightly higher chroma than one prepared with the more translucent dentin powders. Similarly, a translucent powder can be used to enhance incisal translucency (Fig. 24-26). Highly colored glazes, commonly used as surface stains, may be layered within the buildup powders to create special effects (Fig. 24-27).

The use of internal stains presents little technical difficulty for operators familiar with metal-ceramic procedures. However, because the pigment is built into the material, if the desired effect is not obtained through internal staining, the porcelain must be stripped from the substructure.

Another technique for internal characterization is to fire the body powders initially, carve them into the desired mamelon shape, and then apply the subsequent enamel powders. A disadvantage of this approach is that an additional firing is needed.



Fig. 24-26
A and **B,** Natural incisal appearance has been achieved through subtle layering of porcelains of different translucencies.



Fig. 24-27
Porcelain stain was applied intrinsically to create the effect of discolored dentin in these mandibular incisors seen before firing.

Contouring

The appearance of the finished restoration depends on its color, shape, and surface texture, which can be altered by shaping and characterizing dental porcelain to mimic the appearance of natural teeth (see Fig. 24-23*P* to *S*).

The appearance of restorations can be influenced considerably through the selected use of optical illusion (see Chapter 20). The human eye is capable of discerning differences in height and width, but its depth perception is far less developed. Even trained observers experience difficulty when attempting to recognize subtle differences in the third dimension.

Through selective contouring, the apparent shape of a restoration can be made to look quite different from its actual configuration. The perceived size of a tooth depends on the reflection of its line angles and the relative position and spacing of these reflections. Even though an edentulous area on one side may be slightly larger than a space occupied by the corresponding tooth on the contralateral side, a restoration can be made to appear similar (or even identical) through careful mimicking of the line angle distribution and contours immediately adjacent to the line angles. The clinician can create an illusion that the restoration is narrower than it really is (Fig. 24-28). In addition, by simulating the normal distance between line angles superimposed on a pontic in an edentulous area that is otherwise too narrow, it is possible to create the illusion that teeth are of normal size but merely crowded. Careful application of these principles may trick the casual observer into concluding that the teeth overlap and that a portion of the tooth (or restoration) is behind an adjacent tooth when, in reality, the overlap does not exist.

The surface texture of a metal-ceramic restoration should resemble that of the adjacent teeth, including selected characterizing irregularities that exist on those teeth. Several rules of light reflection must be remembered when the clinician attempts to accomplish this:

1. A flat surface reflects primarily parallel light bundles.
2. A convex surface results in divergence of reflected light, whereas a concave surface creates a convergent light bundle.
3. Sharp transitions (e.g., geometric line angles) result in line reflections, but smooth, gently flowing curved surfaces create a reflection pattern with greater surface area.

Thus, a smooth restoration can appear larger than one of identical size that has been characterized or textured. Careful study of adjacent teeth and an understanding of how their reflective patterns should be simulated before characterization are essential. Care must also be taken not to "overcharacterize," which would draw attention to the restoration and reveal that it is artificial.

Glazing and Surface Characterization

Metal-ceramic restorations are glazed to create a shiny surface similar to that of natural teeth (Fig.

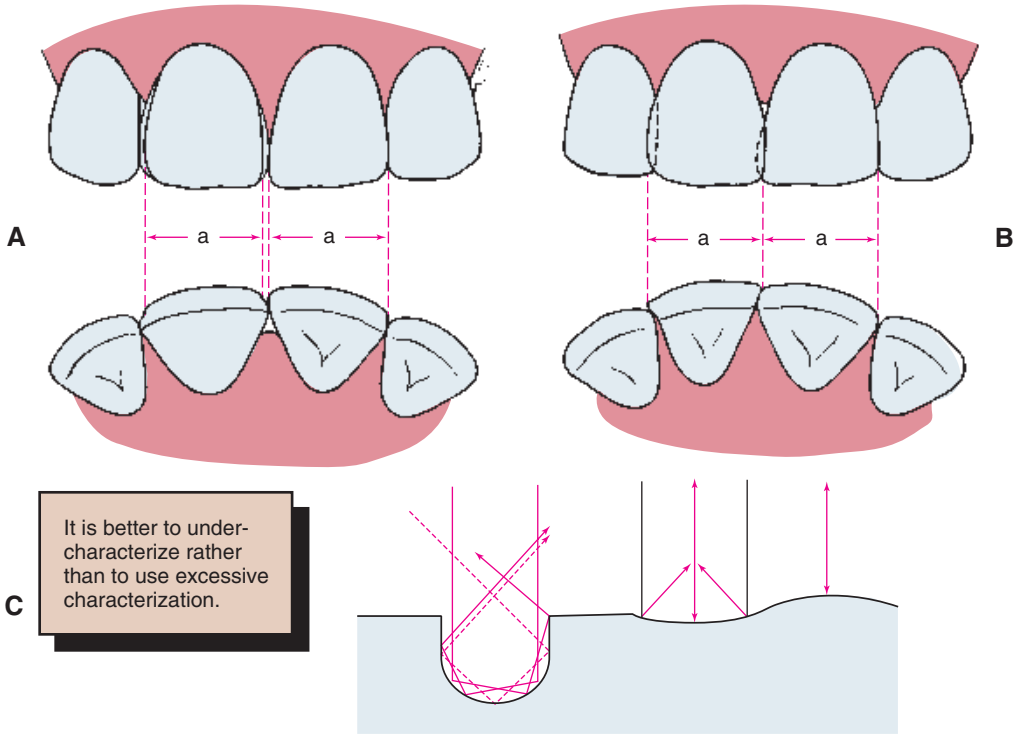


Fig. 24-28

A and **B**, The esthetics of an abnormally sized restoration can be improved by matching the location of the line angles and adjusting the interproximal areas. **C**, The pattern of light reflection depends on the surface texture of the restoration. (***A*** *and* ***B*** *redrawn from Blancheri RL: Optical illusions and cosmetic grindings. Rev Asoc Dent Mex 8:103, 1950.)*



Fig. 24-29
A and **B**, Glazed and polished restorations.

24-29).* The glazing cycle can be performed concurrently with any necessary surface characterization (see Chapter 30).

In *autoglazing*, the contoured bisque bake is raised to its fusion temperature and maintained for a time before cooling. A pyroplastic surface flow occurs, and a vitreous layer or surface glaze is formed. Sharp angles and edges are rounded slightly during this process. Consequently, occlusal contact in porcelain is altered slightly during glazing.

In contrast, in *overglazing*, a separate mix of powder and liquid is applied to the surface of a shaped restoration, and the restoration is subsequently fired. The firing procedure is similar to that for autoglazing, although there are variations among brands. Because most metal-ceramic restorations include low-fusing porcelain, overglazing is not currently in widespread use.

External Characterization

Surface stains are highly pigmented glazes, which can be mixed with glycerin and water (supplied with most commercially available staining kits).

By moistening the bisque firing, mimicking the appearance of the glazed restoration is made possible. After the desired effect has been obtained by placing selected stains on the surface, the restoration is held outside the open muffle of the glazing furnace, and the stain is allowed to dry.

When it turns white and chalky, any excess that may have been accidentally applied to the metal surface is removed, and the restoration is fired. During this staining and glazing bake, a pyroplastic surface flow occurs, and a glassy layer (or autoglaze) forms on the surface in which the stains are incorporated.

*An acceptable alternative is to polish the ceramic (see Chapter 30).

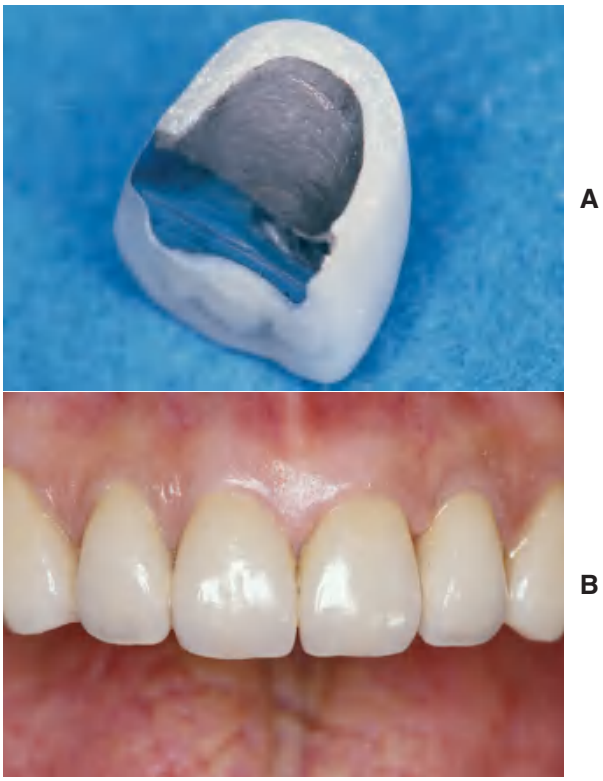


Fig. 24-30
A and **B**, Metal-ceramic restorations with porcelain labial margins combine the excellent esthetics of all-ceramic with the strength of the metal-ceramic technique.

PORCELAIN LABIAL MARGINS

Many patients object to the grayness at the margin associated with metal-ceramic restorations. However, hiding the margin subgingivally may not be possible. If esthetics is of prime importance, a collarless metal-ceramic crown (Fig. 24-30) should be considered. Collarless crowns have a facial margin of porcelain and lingual and proximal margins of metal* (Fig. 24-31).

*Some technicians fabricate a 360-degree porcelain margin to optimize light transmission in the gingival area and provide optimal esthetics. The technique is quite demanding. Preparation for these restorations is similar to that for an all-ceramic crown (see Chapter 11) with a circumferential shoulder with rounded internal line angles.



Fig. 24-31
Schematic of a collarless restoration fabricated with the platinum foil technique. To support the foil during burnishing, a "skirt" of a suitable blockout material has been added to the facial aspect of the die adjacent to the proposed porcelain labial margin. This prevents distortion of the foil upon removal from the die. Alternatively, a blocked-out die can be duplicated in epoxy resin or electroplated.

Advantages and Disadvantages

The collarless crown's most obvious advantage is the esthetic improvement it offers over the conventional metal-ceramic restoration. Plaque removal also is easier when gingival tissues are in contact with vacuum-fired glazed porcelain than when they are contacting highly polished gold. Therefore, porcelain appears to be the material of choice for restorations that will be in contact with gingival tissues.

The difficulties encountered during fabrication, however, limit its application. Although a technically comparable result is feasible,[71,72] the marginal adaptation of these restorations (as currently produced by most commercial laboratories) is slightly inferior to that of cast metal. Because of careless handling, fracture of the unsupported margin is sometimes a problem during evaluation or cementation. Fracture during function is rarely a problem, because the labial margin is not subjected to high tensile stresses.[73] In addition, the collarless metal-ceramic restoration is more time consuming and therefore more costly to make.

Indications and Contraindications

A porcelain labial margin is indicated when a conventional metal-ceramic restoration will not create the desired esthetic result. It is contraindicated when an extremely smooth, 1-mm-wide shoulder cannot be prepared in the area of the ceramic veneer. (In this regard, the conventional metal-ceramic restoration is somewhat more "forgiving.") Although multiple porcelain margins may be used in one fixed prosthesis without sacrificing marginal adaptation, the limitations of the operator and the technical auxiliaries should be carefully and objectively assessed before the dentist and patient commit themselves to a fixed prosthesis consisting of multiple collarless retainers.

Framework Design for Labial Margin

Various framework designs have been proposed with different facial framework reductions[74] (Fig. 24-32). In general, the more metal reduction, the better the esthetic result. However, the technical procedures become more demanding. Removal of up to 2 mm of the labial framework has been shown not to decrease the fracture resistance of the restoration.[75,76]

Methods of Fabrication

Several techniques have been proposed to fabricate porcelain labial margins in metal-ceramic restorations: platinum foil matrix, direct lift or cyanoacrylate resin, and porcelain wax.

Platinum foil matrix technique

The platinum foil technique[4] involves use of a platinum matrix that is spot-welded to the metal substructure. Its primary purpose is to support the porcelain during firing.

Step-by-step procedure (Fig. 24-33)

1. Wax the metal substructure and cast it in the conventional manner. Some technicians prefer to cast a conventional restoration and trim the collar off the casting; others wax the substructure exactly as desired and cast it.
2. To prevent the foil from becoming distorted on removal, block out undercuts apical to the margin. Modeling compound is suitable for this step. Any excess that may have covered the shoulder of the tooth preparation must be carefully cleaned off. Some technicians prefer to use epoxy or electroplated dies so that more pressure can be applied during burnishing without the risk of chipping.
3. Burnish a small piece of platinum foil onto the facial portion of the die where the porcelain margin is to be placed, and extend it a few millimeters onto the axial wall of the preparation.

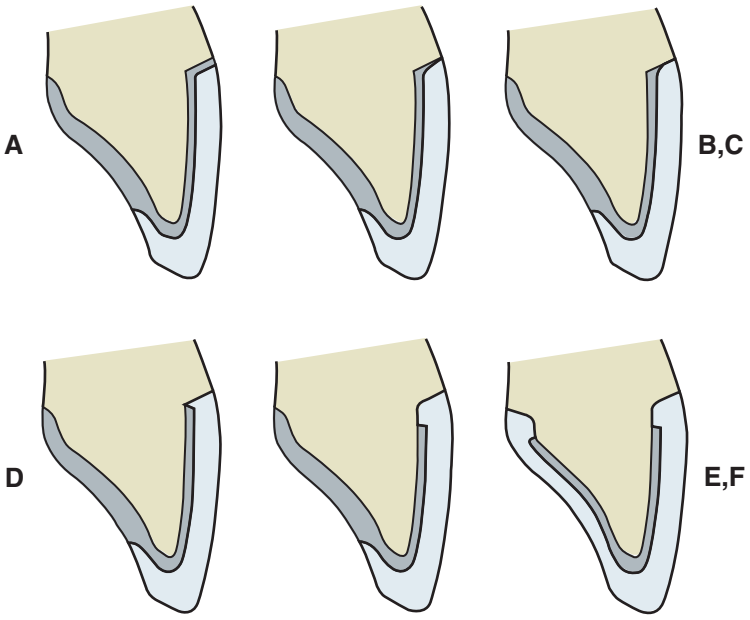


Fig. 24-32
Labial margin designs for metal-ceramic restorations. **A,** A thin metal band provides excellent adaptation but is very unesthetic unless it can be hidden subgingivally. For esthetic reasons, this design is rarely used for anterior teeth. **B,** "Disappearing" margin, sometimes called a conventional margin, is commonly used and is esthetically acceptable in some patients. However, the metal often causes unacceptable grayness of the gingival tooth surface. **C** to **E,** Various cut-back designs for labial porcelain margin restorations. Reducing the metal provides better esthetics but makes the laboratory phase more demanding and may result in margin chipping. **F,** A 360-degree porcelain margin provides excellent light transmission in the gingival area and optimal esthetics; however, the laboratory fabrication is very demanding. This design requires a preparation design that is similar to that for an all-ceramic crown (see Chapter 11) with a circumferential rounded shoulder. Close cooperation between dentist and technician is essential in determining the best labial margin design.



Fig. 24-33
The platinum foil matrix technique. **A,** The definitive cast with modified removable dies. **B,** Castings seated over the platinum foil. **C,** Spot welding the foil to the metal substructure. **D,** The trimmed matrix.

4. After burnishing, trim it so there is a 2- to 3-mm "skirt" lying cervical to the margin.
5. Carefully place the coping over the foil and, if necessary, scrape the die in the cervical area (on only the facial aspect) to allow the casting to seat. To help stabilize the foil, a drop of sticky wax may be applied.
6. Remove the casting from the die, together with the foil, and position the assembly between the electrodes of an orthodontic spot welder. The foil can now be welded to the framework, which should be done as close as possible to the edge of the metal. Four or five welds are usually adequate for attaching the foil to the substructure. The restoration is then fabricated in a conventional manner, although the facial margin is similar to that for the porcelain jacket crown. After oxidizing,* the metal is opaqued. The foil itself is not covered with opaque at this time, however. The restoration is built to contour, and the marginal portion is ditched as for the porcelain jacket crown. Some technicians prefer to paint a thin coat of separating liquid on the foil instead of ditching.
7. When the coronal portion has been shaped to a satisfactory contour, burnish the foil and fill in the ditched portion with cervical porcelain.
8. When the desired contour has been obtained after firing, trim the platinum skirt.
9. Leave the platinum that covers the shoulder portion of the preparation, and seat the crown on the original die for final cervical contouring. During subsequent staining and glazing, the platinum foil will remain in place to support the porcelain and minimize rounding of the margin during firing.
10. When characterization and glazing are satisfactory, remove the foil and cement the restoration after verifying the fit one more time.

Direct lift (cyanoacrylate resin) technique

Because this technique is less time consuming[5] and easier to perform than the platinum foil technique, it is more widely used. The substructure is fabricated in the same manner, but the die is coated with a layer of cyanoacrylate resin, and the porcelain is condensed directly onto it (because the die no longer absorbs moisture from the wet ceramic buildup). Separation is achieved with a porcelain release agent. As with most techniques, a second bake is usually necessary for satisfactory marginal adaptation.

The principal difficulty associated with the cyanoacrylate resin technique occurs during the characterization and glazing firing. Because the porcelain is not supported as in the platinum foil technique, the margin tends to round off slightly; therefore, special shoulder powders are needed.

Step-by-step procedure (Fig. 24-34)

1. Apply cyanoacrylate resin to the labial margin area of the die. This acts as a sealant of the porous stone. Compressed air should be used to minimize the thickness of the film.
2. Apply porcelain release agent to the shoulder of the prepared die.
3. Seat the opaqued casting on the die.
4. Mix shoulder porcelain, and apply it directly to the die and the opaque porcelain. Light tapping assists in condensation and should be done before the dry buildup is separated from the die.
5. After the first firing of the shoulder porcelain, reseat the crown on the die. At this time, the restoration should be examined for margin discrepancies. A second shoulder firing is usually necessary.
6. Relubricate the die, reseat the crown, and apply a thinner mix of shoulder powder to the margin. Vibration helps the porcelain fill the defect completely. After blotting, the restoration can be separated from the die.
7. When the firing is completed, use a water-soluble marking agent to detect premature contacts. The marking agent is applied to the shoulder, and the restoration is then gently tried on the die. The markings will be visible on the porcelain and the inner aspect of the casting.
8. Adjust any areas of contact of the restoration, and proceed with the conventional buildup of body and incisal porcelains, followed by glazing of the final restoration.

Porcelain wax technique

A mixture of body porcelain and wax (6:1 by weight)[77] is applied to the die for final adaptation of the porcelain labial margin of the metal-ceramic restoration.

Step-by-step procedure (Fig. 24-35)

1. After coating the substructure with opaque porcelain, lubricate the die with a porcelain release agent.
2. Apply the porcelain-wax mixture to the cervical shoulder. Use an electric waxing instrument to flow it into the proper areas.
3. With a conventional wax-carving instrument, shape the material and blend it into the opaque.

*Before the oxidation step, applying a framework-repair metal paste (e.g., VITA Metall-Corrector) to the junction between the foil and framework may be helpful. This material fuses during the oxidation firing and helps support the foil during subsequent procedures.

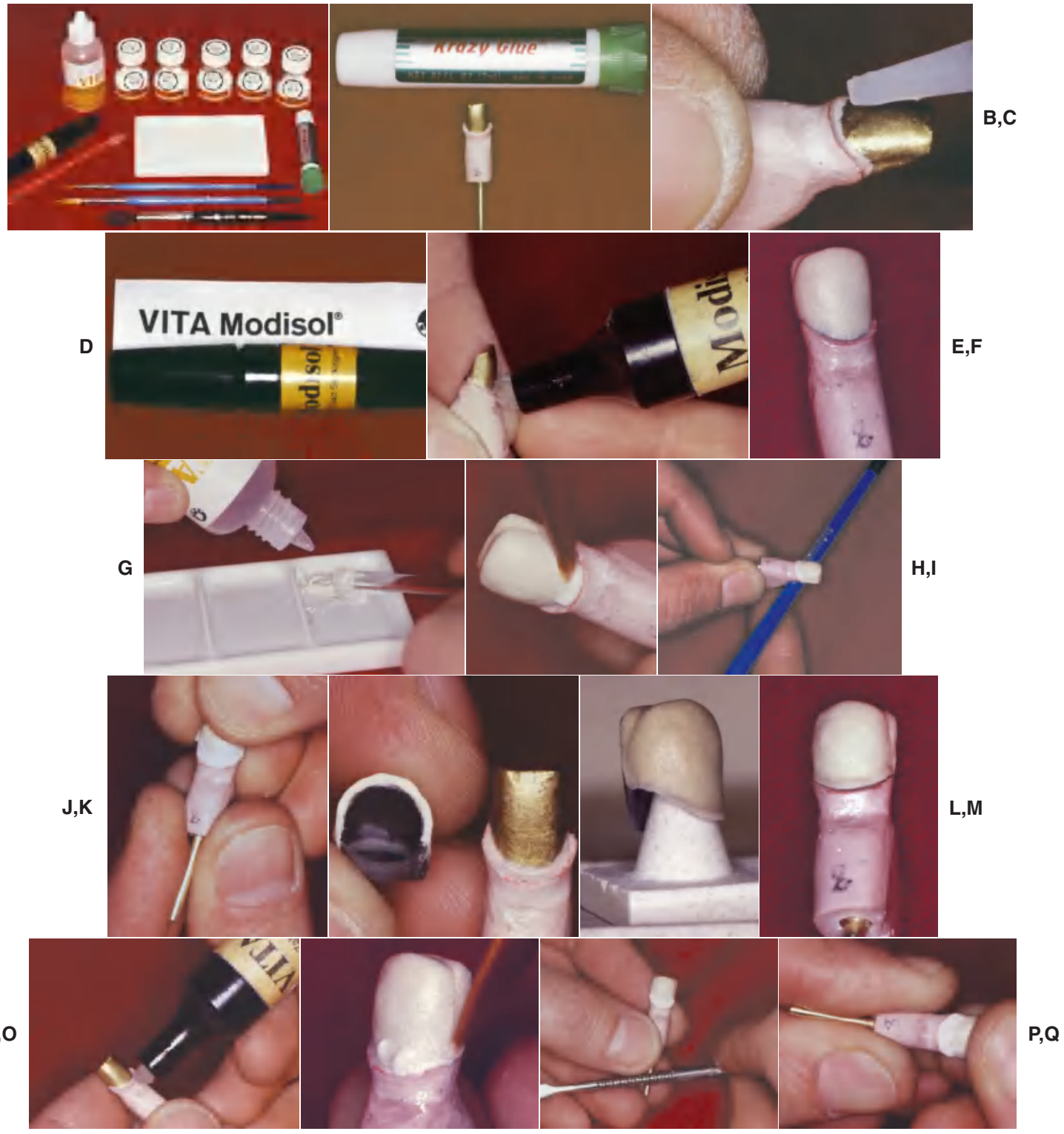


Fig. 24-34

The direct lift (cyanoacrylate resin) technique for a porcelain labial margin. **A,** Armamentarium. **B,** Cyanoacrylate resin serves as a sealant of the porous stone die. **C,** The resin is applied to the die where the porcelain will be in direct contact with the die. Compressed air is used to minimize film thickness. **D,** Recommended separating medium. **E,** The separating liquid is applied to the shoulder of the prepared die. **F,** The opaqued casting seated on the prepared die. **G,** Mixing the shoulder porcelain. **H,** Shoulder porcelain is applied in direct contact with the die and opaque porcelain. **I,** Light tapping is used to assist in condensation. **J,** Separating the dry buildup from the die. **K,** The buildup before firing. **L,** First firing of the shoulder porcelain completed. **M,** The fixed restoration is reseated on the die. Note the minor marginal discrepancy. **N,** Before additional porcelain application, the die is relubricated. **O,** Second application of shoulder porcelain. **P,** Vibration. **Q,** Separating after the second shoulder application.



Fig. 24-34, cont'd

R, Water-soluble marking agent for detecting premature contact. **S,** The marking agent is applied to the shoulder. **T,** The fired restoration is gently tried on the die. **U,** Markings are visible on the porcelain and on the internal aspect of the casting. **V,** Excess porcelain is removed. **W,** The seated restoration. **X,** Internal view of the completed shoulder. **Y,** Conventional buildup with body and incisal powders.

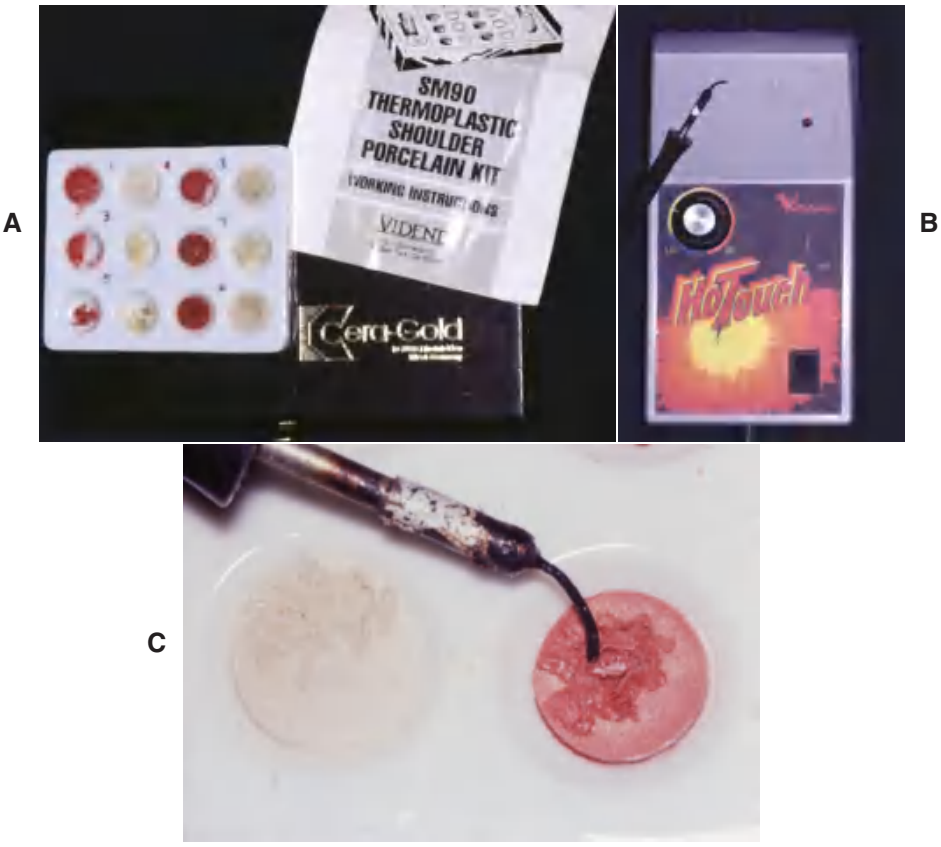


Fig. 24-35

The porcelain wax technique. Special porcelain-wax mixtures (**A**) and electric waxing instruments (**B**) are available for this technique. **C,** The mixture is flowed to place and shaped with conventional carving instruments before firing.

Table 24-2 ADVANTAGES AND DISADVANTAGES OF FABRICATION TECHNIQUES

Method	Advantages	Disadvantages
Platinum foil	No shoulder porcelain (best esthetics)[78] Good marginal adaptation Smooth surface[78] Low plaque accumulation[78]	Time consuming Technically difficult
Wax suspension	Separates easily	Shoulder porcelain needed Less accurate fit[79]
Direct lift	Least time consuming	Shoulder porcelain needed Rougher margins[78]

It separates easily from the die and can be fired in the conventional manner.

4. A second application is needed. Using the electric waxing instrument, keep the mixture liquid long enough so that capillary action can draw it into the marginal discrepancies. The restoration is completed in the conventional manner. If rounding of the margins occurs during glazing, using a shoulder porcelain rather than a body porcelain in the wax mixture is recommended.

Advantages and disadvantages of each technique are summarized in Table 24-2.

TROUBLESHOOTING

Technical failures can occur in the complex metal-ceramic system and are difficult to diagnose. Different errors may lead to problems that appear similar. Table 24-3 summarizes some of these.

Cracks

Surface cracks and fractures in the opaque porcelain are usually of little concern. They can be patched before the body firing begins. Fractures during the bisque bake, however, often are the result of improper condensation, overly rapid drying, or haphazard moisture control. Poor substructure design, resulting in areas of unsupported porcelain, also can lead to porcelain failure (see Chapter 19). After cementation, pinpointing the cause of failure may be difficult. If the substructure is properly designed and the porcelain-metal interface is kept away from direct occlusal contact, cracks and fractures should not develop during normal function.

Bubbles

Even the most experienced ceramist sometimes traps air between the metal and the opaque. Usually this is of little concern. However, if a restoration is fired too many times, the trapped air may appear as blisters that rise to the surface. If this occurs, the porcelain must be stripped, and the procedure is started over.

If bubbles appear after only a few firings, improper casting technique, insufficient metal preparation, and haphazard moisture control can usually be isolated as the cause (Fig. 24-36).

Table 24-3 COMMON REASONS FOR FAILURE OF METAL-CERAMIC RESTORATIONS

Failure	Reason
Fracture during bisque bake	Improper condensation Improper moisture control Poor framework design Incompatible metal-porcelain combination
Bubbles	Too many firings Air entrapment during building of restoration Improper moisture control Poor metal preparation Poor casting technique
Unsatisfactory appearance	Poor communication with technician Inadequate tooth reduction Opaque too thick Excessive firing
Clinical fracture	Poor framework design Centric stops too close to metal-ceramic interface Improper metal preparation

Unsatisfactory Appearance

Poor esthetic results often result from poor communication between the operator and the dental tech-

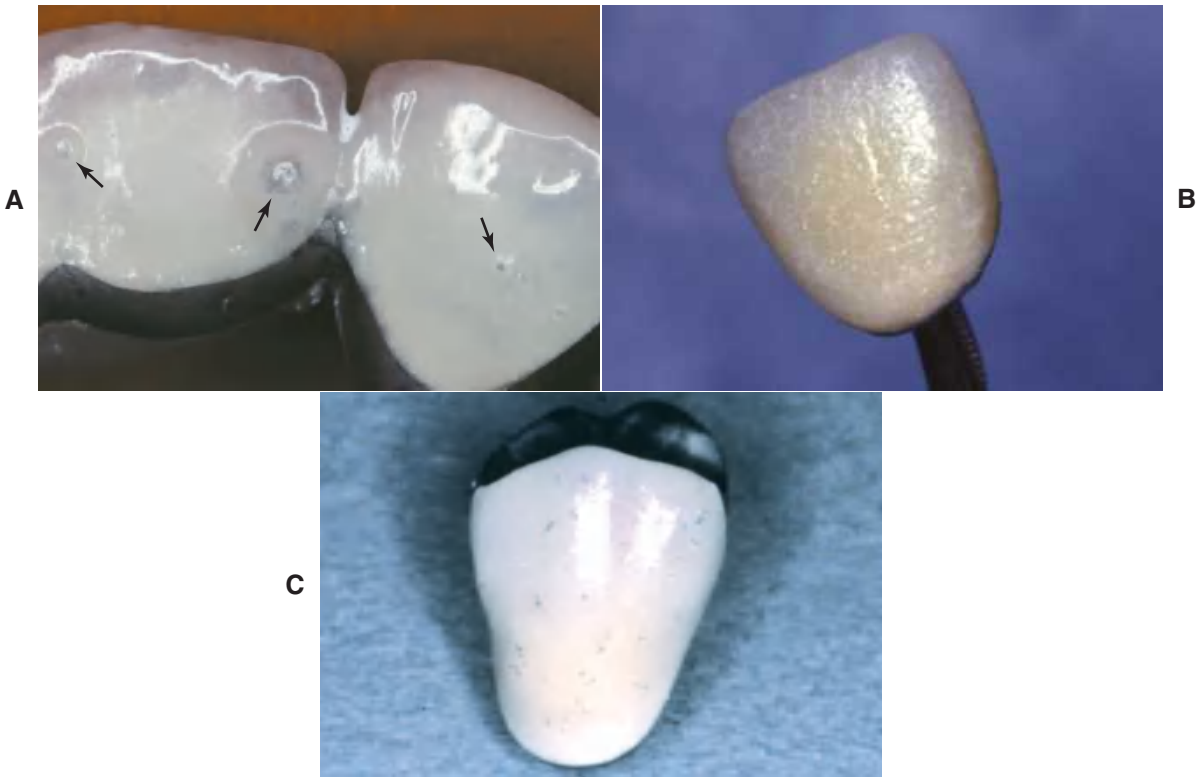


Fig. 24-36
A, Bubbles *(arrows)* have made this metal-ceramic restoration unacceptable. **B,** Devitrified porcelain on a metal-ceramic restoration, the result of an excessive number of firings. **C,** Contamination of the porcelain surface has made this prosthesis unacceptable.

nician (see Chapter 16). An opaque application that is too thick can result in opacity of the veneer. Inadequate tooth reduction, especially in the cervical third and the interproximal areas, is one of the more common causes of a poor esthetic result. Careful communication, based on a thorough understanding and knowledge of relevant laboratory procedures and color science, is essential.

REVIEW OF TECHNIQUE

Fabricating a metal-ceramic restoration involves the following steps:

1. Patterns are waxed to anatomic contour.
2. The cut-back is completed and verified with an index made from the anatomic waxing.
3. The patterns are cast (see Chapter 22) and seated on the die.
4. After finishing (and clinical evaluation if desired [see Chapter 30]), the substructures are opaqued to mask the metal color.
5. Body powders are added to build to contour and cut back to standardize the amount of enamel powder that is added.
6. Enamel powder is added, and the buildup is slightly overcontoured to compensate for firing shrinkage.
7. After preliminary contouring, the bisque bake can be evaluated clinically. The incisal edge position is adjusted for function, esthetics, and phonetics.
8. After contouring, the restorations are glazed, and the metal is polished before cementation.

SUMMARY

Substructure design for metal-ceramic restorations must be based on an understanding of fundamental material properties. Restorations should be waxed to anatomic contour and then cut back in the area that is to be veneered. This allows an even porcelain thickness, which not only is a means of obtaining superior mechanical properties in the completed restoration but also simultaneously helps standardize shade matching.

Metal-ceramic restorations with excellent appearance and good mechanical properties are obtainable if the techniques of metal preparation, framework

STUDY QUESTIONS

1. Discuss the types of dental porcelains used in the fabrication of a metal-ceramic restoration. What are the composition differences among the various powders? How does the handling differ?
2. What are the prerequisites for casting preparation before the initial firing?
3. What is the role of a vacuum in firing a metal-ceramic restoration? Which procedures require a vacuum, and which are performed without it?
4. How do firing schedules vary as a function of the alloy used?
5. What is vitrification? What is devitrification?
6. Discuss the porcelain-metal bond. Which components of the alloy are involved? Which components of the dental porcelain are involved?
7. Discuss two different techniques for fabricating a porcelain labial margin.
8. Describe the causes for fractures and air bubbles during the bisque bake.

design, porcelain manipulation, drying, and firing are carefully followed. Lifelike effects can be achieved by layering cervical, body, and incisal porcelains and by the judicious use of internal characterization and special dentin powders with relatively higher concentrations of opacifiers. Although it may create esthetic problems in many patients, the simplest way to obtain good marginal fit is to use a narrow, 0.2- to 0.3-mm facial collar.

Whenever optimum appearance is desired, the procedures described in this chapter for fabricating a labial porcelain margin should be considered. However, the level of expertise needed to produce excellent marginal adaptation with these techniques is higher than that needed to use a cast margin; this should be considered in treatment planning. When failure occurs, all technical steps and materials should be reevaluated.

GLOSSARY*

abrade \uh-brād\ *vt* (1677)**:** to rub away the external covering or layer of a part—*comp* ATTRITION, EROSION

abra·sion \ă-brā ′shun\ *n* (1656) **1:** the wearing away of a substance or structure (such as the skin or the teeth) through some unusual or abnormal mechanical process **2:** an abnormal wearing away of the tooth substance by causes other than mastication—*comp* ATTRITION, EROSION

aluminous porcelain \a-lōō′mi-nus pôr′si-lin, pōr′-**:** a ceramic material composed of a glass matrix phase with 35% or more of aluminum oxide, by volume

bees' wax *n* (1676)**:** a low-melting wax obtained from honeycomb and used as an ingredient of many dental impression waxes

bisque bake \bĭsk bāk**:** a series of stages of maturation in the firing of ceramic materials relating to the degree of pyro chemical reaction and sintering shrinkage occurring before vitrification (glazing)—called also *biscuit bake*

ce·ram·ics \sa-răm′iks\ *n* **1:** compounds of one or more metals with a nonmetallic element, usually oxygen. They are formed of chemical and biochemical stable substances that are strong, hard, brittle, and inert nonconductors of thermal and electrical energy **2:** the art of making porcelain dental restorations

co·he·sion \kō-hē′zhun\ *n* (1660) **1:** the act or state of sticking together tightly **2:** the force whereby molecules of matter adhere to one another; the attraction of aggregation **3:** molecular attraction by which the particles of a body are united throughout their mass

[1]cop·ing \kō′pĭng\ *n* **1:** a long, enveloping ecclesiastical vestment **2a:** something resembling a cope (as by concealing or covering) **2b:** coping

[2]cop·ing \kō′pĭng\ *n* (ca. 1909)**:** a thin covering or crown—*usage:* see C. IMPRESSION, TRANSFER C.

[1]craze \krāz\ *vb.* **craz·ed** \krāzd\; **craz·ing** \krā′zĭng\ *vt* (14c)**:** to produce minute cracks on the surface or glaze of; to develop a mesh of fine cracks

[2]craze \krāz\ *n* (1534)**:** a crack in a surface or coating (as of glaze or enamel)

de·gas \dē-găs′\ *vt*; **de·gassed** \dē-găsd′\ *pt., pp*; **de·gassing** \dē-găs′ing\ *ppr* (1920) **1:** to remove gas from an object or substance **2:** the name commonly used to denote the first heat cycle (oxidation cycle) in fabrication of a metal ceramic restoration that removes surface impurities from the metallic component and produces surface oxides prior to the application of opaque porcelain

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de·vit·ri·fi·ca·tion \dē-vĭt′ra-fī-kā′shun\ *n* (1832): to eliminate vitreous characteristics partly or wholly; to crystallize

feld·spar \fĕld′spär, fĕl′-\ *n* (1757) **1:** any one of a group of minerals, principally aluminosilicate of sodium, potassium, calcium, or barium, that are essential constituents of nearly all crystalline rocks **2:** a crystalline mineral of aluminum silicate with sodium, potassium, barium, and/or calcium; a major constituent of some dental procelains

feld·spath·ic \fĕld-spăth′ĭk, fĕl′-\ *adj* (ca. 1828): related to or containing feldspar; used especially with reference to porcelain glaze

fir·ing \fīr′ĭng\: the process of porcelain fusion, in dentistry, specifically to produce porcelain restorations

[1]frit \frĭt\ *n* (1662) **1:** the calcined or partly fused matter of which glass is made **2:** a mass of fused porcelain obtained by firing the basic constituents and plunging them into water while hot. The frit is ground to make porcelain powders

glaze \glāz\ *vb* **glazed** \glāzd\; **glaz·ing** \glā′zĭng\ *vt* (14c) **1:** to cover with a glossy, smooth surface or coating **2:** the attainment of a smooth and reflective surface **3:** the final firing of porcelain in which the surface is vitrified and a high gloss is imparted to the material **4:** a ceramic veneer on a dental porcelain restoration after it has been fired, producing a nonporous, glossy or semi-glossy surface—see NATURAL G., OVERGLAZE

intrinsic coloring \ĭn-trĭn′zĭk, -sĭk kŭl′ar-ĭng\: coloring from within; the incorporation of a colorant within the material of a prosthesis or restoration

ka·olin \kā′a-lĭn\ *n* (1727): fine, usually white, clay that is used in ceramics and refractory materials as a filler or extender

mam·e·lon \măm′a-lŏn\ *n*: one of three tubercles sometimes found on the incisal edges of incisor teeth—**mam·e·lon·at·ed** \măm′a-la-nā′tĭd\ *v*, **mam·e·lon·a·tion** \măm′a-la-nā′shun\ *n*

metal ceramic restoration \mĕt′l sa-răm′ĭk rĕs-ta-rā′shun\: a tooth or/and implant retained fixed dental prosthesis that uses a metal substructure upon which a ceramic veneer is fused—see COLLARLESS M.C.R.

mi·cro·crack \mī′krō-krăk\ *n*: in porcelain, one of the numerous surface flaws that contributes to stress concentrations and results in strengths below those theoretically possible

mod·i·fi·er \mŏd′a-fī′ar\ *n*: a substance that alters or changes the color or properties of a substance

natural glaze \năch-ar-al, năch′ral glāz\: the production of a glazed surface by the vitrification of the material itself and without addition of other fluxes or glasses

o·pac·i·ty \ō-păs′ĭ-tē\ *n* (1611): the quality or state of a body that makes it impervious to light

o·paque \ō-pāk′\ *adj* (1641): the property of a material that absorbs and/or reflects all light and prevents any transmission of light

o·ver·glaze \ō′var-glāz\ *adj* (1879): the production of a glazed surface by the addition of a fluxed glass that usually vitrifies at a lower temperature

pig·ment \pĭg′mant\ *n* (14c): finely ground, natural or synthetic, inorganic or organic, insoluble dispersed particles (powder), which, when dispersed in a liquid vehicle, may provide, in addition to color, many other essential properties such as opacity, hardness, durability, and corrosion resistance. The term is used to include an extender, white or color pigments. The distinction between powders that are pigments and those that are dyes is generally considered on the basis of solubility—pigments being insoluble and dispersed in the material, dyes being soluble or in solution as used

platinum foil \plăt′n-um foil\: a precious-metal foil with a high fusing point that makes it suitable as a matrix for various soldering procedures as well as to provide an internal form for porcelain restorations during their fabrication

por·cel·ain \pôr′sa-lĭn, pōr′-\ *n* (known in Europe, ca. 1540): a ceramic material formed of infusible elements joined by lower fusing materials. Most dental porcelains are glasses and are used in the fabrication of teeth for dentures, pontics and facings, metal ceramic restorations, including fixed dental prostheses, as well as all-ceramic restorations such as crowns, laminate veneers, inlays, onlays, and other restorations

porcelain labial margin \pôr′sa-lĭn, pōr′- lā′bē-al mär′jĭn\: the extension of ceramic material to the finish line of the preparation without visible metal substructure in the marginal area—*syn* PORCELAIN BUTT MARGIN

quartz \kwôrts\ *n* (ca. 1631): an allotropic form of silica; the mineral SiO_2 consisting of hexagonal crystals of colorless, transparent silicon dioxide

si·li·ca \sĭl′ĭ-ka\ *n* (ca 1301): silicon dioxide occurring in crystalline, amorphous, and usually impure forms (as quartz, opal, and sand, respectively)

[2]sinter \sĭn′tar\ *vt* (1871): to cause to become a coherent mass by heating without melting

[2]stain \stān\ *vb* (14c) **1:** to suffuse with color **2:** to color by processes affecting chemically or otherwise the material itself **3:** in dentistry, to intentionally alter restorations

through the application of intrinsic or extrinsic colorants to achieve a desired effect, best termed *characterization* or to *characterize* a restoration

static fatigue \stăt′ĭk fa-tēg\: the delayed failure of glass and ceramic materials resulting from stress enhanced chemical reactions aided by water vapor acting on surface cracks. Analogous to stress corrosion occurring in metals

thermal expansion \thûr′mal ĭk-spăn′shun\: expansion of a material caused by heat

trans·luc·en·cy \trănz′lōō′san-sē\ *n* (1611): having the appearance between complete opacity and complete transparency; partially opaque

REFERENCES

1. Ernsmere JB: Porcelain dental work. Br J Dent Sci 43:547, 1900.
2. Johnston JF, et al: Porcelain veneers bonded to gold castings: a progress report. J Prosthet Dent 8:120, 1958.
3. MacEntee MI, Belser UC: Fixed restorations produced by commercial dental laboratories in Vancouver and Geneva. J Oral Rehabil 15:301, 1988.
4. Goodacre CJ, et al: The collarless metal-ceramic crown. J Prosthet Dent 38:615, 1977.
5. Toogood GD, Archibald JF: Technique for establishing porcelain margins. J Prosthet Dent 40:464, 1978.
6. Warpeha WS, Goodkind RJ: Design and technique variables affecting fracture resistance of metal-ceramic restorations. J Prosthet Dent 35:291, 1976.
7. Moore PA, Manor RC: Hydrofluoric acid burns. J Prosthet Dent 47:338, 1982.
8. Felton DA, et al: Effect of air abrasives on marginal configurations of porcelain-fused-to-metal alloys: an SEM analysis. J Prosthet Dent 65:38, 1991.
9. Hamaguchi H, et al: Marginal distortion of the porcelain-bonded-to-metal complete crown: an SEM study. J Prosthet Dent 47:146, 1982.
10. Richter-Snapp K, et al: Change in marginal fit as related to margin design, alloy type, and porcelain proximity in porcelain-fused-to-metal restorations. J Prosthet Dent 60:435, 1988.
11. Weinstein M, et al: Fused Porcelain-to-Metal Teeth. U.S. Patent No. 3,052,982, September 11, 1962.
12. Weinstein M, Weinstein AB: Porcelain-Covered Metal-Reinforced Teeth. U.S. Patent No. 3,052,983, September 11, 1962.
13. Barreiro MM, et al: Phase identification in dental porcelains for ceramo-metallic restorations. Dent Mater 5:51, 1989.
14. Rasmussen ST, et al: Optimum particle size distribution for reduced sintering shrinkage of a dental porcelain. Dent Mater 13:43, 1997.
15. Laub LW, et al: The metal-porcelain interface of gold crowns [Abstract no. 874]. J Dent Res 57:A293, 1978.
16. Seghi RR, et al: Spectrophotometric analysis of color differences between porcelain systems. J Prosthet Dent 56:35, 1986.
17. Rosenstiel SF, Johnston WM: The effects of manipulative variables on the color of ceramic metal restorations. J Prosthet Dent 60:297, 1988.
18. O'Brien WJ, Ryge G: Contact angles of drops of enamels on metals. J Prosthet Dent 15:1094, 1965.
19. Borom MP, Pask JA: Role of "adherence oxides" in the development of chemical bonding at glass-metal interfaces. J Am Ceram Soc 49:1, 1966.
20. Ohno H, Kanzawa Y: Structural changes in the oxidation zones of gold alloys for porcelain bonding containing small amounts of Fe and Sn. J Dent Res 64:67, 1985.
21. Brantley WA, et al: X-ray diffraction studies of oxidized high-palladium alloys. Dent Mater 12:333, 1996.
22. Kerber SJ, et al: The complementary nature of x-ray photoelectron spectroscopy and angle-resolved x-ray diffraction. II. Analysis of oxides on dental alloys. J Mater Eng Perform 7:334, 1998.
23. Cascone PJ: The theory of bonding for porcelain-metal systems. In Yamada HN, Grenoble PB, eds: Dental Porcelain: The State of the Art–1977, p. 109. Los Angeles, University of Southern California School of Dentistry, 1977.
24. Cascone PJ: Oxide formation on palladium alloys and its effects on porcelain adherence [Abstract no. 772]. J Dent Res 62:255, 1983.
25. Lautenschlager EP, et al: Microprobe analyses of gold-porcelain bonding. J Dent Res 8:1206, 1969.
26. Payan J, et al: Changes in physical and chemical properties of a dental palladium-silver alloy during metal-porcelain bonding. J Oral Rehabil 13:329, 1986.
27. Hong JM, et al: The effect of recasting on the oxidation layer of a palladium-silver porcelain alloy. J Prosthet Dent 59:420, 1988.
28. Anusavice KJ, et al: Adherence controlling elements in ceramic-metal systems. I. Precious alloys. J Dent Res 56:1045, 1977.
29. Anusavice KJ, et al: Adherence controlling elements in ceramic-metal systems. II. Nonprecious alloys. J Dent Res 56:1053, 1977.

30. Papazoglou E, et al: New high-palladium casting alloys. Studies of the interface with porcelain. Int J Prosthodont 9:315, 1996.
31. Anusavice KJ: Phillips' Science of Dental Materials, 11th ed, p. 342. Philadelphia, Elsevier Science/Saunders, 2003.
32. Caputo AA: Effect of surface preparation on bond strength of nonprecious and semi-precious alloys. J Calif Dent Assoc 6:42, 1978.
33. Baran GR: The metallurgy of Ni-Cr alloys for fixed prosthodontics. J Prosthet Dent 50:639, 1983.
34. Laub LW, et al: The tensile and shear strength of some base metal/ceramic interfaces [Abstract no. 504]. J Dent Res 56:B178, 1977.
35. Shell JS, Nielsen JP: Study of the bond between gold alloys and porcelain. J Dent Res 41:1424, 1962.
36. Carpenter MA, Goodkind RJ: Effect of varying surface texture on bond strength of one semi-precious and one nonprecious ceramo-alloy. J Prosthet Dent 42:86, 1979.
37. Wagner WC, et al: Effect of interfacial variables on metal-porcelain bonding. J Biomed Mater Res 27:531, 1993.
38. Craig RG, Powers JM, eds: Restorative Dental Materials, 11th ed, p. 578. St. Louis, Elsevier Health Sciences/Mosby, 2002.
39. Meyer JM, et al: Sintering of dental porcelain enamels. J Dent Res 55:696, 1976.
40. Johnston WM, O'Brien WJ: The shear strength of dental porcelain. J Dent Res 59:1409, 1980.
41. Nally JN: Chemico-physical analysis and mechanical tests of the ceramo-metallic complex. Int Dent J 18:309, 1968.
42. Kelly M, et al: Tensile strength determination of the interface between porcelain fused to gold. J Biomed Mater Res 3:403, 1969.
43. Anusavice KJ, et al: Comparative evaluation of ceramic-metal bond tests using finite element stress analysis. J Dent Res 59:608, 1980.
44. O'Brien WJ: Cohesive plateau theory of porcelain-alloy bonding. In Yamada HN, Grenoble PB, eds: Dental Porcelain: The State of the Art–1977, p. 137. Los Angeles, University of Southern California School of Dentistry, 1977.
45. O'Brien WJ: The cohesive plateau stress of ceramic-metal systems [Abstract no. 501]. J Dent Res 56:B177, 1977.
46. ANSI/ADA Specification No. 38 for Metal-Ceramic Systems. Chicago, American Dental Association, 2000.
47. Ringle RD, et al: An x-ray spectrometric technique for measuring porcelain-metal adherence. J Dent Res 62:933, 1983.
48. Mackert JR, et al: Measurement of oxide adherence to PFM alloys. J Dent Res 63:1335, 1984.
49. Papazoglou E, et al: Porcelain adherence to high-palladium alloys. J Prosthet Dent 70:386, 1993.
50. Papazoglou E, et al: Effects of dental laboratory processing variables and in vitro testing medium on the porcelain adherence of high-palladium casting alloys. J Prosthet Dent 79:514, 1998.
51. Adachi M, et al: Oxide adherence and porcelain bonding to titanium and Ti-6Al-4V alloy. J Dent Res 69:1230, 1990.
52. Cai Z, et al: Porcelain adherence to dental cast CP titanium: effects of surface modifications. Biomaterials 22:979, 2001.
53. Sadeq A, et al: Effects of interfacial variables on ceramic adherence to cast and machined commercially pure titanium. J Prosthet Dent 90:10, 2003.
54. Lee KM, et al: SEM/EDS evaluation of porcelain adherence to gold-coated cast titanium. J Biomed Mater Res B Appl Biomater 68:165, 2004.
55. International Organization for Standardization: ISO Standard No. 9693: Dental Porcelain Fused to Metal Restorations. Geneva, Switzerland, International Organization for Standardization, 2000.
56. Lenz J, et al: Bond strength of metal-ceramic systems in three-point flexure bond test. J Appl Biomater 6:55, 1995.
57. Papazoglou E, Brantley WA: Porcelain adherence vs. force to failure for palladium-gallium alloys: critique of metal-ceramic bond testing. Dent Mater 14:112, 1998.
58. Leone EF, Fairhurst CW: Bond strength and mechanical properties of dental porcelain enamels. J Prosthet Dent 18:155, 1967.
59. Knap FJ, Ryge G: Study of bond strength of dental porcelain fused to metal. J Dent Res 45:1047, 1966.
60. Sced IR, McLean JW: The strength of metal/ceramic bonds with base metals containing chromium. Br Dent J 13:232, 1972.
61. Wang RR, et al: Silicon nitride coating on titanium to enable titanium-ceramic bonding. J Biomed Mater Res 46:262, 1999.
62. Terada Y, et al: The masking ability of an opaque porcelain: a spectrophotometric study. Int J Prosthodont 2:259, 1989.
63. McLaren EA: Utilization of advanced metal-ceramic technology: clinical and laboratory procedures for a lower-fusing porcelain. Pract Periodont Aesthet Dent 10:835, 1998.
64. Metzler KT, et al: In vitro investigation of the wear of human enamel by dental porcelain. J Prosthet Dent 81:356, 1999.

65. Rosenstiel SF: Linear firing shrinkage of metal-ceramic restorations. Br Dent J 162:390, 1987.
66. Evans DB, et al: The influence of condensation method on porosity and shade of body porcelain. J Prosthet Dent 63:380, 1990.
67. Rosenstiel SF, Porter SS: Apparent fracture toughness of metal ceramic restorations with different manipulative variables. J Prosthet Dent 61:185, 1989.
68. Mackert JR Jr, Evans AL: Effect of cooling rate on leucite volume fraction in dental porcelains. J Dent Res 70:137, 1991.
69. Asaoka K, Tesk JA: Transient and residual stress in a porcelain-metal strip. J Dent Res 69:463, 1990.
70. Barghi N, et al: Comparison of fracture strength of porcelain-veneered-to-high noble and base metal alloys. J Prosthet Dent 57:23, 1987.
71. Abbate MF, et al: Comparison of the marginal fit of various ceramic crown systems. J Prosthet Dent 61:527, 1989.
72. Belser UC, et al: Fit of three porcelain-fused-to-metal marginal designs in vivo: a scanning electron microscope study. J Prosthet Dent 53:24, 1985.
73. Anusavice KJ, Hojjatie B: Stress distribution in metal-ceramic crowns with a facial porcelain margin. J Dent Res 66:1493, 1987.
74. Touati B, Miara P: Light transmission in bonded ceramic restorations. J Esthet Dent 5:11, 1993.
75. O'Boyle K, et al: An investigation of new metal framework design for metal ceramic restorations. J Prosthet Dent 78:295, 1997.
76. Lehner CR, et al: Variable reduced metal support for collarless metal ceramic crowns: a new model for strength evaluation. Int J Prosthodont 8:337, 1995.
77. Prince J, et al: The all-porcelain labial margin for ceramometal restorations: a new concept. J Prosthet Dent 50:793, 1983.
78. Koidis PT, et al: Color consistency, plaque accumulation, and external marginal surface characteristics of the collarless metal ceramic restoration. J Prosthet Dent 65:391, 1991.
79. Belles DM, et al: Effect of metal design and technique on the marginal characteristics of the collarless metal ceramic restoration. J Prosthet Dent 65:611, 1991.

25

ALL-CERAMIC RESTORATIONS



Isabelle L. Denry, Contributing Author

KEY TERMS

air firing
all-ceramic crowns
aluminum oxide
computer-aided design/computer-aided manufacturer (or computer-assisted machining) (CAD/CAM)
ceramic
ceramic core
core
etching
glass-ceramic
glaze
heat-pressed
microcracks
opaque
platinum foil
porcelain
porosity
refractory cast
silane
slip-cast
stain
stress corrosion
translucency
vacuum firing

All-ceramic inlays, onlays, veneers, and crowns can provide some of the most esthetically pleasing restorations currently available. They can be made to match natural tooth structure accurately in terms of color, surface texture, and **translucency.** Well-made all-ceramic restorations can be virtually indistinguishable from unrestored natural teeth (Fig. 25-1).

Traditionally, **ceramic** crowns have been made on a platinum matrix and were referred to as **porcelain** jacket crowns. More recently, improved materials and techniques have been introduced in an attempt to overcome disadvantages inherent in that traditional method. These improvements, particularly the use of higher strength ceramics and adhesives for bonding the ceramic restoration to tooth structure, have led to a resurgence of interest in all-ceramic restorations, including the more conservative inlays and veneers. With increasing demand for esthetics, all-ceramic restorations are an important part of contemporary dental practice.

This chapter reviews the historical background of ceramic restorations and more recent developments. It outlines the laboratory procedures necessary for the fabrication of all-ceramic inlays, veneers, and crowns and compares the alternatives.

The importance of the design of the tooth preparation to the success of ceramic restorations cannot be overemphasized (see Chapter 11).

HISTORICAL BACKGROUND

The first attempt to use ceramics for making denture teeth was by Alexis Duchateau in 1774. More than a hundred years later, C. H. Land made the first ceramic crowns and inlays with a **platinum foil** matrix technique and was granted a patent in 1887.[1] The popularity of ceramic restorations declined with the introduction of acrylic resin in the 1940s and continued to be low until the disadvantages of resin veneering materials (increased wear, high permeability leading to discoloration and leakage) were realized.[2-4] In 1962, Weinstein and Weinstein patented a



Fig. 25-1
A, All-ceramic crown restoring the right maxillary central incisor. **B** and **C,** Maxillary anterior teeth restored with facial veneers and an all-ceramic fixed dental prosthesis. (***B*** *and* **C,** *Courtesy of Dr. D. H. Ward.)*

leucite-containing porcelain frit for use in metal-ceramic restorations.[5] The presence of leucite, an aluminosilicate with high thermal expansion, allowed a match between the thermal expansion of the ceramic and that of the metal (see Chapter 24). The appearance of ceramic restorations was improved by the introduction of **vacuum firing,** which considerably reduced the amount of **porosity** and therefore resulted in denser and more translucent restorations than could be achieved with **air firing**.[6]

HIGH-STRENGTH CERAMICS

The chief disadvantage of the early restorations was their low strength, which limited their use to low-stress situations, such as those encountered by anterior teeth. Even so, fracture was a fairly common occurrence, which prompted the development of higher strength materials.[7,8] These developments have followed two paths. One approach is to use two ceramic materials to fabricate the restoration. A high-strength but nonesthetic **ceramic core** material is veneered with a lower strength, esthetic porcelain. This approach is similar to the metal-ceramic technique (see Chapter 24), although the color of the ceramic core is more easily masked than that of a metal substructure. The other approach is the development of a ceramic that combines good esthetics with high strength. This has the obvious attraction of not needing the additional thickness of material to mask a high-strength core. However, at present, the strongest dental ceramics are nonesthetic **core** materials.

STRENGTHENING MECHANISMS OF DENTAL CERAMICS

In spite of their excellent esthetic qualities and outstanding biocompatibility, dental ceramics, like all ceramic materials, are brittle. They are susceptible to fracture at the time of placement and during function. Brittle materials such as ceramics contain at least two types of flaws: fabrication defects and surface cracks, from which fracture can initiate. Methods used to improve the strength and clinical performance of dental ceramics include crystalline reinforcement, chemical strengthening, and stress-induced transformation.

Fabrication Defects

Fabrication defects are created during processing and consist of voids or inclusions generated during sintering. Condensation of a ceramic slurry by hand before sintering may introduce porosity. Sintering under vacuum reduces the porosity in dental ceramics from 5.6 to 0.56 volume percent.[9] Porosity on the internal side of clinically failed **glass-ceramic** restorations has been shown to constitute a fracture initiation site.[10] Also, **microcracks** develop within the ceramic upon cooling in leucite-containing ceramics and are caused by thermal contraction mismatch between the crystals and the glassy matrix.[11-13]

Surface Cracks

Surface cracks are induced by machining or grinding. The average natural flaw size varies from 20 to 50 μm.[14] Usually, fracture of the ceramic material takes place from the most severe flaw, which effec-

tively determines the fracture resistance of the restoration. Ceramic engineers analyze failure with a statistical approach, looking at flaw size and spatial distribution.[15]

Crystalline Reinforcement

Strengthening by crystalline reinforcement involves the introduction of a high proportion of crystalline phase into the ceramic material to improve the resistance to crack propagation. The crystals can deflect the advancing crack front to increase the fracture resistance of two-phase materials. Microstructural features that typically lead to crack deflection include (1) weakened interfaces between grains in single-phase materials that may be caused by incomplete sintering and (2) residual strains in two-phase materials.[16] The latter constitutes a major issue in dental ceramics.

A crystalline phase with *greater* thermal expansion coefficient than the matrix produces tangential *compressive* stress (and radial tension) near the crystal-matrix interface. Such tangential stresses tend to divert the crack around the particle. Leucite particles have a greater thermal expansion coefficient than does the surrounding glassy matrix. Upon cooling, compressive stresses develop at the leucite crystal-matrix interface.[12]

Chemical Strengthening

Chemical strengthening is another method used to increase the strength of glasses and ceramics. Chemical strengthening relies on the exchange of small alkali ions for larger ions below the strain point of the ceramic material. Because stress relaxation is not possible in this temperature range, the exchange leads to the creation of a compressive layer at the surface of the ceramic.[17] Finally, any applied load must first overcome this built-in compression layer before the surface can be placed into tension; this results in an increase in fracture resistance. This technique involves the use of alkali salts with a melting point lower than the glass transition temperature of the ceramic material. Ion exchange strengthening has been reported to increase the flexural strength of feldspathic dental porcelain up to 80%, depending on the ionic species involved and the composition of the porcelain.[18,19] The depth of the ion-exchanged layer could be as high as 50 μm.[20] However, this technique is diffusion driven, and its kinetics are limited by time, temperature, and ionic radius of the exchanged ions.

The glass industry also uses thermal tempering (fast cooling) as a strengthening method.[21]

Stress-Induced Transformation

In some ceramic materials such as polycrystalline zirconia, strengthening can be obtained through a stress-induced transformation. Zirconia is monoclinic at room temperature and tetragonal between about 1170° C (2140° F) and 2370° C (4300° F). The transformation between tetragonal and monoclinic zirconia is accompanied by an increase in volume. The tetragonal form can be retained at room temperature by addition of various oxides such as yttrium oxide. Stress can trigger the transformation from tetragonal to monoclinic zirconia, thereby leading to strengthening as a result of an increase in grain volume in the vicinity of the crack tip.[22]

Glazing

The addition of a surface **glaze** can also be used to strengthen ceramics. The principle is the formation of a low-expansion surface layer formed at a high temperature. Upon cooling, the low-expansion glaze places the surface of the ceramic in compression and reduces the depth and width of surface flaws.[23]

With contemporary dental ceramics, self-glazing is the standard technique. This consists of an additional firing in air after the original firing, without application of a low-expansion glaze. However, self-glazing does not significantly improve the flexure strength of feldspathic dental porcelain.[24,25]

Prevention of Stress Corrosion

The strength of ceramics is reduced in moist environments. This weakening is caused by a chemical reaction between water and the ceramic at the tip of the strength-controlling crack, resulting in an increase in the crack size—a phenomenon called ***stress corrosion*** or *static fatigue*.[26] According to Michalske and Freiman,[27] the reaction steps involve the following:

1. The adsorption of water to a strained silicon-oxygen-silicon (Si-O-Si) bond.
2. A concerted reaction involving simultaneous proton and electron transfer.
3. The formation of surface hydroxyls.

Sherrill and O'Brien[28] reported a reduction in fracture strength of about 30% when dental porcelains were fractured in water, and other authors have concluded that stress corrosion is important in the performance of dental ceramic restorations.[29,30]

Ceramic systems such as Captek* that are baked on a metal foil may reduce fracture incidence by

*Captek, Precious Chemicals Co., Inc., Altamonte, Florida.

reducing moisture exposure to the internal surface of the ceramic material, from where the fracture is thought to initiate.[10] In industry, coatings are used to reduce stress corrosion of glass and ceramics, such as optical fibers. Similar coatings have been tried experimentally for their effect on dental ceramics.[31]

ALL-CERAMIC SYSTEMS

The microstructure of some ceramic systems discussed in this chapter is illustrated in Figure 25-2, and their properties are summarized in Table 25-1.

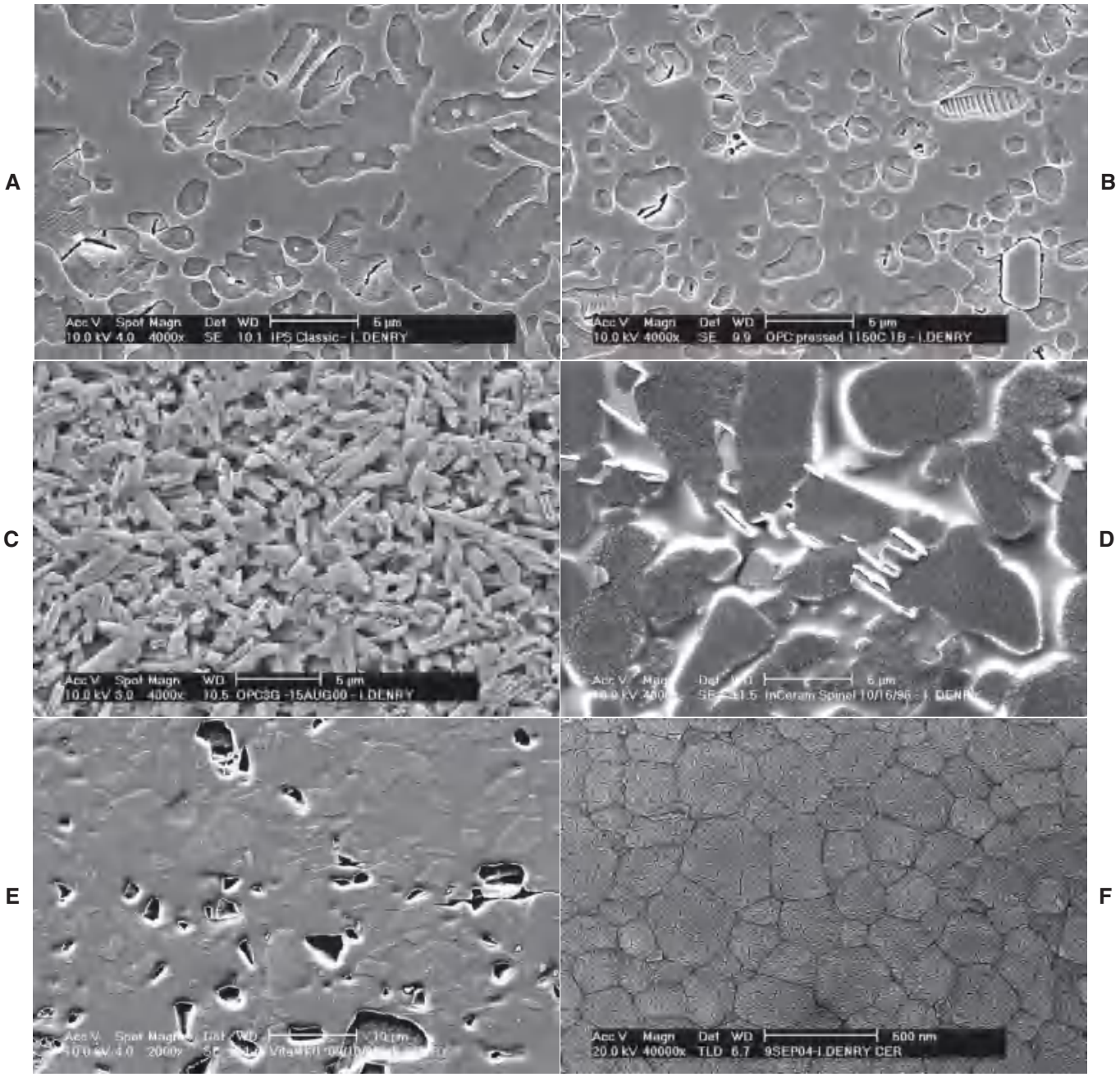


Fig. 25-2

Representative dental ceramics etched to reveal microstructure. **A,** A feldspathic porcelain (IPS Classic). **B,** A leucite-reinforced pressable ceramic (OPC). **C,** A lithium disilicate pressable ceramic (OPC 3G). **D,** A slip-cast spinel ceramic (In-Ceram Spinell). **E,** A feldspathic machinable (VITA Mark II). **F,** A machined and sintered zirconia ceramic (Cercon).

Table **25-1 COMPARISON OF AVAILABLE ALL-CERAMIC SYSTEMS**

	BRAND								
	Captek	**Ceramco 3**	**Cerinate**	**IPS Empress**	**IPS Empress 2**	**Empress Cosmo**	**Finesse**	**In-Ceram**	**In-Ceram Spinell**
Manufacturer	Precious Chemicals	Dentsply	Den-Mat	Ivoclar	Ivoclar	Ivoclar	Dentsply	Vident	Vident
Crystalline phase	Leucite	Leucite	Leucite	Leucite	Lithium disilicate	Lithium phosphate	Leucite	Alumina	Alumina, spinel
Recommended usage	Crowns	Inlays, onlays, veneers	Inlays, onlays, crowns, veneers	Inlays, onlays, crowns, veneers	Anterior 3-unit FDPs, crowns	Endodontic foundation	Inlays, onlays, crowns, veneers	Crowns, veneers	Crowns, veneers
Fabrication	Sintered on metal foil	Sintered	Sintered	Heat-pressed	Heat-pressed	Heat-pressed	Heat-pressed	Slip-cast and sintered	Slip-cast and sintered
Strength	Low	Low	Medium/low	Medium/low	High	Medium	Medium/low	High	High
Fracture toughness	Medium/low	Medium/low	Medium/low	Medium/low	High	Medium	Medium/low	High	High
Translucency	Opaque	Medium	Medium	Medium	Medium	Medium	Medium	Opaque	Medium
Enamel abrasiveness	Medium	Medium	High	Medium	Low	*	Medium	High	High
Marginal fit	Good	Fair	Fair	Fair	Fair	*	*	Fair	Fair

	BRAND								
	In-Ceram Zirconia	**Mark II**	**ProCAD**	**YZ blocs (inVizion)**	**Cercon Zirconia**	**Lava**	**Procera Alumina**	**Procera Zirconia**	**Metal-ceramic**
Manufacturer	Vident	Vident	Ivoclar	Vident	Dentsply	3M ESPE	Nobel Biocare	Nobel Biocare	Various
Crystalline phase	Zirconia-alumina	Feldspar	Leucite	Zirconia	Zirconia	Zirconia	Alumina	Zirconia	Leucite
Recommended usage	3-Unit FDPs	Inlays, onlays, crowns	Inlays, onlays, crowns	Crowns, FDPs	Crowns, FDPs	Crowns, FDPs	Crowns, FDPs	Crowns, FDPs	Crowns, FDPs
Fabrication	Slip-cast and sintered	CAD/CAM	CAD/CAM	CAD/CAM and sintered	CAD/CAM and sintered	CAD/CAM and sintered	CAD/CAM and sintered	CAD/CAM and sintered	Cast framework, sintered porcelain
Strength	Very high	Medium/ low	Medium/ low	Very high	Very high	Very high	High	Very high	Very high
Fracture toughness	Very high	Medium/ low	Medium/ low	Very high	Very high	Very high	Very high	Very high	Medium
Translucency	Opaque	Medium	Medium	Opaque	Opaque	Opaque	Opaque	Opaque	Opaque
Enamel abrasiveness	High	Medium	*	*	*	*	*	*	Medium
Marginal fit		Fair	Fair	*	*	*	*	*	Good

*Not tested.
CAD/CAM, computer-aided design/computer-aided manufacturer (or computer-assisted machining); FDP, fixed dental prosthesis.

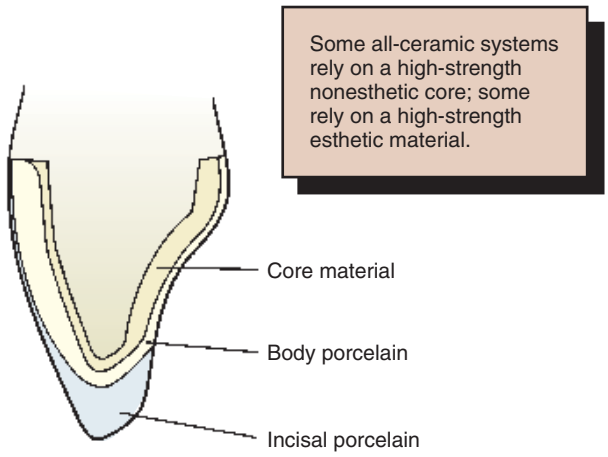


Fig. 25-3
The strength of an aluminous jacket crown is derived from its high-alumina content core, onto which esthetic body and incisal porcelains are fired. This is analogous to the metal-ceramic crown, whose strength is derived from a metal substructure.

Aluminous Core Ceramics

The high-strength ceramic core was first introduced to dentistry by McLean and Hughes[32] in 1965. They advocated using aluminous porcelain, which is composed of **aluminum oxide** (alumina) crystals dispersed in a glassy matrix. Their recommendation was based on the use of alumina-reinforced porcelain in the electrical industry[33] and the fact that alumina has a high fracture toughness and hardness.[34]

The technique devised by McLean[35] involved the use of an **opaque** inner core containing 50% by weight alumina for high strength. This core was veneered by a combination of esthetic body and enamel porcelains with 15% and 5% crystalline alumina, respectively[36] (Fig. 25-3) and matched thermal expansion. The resulting restorations were approximately 40% stronger than those with traditional feldspathic porcelain.[26]

Fabrication procedure

Although declining in popularity with the introduction of innovative all-ceramic products, a technician skilled in the fabrication of the aluminous core porcelain jacket crown produces an exceptionally esthetic restoration. The procedure is outlined in Figures 25-4 to 25-6.

Slip-Cast Ceramics

High-strength core frameworks for all-ceramic restorations can be produced with a **slip-casting** procedure[37] such as the In-Ceram (see Fig. 25-9A).*

*Vident, Brea, California.

Slip-casting is a traditional technique in the ceramic industry and is used to make sanitary ware. The starting medium in slip-casting is a slip that is an aqueous suspension of fine ceramic particles in water with dispersing agents. The slip is applied onto a porous refractory die, which absorbs the water from the slip and leads to the condensation of the slip on the die. The piece is then fired at a high temperature (1150° C [2100°F]). The refractory die shrinks more than the condensed slip, which allows easy separation after firing. The fired porous core is later glass infiltrated, a unique process in which molten glass is drawn into the pores by capillary action at a high temperature.[38] Materials processed by slip-casting tend to exhibit lower porosity and fewer processing defects than do traditionally sintered ceramic materials. The strength of In-Ceram is about three to four times greater than that of earlier alumina core materials,[39,40] a finding that has prompted its use in high-stress situations such as fixed dental prostheses (FDPs) (Fig. 25-7). Two modified porcelain compositions for the In-Ceram technique have been introduced: In-Ceram Spinell* contains a magnesium spinel ($MgAl_2O_4$) as the major crystalline phase, which improves the translucency of the final restoration (Fig. 25-8). In-Ceram Zirconia contains zirconium oxide (ZrO_2) and is said to provide the highest strength.[41,42] Marginal fit of In-Ceram has been reported as very good[43] or good[44] but also poor,[45] which emphasizes the technique sensitivity of the process and the need to select a skilled dental laboratory.

Fabrication procedure

1. Duplicate the working die with an elastomeric impression material (Fig. 25-9*B*) and pour it with the special refractory die material. Any undercuts must be blocked out first, and two coats of die-spacer must be applied. When the die material has fully set (2 hours), remove the die, mark the margins, and apply the wetting agent (see Fig. 25-9*C*).
2. Mix the appropriate shade of alumina slip with ultrasonic agitation (see Fig. 25-9*D*), place the mixture under a vacuum, brush apply it to the plaster die (see Fig. 25-9*E*), and shape it with a blade, trimming back to the margins carefully.
3. The slip is fired in a special furnace (see Fig. 25-9*F*), initially through a prolonged drying cycle to 120° C (248° F) that dries the die material, which shrinks away from the core. Then the

*Note: The product *In-Ceram Spinell* is spelled differently from the mineral spinel.

Text continues on page 785



Fig. 25-4

Platinum matrix fabrication. **A,** A diamond-shaped foil is adapted to the facial surface (a cutting guide is provided with the foil). **B,** Two cuts are made, one to each incisal corner, and a triangle of foil is removed by cutting at 45 degrees toward the corners. **C,** The foil is folded onto the lingual surface and burnished. **D** and **E,** It is then gathered on the lingual surface with tweezers and adapted with finger pressure. **F,** The foil is trimmed to follow the lingual contour evenly. The two ends are separated, and one is trimmed to exactly half the width of the other. **G** and **H,** The long end is folded over the short end, and relieving cuts are made (see Fig. 25-5). Then the three-thickness joint is folded toward the short end. **I,** The foil is adapted with a wooden point, always starting from the incisal edge and working toward the margin. **J,** A beaver-tail burnisher is used to adapt the margin, working the foil toward the internal angle to prevent a perforation. Better adaptation can be achieved by swaging at this stage. The matrix is removed with sticky wax (**K**) and annealed in a Bunsen flame (**L**) to relieve work hardening. **M,** The completed platinum foil matrix.

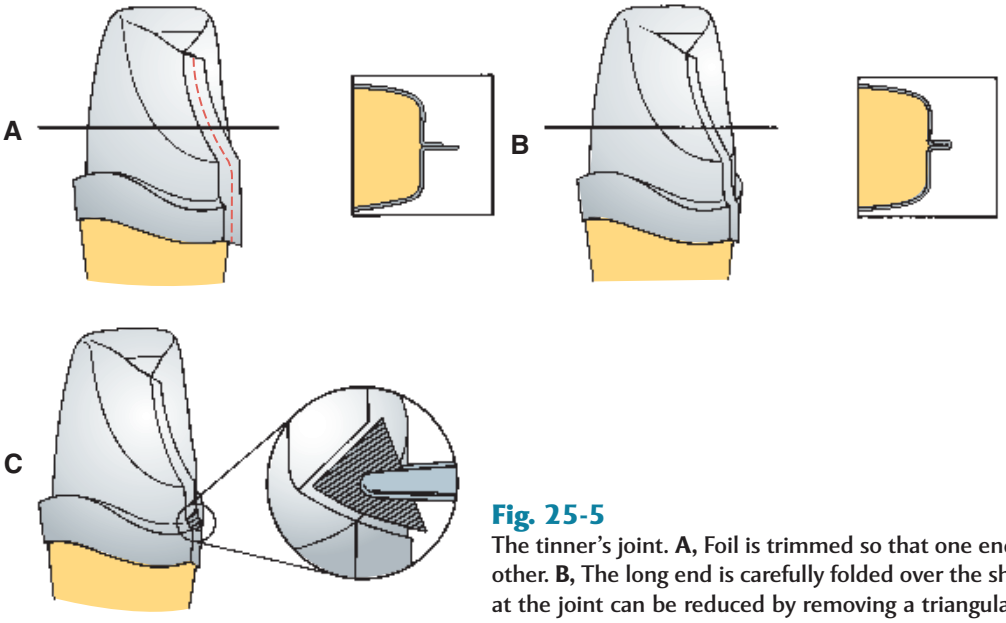


Fig. 25-5
The tinner's joint. **A,** Foil is trimmed so that one end is exactly twice as long as the other. **B,** The long end is carefully folded over the short end. **C,** Margin discrepancy at the joint can be reduced by removing a triangular section of foil.

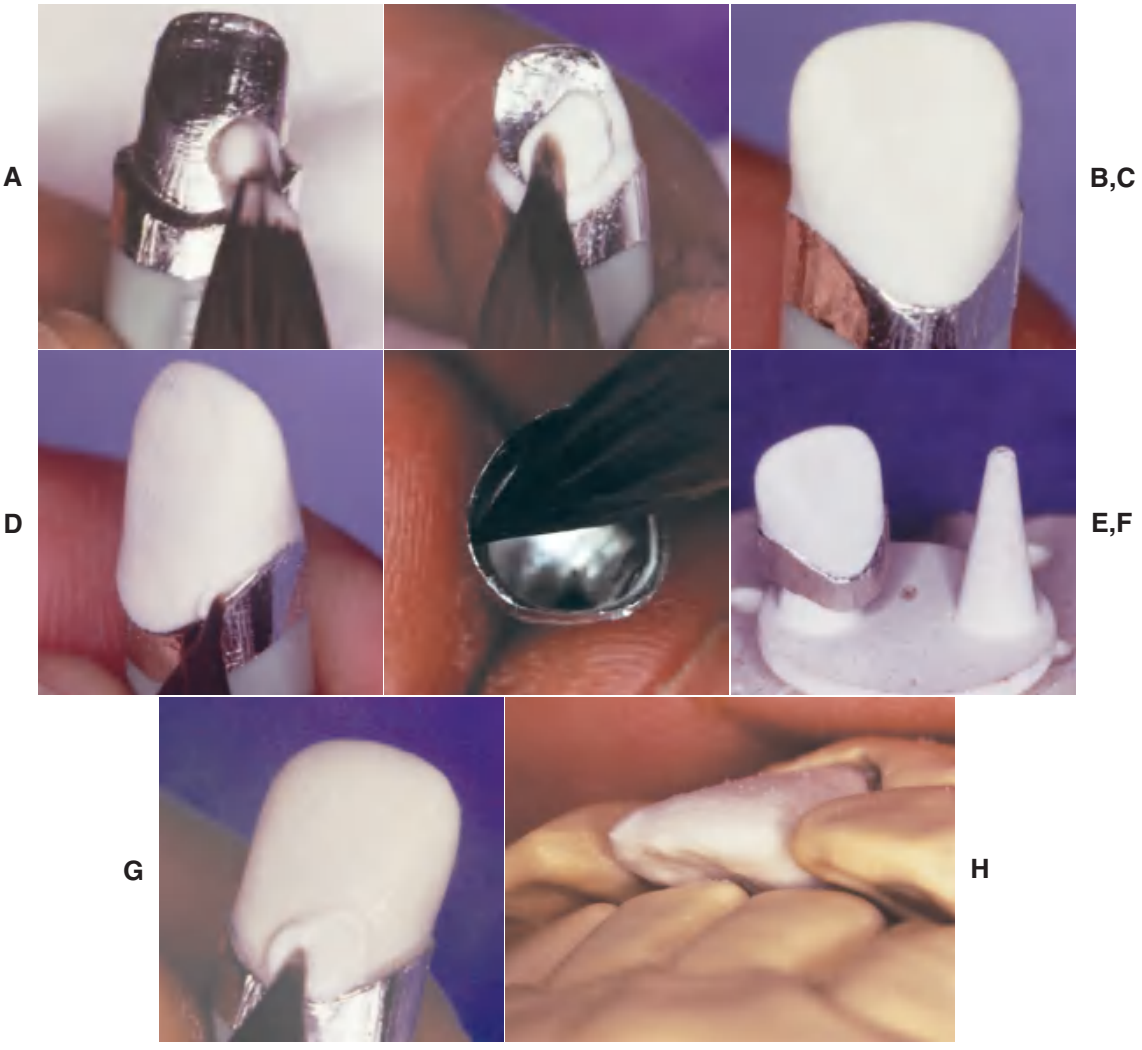


Fig. 25-6
Aluminous core technique. **A** to **C,** The platinum matrix is heated to drive off dissolved gases, and the core porcelain is built up. **D,** A thin blade is used to form a cervical ditch, which will prevent the matrix from becoming distorted during the first firing. **E,** There must be no porcelain particles on the inner aspect. **F,** The fired core should be checked with a thickness gauge. Often additional core material is needed to obtain the recommended dimensions. **G,** The foil is readapted to the margin, and the ditch is filled with additional porcelain. This lingual view shows where the core should be thickest. For esthetic reasons, the core is much thinner on the facial surface. **H,** The core is seated on the definitive cast before the application of body and incisal porcelains.



Fig. 25-7

A to **C,** All-ceramic fixed dental prosthesis (FDP) replacing the maxillary left central incisor, through the use of the In-Ceram system. **D** to **F,** All-ceramic FDP replacing the mandibular left first premolar, through the use of the Empress 2 system. (***D*** *to* ***F,*** *Courtesy of Ivoclar Vivadent, Inc., Amherst, New York.)*



Fig. 25-8

A, Defective maxillary metal-ceramic crowns. Esthetic problems included high value and opacity. **B,** Crowns removed. The preparations are not discolored and thus allow a translucent all-ceramic crown system. **C,** Maxillary all-ceramic crowns with a translucent slip-cast spinel core material. *(Courtesy of Dr. R. B. Miller.)*

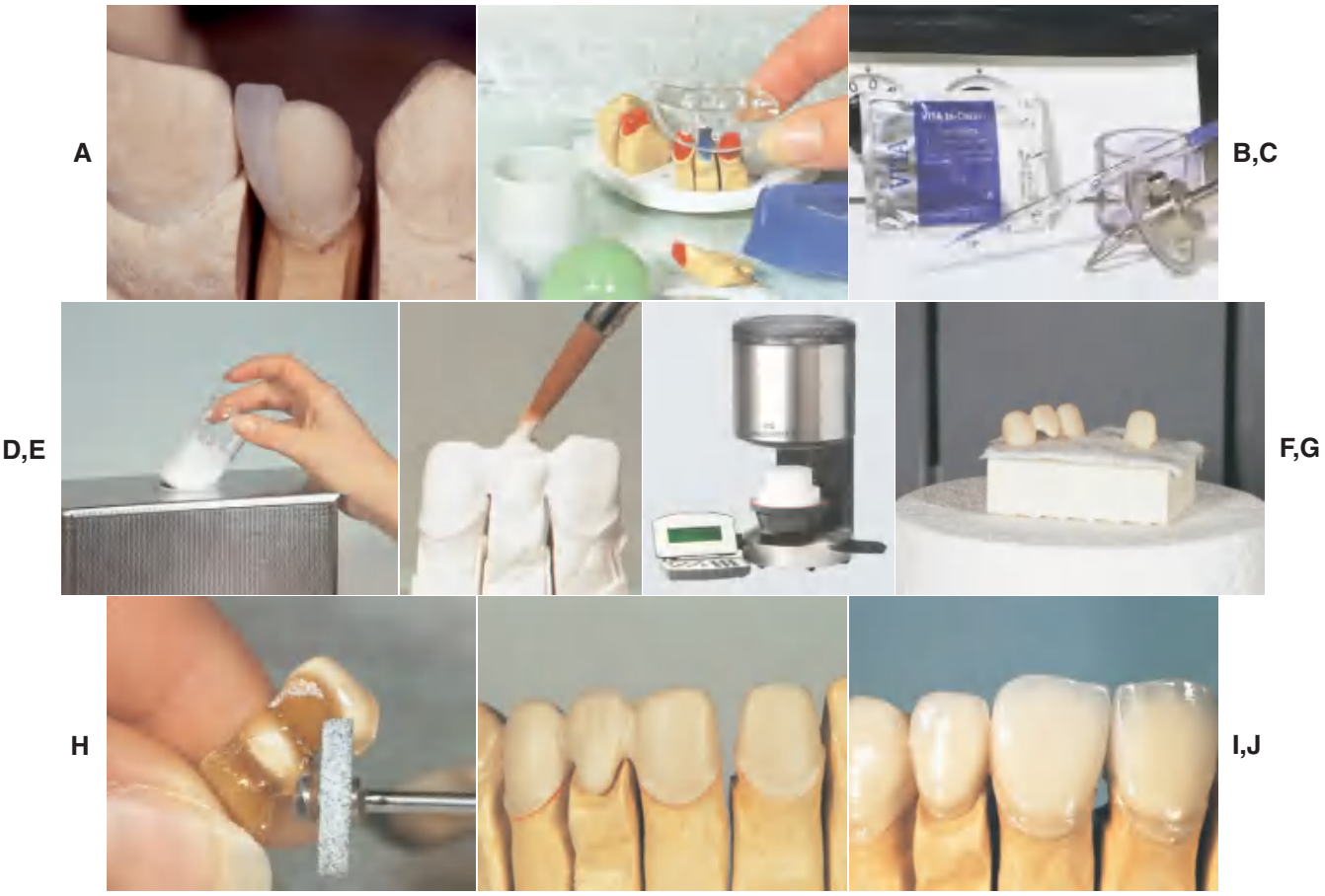


Fig. 25-9

Fabrication of a slip-cast alumina restoration. A, The In-Ceram system relies on a high-strength core veneered with an esthetic feldspathic porcelain. **B,** The definitive cast is duplicated with a special elastomer. **C,** The special plaster die. **D,** The alumina slip is ultrasonically mixed and applied to the plaster die (**E**). **F,** The VITA Inceramat special porcelain furnace. **G,** A special colored infiltration glass is painted on the porous sintered alumina and fired. **H,** Excess glass is carefully removed by grinding and air abrasion. **I,** Finished substructures on the definitive cast. **J,** Body and incisal porcelains are applied and fired in the conventional manner. (***A,*** *Courtesy of Morehead Dental Laboratories, Morehead, Kentucky.* ***B*** *to* ***J,*** *Courtesy of Vident, Brea, California.)*

alumina is fired at 1120° C (2048° F). The resulting core is porous and weak at this stage but can be carefully transferred to the master die after the die spacer is removed. The relatively low sintering shrinkage (about 0.3%) is compensated for by an expansion of the refractory material.

4. Paint a thick coat of the appropriate shade of glass mixture onto the surface of the core (see Fig. 25-9*G*) and fire at 1100° C (2012° F). As the glass melts, it is drawn into the interstices of the alumina by capillary action, producing a dense composite structure with excellent strength properties.
5. Remove excess glass from the core by grinding (see Fig. 25-9*H*) and airborne particle abrasion. Body and incisal porcelain is applied to the core in a manner similar to that for metal-ceramic crowns, as shown in Figure 25-10. Powder distribution is governed by a detailed prescription of the patient's shade (see Chapter 23). With experience, the technician will be able to mix different powders to match almost any shade. If necessary, test firings can be used to help select the correct blend in difficult situations.
6. After moistening the core, mix the powder with modeling liquid and apply in increments with a brush (see Fig. 25-10*A* to *C*).
7. Remove moisture with a paper tissue held against the lingual surface. The capillary action condenses the porcelain particles. Slight vibration brings further moisture to the surface before the next increment is added. To prevent voids from forming between increments, always add to a moist surface.

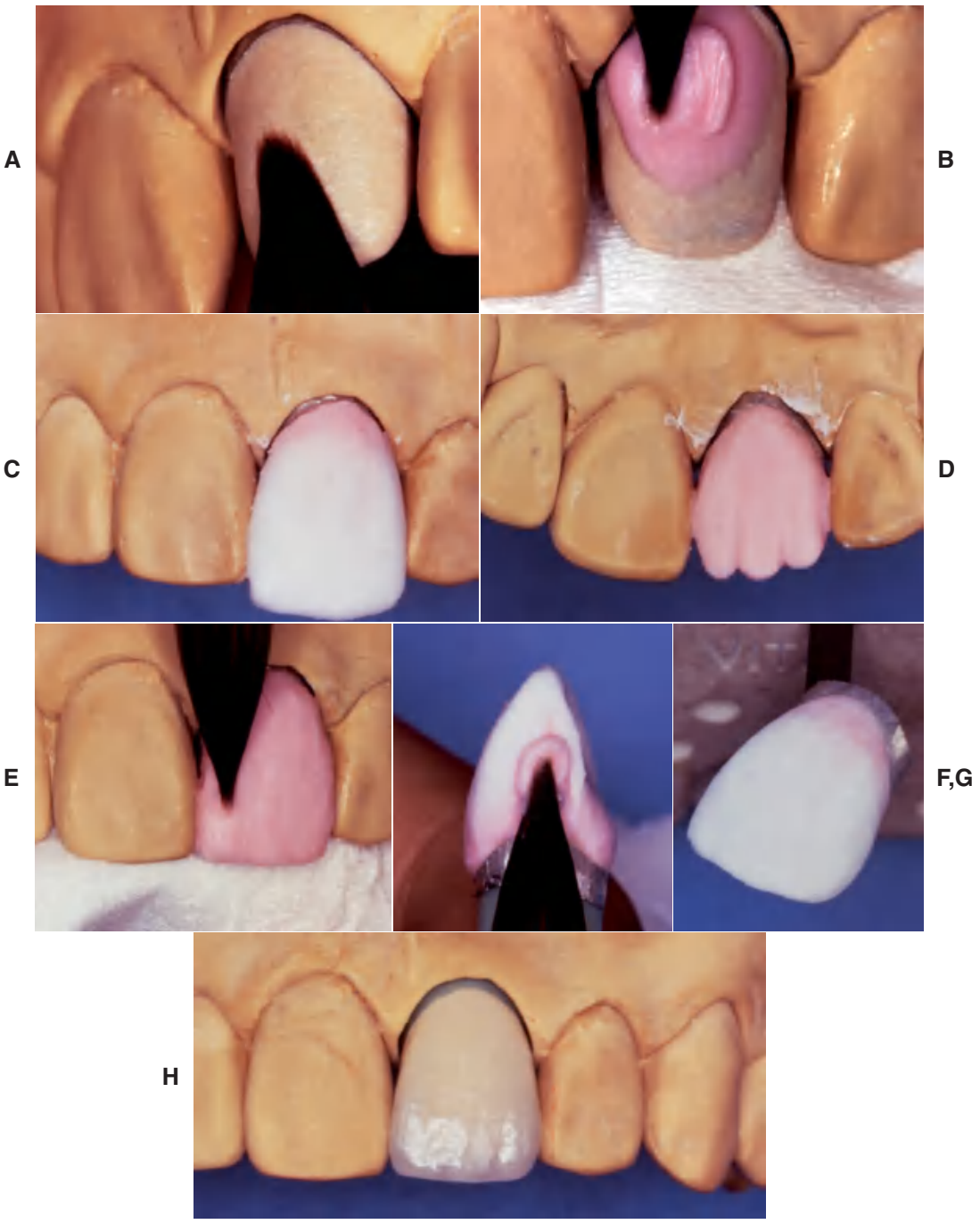


Fig. 25-10
Body and incisal porcelain application. **A,** Moistening the high-strength core. **B** and **C,** Applying gingival and body porcelains. **D,** Cutback for the incisal porcelain. **E,** The incisal porcelain. **F,** Adding to the interproximal areas. **G,** The completed buildup. **H,** The fired crown is seated on the definitive cast.

8. When the crown has the correct shape, cut it back to allow room for incisal porcelain (see Fig. 25-10*D*).
9. Apply incisal porcelain, overbuilding the incisal edge by 1 or 1.5 mm to allow for firing shrinkage (see Fig. 25-10*E*).
10. Lightly condense the buildup with a large whipping brush. Absorb excess moisture with a tissue.
11. Remove the crown from the definitive cast and add material interproximally to allow for shrinkage (see Fig. 25-10*F*).

12. Dry the crown and fire it (see Fig. 25-10*G* and *H*).

Heat-Pressed Ceramics

Leucite based

Heat-pressed ceramics have been popular in restorative dentistry since the early 1990s. The restorations are waxed, invested, and pressed in a manner somewhat similar to that for gold casting. Marginal adaptation seems to be better with heat pressing than with the high-strength alumina core materials,[45] although the results from individual dental laboratories may not support the research findings. Most heat-pressed materials contain leucite as a major reinforcing crystalline phase, dispersed in a glassy matrix. The crystal size varies from 3 to 10 μm, and the leucite content varies from about 35% to about 50% by volume, depending on the material. Research has shown that residual tangential stresses remain around the leucite crystals after cooling.[12] Ceramic ingots are pressed at a high temperature (about 1165° C [2130° F]) into a refractory mold made by the lost-wax technique. The ceramic ingots are available in different shades. Two finishing techniques can be used: a characterization technique (surface **stain** only) and a layering technique, involving the application of a veneering porcelain (Fig. 25-11*G* and *H*). The two techniques lead to comparable mean flexural strength values for the resulting porcelain composite.[46] The thermal expansion coefficient of the core material for the veneering technique is usually lower than that of the



Fig. 25-11

Heat-pressed ceramic technique. **A,** Ceramic inlay restoration for a maxillary molar. A wax pattern is made in a manner similar to that for conventional gold castings. **B,** After the pattern is invested, it is burned out, and a ceramic ingot and alumina plunger are placed in the heated mold. **C** and **D,** The pressing is done under vacuum at 1165° C. **E,** Sprue removal. **F,** The pressed restoration seated on the die. **G** and **H,** For esthetic anterior restorations, only the dentin-colored ceramic is pressed. The incisal porcelain is brush applied in the conventional manner.



Fig. 25-11, cont'd

I, Three-unit fixed dental prosthesis and veneer waxed to anatomic contour. **J,** The technician ensures that the connector size is adequate (4 × 4 mm). **K,** A silicone putty matrix is used to aid in cut-back of the wax pattern. **L,** Framework is sprued and invested (**M**), and the lithium-silicate ceramic is pressed into the mold. **N,** The pressed restoration.

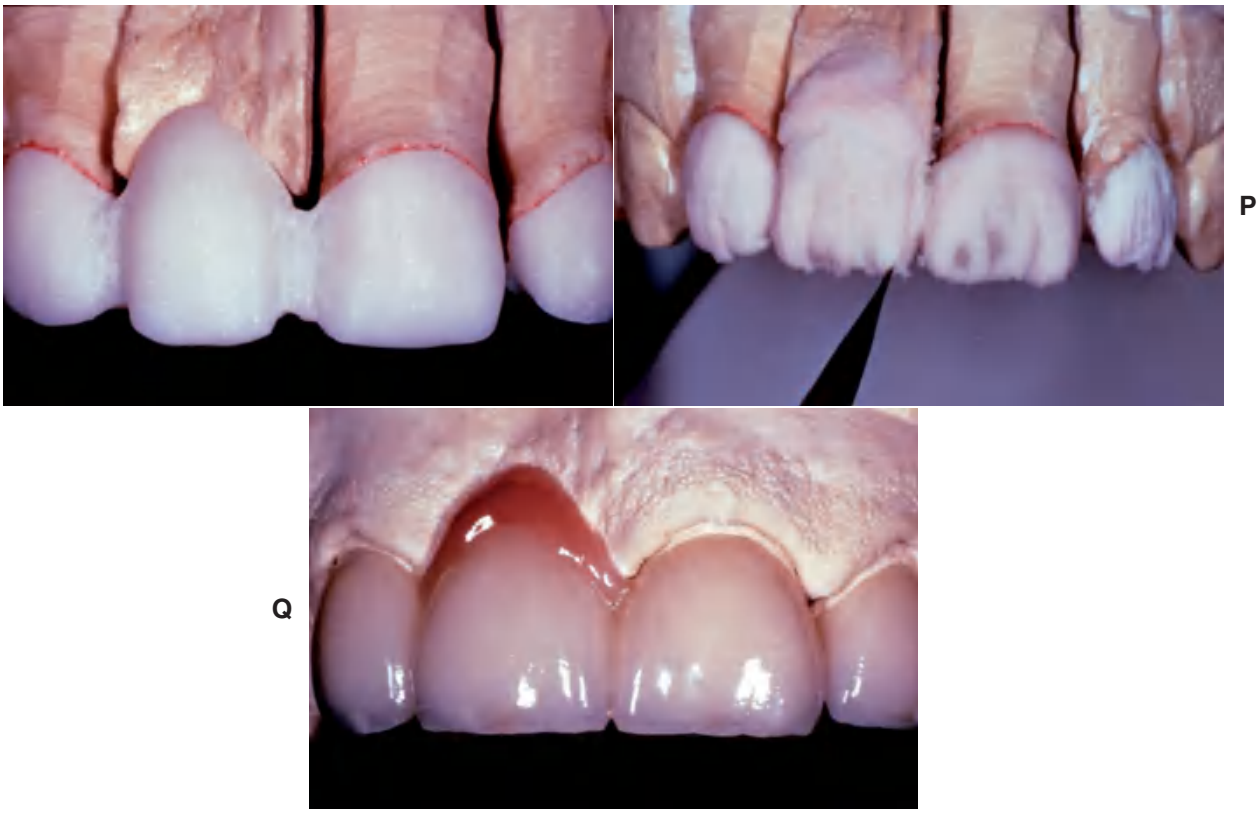


Fig. 25-11, cont'd

O, Framework on definitive cast. P, Applying veneering porcelain. Q, Completed restorations. *(Courtesy of Ivoclar Vivadent, Inc., Amherst, New York.)*

material for the staining technique to be compatible with the thermal expansion coefficient of the veneering porcelain. Among the currently available leucite-containing materials for heat-pressing are IPS Empress,* Optimal Pressable Ceramic,† and two lower fusing materials, Cerpress‡ and Finesse.§

Lithium silicate based

IPS Empress 2 is an example of the second generation of heat-pressed dental ceramics. The major crystalline phase of the core material is a lithium disilicate. The material is pressed at 920° C (1690° F) and layered with a glass containing some dispersed apatite crystals.[47,48]

The indications for second-generation pressable dental ceramics include crowns and anterior three-unit FDPs.

*Ivoclar Vivadent, Inc, Amherst, New York.
†Pentron Laboratory Technologies, LLC, Wallingford, Connecticut.
‡Leach & Dillon, Cranston, Rhode Island.
§Dentsply Ceramco, York, Pennsylvania.

Fabrication procedure

1. Wax the restoration to final contour, sprue, and invest as with conventional gold castings (see Fig. 25-11*A*). If the veneering technique is used, only the body porcelain shape is waxed.
2. Heat the investment to 800° C (or recommended temperature) to burn out the wax pattern.
3. Insert a ceramic ingot of the appropriate shade and alumina plunger in the sprue (see Fig. 25-11*B*) and place the refractory in the special pressing furnace (Fig. 25-11*C*).
4. After heating to 1165° C, the softened ceramic is slowly pressed into the mold under vacuum (see Fig. 25-11*D*).
5. After pressing, recover the restoration from the investment by airborne particle abrasion, remove the sprue (see Fig. 25-11*E*), and refit it to the die (Fig. 25-11*F*). Esthetics can be enhanced by applying an enamel layer of matching porcelain (see Fig. 25-11*G* and *H*) or by adding surface characterization. The procedure for an FDP is similar (see Fig. 25-11*I* to *Q*).

Machined Ceramics

The evolution of **computer-aided design/computer-aided manufacturer (or computer-assisted machining) (CAD/CAM)** systems for the production of machined inlays, onlays, veneers, and crowns led to the development of a new generation of ceramics that are machinable.

Cerec system

The Cerec system* has been marketed since the 1980s, with the improved Cerec 2 system introduced in the mid-1990s and the Cerec 3 in 2000. The equipment consists of a computer-integrated imaging and milling system, with the restorations designed on the computer screen (Fig. 25-12*A*). Several materials can be used with this system: VITA Mark II,† ProCad.‡ and In-Ceram Alumina and Spinell.§ VITA Mark II contains a feldspar (sanidine, $KAlSi_3O_8$) as a major crystalline phase within a glassy matrix. ProCad is a leucite-containing ceramic designed for making machined restorations. In-Ceram Alumina and Spinell are machined before the infiltration and veneering stages. Composite resin blocks are also available. Weaknesses of the earlier Cerec system include the poor marginal fit of the restorations[49] and the lack of sophistication in the machining of the occlusal surface. The marginal adaptation of Cerec 3 is improved,[50] and the occlusal anatomy can be shaped. The most recently introduced version of the CAD/CAM software¶ allows complete tridimensional visualization of the projected restoration with "virtual seating" capabilities. The various surfaces of the virtual restoration can be modified in all three dimensions before machining.

Fabrication procedure

1. Tooth preparation follows typical all-ceramic guidelines.
2. Coat the preparation with opaque powder.
3. Image the preparation with the optical scanner, aligning the camera with the path of insertion of the restoration (Fig. 25-12*B*). When the best view is obtained, store it in the computer (Fig. 25-12*C*).
4. Identify and mark the margins and contours on the computer screen. The computer software assists with this step (Fig. 25-12*D*).
5. Insert the appropriate shade of ceramic block in the milling machine. The fabrication time for a crown is about 20 minutes (Fig. 25-12*E* to *H*). Additional characterization is achieved with stains (Fig. 25-12*I* to *L*).
6. Try the restoration back in the mouth, etch, and silanate and lute it to place as described in Chapter 31.

*Sirona Dental Systems, LLC, Charlotte, North Carolina.
†Vident, Brea, California.
‡Ivoclar Vivadent, Inc., Amherst, New York.
§VITA Zahnfabrik, Bad Säckingen, Germany.
¶Cerec 3D, Sirona Dental Systems, LLC, Charlotte, North Carolina.

Machined and Sintered Ceramics

Extensive research in the field of zirconia ceramics and CAD/CAM technology has led to the development of zirconia ceramics for dental restorations.[51] The material used is tetragonal zirconia stabilized with 3 mole percent yttrium oxide. Enlarged zirconia copings are machined from presintered zirconia blocks to compensate for the sintering shrinkage. The restorations are later sintered at a high temperature (1350° to 1450° C [2460° to 2640° F], depending on the manufacturer) for several hours. Matching veneering ceramics are available to achieve an esthetic restoration. These core materials exhibit very high strength and high fracture toughness. Long-term data are needed to assess the clinical performance of these ceramics.

Procera AllCeram system*

The Procera AllCeram system (Fig. 25-13) involves an industrial CAD/CAM process.[52,53] The die is mechanically scanned by the technician, and the data are sent to a work station, where an enlarged die is milled by a computer-controlled milling machine. This enlargement is necessary to compensate for the sintering shrinkage. Aluminum oxide powder is then compacted onto the die, and the coping is milled before sintering at a very high temperature (>1550° C [>2820° F]). The coping is further veneered with an aluminous ceramic with matched thermal expansion. The restorations seem to have good clinical performance[54] and marginal adaptation,[55,56] provided that the scanning is done skillfully.[57]

Step-by-step procedure

1. Tooth preparation (see Fig. 25-13) follows all-ceramic guidelines.
2. The cast is made in the conventional way, but the die is ditched to make the margin easier to identify during scanning.
3. The die is mapped through the use of a contact scanner.

*Nobel Biocare, USA, Inc., Yorba Linda, California.



Fig. 25-12

Cerec 3 computer-assisted design/computer-assisted machining (CAD/CAM) system. **A,** The Cerec 3 system consists of an imaging system, a computer, and a milling system. **B,** Making an optical impression. **C,** Image of a prepared tooth. **D,** The preparation is marked and the restoration designed on the computer screen. **E** and **F,** Blocks are available in different ceramic systems, as is composite resin (**G**). **H,** The restoration is machined from the block.



Fig. 25-12, cont'd

I, Defective amalgam restorations. **J,** Defective restorations replaced with Cerec 3 inlays. **K,** Defective cast metal crown. **L,** The defective crown replaced with CAD/CAM ceramic crown. *(**A** to **D, I** to **L,** Courtesy of Sirona Dental Systems, Charlotte, North Carolina; **E,** Courtesy of Vident, Brea, California; **F,** Courtesy of Ivoclar Vivadent, Inc., Amherst, New York; **G,** Courtesy of 3M ESPE, St. Paul, Minnesota.)*



Fig. 25-13

The Procera All Ceram system. **A,** Tooth preparations for Procera crown on the maxillary anterior teeth. **B,** Completed restorations. **C,** Tooth preparations for Procera fixed dental prosthesis. **D,** High-strength framework. Body and incisal porcelains will be subsequently applied. *(**A** and **B,** Courtesy of Dr. E. van Dooren; **C** and **D,** Courtesy of Dr. E. Hagenbarth.)*

4. The shape of the prepared tooth is transferred to the computer screen.
5. The design of the restoration is transferred to the manufacturer via computer line.
6. The production process starts with milling an enlarged die to compensate for the sintering shrinkage.
7. An enlarged high-alumina coping is milled; it shrinks to the desired shape after sintering.
8. The coping is returned to the laboratory, and body and incisal porcelains are applied in the conventional manner.

Lava system*

In the Lava system (Fig. 25-14), a CAD/CAM procedure is used for the fabrication of zirconia frameworks all-ceramic restorations.[58] The preparations are scanned, and frameworks are milled from presintered zirconia blanks. The size of the frameworks is precisely increased to allow for the shrinkage that occurs during sintering. Once a framework has been sintered, it is veneered with layered esthetic porcelains in a manner similar to that for the metal-ceramic technique.

*3M ESPE, St. Paul, Minnesota.

Metal-Reinforced Systems

High-gold substructure systems are designed to overcome some of the disadvantages inherent in the porcelain jacket crown technique. The systems rely on different ways of creating a thin coping onto which the ceramic is fired. In strictest terms, therefore, they are metal-ceramic, as opposed to **all-ceramic crowns.**



Fig. 25-14
The Lava system. **A,** Lava computer-assisted design/computer-assisted machining (CAD/CAM) designing and milling machine. **B,** Computer design of framework. **C** and **D,** Framework milled from zirconia block.



Fig. 25-14, cont'd

E, Veneering porcelain. **F,** Teeth prepared for posterior all-ceramic partial fixed dental prosthesis. **G,** Completed restoration. **H,** Framework evaluation for anterior partial fixed dental prosthesis. **I,** Completed anterior partial fixed dental prosthesis. (***A*** *to* ***E,*** *Courtesy of 3M ESPE, St. Paul, Minnesota;* ***F*** *and* ***G,*** *courtesy of Dr. L. Jones and M. Roberts, CDT;* ***H*** *and* ***I,*** *courtesy of Dr. V. Bonatz.)*

The Captek system

In the Captek* system, the coping is produced from two metal-impregnated wax sheets that are adapted to a die and fired. The first sheet forms a porous gold-platinum-palladium layer that is impregnated with 97% gold when the second sheet is fired.[59] Advantages of the system include excellent esthetics and marginal adaptation.[60]

*Captek, a Division of Precious Chemicals Co., Inc., Altamonte Springs, Florida.

Fabrication procedure

1. Duplicate the working die in the special refractory material (Fig. 25-15*A*).
2. Cut a piece of the gold-platinum-palladium impregnated wax sheet (Fig. 25-15*B*).
3. Adapt the foil to the die (Fig. 25-15*C*). Then it is fired to 1075° C (1965° F), forming a porous metal coping.
4. Adapt the second gold-impregnated wax (Fig. 25-15*D*) and refire (Fig. 25-15*E*). Capillary action draws the gold into the porous gold-platinum-palladium structure to form the finished coping.



Fig. 25-15
The Captek system. A, Duplicated refractory die. **B,** Trimming the metal-impregnated wax sheet. **C,** Adapting the first sheet to the die. The first layer is fired to form a porous coping. **D,** Adapting the second metal-impregnated wax sheet. **E,** Fired framework. **F,** Sectioned Captek crown showing coping design. **G,** Defective metal-ceramic crown on the maxillary incisors replaced with Captek crowns (**H**). **I,** Partial fixed dental prosthesis frameworks can be fabricated with special pontic components. *(Courtesy of Captek, a Division of Precious Chemicals, Altamonte Springs, Florida.)*

5. Build up the opaque body and incisal porcelains in a manner similar to that for a conventional metal-ceramic crown (Fig. 25-15*F*).
6. Glaze the completed restoration, and polish the metal foil at the margin (Fig. 25-15*G* and *H*). The procedure has been adapted for FDPs (Fig. 25-15*I*).

SELECTION OF ALL-CERAMIC SYSTEMS

The primary purpose in recommending an all-ceramic restoration is to achieve the best possible esthetic result. Typically this is at the risk of reduced restoration longevity, because of the potential for fracture of the ceramic material, and the restoration may have a slightly inferior marginal adaptation than does a metal-ceramic crown.

Fracture Resistance

Most hazards of restoration failure are removed if these restorations are confined to lower stress anterior teeth, and patients are carefully evaluated for evidence of parafunctional activity. Although laboratory testing of strength and fracture toughness has identified promising materials,[38,61] clinical studies have consistently shown good performance on anterior teeth and yet poor performance on molars and for FDPs.[62-64] Although the newer materials, such as alumina- and zirconia-based ceramics, promise

higher strength (see Table 25-1), the long-term data to determine whether they are satisfactory, particularly for FDPs, are lacking.[48,65,66]

Esthetics

A knowledge of the available ceramic systems is needed to select a material that will provide the best esthetics for a particular patient. This is especially important when a single maxillary incisor is matched to an adjacent tooth. Careful consideration should also be given to the availability of laboratory support, because no dental laboratory invests in the expensive equipment needed for all the various systems. The marginal adaptation of the system is very important, even when resin bonding is used. When selecting a system, the dentist should carefully evaluate the internal and marginal adaptation, using an elastomeric detection paste.* Although research studies have identified differences among the various systems[67] (see Table 25-1), these results may not represent an individual laboratory's results. The translucency of the adjacent teeth and discoloration of the tooth being restored also must be considered when the most appropriate system is selected.[68] A more opaque, high-strength core, ceramic system (e.g., In-Ceram or Procera) would not be a good choice for highly translucent teeth. However, such a system might be a good choice if the tooth exhibits discoloration that would not be well masked by a more translucent material. Conversely, when fracture is a concern, the higher strength materials should normally be given preference (see Table 25-1).

Abrasiveness

One concern with ceramic restorations is the potential for abrasion of the opposing enamel, particularly in patients with parafunctional habits. Whenever possible, a low-abrasion material should be considered. Abrasiveness has been studied in vitro,[69-74] and the results are summarized in Table 25-1.

PORCELAIN LABIAL VENEER

Porcelain labial veneers (see Chapter 11) can be fabricated by means of a refractory die technique, as well as on a platinum matrix† and with heat-pressed-ceramics. The heat-pressed technique is popular, but there are limitations to the esthetic effect when one ceramic color is pressed. The platinum matrix technique is tedious and somewhat challenging to learn, but once acquired, it enables the technician to make veneers with better marginal adaptation than does the refractory technique.[75] Therefore, the platinum matrix technique is described here. Many of the steps are similar to those of the porcelain jacket crown technique (see Fig. 25-4).

Step-by-Step Procedure

1. Modify the working die by blocking out tooth undercuts with modeling plastic.
2. Adapt the platinum foil (0.025 mm [0.001 inch]) in the same manner as described for the porcelain jacket crown, covering the entire tooth. Some technicians prefer to adapt the foil to the facial surface only, but distortion of the foil during firing of the porcelain seems to lead to inferior marginal adaptation.[76] Careful adaptation is essential for a good fit, especially at the proximal incisal margin, where the tinner's joint is made.
3. Remove, clean, and degas the foil. Airborne particle abrasion can be used for this step.
4. Build up and fire the veneers. This is generally done in two or three layers, particularly if the veneer is necessary to mask tetracycline staining and a more opaque initial layer is applied. Sometimes tetracycline staining can be more effectively masked by incorporating the complementary hue in the ceramic buildup, rather than fabricating a veneer that is unesthetically opaque looking. With experience, a technician can achieve excellent results with porcelain labial veneers. Special formulations of porcelain are available for veneers. Some are based on traditional jacket or metal-ceramic porcelain systems; higher-strength, high-leucite content formulations are also available. Fracture of porcelain labial veneers is sometimes encountered in practice, even though the restorations are generally placed in low-stress situations. At present, there is little information about the incidence of veneer fracture or whether a high-strength ceramic has better performance than a traditional formulation. When a fracture does occur, the broken pieces are often still firmly bonded to the tooth. At that point, it is probably not necessary to replace the restoration unless the fracture line is stained or the ceramic is chipped.
5. Contour and glaze the facings. The veneers should be shaped to final contour at this stage.
6. Remove the foil before try-in. The steps for **etching**, silanating, and luting the veneers are presented in Chapter 31.

*This must be thoroughly removed before the restoration is bonded.
†Porcelain labial veneers can also be made with the machinable systems.

INLAYS AND ONLAYS

Refractory Dies

Ceramic restorations are normally made through the use of the heat-pressed systems, but some technicians prefer a refractory die (Fig. 25-16). Marginal adaptation can be excellent, depending more on the technician's skill than on the ceramic material used.[78]

Step-by-Step Procedure

1. Pour an elastomeric impression of the prepared teeth in type IV or V stone; then repour it or duplicate it in ceramic refractory, using an appropriate removable die system. The Di-Lok (see Chapter 17) or a similar system is convenient for this technique. The dies need to be separated very carefully because the refractory is friable and breaks if mishandled.
2. Trim the **refractory cast** as far as possible to minimize the quantity of ammonia released during decontamination.
3. Mark the margins lightly with a special pencil (V.H.T.*)
4. Decontaminate the cast by firing according to the manufacturer's instructions. Normally this is done in two stages: the first in a burnout furnace, the second under vacuum in a porcelain furnace.
5. Allow the cast to cool, and then soak it in soaking liquid or distilled water for 5 minutes. This seals the die and prevents moisture from being drawn out of the porcelain buildup.
6. Apply an initial layer of porcelain to the refractory cast and fire according to the manufacturer's directions. With some systems, a higher strength core material is used as the initial coat.
7. Build up the restorations onto moist dies; for inlays, leave short of the margins.
8. Make a relieving cut through the central fossa, and fire the porcelain.
9. Fill in the central fossa area and build up to the margins.
10. Contour and refine occlusion and proximal contacts. Glaze according to the manufacturer's instructions.
11. Remove the investment with a bur and 50-µm alumina in an airborne particle abrasion unit. Transfer the restorations to the master dies on the mounted cast.
12. If necessary, adjust the restoration margins and occlusion with fine-grit diamond stones. Polish with diamond polishing paste.

*Whip Mix Corporation, Louisville, Kentucky.

ALL-CERAMIC PARTIAL FIXED DENTAL PROSTHESES

All-ceramic FDPs have a checkered history. Their construction was attempted with aluminous porcelain by connecting alumina cores with pure alumina rods. These restorations were usually unsuccessful; either they fractured or the restorations encroached excessively into the embrasures, resulting in hygiene deficiencies. Leucite-containing heat-pressed ceramics do not appear to possess adequate strength for FDPs, except in very low-stress situations. Clinical trials of posterior ceramic FDPs have yielded disastrous results.[33,77] The InCeram Zirconia has much higher laboratory strength than these materials and might be suitable for FDP frameworks. In-Ceram Alumina was somewhat successful for anterior FDPs (see Fig. 25-7). The more recent lithium disilicate heat-pressed ceramic, Empress 2, and the CAD/CAM Procera systems have also been recommended as suitable for anterior FDPs. Although the newer materials might be successful for FDPs, their manufacturers recommend a design with substantial connectors (typically 4 × 4 mm, as opposed to 2 × 3 mm recommended for metal connectors). These dimensions can lead to problems with adequate access for cleaning and poor esthetics.

ALL-CERAMIC FOUNDATION RESTORATIONS

All-ceramic materials have been used as foundation restorations for endodontically treated teeth[78,79] to overcome esthetic problems associated with metal post and core systems (see Chapter 12). The post is made of zirconia,* chosen for its excellent strength,[80] and, depending on the system, the core material can be composite resin or a pressable ceramic.†

RESIN-BONDED CERAMICS

The performance of all-ceramic restorations has been enhanced by the use of resin bonding. This technique was first devised for the porcelain laminate veneer technique[81,82] and has been applied to other ceramic restorations. The technique entails the

*CosmoPost, Ivoclar Vivadent; Biopost, Incermed SA, Lausanne, Switzerland; TZP-post, Maillefer, Ballaigues, Switzerland.

†Empress, Cosmo, Ivoclar Vivadent, Inc., Amherst, New York.



Fig. 25-16

Fabrication of facial veneers and ceramic onlay with the refractory die technique. **A,** A surfactant debubblizer is used to spray the impression, after which it is lightly blown dry. **B,** Pouring the impression with die stone. **C,** Marking the preparation margins before die spacing and duplicating the cast with an elastomeric duplicating material (**D**). **E,** The mold is filled with the refractory investment. **F,** A die-lock system can be used; alternatively, a reverse dowel pin can be used with the dowel pin remaining in the cast base (**G**). **H,** As another alternative, special high-heat dowel pins* can be used. **I,** Marking margins with special pencil.† **J,** Decontaminating the investment. **K,** The blue margin marking turns red during this firing. **L,** The dies are soaked in distilled water until bubbling disappears. **M,** Adjacent proximal areas are coated with die hardener to prevent moisture from being absorbed into the cast.

*Thermo-pins II, Pentron Laboratory Technologies, LLC, Wallingford, Connecticut.
†VHT, Whip Mix Corporation, Louisville, Kentucky.



Fig. 25-16, cont'd
N, The initial porcelain application. **O** and **P**, Firing the first application. **Q,** Additional firing is needed to compensate for shrinkage. **R,** The veneer built up to final contour and glazed. **S,** Investment removed with a bur and air abrasion unit (**T**). **U,** Finished veneer on definitive cast. **V,** Inlays and onlays are made in a similar manner. *(Courtesy of Whip Mix Corporation, Louisville, Kentucky.)*

use of hydrofluoric acid or a less toxic substitute to etch the ceramic and a **silane*** coupling agent to bond a resin luting agent to the ceramic. The luting agent is bonded to enamel after etching with phosphoric acid, as with resin-retained FDPs (see Chapter 26), and bonded to dentin with a dentin-bonding agent. Significant reduction in the fracture incidence of some types of ceramic crowns has been reported when an adhesive cement has been used,[83] although one retrospective study failed to reveal an improvement in comparison with traditional cements.[84] Resin bonding does not appear to improve the fracture resistance of the high-strength alumina core materials such as In-Ceram and Procera. Nevertheless, for feldspathic and leucite-reinforced ceramics, resin bonding is now the recommended procedure and is also used extensively for luting ceramic inlays and onlays.[85]

Etching and Silanating the Restoration

1. Support the restoration in soft wax with the fitting surface uppermost.
2. Apply a 1-mm coat of the etching gel† to the fitting surface only.
3. The etching time depends on the ceramic material. Feldspathic porcelain is typically etched for 5 minutes.

*Compounds of silicon and hydrogen and other monomeric compounds that are used as coupling agents, inorganic materials to organic resins.

†Ceram-Etch gel (9.5% hydrofluoric acid), Gresco Products, Inc., Stafford, Texas (or the ceramic manufacturer's recommended product).

STUDY QUESTIONS

1. Discuss the advantages and disadvantages, indications, and contraindications of all-ceramic crowns.
2. Which all-ceramic system might be considered for a partial fixed dental prosthesis? What are the limitations with all-ceramic restorations in this application?
3. Compare the fabrication steps for a slip-cast versus a heat-pressed ceramic system. What are the advantages of each?
4. Describe the fabrication steps for laminate veneers.
5. What are the currently available CAD/CAM systems? What are the advantages and limitations of these restorations?

4. Very carefully rinse away the gel under running water. The gel is very caustic; it should not be allowed to contact skin or eyes.
5. Continue to rinse until all the gel color has been removed.
6. Dry the ceramic with oil-free air. A hair dryer is recommended to ensure that the ceramic is not contaminated.
7. Apply the silane according to the manufacturer's recommendations. Some manufacturers recommend a heat-cured silane coupling agent for increased bond strength, rather than a chemically activated silane. Heat curing is normally done by the laboratory, and care must be taken to clean the fitting surface thoroughly with alcohol before cementation.

The cementation procedures are presented in Chapter 31.

SUMMARY

For many years, porcelain jacket crowns have been the most esthetic of fixed restorations. Unfortunately, they have a number of disadvantages in comparison with the more popular metal-ceramic crowns, including inferior mechanical properties and increased technical difficulties associated with obtaining adequate margin fit.

Improved materials and the bonded ceramic technique have renewed interest in all-ceramic restorations. Porcelain laminate veneers have proved to be conservative and esthetic alternatives to complete coverage. Porcelain inlays and onlays may provide a durable alternative to posterior composite resins without the extensive tooth preparation needed for crowns. The highest-strength materials may be suitable for high-stress applications, including FDPs. However, they are relatively new and still lack the support of long-term clinical experience and research.

GLOSSARY*

aluminum oxide \a-lōō′mi-num ŏk′sīd′\ **1:** a metallic oxide constituent of dental porcelain that increases hardness and viscosity **2:** a high strength ceramic crystal dispersed throughout a glassy phase to increase its strength as in aluminous dental porcelain used to fabricate aluminous porcelain crowns **3:** a finely ground ceramic particle (frequently 50 μm) often used in conjunction with air-borne particle abrasion of metal castings before the application of porcelain as with metal ceramic restorations

anterior open occlusal relationship \ăn-tîr′ē-or ō′pen a-klōō′zal rĭ-lā′shen-shĭp′**:** the lack of anterior tooth contact in any occluding position of the posterior teeth

bisque bake \bĭsk bāk\: a series of stages of maturation in the firing of ceramic materials relating to the degree of pyro chemical reaction and sintering shrinkage occurring before vitrification (glazing)—called also *biscuit bake*

CAD-CAM: *acronym* for *Computer Aided Design-Computer Aided Manufacturer* (or *Computer Assisted Machining*)

castable ceramic \kăst′a-bl se-răm′ik**:** for dental applications, a glass-ceramic material that combines the properties of a restorative material for function with the capability to be cast using the lost wax process

ce·ram \sa-răm\ *n***:** a heat treatment process that converts a specially formulated glass into a fine grained glass-ceramic material

[1]ce·ram·ic \sa-răm′ik\ *adj* (1850)**:** of or relating to the manufacture of any product made essentially from a nonmetallic mineral (as clay) by firing at a high temperature

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ceramic crown \sa-răm′ik kroun**:** a ceramic fixed dental prosthesis that restores a clinical crown without a supporting metal framework

ceramic flux \sa-răm′ĭk flŭks**:** a glass modifier; metallic ions such as calcium, potassium or sodium, usually as carbonates, which interrupt the oxygen/silica bond, thus enhancing fluidity

ce·ram·ics \sa-răm′iks\ *n* **1:** compounds of one or more metals with a nonmetallic element, usually oxygen. They are formed of chemical and biochemical stable substances that are strong, hard, brittle, and inert nonconductors of thermal and electrical energy **2:** the art of making porcelain dental restorations

cermet \sûr′mĕt\ (1998)**:** fused glass powder with silver particles formed through high temperature sintering of a mixture of the two minerals

[1]cop·ing \kō′pĭng\ *n* **1:** a long, enveloping ecclesiastical vestment **2a:** something resembling a cope (as by concealing or covering) **2b:** coping

[2]cop·ing \kō′pĭng\ *n* (ca. 1909)**:** a thin covering or crown—*usage:* see C. IMPRESSION, TRANSFER C.

core \kôr, kōr\ *n* (14c)**:** the center or base of a structure

[1]etch \ĕch\ *vb, vt* (1634) **Ia:** to produce a retentive surface, especially on glass or metal, by the corrosive action of an acid **Ib:** to subject to such etching **2:** to delineate or impress clearly

[2]etch \ĕch\ *n* (1896) **1:** the effect or action of an etching acid on a surface **2:** a chemical agent used in etching

etch·ant \ĕch′ănt\ *n***:** an agent that is capable of etching a surface

etch·ing \ĕch′ing\ *vt* (1632) **1:** the act or process of selective dissolution **2:** in dentistry, the selective dissolution of the surface of tooth enamel, metal, or porcelain through the use of acids or other agents (etchants) to create a retentive surface

fir·ing \fīr′ĭng**:** the process of porcelain fusion, in dentistry, specifically to produce porcelain restorations

flu·o·res·cence \flŏŏ-rĕs′ens\ *n* (1852)**:** a process by which a material absorbs radiant energy and emits it in the form of radiant energy of a different wavelength band, all or most of whose wavelengths exceed that of the absorbed energy. Fluorescence, as distinguished from phosphorescence, does not persist for an appreciable time after the termination of the excitation process

glass-ceramic \glăs sa-răm′ik**:** a solid material, partly crystalline and partly glassy, formed by controlled crystallization of a glass

glaze \glāz\ *vb* **glazed** \glāzd\; **glaz·ing** \glā′zĭng\ *vt* (14c) **1:** to cover with a glossy, smooth surface or coating **2:** the attainment of a smooth and reflective surface **3:** the final firing of porcelain in which the surface is vitrified and a high gloss is imparted to the material **4:** a ceramic veneer on a dental porcelain restoration after it has been fired, producing a nonporous, glossy or semi-glossy surface—see NATURAL G., OVERGLAZE

hydroxyapatite ceramic \hī-drŏk′sē-ăp′a-tīt sa-răm′ĭk**:** a composition of calcium and phosphate in physiologic ratios to provide a dense, non-resorbable, biocompatible ceramic used for dental implants and residual ridge augmentation

in·lay \ĭn-lā′, ĭn′lā′\ *n* (1667)**:** a fixed intracoronal restoration; a dental restoration made outside of a tooth to correspond to the form of the prepared cavity, which is then luted into the tooth

intrinsic coloring \ĭn-trĭn′zĭk, -sĭk kŭl′ar-ĭng**:** coloring from within; the incorporation of a colorant within the material of a prosthesis or restoration

ion exchange strengthening \ī′an, ī′ŏn′ ĭks-chănj′ strĕngk′tha-nĭng**:** the chemical process whereby the surface of a glass is placed in compression by the replacement of a small ion by a larger one while maintaining chemical neutrality

mam·e·lon \măm′a-lŏn\ *n***:** one of three tubercles sometimes found on the incisal edges of incisor teeth—**mam·e·lon·at·ed** \măm′a-la-nā′tĭd\ *v,* **mam·e·lon·a·tion** \măm′a-la-nā′shun\ *n*

mi·cro·crack \mī′krō-krăk\ *n***:** in porcelain, one of the numerous surface flaws that contributes to stress concentrations and results in strengths below those theoretically possible

natural glaze \năch-ar-al, năch′ral glāz**:** the production of a glazed surface by the vitrification of the material itself and without addition of other fluxes or glasses

o·paque \ō-pāk′\ *adj* (1641)**:** the property of a material that absorbs and/or reflects all light and prevents any transmission of light

o·ver·glaze \ō′var-glāz\ *adj* (1879)**:** the production of a glazed surface by the addition of a fluxed glass that usually vitrifies at a lower temperature

pig·ment \pĭg′mant\ *n* (14c)**:** finely ground, natural or synthetic, inorganic or organic, insoluble dispersed particles (powder), which, when dispersed in a liquid vehicle, may provide, in addition to color, many other essential properties such as opacity, hardness, durability, and corrosion resistance. The term is used to include an extender, white or color pigments. The distinction between powders that are pigments and those that are dyes is generally considered on the basis of solubility—pigments being insoluble and dispersed in the material, dyes being soluble or in solution as used

platinum foil \plăt′n-um foil\: a precious-metal foil with a high fusing point that makes it suitable as a matrix for various soldering procedures as well as to provide an internal form for porcelain restorations during their fabrication

por·cel·ain \pôr′sa-lĭn, pōr′-\ *n* (known in Europe, ca. 1540): a ceramic material formed of infusible elements joined by lower fusing materials. Most dental porcelains are glasses and are used in the fabrication of teeth for dentures, pontics and facings, metal ceramic restorations, including fixed dental prostheses, as well as all-ceramic restorations such as crowns, laminate veneers, inlays, onlays, and other restorations

po·ros·i·ty \pa-rŏs′ĭ-tē, pô-\ *n, pl* **-ties** (14c) **1:** the presence of voids or pores within a structure **2:** the state or quality of having minute pores, openings or interstices—see BACK PRESSURE P., OCCLUDED GAS P., SHRINKSPOT P., SOLIDIFICATION P.

refractory cast \rĭ-frăk′ta-rē kăst\: a cast made of a material that will withstand high temperatures without disintegrating—called also *investment cast*

si·li·ca \sĭl′ĭ-ka\ *n* (ca 1301): silicon dioxide occurring in crystalline, amorphous, and usually impure forms (as quartz, opal, and sand, respectively)

[2]sinter \sĭn′tar\ *vt* (1871): to cause to become a coherent mass by heating without melting

[2]stain \stān\ *vb* (14c) **1:** to suffuse with color **2:** to color by processes affecting chemically or otherwise the material itself **3:** in dentistry, to intentionally alter restorations through the application of intrinsic or extrinsic colorants to achieve a desired effect, best termed *characterization* or to *characterize* a restoration

static fatigue \stăt′ĭk fa-tēg\: the delayed failure of glass and ceramic materials resulting from stress enhanced chemical reactions aided by water vapor acting on surface cracks. Analogous to stress corrosion occurring in metals

trans·luc·en·cy \trănz′lōō′san-sē\ *n* (1611): having the appearance between complete opacity and complete transparency; partially opaque

veneer \va-nîr′\ *n* (1702): 1. a thin sheet of material usually used as a finish 2. a protective or ornamental facing 3. a superficial or attractive display In multiple layers, frequently termed a *laminate veneer*

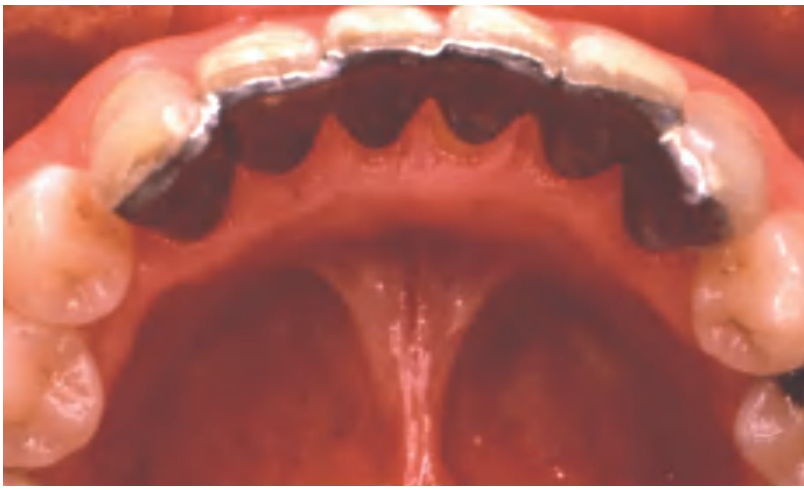
REFERENCES

1. Ernsmere JB: Porcelain dental work. Br J Dent Sci 43:547, 1900.
2. Ehrlich A: Erosion of acrylic resin restorations [Letter]. J Am Dent Assoc 59:543, 1959.
3. Söremark R, Bergman B: Studies on the permeability of acrylic facing material in gold crowns, a laboratory investigation using Na. Acta Odontol Scand 19:297, 1961.
4. Lamstein A, Blechman H: Marginal seepage around acrylic resin veneers in gold crowns. J Prosthet Dent 6:706, 1956.
5. Weinstein M, Weinstein AB: Fused Porcelain-to-Metal Teeth. U.S. Patent No. 3,052,982, September 11, 1962.
6. Vines RF, Semmelman JO: Densification of dental porcelain. J Dent Res 36:950, 1957.
7. Hondrum SO: A review of the strength properties of dental ceramics. J Prosthet Dent 67:859, 1992.
8. Denry IL: Recent advances in ceramics for dentistry. Crit Rev Oral Biol Med 7:134, 1996.
9. Jones DW, Wilson HJ: Some properties of dental ceramics. J Oral Rehab 2:379, 1975.
10. Kelly JR, et al: Fracture surface analysis of dental ceramics: clinically failed restorations. Int J Prosthodont 3:430, 1990.
11. Mackert JR Jr: Isothermal anneal effect on microcrack density around leucite particles in dental porcelain. J Dent Res 73:1221, 1994.
12. Mackert JR Jr: Effect of thermally induced changes on porcelain-metal compatibility. In Preston JD, ed: Perspectives in Dental Ceramics, Proceedings of the Fourth International Symposium on Ceramics, pp 53-64. Chicago, Quintessence Publishing, 1988.
13. Mackert JR Jr, Williams AL: Microcracks in dental porcelain and their behavior during multiple firing. J Dent Res 75:1484, 1996.
14. Anusavice KJ, et al: Influence of initial flaw size on crack growth in air-tempered porcelain. J Dent Res 70:131, 1991.
15. Weibull W: A statistical theory of the strength of material. Ing Vetensk Akad Proc 151:1, 1939.
16. Davidge RW, Green TJ: The strength of two-phase ceramic/glass materials. J Mater Sci 3:629, 1968.
17. Dunn B, et al: Improving the fracture resistance of dental ceramic. J Dent Res 56:1209, 1977.
18. Seghi RR, et al: The effect of ion-exchange on the flexural strength of feldspathic porcelains. Int J Prosthodont 3:130, 1990.
19. Denry IL, et al: Enhanced chemical strengthening of feldspathic dental porcelain. J Dent Res 72:1429, 1993.
20. Anusavice KJ, et al: Strengthening of porcelain by ion exchange subsequent to thermal tempering. Dent Mater 8:149, 1992.
21. Anusavice KJ, Hojjatie B: Effect of thermal tempering on strength and crack propagation behavior

of feldspathic porcelains. J Dent Res 70:1009, 1991.
22. Garvie RC, et al: Ceramic steel? Nature 258:703, 1975.
23. Denry IL, et al: Effect of heat treatment on microcrack healing behavior of a machinable dental ceramic. J Biomed Mater Res 48:791, 1999.
24. Fairhurst CW, et al: The effect of glaze on porcelain strength. Dent Mater 8:203, 1992.
25. Griggs JA, et al: Effect of flaw size and auto-glaze treatment on porcelain strength [Abstract no. 1658]. J Dent Res 74:219, 1995.
26. McLean JW, Kedge MI: High-strength ceramics. Quintessence Int 18:97, 1987.
27. Michalske TA, Freiman SW: A molecular interpretation of stress corrosion in silica. Nature 295:511, 1982.
28. Sherrill CA, O'Brien WJ: Transverse strength of aluminous and feldspathic porcelain. J Dent Res 53:683, 1974.
29. Morena R, et al: Fatigue of dental ceramics in a simulated oral environment. J Dent Res 65:993, 1986.
30. Rosenstiel SF, et al: Stress-corrosion and environmental aging of dental ceramics [Abstract no. 823]. J Dent Res 71:208, 1992.
31. Rosenstiel SF, et al: Fluoroalkylethyl silane coating as a moisture barrier for dental ceramics. J Biomed Mater Res 27:415, 1993.
32. McLean JW, Hughes TH: The reinforcement of dental porcelain with ceramic oxides. Br Dent J 119:251, 1965.
33. Batchelor RW, Dinsdale A: Some physical properties of porcelain bodies containing corundum. In Transactions, Seventh International Ceramics Congress, p. 31. London, 1960.
34. Dinsdale A, et al: The mechanical strength of ceramic tableware. Trans Br Ceram Soc 66:367, 1967.
35. McLean JW: A higher strength porcelain for crown and bridge work. Br Dent J 119:268, 1965.
36. Jones DW: Ceramics in dentistry. II. Dent Techn 24:64, 1971.
37. Claus H: Vita In-Ceram, a new procedure for preparation of oxide-ceramic crown and bridge framework. Quintessenz Zahntech 16:35, 1990.
38. Pröbster L, Diehl J: Slip-casting alumina ceramics for crown and bridge restorations. Quintessence Int 23:25, 1992.
39. Seghi RR, et al: Flexural strength of new ceramic materials. J Dent Res 69:299, 1990.
40. Wolf WD, et al: Mechanical properties and failure analysis of alumina-glass dental composites. J Am Ceram Soc 79:1769, 1996.
41. McLaren EA: All-ceramic alternatives to conventional metal-ceramic restorations. Compend Contin Educ Dent 19:307, 1998.
42. Sorensen JA, et al: Core ceramic flexural strength from water storage and reduced thickness [Abstract no. 906]. J Dent Res 78:219, 1999.
43. Shearer B, et al: Influence of marginal configuration and porcelain addition on the fit of In-Ceram crowns. Biomaterials 17:1891, 1996.
44. Pera P, et al: In vitro marginal adaptation of alumina porcelain ceramic crowns. J Prosthet Dent 72:585, 1994.
45. Sulaiman F, et al: A comparison of the marginal fit of In-Ceram, IPS Empress, and Procera crowns. Int J Prosthodont 10:478, 1997.
46. Lüthy H, et al: Effects of veneering and glazing on the strength of heat-pressed ceramics. Schweiz Monatssch Zahnmed 103:1257, 1993.
47. Höland W, et al: A comparison of the microstructure and properties of the IPS Empress® 2 and the IPS Empress® glass-ceramics. J Biomed Mater Res 53:297, 2000.
48. Culp L: Empress 2. First year clinical results. J Dent Technol 16:12, 1999.
49. Anusavice KJ: Recent developments in restorative dental ceramics. J Am Dent Assoc 124:72, 1993.
50. Estafan D, et al: Scanning electron microscope evaluation of CEREC II and CEREC III inlays. Gen Dent 51:450, 2003.
51. Filser F, et al: Net-shaping of ceramic components by direct ceramic machining. Assembly Autom 23:382, 2003.
52. Hegenbarth EA: Procera aluminum oxide ceramics: a new way to achieve stability, precision, and esthetics in all-ceramic restorations. Quintessence Dent Technol 19:21, 1996.
53. Andersson M, et al: Procera: a new way to achieve an all-ceramic crown. Quintessence Int 29:285, 1998.
54. Oden A, et al: Five-year clinical evaluation of Procera AllCeram crowns. J Prosthet Dent 80:450, 1998.
55. May KB, et al: Precision of fit: the Procera AllCeram crown. J Prosthet Dent 80:394, 1998.
56. Smedberg JI, et al: Two-year follow-up study of Procera-ceramic fixed partial dentures. Int J Prosthodont 11:145, 1998.
57. Naert I, et al: Precision of fit and clinical evaluation of all-ceramic full restorations followed between 0.5 and 5 years. J Oral Rehabil 32:51, 2005.
58. Suttor D: Lava zirconia crowns and bridges. Int J Comput Dent 7: 67, 2004.
59. Shoher I: Vital tooth esthetics in Captek restorations. Dent Clin North Am 42:713, 1998.

60. Zappala C, et al: Microstructural aspects of the Captek alloy for porcelain-fused-to-metal restorations. J Esthet Dent 8:151, 1996.
61. Seghi RR, et al: Relative fracture toughness and hardness of new dental ceramics. J Prosthet Dent 74:145, 1995.
62. Kelsey WP, et al: 4-Year clinical study of castable ceramic crowns. Am J Dent 8:259, 1995.
63. Hankinson JA, Cappetta EG: Five years' clinical experience with a leucite-reinforced porcelain crown system. Int J Periodont Restor Dent 14:138, 1994.
64. Sorensen JA, et al: In-Ceram fixed partial dentures: three-year clinical trial results. J Calif Dent Assoc 26:207, 1998.
65. Pospiech P, et al: Clinical evaluation of Empress-2 bridges: first results after two years [Abstract no 1527]. J Dent Res 79:334, 2000.
66. Sorensen JA, et al: A clinical investigation on three-unit fixed partial dentures fabricated with a lithium disilicate glass-ceramic. Pract Periodontics Aesthet Dent 11:95, 1999.
67. Sulaiman F, et al: A comparison of the marginal fit of In-Ceram, IPS Empress, and Procera crowns. Int J Prosthodont 10:478, 1997.
68. Holloway JA, Miller RB: The effect of core translucency on the aesthetics of all-ceramic restorations. Pract Periodontics Aesthet Dent 9:567, 1997.
69. Seghi RR, et al: Abrasion of human enamel by different dental ceramics in vitro. J Dent Res 70:221, 1991.
70. Hacker CH, et al: An in vitro investigation of the wear of enamel on porcelain and gold in saliva. J Prosthet Dent 75:14, 1996.
71. Metzler KT, et al: In vitro investigation of the wear of human enamel by dental porcelain. J Prosthet Dent 81:356, 1999.
72. al-Hiyasat AS, et al: Investigation of human enamel wear against four dental ceramics and gold. J Dent 26:487, 1998.
73. Ramp MH, et al: Evaluation of wear: enamel opposing three ceramic materials and a gold alloy. J Prosthet Dent 77:523, 1997.
74. Sorensen JA, et al: Three-body in vitro wear of enamel against dental ceramics [Abstract no. 909]. J Dent Res 78:219, 1999.
75. Wall JG, et al: Cement luting thickness beneath porcelain veneers made on platinum foil. J Prosthet Dent 68:448, 1992.
76. Dietschi D, et al: In vitro evaluation of marginal fit and morphology of fired ceramic inlays. Quintessence Int 23:271, 1992.
77. Christensen R, Christensen G: Service potential of all-ceramic fixed prostheses in areas of varying risk [Abstract no. 1716]. J Dent Res 71:320, 1992.
78. Kakehashi Y, et al: A new all-ceramic post-and-core system: clinical, technical, and in vitro results. Int J Periodont Restor Dent 18:586, 1998.
79. Zalkind M, Hochman N: Esthetic considerations in restoring endodontically treated teeth with posts and cores. J Prosthet Dent 79:702, 1998.
80. Asmussen E, et al: Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent 27:275, 1999.
81. McLaughlin G: Porcelain fused to tooth—a new esthetic and reconstructive modality. Compend Contin Educ Gen Dent 5:430, 1984.
82. Calamia JR: Etched porcelain veneers: the current state of the art. Quintessence Int 16:5, 1985.
83. Malament KA, Grossman DG: Bonded vs. nonbonded DICOR crowns: four-year report [Abstract no. 1720]. J Dent Res 71:321, 1992.
84. Sjögren G, et al: Clinical evaluation of all-ceramic crowns (Dicor) in general practice. J Prosthet Dent 81:277, 1999.
85. Schaffer H, Zobler C: Complete restoration with resin-bonded porcelain inlays. Quintessence Int 22:87, 1991.

26



RESIN-BONDED FIXED DENTAL PROSTHESES

Van P. Thompson

KEY TERMS

base metal
bonding
cantilever
cement
cementation
grooves
micromechanical retention
noble metal
resin
resin-bonded prosthesis
resistance form
retainer
retention
retention form
undercut

Resin-bonded fixed dental prostheses (FDPs) have had variable popularity since the technique for splinting mandibular anterior teeth with a perforated metal casting was described by Rochette in 1973.[1] His work suggested an alternative to conventional metal-ceramic fixed FDPs and its substantial removal of tooth structure needed to create strong, anatomically contoured, and esthetic restorations (see Chapter 7). A prosthesis that requires minimal removal of tooth structure is appealing, particularly for abutment teeth that are intact and caries free. The primary goal of the resin-bonded partial FDP is the replacement of missing teeth and maximum conservation of tooth structure.

The advent of electrolytic etching of the metal surface to provide **micromechanical retention** for metal adhesion to enamel led to the technique's broad application.[2] The restoration is simple in concept and consists of one or more pontics supported by thin metal **retainers** bonded lingually and proximally to the enamel of the abutment teeth (Fig. 26-1). These conservative prostheses depend on **bonding** between etched enamel and the metal casting and require precise and defined metal engagement of the abutment. The early use of these bonded retainers tested the limits of its application. There was a limited understanding of the treatment planning required and of the degree of resistance and **retention form** necessary. In general use, poor design of the early retainers (with some bonded only to lingual enamel) was compounded by the difficulty of properly etching the metal. As a result, several failures occurred, and the technique was used more conservatively from 1986 to 1996. During and since that period, design parameters have been enumerated and tested clinically.[3-5] Such designs, combined with new technologies for adhesive bonding of resin to most alloys, have led to a simpler, more reliable prosthetic procedure that complements the dentist's prosthodontic armamentarium.



Fig. 26-1
A, Facial view of resin-bonded retainer replacing the right central incisor, which was lost as a result of trauma. **B,** Lingual view of the retainer. Note the extension of the retainer over the marginal ridges of both abutment teeth, which is an aspect of all designs for anterior retainers.

DEVELOPMENT OF RESIN-BONDED FIXED DENTAL PROSTHESES

Bonded Pontics

The earliest resin-bonded prostheses were extracted natural teeth or acrylic teeth used as pontics bonded to the proximal and lingual surfaces of abutment teeth with composite resin.[6,7] The composite resin connectors were brittle and required supporting wire or a stainless steel mesh framework. These bonded pontics were limited to short anterior spans and had a limited lifetime, with degradation of the composite resin bond to the wire or mesh and subsequent fracture. Such restorations should be presented to patients only as short-term replacements.[8-10]

Cast Perforated Resin-Bonded Fixed Dental Prostheses (Mechanical Retention)

In 1973, Rochette[1] introduced the concept of bonding metal to teeth by using flared perforations of the metal casting to provide mechanical retention.

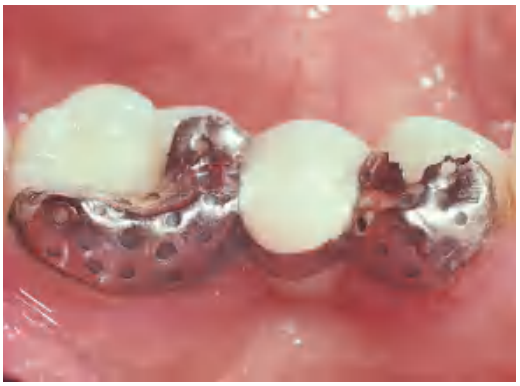


Fig. 26-2
Lingual view of an early perforated resin-bonded fixed dental prosthesis replacing a premolar at the 13-year recall. Note the loss of resin from the perforations, the poor gingival embrasures, and the generalized wear of the occlusal composite resin restoration on the molar abutment.

He used the technique principally for periodontal splinting but also included pontics in his design. Howe and Denehy[11] recognized the metal framework's improved retention (over bonded pontics) and began using FDPs with cast-perforated metal retainers bonded to abutment teeth and metal-ceramic pontics to replace missing anterior teeth. Their design recommendation, extending the framework to cover a maximum area of the lingual surface, suggested little or no tooth preparation. Patient selection limited these FDPs to mandibular teeth or situations with minimal occlusal contact. The restorations were bonded with a heavily filled composite resin as a luting medium.

This concept was expanded to replacement of posterior teeth by Livaditis.[12] Perforated retainers were used to increase resistance and retention. Cast retainers were extended interproximally into the edentulous areas and onto occlusal surfaces. The design included a defined occlusogingival path of placement by tooth modification, which involved lowering the proximal and lingual height of contour of the enamel on the abutment teeth. These restorations were placed in normal occlusion; many have survived and have been seen on recall for up to 13 years (Fig. 26-2). Despite this success, the perforation technique presents the following limitations:

1. Weakening of the metal retainer by the perforations.
2. Exposure to wear of the resin at the perforations.
3. Limited adhesion of the metal provided by the perforations.[13]

Clinical results with the perforated technique were monitored for 15 years in a study at the

Table 26-1 **ESTIMATE TIME TO 50% FAILURE (DEBONDINGS) IN STUDIES WITH AT LEAST 10-YEAR MEAN**

Study	Months to 50% failure
UNIVERSITY OF IOWA	
Perforated design	110
Etched metal*	250
UNIVERSITY OF MARYLAND	
Etched metal†	190

*Boyer et al, 1993: 143 anterior and 30 posterior fixed dental prostheses (FDPs).[14]
†de Rijk et al, 1996: 61 anterior and 84 posterior FDPs.[72]

University of Iowa.[14] The results from this well-controlled study suggest that for anterior FDPs, the perforated retainers have a 50% failure at 110 months and 63% at about 130 months (Table 26-1).

Etched Cast Resin-Bonded Fixed Dental Prostheses (Micromechanical Retention—"Maryland Bridge")

A technique for the electrolytic etching of cast **base metal** retainers was developed at the University of Maryland by Thompson and Livaditis.[2,15] Etched cast retainers have definite advantages over the cast-perforated restorations:

1. Retention is improved because the resin-to-etched metal bond can be substantially stronger than the resin-to-etched enamel. The retainers can be thinner and still resist flexing.
2. The oral surface of the cast retainers is highly polished and resists plaque accumulation.

During the course of this work, the need for a composite resin with a low film thickness for luting the casting became apparent. This led to the first generation of resin **cements,** which allowed micromechanical bonding into the **undercuts** in the metal casting created by etching and simultaneously provided adequate strength and allowed complete seating of the cast retainers. Comspan,* the first of these cements, was moderately filled (60% by weight) with a film thickness of approximately 20 μm.[16] Such cements are not chemically adhesive to the metal.

Electrolytic etching of base metal alloys proved to be critically dependent on the base metal alloy and attention to detail in the laboratory. Initial etching

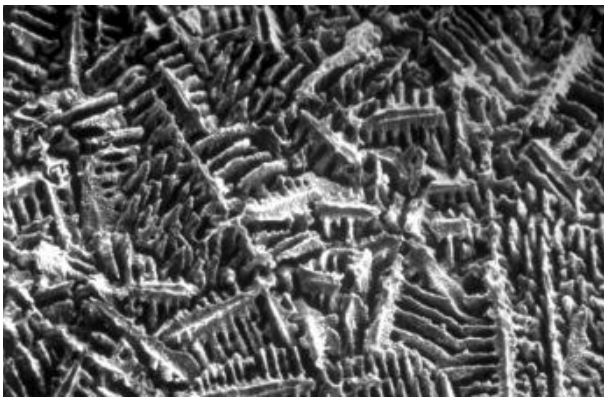


Fig. 26-3
Scanning electron micrograph (SEM) at 1000× magnification of a nickel-chromium-molybdenum-aluminum-beryllium (Ni-Cr-Mo-Al-Be) alloy electrolytically etched. The microstructure is selectively removed to create a highly undercut surface that can be wet by hydrophobic composite resins.

methods were developed for a nickel-chromium (Ni-Cr) alloy† and a nickel-chromium-molybdenum-aluminum-beryllium (Ni-Cr-Mo-Al-Be) alloy.[17‡] These methods were followed by simplified techniques,[18] chemical etching,[19] or gel etching.[20] They all yield similar results, provided that the technique is optimized for a specific alloy.[21] Proper etching requires evaluation of the alloy surface with a scanning electron microscope. The degree of undercut created by this etching process can be seen in Figure 26-3. Lack of attention to detail can result in electropolishing or surface contamination.[22] With time, both severely degrade bond strengths in a moist environment.

Highly variable results were reported for dental laboratories in etching the same alloy.[23] Etching and bonding techniques were adopted on the basis of bond strength testing of specimens subjected to only 24 hours or 7 days of water exposure. When resin-to-metal test specimens were aged for 6 months in water and then thermally stressed by 10,000 or more thermal cycles, large reductions in bond strengths were recorded.[24,25] Therefore, data from specimens that have not been aged and thermally stressed should be viewed skeptically. Even particle abrasion provides initially high resin-to-metal bonds, which can degrade to almost zero with time.[26]

Well-researched and tested resin systems for direct adhesion to metal surfaces have now completely supplanted metal etching as retention mechanisms.[27] This is discussed subsequently.

*Dentsply Caulk, Milford, Delaware.

†Biobond C & B Flux, Dentsply International, York, Pennsylvania.
‡Rexillium III, Pentron Clinical Technologies, LLC, Wallingford, Connecticut.

Macroscopic Mechanical Retention Resin-Bonded Fixed Dental Prostheses ("Virginia Bridge")

As a result of concerns about etching base metal and the desire to use alternative alloys, several methods have been developed to provide visible macroscopic mechanical undercuts on the inner surface of FDP retainers. The first was developed at the Virginia Commonwealth University School of Dentistry and is known as the *Virginia Bridge*.[28] It involves a "lost salt crystal" technique. On the definitive cast, the abutments are coated with a model spray, and a lubricant is then applied. Within the outlines of the retainers, specially sized salt crystals* (150 to 250 μm) are sprinkled over the surface in a uniform monolayer, leaving a 0.5-mm border without crystals at the periphery of the pattern. This is followed by application of a resin pattern. After pattern investment, the salt crystals are dissolved from the surface of the pattern. Adequate bond strengths are possible with this method,[29] but casting thickness must be increased to allow for the retention layer. Although no long-term results have been reported with this technique, it does allow the use of almost any metal-ceramic alloy. In general, however, macroscopic mechanical retention methods have been supplanted by direct adhesion with resin, which is possible for most casting alloys if the correct surface treatment is provided.

Chemical Bonding Resin-Bonded Fixed Dental Prostheses (Adhesion Bridges)

During the 1980s and early 1990s, when etched castings were the method of choice for retention of resin-bonded FDPs, extensive research was under way in Japan to develop adhesive systems for direct bonding of metal for this application. The first of these resin systems† is based on a formulation of a methyl methacrylate polymer powder and methyl methacrylate liquid modified with the adhesion promoter 4-methacryloxyethyl-trimellitic anhydride (4-META).[30] It was developed with a unique tri-n-butylborane catalyst system that is added to the liquid before combining with the powder. On base metal alloys, Super-Bond has the highest initial bond strengths of any adhesive resin system. Unfortunately, the hydrolytic stability of these bonds over time depended on the alloy's Cr-Ni ratio.[31,32] Its advantages include its lower elastic modulus and higher fracture toughness in comparison with bisphenol-A-glycidyl dimethacrylate (bisGMA)–based resin cements,[33,34] yielding better clinical results with less well-adapted castings.[35] This system had shown poor clinical results with bonding high-gold content alloy retainers to abutment teeth.[36] However, alloy primers have been developed that provide a more stable bond to noble alloy surfaces,[37,38] which has been confirmed in a clinical study.[39]

Super-Bond's introduction was followed by a bisGMA-based composite resin luting cement* that is modified with the adhesion promoter 10-methacryloxydecyl dihydrogen phosphate (MDP). MDP's chemical structure and use are described in the literature.[40]

Panavia resin luting agent has shown excellent bonds to particle-abraded Ni-Cr and chromium-cobalt (Cr-Co) alloys[41,42] as well as tin-plated gold and gold palladium-based alloys.[21,43]

Panavia has a tensile bond to etched enamel (10 to 15 MPa) comparable with that of the traditional bisGMA low-film thickness composites (e.g., Comspan and Conclude). The combination of metal electrolytic etching, followed by application of an adhesive such as Panavia, does not improve the tensile bond to the alloy, and its strength is actually slightly lower than that of the bond of Panavia to airborne particle abraded (sandblasted) base metal alloys.[44] The most recent versions are Panavia 21 and Panavia F 2.0, the latter being a dual cure system (chemical and visible light) that releases fluoride. Both incorporate a self-etching primer system (ED Primer) for bonding to enamel and dentin.

Tin plating of noble alloys allows resin-to-metal bond tensile bond strengths only slightly lower than those for either the electrolytically etched or particle abraded Ni-Cr-Be alloys (18 to 30 MPa). However, tensile bond strengths are certainly greater than the bond to etched enamel.[45,46] Tin plating of the metal surface also requires particle abrasion of the alloy surface just before bonding for adequate tin nucleation sites (Fig. 26-4).[47,48] Tin plating can be completed in the dental laboratory, chairside, or intraorally to achieve metal bonding. One popular tin-plating system† (Fig. 26-5*A*) involves the use of a tin amide solution, which is applied to the metal surface with a saturated cotton pledget held on the end of a battery-powered probe (4 V). The probe is grounded elsewhere on the metal (Fig. 26-5*B*). Tin-plating times are usually 5 to 10 seconds, and a light gray surface is produced. Plating is followed by

*Virginia technique kit, Richmond, Virginia.
†Super-Bond C&B, Sun Medical Co., Ltd., Osaka, Japan (also known as C&B MetaBond, Parkell, Inc., Farmingdale, New York.

*Panavia, Kuraray Company, Osaka, Japan.
†Tin Plater, Danville Engineering, San Ramon, California.

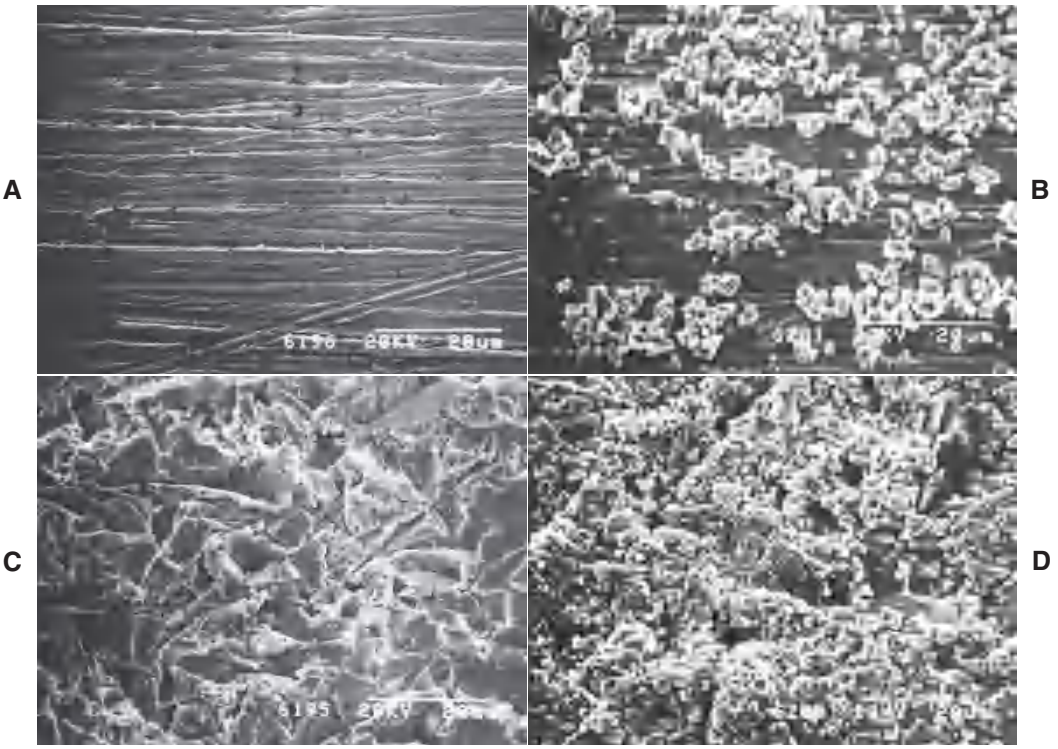


Fig. 26-4
Variations in tin-plating patterns with two surface treatments. **A,** Sandpaper (600 grit) prepared gold alloy (Firmilay, Jelenko, Armonk, New York) surface. **B,** Tin plating exhibiting local clumping and random distribution of tin particles. **C,** Gold alloy surface after 50 μm alumina particle abrasion. **D,** Particle-abraded gold alloy surface after tin plating with an even distribution of fine tin particles.



Fig. 26-5
Intraoral tin plating. **A,** Tin-plating system in which direct current is used to deposit tin from an amide solution (Tin Plater, Danville Engineerng, San Ramon, California). **B,** Tin plater in use intraorally. Note the gray color change. The tin is being deposited from the solution and carried to the metal in the cotton pledget affixed to one electrode of the plater; the circuit is completed with the alligator clip, which is in electrical contact with the prosthesis.

copious rinsing with water and drying; the adhesive resin is then applied.

Particle abrasion of the alloy surface with 50 μm alumina before bonding or tin plating not only creates a roughened, higher surface area substrate for bonding but also creates a molecular coating of alumina.[49] The alumina on the surface aids in oxide bonding of the phosphate-based adhesive systems (e.g., Panavia to alloy surfaces). Studies of this bonding mechanism are also reinforced by laboratory data on bonding to alumina and zirconia surfaces.[50-52]

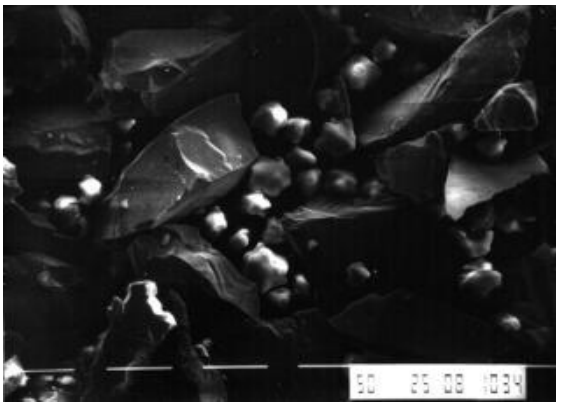


Fig. 26-6
Scanning electron micrograph of air abrasion particles (Rocatec Special, 3M ESPE, Norristown, Pennsylvania) composed of a mixture of 50-µm alumina (*dark irregular particles*) and smaller silicate particles (*light color*) used for final abrasion of metals, during which a molecular coating of silicate is tribochemically deposited on the metal. This silicate layer on the metal allows reaction with a silane-priming solution for subsequent bonding of resin to the metal.

These adhesive systems have now shown nearly the same degree of long-term clinical bonding (since 1983 in Japan) as the conventional composites on etched base metal (since 1981 in the United States).[15] Laboratory data support their efficacy. The favorable findings for direct adhesion to base metal have rendered alloy etching and macroscopic retention mechanisms obsolete.[53] This simplifies the laboratory and clinical procedures for placement of resin-bonded FDPs.

A laboratory method for resin bonding to both base and **noble metal** is the Rocatec System.* In this method, the metal surface is initially particle abraded with 120-µm alumina. This is followed by abrasion with a special silicate particle–containing alumina (Fig. 26-6). This second particle abrasion step deposits a molecular coating of silica and alumina on the alloy surface. Silane is then applied to the surface, making it adhesive to composite resin. Various silane application techniques have been compared by Norling and colleagues.[54] The Rocatec system has been compared with Panavia for bonding to a range of surfaces and is adequate in this regard.[25,27,49] However, it requires careful laboratory technique and is generally confined to bonding composite resin veneers to alloy castings because of the concern that the silane-treated surface may become contaminated before or during the clinical bonding procedures.

*3M ESPE, Norristown, Pennsylvania.

Table 26-2 **Adhesive Resin Cements and Primers for Noble Alloys**

Cement	Primer	Manufacturer
Bistite II DC	Metaltite	Tokyuyama Dental
CBMetabond	MTL-V Primer	Parkell Inc.
Linkmax	Metal Primer II	GC America
Multilink	Multilink Primer	Ivoclar Vivadent
Panavia 21	Alloy Primer	Kuraray America
Self Adhesive Systems		
Maxcem		Kerr Dental
Rely X Unicem		3M-ESPE

Since the mid-1990s, several competing primer and cement systems for direct adhesive bonding to noble alloys have evolved (Table 26-2). All entail particle abrasion of the alloy surface, followed by application of a primer and then the resin cement. These primers have been studied in the laboratory[55-59] and evaluated clinically.[39,60] Their usage is justified and simplifies bonding to both gold- and palladium-based alloys.

Changing the method of attachment of the resin to the metal framework does not change the design of the framework itself, because the limiting factor in the system is still the bond of resin to enamel. The evolution of Japanese designs for resin-bonded FDPs[61] has paralleled that in North America and Europe. There is an almost universal agreement concerning the need for mechanical retention of the framework to limit the stress on the bond interfaces (resin-to-metal and resin-to-enamel) and in the composite resin, which can become fatigued with time.[62-64]

DESIGN CONCEPTS

The guidelines for optimum design of resin-retained FDPs have been empirically derived. The principle underlying these restorations has always been that it is necessary to cover as much enamel surface as possible, as long as occlusion, esthetics, or periodontal health is not compromised. To emphasize the significance of maximum enamel coverage, Crispin and associates[65] reported 3-year failure rates of up to 50% when using small bonded areas and minimal retention designs.

The initial designs of etched cast retainers included an "interproximal wraparound" concept developed to resist occlusal forces and provide a broader area for bonding. Enamel preparations consisted of creating occlusal clearance, placement of occlusal/cingulum rests, and lowering the lingual and proximal height of contour, thus creating proximal extensions.

Frameworks should seat in an occlusogingival direction and should have no facial-lingual displacement (Fig. 26-7*A*). The contemporary design has improved retention with well-placed and precise **grooves** on abutment teeth (Fig. 26-7*B*). It is detailed in the following sections. Contemporary mouth preparations, in an effort to minimize failures, do not preserve as much tooth structure as did their predecessors; nevertheless, they are still limited to enamel and conform to conservative design principles. The new designs have been tested in laboratory studies.[66,67]

Three principles are fundamental to achieve predictable results with resin-bonded FDPs: proper patient selection, correct enamel modification, and framework design. The treatment is not a panacea, and if any of the contraindications are present, the patient should be treated with a conventional FDP or an implant-supported prosthesis.

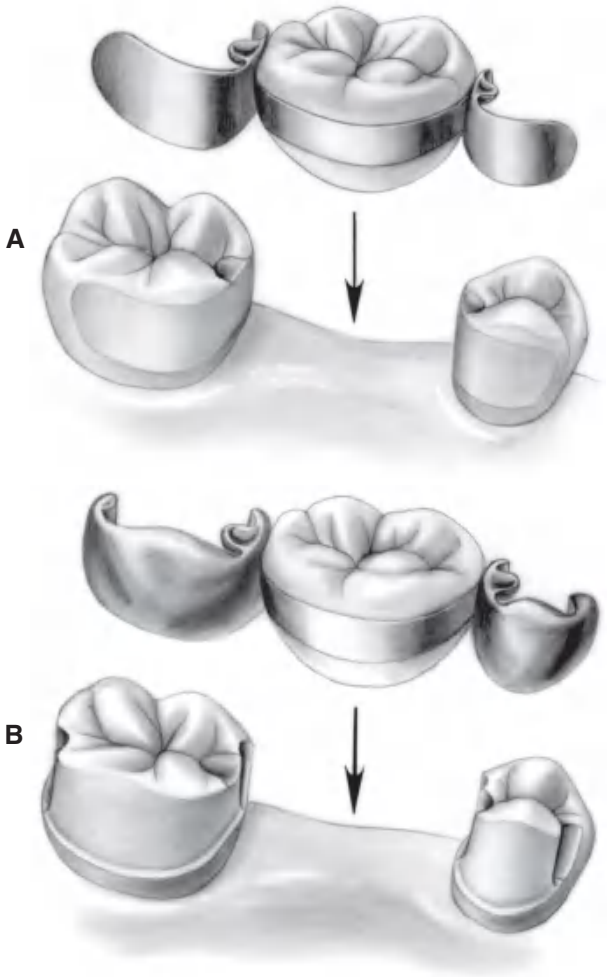


Fig. 26-7
Comparison of initial and contemporary posterior resin-bonded fixed dental prosthesis designs. **A,** Original design. Minimal modification of lingual and proximal enamel allowed sufficient buccal extension of the metal. Once seated, the retainer could not be displaced from buccal to lingual aspects. **B,** More extensive enamel preparation is now used with proximal grooves at the buccal-proximal line angles of the edentulous space. Note that with this design, the abutment teeth cannot be displaced from the retainer.

ADVANTAGES

When used appropriately, resin-bonded FDPs offer several advantages over conventional fixed prosthodontics (Box 26-1). Because of the unique preparation design, minimal tooth structure needs to be removed. In general, the preparation is confined to enamel only. Because of the conservative nature of the preparation, the potential for pulpal trauma is minimized. Anesthesia is not routinely used during tooth preparation (without anesthesia, it is possible to monitor the proximity of the preparation to the dentoenamel junction by the patient's comfort level). The prosthesis can often be kept entirely supragingival; as a result, periodontal irritation is kept to a minimum. In a periodontal evaluation of restorations that averaged 10 years in service, the periodontal response was not significantly different from that for unrestored contralateral teeth.[68] Only when the retainer gingival margins were less than 0.5 mm from the gingival crest was there a correlation with a detrimental gingival response. Concurrently, impression making is simplified because of the supragingival margins. Because the abutment teeth are, in addition to being nonsensitive, maintained with normal proximal contacts, fabrication of traditional interim restorations (see Chapter 15) is usually not required other than in selected patients. However, judicious placement of composite resin is important for maintaining occlusal clearances after the final impression and until the final restoration is bonded.[69] (see Fig. 26-14.) Chair time is significantly reduced in comparison with that for conventional fixed prosthodontics, and the cost incurred by the patient is lower. Both may be reduced by as much as 50%.[70]

The restoration can be rebonded, in which particle abrasion and adhesive resin systems are used (as long as the debonding occurred with no sequelae involving the abutment teeth). If one retainer

Box **26-1** **Advantages and Disadvantages of Resin-Bonded Fixed Dental Prostheses**

ADVANTAGES

Minimal removal of tooth structure
Minimal potential for pulpal trauma
Anesthesia not usually required
Supragingival preparation
Easy impression making
Interim restoration not usually required
Reduced chair time
Reduced patient expense
Rebonding possible

DISADVANTAGES

Reduced restoration longevity
Enamel modifications are required
Space correction is difficult
Good alignment of abutment teeth is required
Esthetics is compromised on posterior teeth

INDICATIONS

Replacement of missing anterior teeth in children and adolescents
Short span
Unrestored abutments
Single posterior tooth replacement
Significant clinical crown length
Excellent moisture control

CONTRAINDICATIONS

Parafunctional habits
Long edentulous spans
Restored or damaged abutments
Compromised enamel
Significant pontic width discrepancy
Deep vertical overlap
Nickel allergy

remains bonded, it can be gently loosened with a monobevel, single-ended instrument and a soft mallet. Any deformation of the metal framework in relation to the tooth structure can cause a crack to propagate through the luting composite resin. The monobevel chisel is positioned at an incisal or occlusal edge at an oblique angle to the long axis of the tooth along a mesial or distal line angle. The mallet should be used lightly (limited by patient response); repeated tapping causes debonding. However, with mechanically retentive designs, which include grooves and slots, the framework may require sectioning and removal of the sections (Fig. 26-8). As an alternative, ultrasonic scalers have been proposed to help remove partially debonded prostheses.[69] Ultrasonic scalers with special tips are available for this specific purpose. They are applied at the incisal and gingival margins, but the procedure requires a high-power setting and can take considerable time. The debonding rate with rebonded restorations is high,[71] and design modifications and a new or alternative restoration should be considered.

DISADVANTAGES

The primary disadvantage associated with resin-bonded FDPs relates to the fact that their longevity is less than that of conventional prostheses. This has been the subject of considerable investigation. Studies of first-generation etched metal FDPs at the University of Iowa (more anterior prostheses than posterior) and the University of Maryland (more posterior prostheses than anterior), with an average service time of more than 10 years, have revealed relative success. According to the results, an estimated 50% will fail after 250 months and 190 months, respectively (see Table 26-1).[14,72,73] These studies also indicate that the rate of debondings does not increase with time.

In a study conducted in a private practice setting, contemporary designs with a mean service time of 6 years achieved a 93% success rate.[3] This differs with the findings in a multicenter study in Europe, in which debonding rates increased with the time after placement (almost 50% at 5 years) and were related to preparation design, luting agent selection, and the area of placement within the dental arch.[74] Another European study revealed retention rates of 60% at 10 years for early designs. In one study, posterior and mandibular resin-bonded FDPs demonstrated higher dislodgment rates,[75] which may have resulted from occlusal forces (see Chapter 4) and increased isolation difficulty during the bonding procedure.[71,76] In light of these studies, the likelihood of eventual debonding should be discussed with the patient before treatment. In comparison, a meta-analysis of clinical studies of conventional FDPs indicated a doubling of the failure rate for every 5 years of service from 0 to 15 years.[77] When these results are projected from 15 years to 20 years, a 50% failure rate for conventional FDPs would take about 20 years.[73]

Extensive enamel modifications are required with retentive design to the proximal and lingual surfaces of the abutment teeth (see Fig. 26-7*B*). If the restoration is removed, composite resin bonding could restore the enamel contours, but transition to a more traditional prosthesis is likely. Enamel is limited in



Fig. 26-8
Removal of a retainer with a contemporary design. **A,** The retainer has been sectioned with a carbide bur to allow separation of the mesial and distal retentive features. The monobevel chisel is oriented to provide a wedging action between the metal and the enamel, which allows a crack to propagate through the brittle resin. **B,** The cracking of the resin has propagated debonding between the metal and the resin. The mesial retainer half can now be removed in a similar manner. This retainer was removed because of fatigue fracture of the metal at the junction of the pontic metal with the premolar retainer arm (not shown), where the retainer was thinner than 1 mm. The poor periodontal support of the molar abutment allowed large lateral movements of the pontic and molar during function.

thickness, which requires precision in design and preparation with attention to detail.[78] Enamel lingual surfaces of anterior teeth are almost always thinner than 0.9 mm.[79]

Space correction is difficult with resin-bonded FDPs. When the pontic space is greater or less than the dimensions of a normal tooth, achieving an esthetic result with this restoration is difficult. As with conventional fixed prostheses, treatment of diastemata is demanding, although a **cantilever** option may be appropriate.

Good alignment of abutment teeth is required because the prosthesis's path of placement is limited by potential penetration of the enamel thickness. However, some posterior teeth, which are mesially or mesiolingually tilted, can be onlayed with a bonded retainer (see Figs. 26-18 and 26-20).

Esthetics is compromised on posterior teeth. Posterior resin-bonded FDP design requires the extension of the metal framework onto the occlusal surface of posterior teeth. These occlusal rests and occasional onlaying of cusps are visible, which might be objectionable to some patients (see Fig. 26-18).

Clinical indications and contraindications are quite specific. In the presence of any contraindications, a conventional FDP or an implant-supported crown should be considered.

INDICATIONS

In the treatment plan for any fixed prosthesis, the patient's individual needs must be properly identified. The presence of any existing disease, its causes, and how it relates to the treatment prognosis must



Fig. 26-9
Resin-bonded fixed dental prostheses are particularly useful in the treatment of young patients with congenitally missing teeth. Note the unusual tooth pattern with the first premolar in the canine space and the missing lateral incisors.

be assessed. Periodontal and general dental health must be reestablished, and the proposed abutment teeth should not exhibit mobility; however, periodontal splinting of teeth with a resin-retained FDP has been successful with strict provision of mechanical retention of each tooth within the alloy framework.

Resin-bonded restorations have been used for many years to replace missing anterior teeth in children (Fig. 26-9).[11] Conventional fixed prosthodontic techniques are generally contraindicated in young patients because of management problems, inadequate plaque control, the large size of the pulps, and the fact that children routinely participate in sports. One or two anterior teeth with mesial and distal abutments can generally be replaced with a resin-

bonded FDP. Depending on circumstances, a greater number of teeth can be involved.

Sound teeth or those with minimal restorations are suitable as an abutment with a resin-bonded retainer. For bonding to anterior teeth, the presence of Class III restorations is not a contraindication to a bonded retainer. However, large multiple restorations or a Class IV restoration would limit the resulting bond and the abutment's mechanical integrity. In the posterior region, existing Class II lesions proximal to the edentulous space can be incorporated into the retainer design. Minimal or moderate alloy restorations in the abutment teeth should be replaced with dentin bonding and composite resin, or they can sometimes be incorporated into the preparation design. The incorporation of a mesio-occlusal amalgam into the retainer design, shown in Figure 26-10, was placed before the advent of high-strength dentin bonding systems. The appearance of the restoration at the 9-year recall appointment is also presented.



Fig. 26-10

A, Preparation for resin-bonded fixed dental prosthesis incorporating an existing amalgam restoration by use of a shallow inlay preparation, in which the amalgam reduction is short of the depth of the dentoenamel junction (with current dentin bonding technology, a composite resin base would be substituted for the amalgam). Note the shallow distal rest on the premolar and the lack of mesiolingual slot/groove preparation on the premolar abutment. **B,** Appearance of the restoration at 9-year recall appointment, in which luting resin is still present as a sealant in the molar lingual groove.

As demonstrated in clinical studies, single posterior teeth can be replaced with resin-bonded FDPs.[3,72]

Significant clinical crown length should be present to maximize retention and **resistance form.** In addition to replacing missing teeth, the **resin-bonded prosthesis** can be used for periodontal splinting and postorthodontic fixation.

The restorations may be used both anteriorly and posteriorly. However, excellent moisture control must be practiced during **cementation.**

Proper patient selection also requires an aggressive and ongoing follow-up program to detect debonding and the presence of caries resulting from debonding. However, caries rates on bonded retainers are low.[80,81]

CONTRAINDICATIONS

Because of the apparent advantages of resin-retained restorations, they have often been used in inappropriate circumstances, which led to failures that reduced patients' (and dentists') confidence in the technique. Fortunately, these failures were usually correctable by more conventional methods. If any of the following contraindications exist in a particular clinical situation, an alternative approach to treatment should be selected.

In patients with parafunctional habits, the use of resin-bonded FDPs should be considered cautiously, because the resistance to displacement of these retainers is lower than in conventional FDPs. They should be used judiciously when above-average lateral forces are likely to be applied (e.g., in a patient with parafunctional habits or in a patient who requires an anterior tooth replacement in the presence of an unstable or nonexistent posterior occlusion). In these instances, all means of mechanical retention of the framework (grooves, occlusal rests, interproximal extension of metal) (see Fig. 26-7*B*) should be used. The patient should be informed about the possibility of debonding. Periodontal splints can also be fabricated, but they require strict attention to mechanical retention.[82,83]

Long edentulous spans should be avoided because they place excessive force on the metal retention mechanism; with repeated loading, fatigue of the bonding interfaces or even the metal is possible.

Retention is dependent on an adequate surface area of enamel and sufficient clinical crown for proximal contouring and placement of grooves. This can be difficult if the abutment teeth have short clinical crowns (Fig. 26-11). Surgical crown lengthening may therefore be necessary as a way to increase the bondable surface area and because subgingival margins must be avoided.

Extensively restored or damaged teeth are unsuitable as abutments. One sound abutment and one extensively restored abutment can be incorporated into a combination FDP. In one retrospective clinical study with restorations in function for an average of more than 10 years, combination FDPs with one conventional retainer and one bonded retainer were very successful.[84]

Compromised enamel on abutment teeth as a result of hypoplasias, demineralizations, or congenital problems (e.g., amelogenesis imperfecta or dentinogenesis imperfecta) adversely affects resin bond strength.

As previously mentioned, edentulous spaces that are larger or smaller than normal tooth size or diastemas are not easily accommodated. The labiolingual thickness of anterior abutment teeth and translucency of the enamel should be assessed to determine whether the shade of the abutment teeth will be changed (a consequence of reduction of tooth translucency by the metal retainer[85,86]). Graying of the abutments can be eliminated with opaque resins and by limiting the incisal extent of the metal on the lingual surface. Translucent resins cause optical coupling of the metal to the tooth; appreciable graying of the enamel results. A trial insertion of the metal with water between the metal and the tooth provides a preview of the possible graying. Similarly, when the pontic of a resin-bonded FDP is custom stained, a trial resin that does not polymerize should be used to visualize the final shade of the abutment teeth with the metal backing (Fig. 26-12).

The presence of a deep vertical overlap prevents adequate enamel reduction and can place excessive forces on resin-bonded FDPs; this situation should be approached cautiously.

Nickel-based alloys have been the primary metal for resin-bonded FDPs. Patients who are allergic to nickel should be identified and offered an alternative.[87] Tin plating and laboratory-applied bonding systems allow the use of noble alloys. However, with the lower elastic modulus of most noble alloys, the metal thickness should be increased approximately 30% to 50% to make the stiffness of the noble metal framework equal to that of base metal.[88] This is an important factor in treatment planning and can influence the amount of occlusal clearance required for the metal (which is critical in patients with an increased vertical overlap).



Fig. 26-11
Minimal clinical crown length is available for adequate retention as a result of hyperplastic gingival tissue on the maxillary canines. Surgical crown lengthening is indicated.

FABRICATION

In the fabrication of resin-bonded FDPs, attention to detail in the following three phases is necessary for predictable success:



Fig. 26-12
A, Evaluation of resin-bonded fixed dental prosthesis for characterization of the pontic showing extensive graying of the central incisor abutment when translucent resin optically couples the dark metal to the tooth. **B,** Use of opaque resin prevents the darkening of the abutment and raises the value slightly. Opaque and translucent resins can be combined to provide the correct shade for the abutment; the pontic can then be characterized accordingly.

1. Preparation of the abutment teeth.
2. Design of the restoration.
3. Bonding.

Preparation of the Abutment Teeth

Whether anterior or posterior teeth are prepared, common principles dictate tooth preparation design. A distinct path of placement must exist, proximal undercuts must be removed to provide "planes of metal" on the lingual and proximal surfaces, occlusal rest seats and proximal groove/slots must provide resistance form, and a definite and distinct gingival margin should be established wherever possible (Fig. 26-13).

On anterior teeth, the procedure is similar in many ways to the lingual reduction needed for a pinledge preparation (see Chapter 10), but the amount of reduction is less because the enamel must not be penetrated. If necessary, the opposing teeth can be recontoured to increase interocclusal clearance. There must be sufficient enamel area for successful bonding, and the metal retainers must encompass enough tooth structure and have sufficient resistance form to prevent the individual abutment tooth from being displaced in any direction out of the framework.

Rotary instrument selection depends on the operator's preference. Gingival margins and circumferential preparation are easily accomplished with a chamfer or round-tipped diamond. Occlusal rest seats and cingulum notches can be prepared with a diamond or carbide inverted cone bur. The other crucial retentive features (e.g., slots, grooves) can be made with a tapered fissure bur.

The dentist should determine the restoration design before beginning tooth preparation. This may include surveying the abutment teeth and making diagnostic preparations on a cast.



Fig. 26-13
Preparation design for anterior resin retainer fixed dental prosthesis. Note the lowering of the height of contour in the interproximal, the slight extension of the metal toward the facial aspect (but not so much that it compromises esthetics), and the use of small but distinct proximal grooves.

Step-by-step procedure

1. Leave the margins about 1 mm from the incisal or occlusal edge, and, if possible, 1 mm from the gingival margin. Definite rests and grooves provide resistance form for the retainers and assist in positive seating during cementation. Small, defined gingival margins (where possible) guide the laboratory as to the gingival extent of the retainer. To enhance resistance, more than half the circumference of the tooth should be prepared (i.e., the concept of greater-than-180-degree wraparound, which is particularly important for posterior teeth).
2. Make an accurate impression. Marginal fit is as crucial for a resin-bonded restoration as for a conventional FDP. Bond strengths are reduced with thick resin layers.[35]
3. Provide temporary occlusal stops. Significant supraocclusion of the abutment teeth can occur rapidly, particularly in younger patients or patients with reduced periodontal support. This can be avoided on anterior teeth by placing a small amount of composite resin on the opposing mandibular teeth. This is rarely needed for posterior teeth unless significant onlaying of the abutment is planned (in which case small composite resin stops can be bonded to the enamel) (Fig. 26-14). The resin is removed just before placement of the resin-bonded FDP.

Anterior Tooth Preparation and Framework Design

When designing the anterior prosthesis, use the largest possible surface area of enamel that will not compromise the esthetics of the abutment teeth. The retentive retainers (wings) should extend one tooth mesial and distal if a single tooth is replaced (Fig. 26-15). If two teeth are replaced, double abutments on either side can be considered, but only if the periodontal support of the abutments is compromised. With proper mechanically retentive designs, two maxillary incisor pontics can be retained by two lateral incisors, unless the latter have short clinical crowns or a deep vertical overlap is present. If a com-



Fig. 26-14
Temporary replacement of occlusal stops is crucial whenever they have been removed as a result of enamel recontouring. The composite resin stops shown here will be removed when this posterior inlay/onlay resin-bonded fixed dental prosthesis is bonded.



Fig. 26-15
Clinical view of an anterior prosthesis demonstrating the extent of coverage of the metal retainer, which forms planes on the mesial and distal lingual surfaces.



Fig. 26-16
A, Preparation design for an anterior prosthesis. Proximal grooves have been prepared on the mesial and distal surfaces of the abutment teeth. This mechanical retention is particularly important on the canine, where a distinct wear facet is seen. **B,** The gold alloy retainer is thicker than if a base metal alloy had been used. Note the extent of the metal into the canine distal proximal embrasure, whereas the central mesial extension has been limited because of the incisor diastema.

bination of tooth replacement and splinting is used, the framework may cover more teeth.

Cantilevering pontics with resin-bonded FDPs is also possible. This has been successful in selected situations in the anterior region[89] and is particularly useful for replacement of lateral incisors for which cantilevers from either the central incisor or canine are possible. The retainer design is critical and requires adequate mechanical engagement of the abutment tooth.

The gingival margin should be designed so that there exists a slight supragingival chamfer that delineates the gingival extension of the preparation. Any undercut enamel is removed at this time. The chamfer finish line should extend incisally through the distal marginal ridge area so that mesial, lingual, and distal "planes" are created (see Fig. 26-15). Abutments should have parallel proximal surfaces whenever possible.

The finish line on the proximal surface, adjacent to the edentulous space, should be placed as far facially as practical. A 0.5-mm-deep slot, prepared with a tapered carbide bur, should be placed slightly lingual to the labial termination of the proximal reduction (Fig. 26-16). Great care in paralleling the proximal grooves is required. A paralleling instrument is very helpful during this procedure, and its importance has been demonstrated in highly successful clinical studies.[4,5] This device is also helpful when many teeth are to be incorporated in the framework (e.g., an extensive periodontal splint).

The occlusion is assessed to ensure at least 0.5 mm of interocclusal clearance for the metal retainers in maximum intercuspation and throughout the

lateral and protrusive excursive pathways. If inadequate clearance exists, selective enameloplasty is performed. On occasion, additional clearance can be obtained by reducing the opposing teeth. However, this is contraindicated if there is wear or attrition on the incisal edges.

The restoration must extend labially past the proximal contact point. To optimize esthetics, the proximal wrap in the anterior region may be achieved in part with the porcelain pontic[78,90] (see Fig. 26-15).

Preparation of mandibular anterior teeth is similar to that for the maxillary incisors. Lingual enamel thickness is 11% to 50% less than for maxillary teeth, and tooth preparation must therefore be more conservative.[78,80] Periodontal splinting and combinations of splinting and tooth replacement are commonly used in the mandibular anterior region (Fig. 26-17). These present a challenge: providing mechanical retention can prove difficult.



Fig. 26-17
Mandibular anterior resin-bonded fixed dental prostheses. **A,** Note the inadequate abutment tooth lingual metal coverage and lack of extension into the proximal embrasures. A debonding is present on the right lateral incisor. **B,** A 10-year recall view, in which a more appropriate design has been employed.

Posterior Tooth Preparation and Framework Design

The basic framework for the posterior resin-bonded FDP consists of three major components: the occlusal rest (for resistance to gingival displacement), the retentive surface (for resistance to occlusal displacement), and the proximal wrap and proximal slots (for resistance to torquing forces) (see Fig. 26-7*B*).

A spoon-shaped occlusal rest seat, similar to that described for a partial removable dental prosthesis (see Chapter 21), is placed in the proximal marginal ridge area of the abutments adjacent to the edentulous space. An additional rest seat may be placed on the opposite side of the tooth (Fig. 26-18). The rest is an important retention feature and simultaneously provides resistance to both occlusal and lateral forces. It should be designed to function as a shallow "pin."

To resist occlusal displacement, the restoration is designed to maximize the bonding area without unnecessarily compromising periodontal health or esthetics. Proximal and lingual axial surfaces are reduced to lower their height of contour to approximately 1 mm from the crest of the free gingiva. The proximal surfaces are prepared so that parallelism



Fig. 26-18
A, Preparation for large premolar pontic. The first premolar has been prepared with mesial and distal rests and a distobuccal groove. **B,** The final restoration, which displays extensive metal on the occlusal surface of the premolar. This may be esthetically unacceptable for some patients.

results without undercuts. In the interproximal area, a gingival chamfer is not desirable to avoid enamel penetration. The result is a knife-edge margin. Occlusally, the framework should be extended high on the cuspal slope, well beyond the actual area of enamel recontouring (provided that it does not interfere with the occlusion) (Fig. 26-19).

Resistance to lingual displacement is more easily managed in the posterior region of the mouth. A single path of placement should exist. The alloy framework should be designed to engage at least 180 degrees of tooth structure when viewed from the occlusal aspect. This proximal wrap enables the restoration to resist lateral loading by engaging the underlying tooth structure and is assisted in this regard by grooves in the proximal aspect just lingual to the buccal line angle. Distal to the edentulous space, the retainer resistance is augmented by a groove at the lingual proximal line angle. Moving a properly designed resin-bonded FDP in any direction except parallel to its path of placement should not be possible, nor should it be possible to displace any tooth to the buccal aspect from the framework (see Figs. 26-7*B*, 26-18, and 26-19).



Fig. 26-19
A, Preparation for a maxillary premolar prosthesis. A groove has been placed at the mesial extension of the premolar retainer arm to eliminate the use of a mesial occlusal rest. This could compromise esthetics. Note that the lingual groove preparation on the molar extends gingivally as the preparation is carried down the buccal slope of the groove, which adds mechanical retention. **B,** The completed prosthesis.

In general, preparation differs between maxillary and mandibular molar teeth only on the lingual surfaces. The lingual wall of the mandibular tooth may be prepared in a single plane. The lingual surface of the maxillary molars requires a two-plane reduction because of occlusal function and the taper of these functional cusps in the occlusal two thirds. However, the mandibular lingual retainer may be carried over the lingual cusps to augment resistance and retention form on short clinical crowns of mesially and lingually inclined molars (this may require a two-plane modification[78,91]) (Fig. 26-20).

A wide range of extensions of the casting onto the occlusal surfaces of posterior teeth is possible. They include shoeing of cusps, encircling of cusps, and extensions of metal through the central fossa from a mesial to distal direction with the lingual cusps exposed. The clinician is limited only by imagination, available enamel, occlusion, and the display of metal tolerated by the patient. Several examples of preparations and restorations are presented in Figures 26-21 and 26-22.

On occasion, a combination restoration can be used. This type of FDP includes a resin-bonded retainer on one of the abutment teeth and a conventional cast restoration on the other. As previously noted, this type of FDP has been very successful in clinical studies.[84] Periodontal splinting is the most demanding of the restoration designs; splints and splint-FDP combinations require care in designing adequate mechanical retention. An example of multiple rest design with interproximal extension of the metal is shown in Figure 26-23. The posterior splint-FDP entails the use of multiple rests and distinct mechanical retention of the abutment in the retainer, which can be important when the abutment is the most distal tooth in the arch (Fig. 26-24). The anterior splint must engage as much enamel as possible to aid in retention (Fig. 26-25) and is more demanding in tooth alignment and preparation design.

Laboratory Procedures

1. Wax the framework and cast it in a nickel-chromium or noble metal-ceramic alloy. Different alloys require different surface preparation or tin plating; the dentist should use an alloy that has been well tested with the adhesive composite resin of choice (see later discussion).

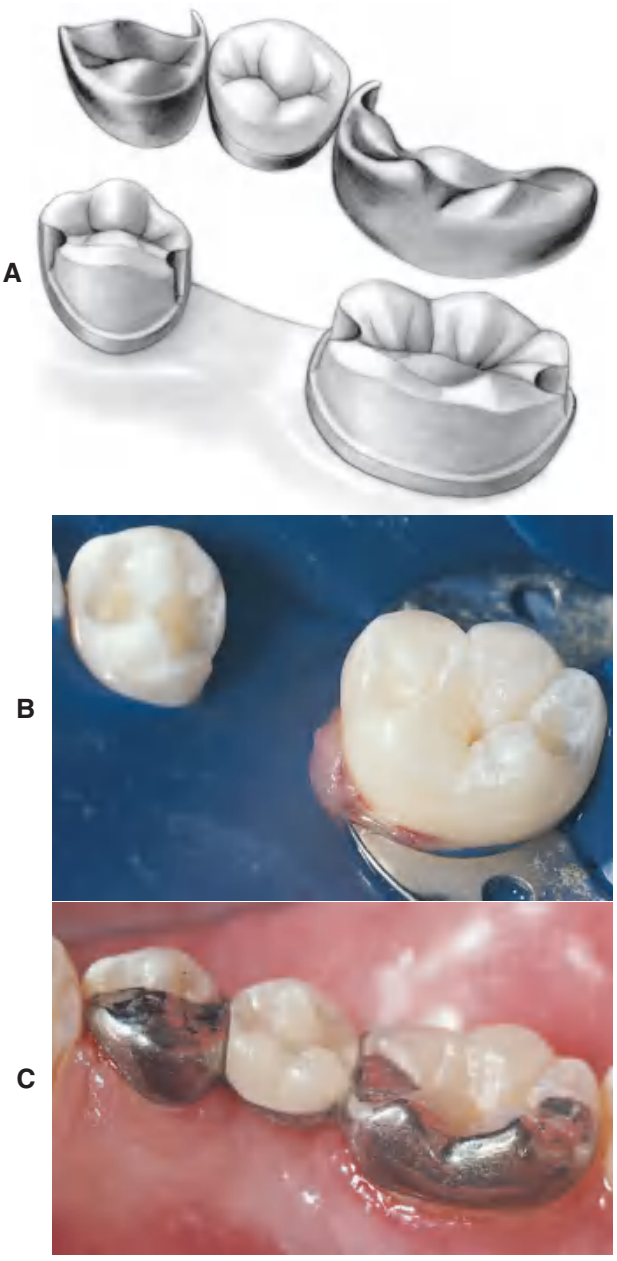


Fig. 26-20

A, Schematic of a resin-bonded fixed dental prosthesis onlay design. A thin veneer of metal is extended onto the occlusal surface of the teeth with approximately 0.5 mm reduction of the enamel where necessary. **B,** Preparation of molar and premolar. The lingual cusp of the premolar is covered to add additional mechanical retention on this short clinical crown. **C,** Completed restoration. The lingual cusps of the molar could also have been onlayed. However, the mesial and distal rests were deemed sufficient in this situation.

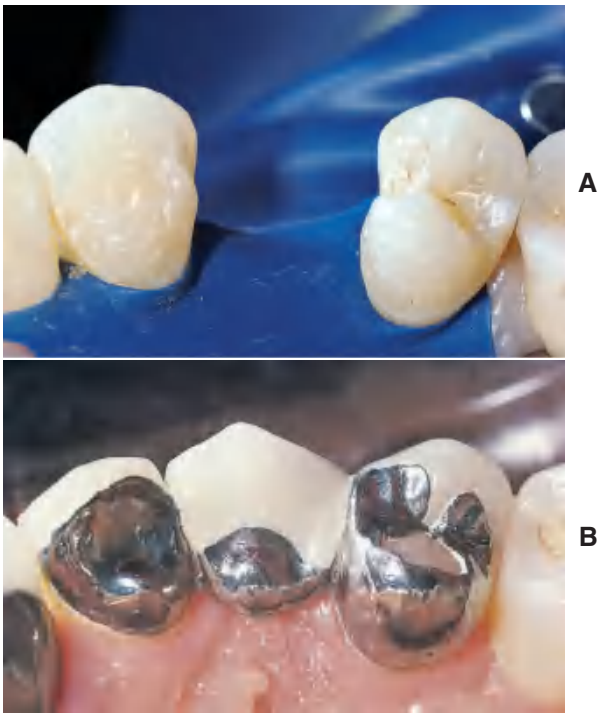


Fig. 26-21

A, Preparations for a premolar resin-bonded fixed dental prosthesis. The distal aspect of the canine had a small Class III composite resin restoration. This has been replaced and modified to create a distal slot for the retainer. The premolar has both mesial and distal occlusal rest preparations. **B,** Bonded prosthesis. The gingival margin of the restoration is very close to the free gingival crest (the ideal is 1 mm above the gingival crest). Meticulous plaque control is essential.



Fig. 26-22
A, Incorporation of an amalgam restoration into a resin-bonded fixed dental prosthesis (FDP). Note the margin placement at the gingival level, the use of two distal grooves, and a distinct gingival finish line on the canine abutment. **B,** Another completed resin-bonded FDP with an inlay component.

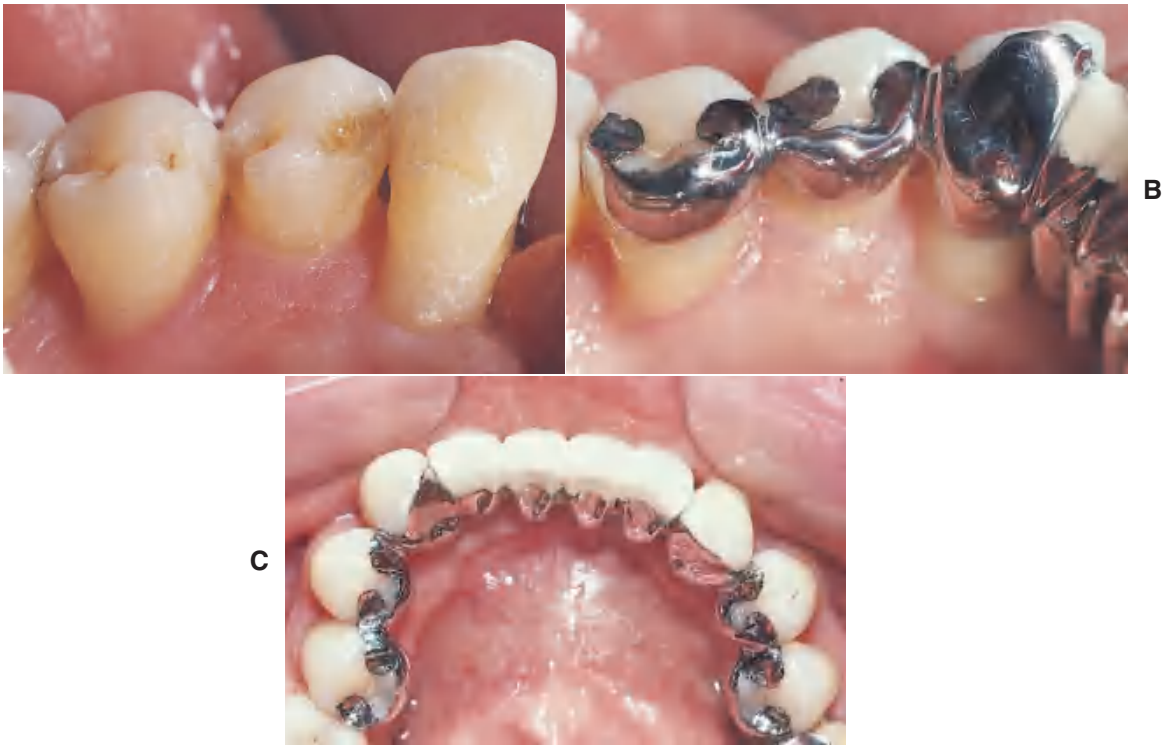


Fig. 26-23
A, One portion of the mandibular arch with teeth prepared as abutments for a resin-bonded splint replacing the mandibular incisors. Here both mesial and distal rests are used, in addition to extending the preparation into the proximal contact area. **B,** A bonded restoration. The extension to the second premolar was intended to help stabilize these mobile teeth, on the basis of a consultation with the periodontist. **C,** The completed restoration. The use of multiple rests on each posterior abutment is evident.



Fig. 26-24
Long-term recall of a resin-bonded fixed dental prosthesis. Particular care has been exercised in providing mechanical engagement of the second premolar—the most distal abutment in the arch.



Fig. 26-25
Anterior splint seen at 12-year recall appointment. Note the extension of the metal to engage as much lingual enamel as possible, extending over marginal ridges and into the interproximal areas wherever possible.

2. Build up the pontic in porcelain, fire it, and contour it.
3. Evaluate the restoration clinically; when the fit is satisfactory, characterize and glaze it. As previously noted, opaque resins are necessary to prevent metal from graying the abutment teeth. Depending on the opacity of the resin and tooth translucency, the value of the abutment may be increased. Evaluation for anterior teeth should involve a try-in paste for proper characterization of the pontic. Any remaining try-in paste will be burned out during the glaze firing. After this is completed, the restoration can be polished. Regular finishing compound is suitable.
4. Clean the fitting surface with a particle abrasion unit, using aluminum oxide (50 µm at a minimum of 40 psi [0.3 MPa] pressure); rinse thoroughly with water, and dry. If the restoration is evaluated again, particle abrasion should be repeated just prior to bonding.

Bonding the Restoration

Cements (bonding agents)

Composite resins play an important role in bonding the metal framework to etched enamel. A variety of resin adhesives have been introduced specifically for this purpose. Conventional bisGMA-type resins (e.g., Comspan*) originally used for luting resin-bonded FDPs have been replaced by these more recently developed resin-metal adhesives, which continue to improve.

As mentioned earlier in this chapter, Panavia 21† is an adhesive monomer (MDP), a glass-filled bisGMA composite with a long history of successful application (Fig. 26-26*B*). Panavia 21 exhibits excellent bond strengths with base metal alloys and tin-plated noble metals. It has an anaerobic setting reaction and does not set in the presence of oxygen. To ensure a complete cure, the manufacturer provides a polyethylene glycol gel‡ that can be placed over the restoration margins. The gel creates an oxygen barrier and can be washed away after the material has completely set. The latest version of this luting agent§ is both chemically and light cured; as an alternative to the gel, a curing light can be used to polymerize the margins. Panavia 21 is supplied in opaque and tooth-colored (TC) forms. Because of the anaerobic setting reaction, both types can be mixed and do not set until air is excluded (as in seating of the restoration). This allows the application of opaque to the lingual aspect of an anterior retainer and the translucent tooth color to the interproximal aspect so that an opaque line is not visible from the facial aspect. Both types can be mixed ahead of time and applied to the bonding surfaces of the retainer at a convenient time (Fig. 26-26*C*). This method makes it possible to mask the unesthetic metallic gray retainer, thus preventing it from showing through translucent enamel.[92]

*Dentsply Caulk, Milford, Delaware.

†Kuraray America, Inc., New York, New York.
‡Oxyguard II.
§Panavia F 2.0.



Fig. 26-26
Bonding procedures using an adhesive resin. **A,** Anterior resin-bonded fixed dental prosthesis preparation with mesial and distal groove retention based on the presence of incisal wear facets. Note the use of rubber dam for moisture control. **B,** Anaerobic-setting adhesive composite resin paste-dispensing system. **C,** Use of both opaque and translucent composite resin with the opaque on the lingual aspect and the translucent in the interproximal aspect for esthetics. **D,** The restoration has been seated, and the excess resin has been removed while the resin between the retainers and the enamel sets anaerobically. The margin resin and excess remain nonsetting. **E,** Oxygen-barrier gel is applied for margin resin setting. **F,** The final restoration, which was cast from a high-gold content alloy and tin plated. To provide good mechanical retention, the casting is increased in thickness by 50%, in comparison with a higher stiffness (elastic modulus) base metal alloy.

Step-by-Step Bonding Procedures

Step-by-step procedure with Panavia 21 resin adhesive cement

As for any adhesive luting system, the manufacturer's instructions must be closely followed to maximize the cemented restoration's physical properties (see Fig. 26-26).

1. Clean the teeth with pumice and water. Isolate them with the rubber dam, and acid etch with 37% phosphoric acid for 30 seconds. Rinse, dry, and maintain air drying until the primer is applied (see Fig. 26-26*A*). The assistant should dispense and mix the Panavia 21 cement during the etching process and set it aside until step 3. The assistant should then mix the Panavia ED Primer and give it to the operator, who is keeping the etched teeth dry.
2. Apply the Panavia ED Primer to the etched surface. Although Panavia ED Primer is a "self-etching" primer, it should not be used without enamel etching, because bonded retainer surfaces are not "freshly prepared enamel." After preparation, they acquire a salivary pellicle, which limits the self-etching capabilities of this type of product.[93]

3. Apply the premixed Panavia 21 cement (both opaque and tooth-colored if it is an anterior retainer) to the inner surface of the casting (see Fig. 26-26*C*).
4. Dry the Panavia ED Primer to ensure evaporation of the solvent (this should remain on the enamel surface for 30 seconds before drying).
5. Seat the casting firmly, and maintain pressure while removing the excess resin cement with a brush or pledget. The cement sets within 60 to 90 seconds under the casting but not at the margins, which are exposed to air (see Fig. 26-26*D*).
6. Light-cure the margins or apply Oxyguard II to exclude air (see Fig. 26-26*E*).
7. Rinse away Oxyguard II after 2 minutes, and remove residual cement with a sharp hand instrument (see Fig. 26-26*F*). Major finishing, polishing, and occlusal adjustments should be performed before the restoration is bonded. The tensile strength of the bonded prosthesis can be adversely affected by the heat or vibrations produced with rotary instruments.[94] However, minor adjustments and removal of excess resin can be accomplished with judicious use of these instruments.

POSTOPERATIVE CARE

All resin-bonded restorations should be scrutinized at the regular recall examinations (see Chapter 32). Because debonding or partial debonding can occur without complete loss of the prosthesis, visual examination and gentle pressure with an explorer should be performed to confirm such a complication. Because debonding is most commonly associated with biting or chewing hard food,[94] patients should be warned about this danger. If the patient perceives any changes in the restoration, he or she should seek early attention. Early diagnosis and treatment of a partially debonded prosthesis can prevent significant caries (Fig. 26-27).[94]

The restoration can usually be rebonded successfully. The bonding surface should be cleaned with airborne particle abrasion and the enamel surface refreshed by careful removal of the remaining resin with rotary instruments, followed by etching. If a prosthesis debonds more than twice, reevaluating the preparation and remaking the prosthesis is probably necessary.

Attention to periodontal health is crucial, because this retainer design has the potential to accumulate excess plaque as a result of lingual overcontouring and the gingival extent of the margins.[68] The patient should be taught appropriate plaque-control measures (see Chapter 32). Calculus removal is recommended with hand instruments over ultrasonic scalers to reduce the risk of debonding.



Fig. 26-27
Maxillary three-unit, resin-bonded fixed dental prosthesis. The distal retainer became debonded, but this was not detected promptly, which resulted in a carious lesion.

REVIEW OF TECHNIQUE

The following list summarizes the steps involved in preparation and placement of a resin-bonded FDP:

1. Patient selection is generally limited to those with sound abutments with minimal or no restorations. Occlusion must be stable.
2. Tooth preparations consist of creating a large lingual bonding area with proximal wrap; a definite, single path of insertion; occlusal, incisal, or cingulum rest seats; and proximal grooves/slots.
3. An accurate elastomeric impression material should be used.
4. Careful laboratory technique is necessary to ensure a well-fitting and esthetic casting.
5. Specially formulated resin-luting agents that are capable of adhering to the alloy prescribed should be used to bond the prosthesis.

SUMMARY

One of the basic principles of tooth preparation for fixed prosthodontics is conservation of tooth structure. This is the primary advantage of resin-bonded FDPs. Precision and attention to detail are just as important in resin-bonded FDPs as they are in conventional prostheses. To provide a long-lasting prosthesis, the practitioner must plan and fabricate a resin-bonded restoration with the same diligence used for conventional restorations. The techniques can be very rewarding but must be approached carefully. Careful patient selection is an important factor in predetermining clinical success.

STUDY QUESTIONS

1. Discuss the indications and contraindications of resin-bonded FDPs.
2. When the replacement of a congenitally missing lateral incisor with a resin-bonded fixed prosthesis is planned, a cantilevered design is considered. Is a single-abutment design better or worse than a two-abutment design? Why?
3. List the various bonding techniques used for resin-bonded FDPs. Which one is currently recommended? Why?
4. Discuss the tooth preparations needed for anterior resin-bonded FDPs. How does the preparation differ for posterior abutments?

GLOSSARY*

ad·he·sion \ăd-hē′zhun\ *n* (1624) **1:** the property of remaining in close proximity, as that resulting from the physical attraction of molecules to a substance or molecular attraction existing between the surfaces of bodies in contact **2:** the stable joining of parts to each other, which may occur abnormally **3:** a fibrous band or structure by which parts abnormally adhere—*comp* CAPSULAR FIBROSIS, FIBROUS A., INTRACAPSULAR A., MYOFIBROTIC CAPSULAR CONTRACTURE

airborne-particle abrasion \âr′bôrn′ păr′tĭ-kal a-brā′zhun**:** the process of altering the surface of a material through the use of abrasive particles propelled by compressed air or other gases

antiflux \ăn′tē-flŭks′\ *n***:** materials that prevent or confines solder attachment or flow

autopolymerizing resin \ô′tō-pŏl-a-mĕr-ī′zing rĕz′ĭn**:** a resin whose polymerization is initiated by a chemical activator

base metal \bās mĕt′l\: any metallic element that does not resist tarnish and corrosion—see NOBLE METAL

bond strength \bŏnd strĕngkth, strĕngth**:** the force required to break a bonded assembly with failure occurring in or near the adhesive/adherens interface

bond·ing \bŏn′dĭng\ *n* (1976) **1:** joining together securely with an adhesive substance such as cement or glue **2:** the procedure of using an adhesive, cementing material or fusible ingredient to combine, unite, or strengthen **3:** adhesive technique in dentistry involving conditioning of enamel and/or dentin so as to create tags in the tooth structure for mechanical retention of restorative material.

bonding agent \bŏn′dĭng ā′jent**:** a material used to promote adhesion or cohesion between two different substances, or between a material and natural tooth structures

can·ti·lever \kăn′tl-ē′ver\ *n* (1667): a projecting beam or member supported on one end

cantilever fixed dental prosthesis \kăn′tl-ē′ver fĭkst dĕn′tl prŏs thē′sis**:** a fixed dental prosthesis in which the pontic is cantilevered, i.e., is retained and supported only on one end by one or more abutments

cat·a·lyst \kăt′l-ĭst\ *n* (1902)**:** a substance that accelerates a chemical reaction without affecting the properties of the materials involved

[1]ce·ment \sĭ-mĕnt\ *n* (14c) **1:** a binding element or agent used as a substance to make objects adhere to each other, or something serving to firmly unite **2:** a material that, on hardening, will fill a space or bind adjacent objects—syn *luting agent*

[2]ce·ment \sĭ-mĕnt\ *vt* (15c): to unite or make firm by or as if by cement; to lute

ce·men·ta·tion \sē′mĕn-tā′shun**:** **1:** the process of attaching parts by means of a cement **2:** attaching a restoration to natural teeth by means of a cement (GPT-4)

[1]etch \ĕch\ *vb, vt* (1634) **Ia:** to produce a retentive surface, especially on glass or metal, by the corrosive action of an acid **Ib:** to subject to such etching **2:** to delineate or impress clearly

[2]etch \ĕch\ *n* (1896) **1:** the effect or action of an etching acid on a surface **2:** a chemical agent used in etching

etch·ant \ĕch′ănt\ *n***:** an agent that is capable of etching a surface

etch·ing \ĕch′ing\ *vt* (1632) **1:** the act or process of selective dissolution **2:** in dentistry, the selective dissolution of the surface of tooth enamel, metal, or porcelain through the use of acids or other agents (etchants) to create a retentive surface

groove \grōōv\ *n***:** a long narrow channel or depression, such as the indentation between tooth cusps or the retentive features placed on tooth surfaces to augment the retentive characteristics of crown preparations

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guiding planes \gī′dĭng plānz\: vertically parallel surfaces on abutment teeth or/and dental implant abutments oriented so as to contribute to the direction of the path of placement and removal of a removable partial denture

[1]lute \lōōt\ *n* (15c): a substance, such as cement or clay, used for placing a joint or coating a porous surface to make it impervious to liquid or gas—see CEMENT

[2]lute \lōōt\ *vt;* **lut·ed** \lōō′tĭd\; **lut·ing** \lōō′tĭng\: to fasten, attach, or seal—see CEMENT

noble metal \nō′bal mĕt′l\: those metal elements that resist oxidation, tarnish, and corrosion during heating, casting, or soldering and when used intraorally; examples include gold and platinum—*comp* BASE METAL

nonprecious metal: see BASE METAL

par·al·lel·o·me·ter \păr′a-lĕ-lŏm′ĭ-tar\ *n* **1:** an instrument used for determining the exact parallel relationships of lines, structures, and surfaces in dental casts and prostheses **2:** an apparatus used for making one object parallel with another object, as in paralleling attachments and abutments for fixed dental prostheses or precision attachments for removable partial dentures

precious metal alloy \prĕsh′as mĕt′l ăl′oi′, a-loi′\: an alloy predominantly composed of elements considered precious, i.e., gold, the six metals of the platinum group (platinum, osmium, iridium, palladium, ruthenium, and rhodium), and silver

res·in \rĕz′ĭn\ *n* (14c) **1:** any of various solid or semisolid amorphous natural organic substances that usually are transparent or translucent and brown to yellow; usually formed in plant secretions; are soluble in organic solvents but not water; are used chiefly in varnishes, inks, plastics, and medicine; and are found in many dental impression materials **2:** a broad term used to describe natural or synthetic substances that form plastic materials after polymerization. They are named according to their chemical composition, physical structure, and means for activation of polymerization—see AUTOPOLYMERIZING R, COPOLYMER R.

resin-bonded prosthesis \rĕz′ĭn-bŏn′dĭd prŏs-thē′sĭs\: a fixed dental prosthesis that is luted to tooth structures, primarily enamel, which has been etched to provide mechanical retention for the resin cement. Early design incorporated perforations on the lingual plate (Rochette Bridge) through which the resin bonded material passed to achieve a mechanical lock; subsequently, use of acid etching of the metal plate (Maryland Bridge) eliminated the need for perforations.

Rochette, Alain L. Attachment of a splint to enamel of lower anterior teeth J Pros Dent 1973; 30: 418-423.

Livaditis, GJ, Thompson, VP.: Etched castings: an improved retentive mechanism for resin-bonded retainers J Pros Dent 1982; 47-52

resin-bonded splint \rĕz′ĭn bŏn′dĭd splĭnt\: a fixed splint made of heavy wire, fibrous resin materials or/and cast metal that is bonded to the labial or lingual surface of natural teeth with an acid etch technique. It is used to stabilize traumatically displaced or periodontally compromised teeth

resistance form \rĭ-zĭs′tans form\: the features of a tooth preparation that enhance the stability of a restoration and resist dislodgment along an axis other than the path of placement

re·tain·er \rĭ-tā′nar\ *n* (1540): any type of device used for the stabilization or retention of a prosthesis—see DIRECT R., FIXED PARTIAL DENTURE R., INDIRECT R.

re·ten·tion \rĭ-tĕn′shun\ *n* (15c): that quality inherent in the dental prosthesis acting to resist the forces of dislodgment along the path of placement—see DIRECT R, INDIRECT R.

retention form \rĭ-tĕn′shun form\: the feature of a tooth preparation that resists dislodgment of a crown in a vertical direction or along the path of placement

Rochette Bridge [Alain L. Rochette, French physician and dentist]: a resin-bonded fixed dental prosthesis incorporating holes within the metal framework and lutes to the lingual aspect of teeth adjacent to an edentulous space that replaces one or more teeth—see RESIN-BONDED PROSTHESIS

Rochette, Alain L. Attachment of a splint to enamel of lower anterior teeth JPD 1973; 30:418-23

semiprecious metal alloy \sĕm′ē-prĕsh′as mĕt′l ăl′oi′, a-loi′\: an alloy composed of precious and base metals. There is no distinct ratio of components separating semiprecious alloys from another group

span length \spăn lĕngkth\: the length of a beam between two supports

[1]un·der·cut \ŭn′dur-kŭt\ *n* (1859) **1:** the portion of the surface of an object that is below the height of contour in relationship to the path of placement **2:** the contour of a cross-sectional portion of a residual ridge or dental arch that prevents the insertion of a prosthesis **3:** any irregularity in the wall of a prepared tooth that prevents the withdrawal or seating of a wax pattern or casting

[2]un·der·cut \ŭn′dur-kŭt\ *v* (ca. 1598): to create areas that provide mechanical retention for materials placement

REFERENCES

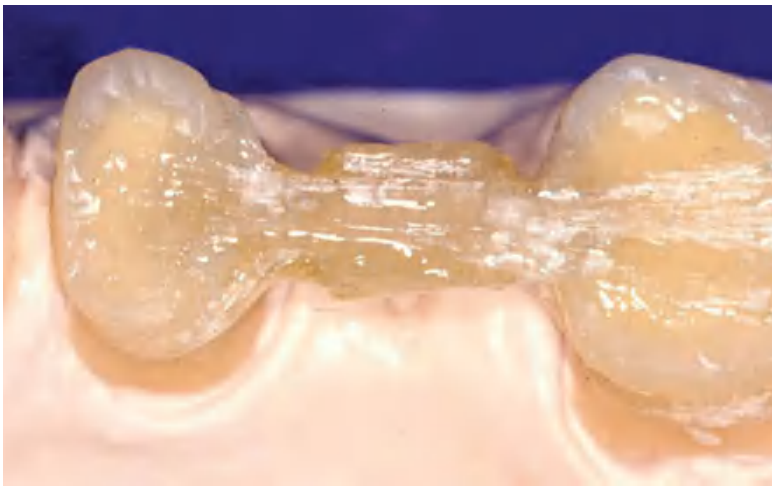
1. Rochette A: Attachment of a splint to enamel of lower anterior teeth. J Prosthet Dent 30:418, 1973.

2. Livaditis G, Thompson VP: Etched castings: an improved retentive mechanism for resin-bonded retainers. J Prosthet Dent 47:52, 1982.
3. Barrack G, et al: A long-term prospective study of the etched-cast restoration. Int J Prosthodont 6:428–34, 1993.
4. Brabant A: Indication and design: the key to successful resin-bonded fixed partial dentures. In: Degrange M, Roulet J-F, eds: Minimally Invasive Restorations with Bonding, pp 201–210. Chicago, Quintessence Publishing, 1997.
5. Marinello CP, et al: Resin-bonded fixed partial dentures and extracoronal attachments for removable partial dentures. In: Degrange M, Roulet J-F, eds: Mininally Invasive Restorations with Bonding, pp 221–240. Chicago, Quintessence Publishing, 1997.
6. Ibsen R: Fixed prosthetics with a natural crown pontic using an adhesive composite. J South Calif Dent Assoc 41:100, 1973.
7. Portnoy J: Constructing a composite pontic in a single visit. Dent Surv 39:30, 1973.
8. Heymann H: Resin-retained bridges: The natural-tooth pontic. Gen Dent 31:479, 1983.
9. Heymann H: Resin-retained bridges: The acrylic denture-tooth pontic. Gen Dent 32:113, 1984.
10. Jordan R, et al: Temporary fixed partial dentures fabricated by means of the acid-etch resin technique: a report of 86 cases followed for up to three years. J Am Dent Assoc 96:994, 1978.
11. Howe D, Denehy GE: Anterior fixed partial dentures utilizing the acid-etch technique and a cast metal framework. J Prosthet Dent 37:28, 1977.
12. Livaditis G: Cast metal resin-bonded retainers for posterior teeth. J Am Dent Assoc 101:926, 1980.
13. Williams VD, et al: The effect of retainer design on the retention of filled resin in acid-etched fixed partial dentures. J Prothet Dent 48:417, 1982.
14. Boyer DB, et al: Analysis of debond rates of resin-bonded prostheses. J Dent Res 72:1244, 1993.
15. Thompson VP, et al: Resin bond to electrolytically etched non-precious alloys for resin bonded prostheses. J Dent Res 60:377, 1981.
16. Levine W: An evaluation of the film thickness of resin luting agents. J Prosthet Dent 62:175, 1989.
17. Livaditis GJ, et al: Etched casting resin bonded retainers, Part 1: Resin bond to electrolytically etched non-precious alloys. J Prosthet Dent 50:771, 1983.
18. McLaughlin G, et al: Comparison of bond strengths using one-step and two-step alloy etching techniques. J Prosthet Dent 53:516, 1985.
19. Livaditis G: A chemical etching system for creating micromechanical retention in resin-bonded retainers. J Prosthet Dent 56:181, 1986.
20. Doukoudakis A, et al: A new chemical method for etching metal frameworks of the acid-etched prosthesis. J Prosthet Dent 58:421, 1987.
21. Re G, et al: Shear bond strengths and scanning electron microscope evaluation of three different retentive methods for resin-bonded retainers. J Prosthet Dent 59:568, 1988.
22. Wiltshire WA: Tensile bond strengths of various alloy surface treatments for resin bonded bridges. Quintessence Dent Technol 10:227, 1986.
23. Sloan KM, et al: Evaluation of laboratory etching of cast metal resin-bonded retainers [Abstract no. 1220]. J Dent Res 63:305, 1983.
24. Kern M, et al: Influence of prolonged thermal cycling and water storage on the tensile bond strength of composite to NiCr alloy. Dent Mater 10:19, 1994.
25. Kern M, et al: Durability of resin bonds to a cobalt-chromium alloy. J Dent 23:47, 1995.
26. Thompson VP, et al: [Bonded bridge technics: electrolytic etching of NiCr alloy]. Dtsch Zahnarztl Z 41:829, 1986.
27. Ozcan M, et al: A brief history and current status of metal-and ceramic surface-conditioning concepts for resin bonding in dentistry. Quintessence Int 29:713, 1998.
28. Moon P: Resin bonded bridge tensile bond strength utilizing porous patterns. J Dent Res 63:320, 1984.
29. Moon P: Bond strengths of the lost salt procedure: a new retention method for resin-bonded fixed prostheses. J Prosthet Dent 57:435, 1987.
30. Masuhara E: A Dental Adhesive and Its Clinical Application. Tokyo, Quintessence, 1982.
31. Ohno H, et al: The adhesion mechanism of dental adhesive resin to alloy—relationship between Co-Cr alloy surface structure analyzed by ESCA and bonding strength of adhesive resin. Dent Mater 5:46, 1986.
32. Salonga JP, et al: Bond strength of adhesive resin to three nickel-chromium alloys with varying chromium content. J Prosthet Dent 72:582, 1994.
33. Asmussen E, et al: Adherence of resin-based luting agents assessed by the energy of fracture. Acta Odontol Scand 51:235, 1993.
34. Northeast SE, et al: Tensile peel failure of resin-bonded Ni/Cr beams: an experimental and finite element study [see comments]. J Dent 22:252, 1994.
35. Degrange M, et al: Bonding of luting materials for resin-bonded bridges: clinical relevance of in vitro tests. J Dent 22:S28, 1994.
36. Hannsson O: Clinical results with resin-bonded prostheses and an adhesive cement. Quintessence Int 25:125, 1994.

37. Matsumura H, et al: Adhesive bonding of noble metal alloys with a triazine dithiol derivative primer and an adhesive resin. J Oral Rehabil 26:877, 1999.
38. Matsumura H, et al: Bonding of silver-palladium-copper-gold alloy with thiol derivative primers and tri-n-butylborane initiated luting agents. J Oral Rehabil 24:291, 1997.
39. Hikage S, et al: Clinical longevity of resin-bonded bridges bonded using a vinyl-thiol primer. J Oral Rehabil 30:1022, 2003.
40. Yamashita A: A Dental Adhesive and Its Clinical Application. Tokyo, Quintessence, 1983.
41. Omura I, et al: Adhesive and mechanical properties of a new dental adhesive. J Dent Res 63:233, 1984.
42. Tjan A, et al: Bond strength of composite to metal mediated by metal adhesive promoters. J Prosthet Dent 57:550, 1987.
43. Imbery TA, et al: Tensile strength of three resin cements following two alloy surface treatments. Int J Prosthodont 5:59, 1992
44. Thompson V: Cast-bonded retainers. In: Wei SHY, ed: Textbook of Pediatric Dentistry: Total Patient Care, pp 233-245. Philadelphia, Lea & Febiger, 1988.
45. Breeding LC, et al: The effect of metal surface treatment on the shear bond strengths of base and noble metals bonded to enamel. J Prosthet Dent 76:390, 1996.
46. Dixon DL, et al: Shear bond strengths of a two-paste system resin luting agent used to bond alloys to enamel. J Prosthet Dent 78:132, 1997.
47. Bertolotti RL, et al: Intraoral metal adhesion utilized for occlusal rehabilitation. Quintessence Int 25:525, 1994.
48. Wood M, et al: Repair of porcelain/metal restoration with resin bonded overcasting. J Esthet Dent 4:110, 1992.
49. Kern M, et al: Effects of sandblasting and silica-coating procedures on pure titanium. J Dent 22:300, 1994.
50. Kern M, et al: Bonding to alumina ceramic in restorative dentistry: clinical results over up to 5 years. J Dent 26:245, 1998.
51. Kern M, et al: Sandblasting and silica-coating of dental alloys: volume loss, morphology and changes in the surface composition. Dent Mater 9:151, 1993.
52. Kern M, et al: Bonding to zirconia ceramic: adhesion methods and their durability. Dent Mater 14:64, 1998.
53. Barrack G: A look back at the adhesive resin-bonded cast restoration. J Esthet Dent 7:263, 1995.
54. Norling B, et al: Resin-metal bonding via three silica deposition processes [Abstract no. 993]. J Dent Res 70:390, 1991.
55. Yoshida K, et al: Effects of adhesive primers on bond strength of self-curing resin to cobalt-chromium alloy. J Prosthet Dent 77:617, 1997.
56. Aguilar LT, et al: Tensile bond strength of adhesive systems—effects of primer and thermocycling. Pesqui Odontol Bras 16:37, 2002.
57. Matsumura H, et al: Evaluation of two thione primers and composite luting agents used for bonding a silver-palladium-copper-gold alloy. J Oral Rehabil 29:842, 2002.
58. Shimizu H, et al: Use of metal conditioners to improve bond strengths of autopolymerizing denture base resin to cast Ti-6Al-7Nb and Co-Cr. J Dent June 30 (Epub) 2005.
59. Watanabe I, et al: Shear bond strengths of laboratory-cured prosthetic composite to primed metal surfaces. Am J Dent 16:401, 2003.
60. Chadwick RG, et al: A retrospective observational study of the effect of surface treatments and cementing media on the durability of gold palatal veneers. Oper Dent 29:608, 2004.
61. Yamashita A, et al: Adhesion bridge background and clinical procedure. In: Gettleman L, et al, eds: Adhesive Prosthodontics: Adhesive Cements and Techniques, pp 61-76. Nijmegen, The Netherlands, Eurosound, 1988.
62. Aquilino S, et al: Tensile fatigue limits of prosthodontic adhesives. J Dent Res 70:208, 1991.
63. Saunders W: The effect of fatigue impact forces upon the retention of various designs of resin-retained bridgework. Dent Mater 3:85, 1987.
64. Zardiakas L, et al: Tensile fatigue of resin cements to etched metal and enamel. Dent Mater 4:163, 1988.
65. Crispin B, et al: Etched metal bonded restoration: three years of clinical follow-up. J Dent Res 65:311, 1986.
66. el Salam Shakal MA, et al: Effect of tooth preparation design on bond strengths of resin-bonded prostheses: a pilot study. J Prosthet Dent 77:243, 1997.
67. Pegoraro LF, et al: A comparison of bond strengths of adhesive cast restorations using different designs, bonding agents, and luting resins. J Prosthet Dent 57:133, 1987.
68. Romberg E, et al: 10-Year periodontal response to resin bonded bridges. J Periodontol 66:973, 1995.
69. Krell KV, et al: Ultrasonic debonding of anterior etched-metal resin bonded retainers. Gen Dent 34:378, 1986
70. Creugers NH, et al: A method to compare cost-effectiveness of dental treatments: adhesive

bridges compared to conventional bridges. Community Dent Oral Epidemiol 20:280, 1992.
71. Creugers NH, et al: Risk factors and multiple failures in posterior resin-bonded bridges in a 5-year multi-practice clinical trial. J Dent 26:397, 1998.
72. de Rijk WG, et al: Maximum likelihood estimates for the lifetime of bonded dental prostheses. J Dent Res 75:1700, 1996.
73. Thompson VP, et al: Longevity of resin-bonded fixed partial dentures: better than conventional fixed restorations? In Degrange M, Roulet J-F, eds: Minimally Invasive Restorations with Bonding, pp 185-200. Chicago, Quintessence Publishing, 1997.
74. Creugers NH, et al: Long-term survival data from a clinical trial on resin-bonded bridges. J Dent 25:239, 1997.
75. De Kanter RJ, et al: A five-year multi-practice clinical study on posterior resin-bonded bridges. J Dent Res 77:609, 1998.
76. Olin PS, et al: Clinical evaluation of resin-bonded bridges: a retrospective study. Quintessence Int 22:873, 1991.
77. Creugers NHJ, et al: A meta-analysis of durability on conventional fixed bridges. Community Dent Oral Epidemiol 22:448, 1994.
78. Eshleman J, et al: Tooth preparation designs for resin-bonded fixed partial dentures related to enamel thickness. J Prosthet Dent 60:18, 1988.
79. Shillingburg HT, et al: Thickness of enamel and dentin. J South Calif Dental Assoc 41:33, 1973.
80. Djemal S, et al: Long-term survival characteristics of 832 resin-retained bridges and splints provided in a post-graduate teaching hospital between 1978 and 1993. J Oral Rehabil 26:302, 1999.
81. Wood M, et al: Resin-bonded fixed partial dentures. II. Clinical findings related to prosthodontic characteristics after approximately 10 years. J Prosthet Dent 76:368, 1996.
82. Marinello CP, et al: Experiences with resin-bonded bridges and splints—a retrospective study. J Oral Rehabil 14:251, 1987.
83. Marinello CP, et al: First experiences with resin-bonded bridges and splints—a cross-sectional retrospective study, Part II. J Oral Rehabil 15:223, 1988.
84. Wood M, et al: Ten-year clinical and microscopic evaluation of resin-bonded restorations. Quintessence Int 27:803, 1996.
85. Simonsen R, et al: Etched Cast Restorations: Clinical and Laboratory Techniques. Chicago, Quintessence Publishing, 1983.
86. Wood M, et al: Adhesive resin bonded cast restorations. In: Dale BG, Aschheim KW, eds: Esthetic Dentistry: A Clinical Approach to Techniques and Materials, pp 151-162. Philadelphia, Lea & Febiger, 1992.
87. Blanco-Dalmau L: The nickel problem. J Prosthet Dent 48:99, 1982.
88. Nakabayashi N, et al: Relationship between the shape of adherend and the bond strength. Jpn J Dent Mater 6:422, 1987.
89. Briggs P, et al: The single unit, single retainer, cantilever resin-bonded bridge. Br Dent J 181:373, 1996.
90. Simonsen R, et al: General considerations in the framework design and tooth modification. Quintessence Dent Technol 7:21, 1983.
91. Simonsen R, et al: Posterior design principles in etched cast restorations. Quintessence Int 3:311, 1983.
92. Caughman WF, et al: A double-mix cementation for improved esthetics of resin-bonded prostheses. J Prosthet Dent 58:48, 1987.
93. Caughman W, et al: The effect of finishing resin-bonded fixed partial dentures on postcementation tensile strength. J Prosthet Dent 59:149, 1988.
94. Gilmour ASM: Resin bonded bridges: a note of caution. Br Dent J 167:140, 1988.

27



FIBER-REINFORCED COMPOSITE FIXED PROSTHESES

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KEY TERMS

all-polymer prostheses
braided
fiber architecture
fiber-reinforced composite (FRC)
flexure strength
glass fiber
polyethylene
unidirectional
woven

Fiber-reinforced fixed prostheses are an innovative alternative to traditional metal-ceramic restorations. They should be considered for certain patients because they provide a conservative approach to replacing missing teeth and overcome some of the drawbacks of conventional prostheses. The restoration consists of a **fiber-reinforced composite** (**FRC**) substructure veneered with a particulate composite material. The substructure provides strength, and the veneer, because it is laboratory processed, exhibits better physical properties and esthetics than do direct placement composite restoratives (Fig. 27-1). The following topics are included in this chapter:

1. The advantages of the clinical use of an FRC prosthesis.
2. A description of the composition, mechanical properties, and handling characteristics of FRC materials.
3. A review of the clinical applications and limitations of these materials in fixed prosthodontics.

ADVANTAGES AND DISADVANTAGES

As discussed in Chapter 24, the most common fixed prostheses are composed of a metal substructure veneered with a ceramic material. The substructure provides mechanical integrity, whereas the ceramic



Fig. 27-1
A, Fiber-reinforced composite (FRC) substructure. **B,** Completed polymer fixed prostheses consisting of the substructure and particulate composite veneer material. **C,** Tissue side view of the completed polymer fixed prostheses. **D**, Cemented FRC prostheses cemented in mouth.

imparts the necessary esthetics. The metal-ceramic prosthesis has an excellent clinical service record but continues to exhibit several drawbacks. Although the metal substructure is strong and durable, there are biologic concerns, especially when base metal alloys (commonly used in clinical practice) are selected. They may undergo corrosion[1-3] and/or may elicit an allergic reaction from some patients.[4-8] Certain constituents of some base metal alloys may cause acute and chronic health hazards for laboratory personnel.[9,10] In addition, the metal framework is opaque with a dark oxide layer, which is not esthetically pleasing. This must be covered with a porcelain veneer to produce a lifelike appearance.

Porcelain is a brittle material and can fracture, which is a leading cause of restoration failure.[11-14] When this occurs, porcelain can sometimes be repaired with acrylic or composite resin[15-18] bonded with silane coupling agents or 4-methacryloxyethyltrimellitic anhydride (4-META) to promote adhesion (see Chapter 32). Porcelain is also abrasive to opposing enamel and can severely damage unrestored opposing teeth.[19-23] Porcelain has been implicated in severe occlusal wear, particularly when it is not glazed or highly polished (see Chapter 19). In one survey, less wear on opposing teeth was cited as the single major need for change in posterior tooth-colored crowns.[24]

Because of these problems and concerns, alternatives to metal-ceramic materials continue to be explored. All-ceramic and all-particulate composite prostheses have been described in the dental literature.[25,26] Recorded problems include low resilience and toughness, which result in clinical failure.

As with the porcelain surfaces of metal-ceramic prostheses, the surfaces of the all-ceramic prostheses are abrasive to tooth enamel and can potentially damage unrestored opposing teeth. Conversely, the composite materials have historically exhibited less than adequate occlusal wear resistance and color stability over time, but newer composites continue to improve with regard to these characteristics. Light-, heat-, and vacuum-polymerized laboratory-processed particulate composite materials are now commercially available and are made of new polymer formulations with improved filler particle distribution.[27] These improved materials demonstrate better physical properties, such as hardness and wear resistance. However, particulate composites are brittle and need the support of a substructure with good flexure properties.

FRCs have good **flexure strength** and other physical characteristics that make them suitable fixed



Fig. 27-2
A, Fiber-reinforced composite (FRC) substructure for a three-unit polymer fixed dental prosthesis (FDP). **B,** Particulate composite veneers completed over FRC substructure. **C,** Internal surface of FRC-reinforced polymer FDP.

prosthesis substructure materials.[28-30] In addition, the FRC substructure is translucent and requires no opaque masking. This allows a relatively thin layer of particulate covering composite and excellent esthetics. FRCs have been used to make two-phase **all-polymer prostheses** composed of an internal **glass fiber**-reinforced composite substructure covered by a particulate composite (Fig. 27-2).

AVAILABLE MATERIALS

FRC materials are categorized according to the following characteristics:
1. Type of fiber.
2. Fiber orientation.
3. Whether the resin impregnation of the fiber is performed by the dentist/laboratory technician or by the manufacturer

The most commonly used fibers in dental applications are glass, **polyethylene,** and carbon. **Fiber architectures** in dentistry include **"unidirectional"** patterns, in which all fibers are parallel, and **braided** and **woven** patterns. Commercially available non-resin-impregnated materials include polyethylene weaves (e.g., Ribbond* and Construct†) and glass weaves (e.g., GlasSpan‡). These products need to have the resin added to the fibers by hand. Resin-preimpregnated materials include everStick and StickNET,§ which are hand formed and available in both unidirectional and woven-glass forms; FibreKor,‖ which is hand formed and available as a unidirectional glass material; and Splint-It,¶ which is also hand formed and available in both unidirectional and woven glass forms (Fig. 27-3).

Different FRC materials exhibit different handling and mechanical properties. Fiber type, fiber orientation, and the quality of fiber impregnation with the resin matrix have a substantial effect on handling characteristics and physical properties. As seen in Table 27-1, glass materials with a unidirectional architecture exhibit flexural properties that are superior to the polyethylene materials with a woven or braided architecture. These glass materials have a flexural strength that is more than twice the strength of polyethylene materials and a flexural modulus almost eight times as great.[16] Because of their good handling characteristics, the braided and woven polyethylene products may be useful for other dental applications (e.g., operatory fabrication of periodontal splints).

INDICATIONS

Indications for selecting a fiber-reinforced polymer prosthesis include the following:
1. The need for a restoration with excellent appearance that opposes denture teeth placed on a partial removable dental prosthesis or a complete denture.

*Ribbond, Inc., Seattle, Washington.
†Kerr Corporation, Orange, California.
‡GlasSpan, Inc., Exton, Pennsylvania.
§Ivoclar Vivadent, Amherst, New York.
‖Pentron Clinical Technologies, LLC, Wallingford, Connecticut.
¶Pentron Clinical Technologies, LLC, Wallingford, Connecticut.

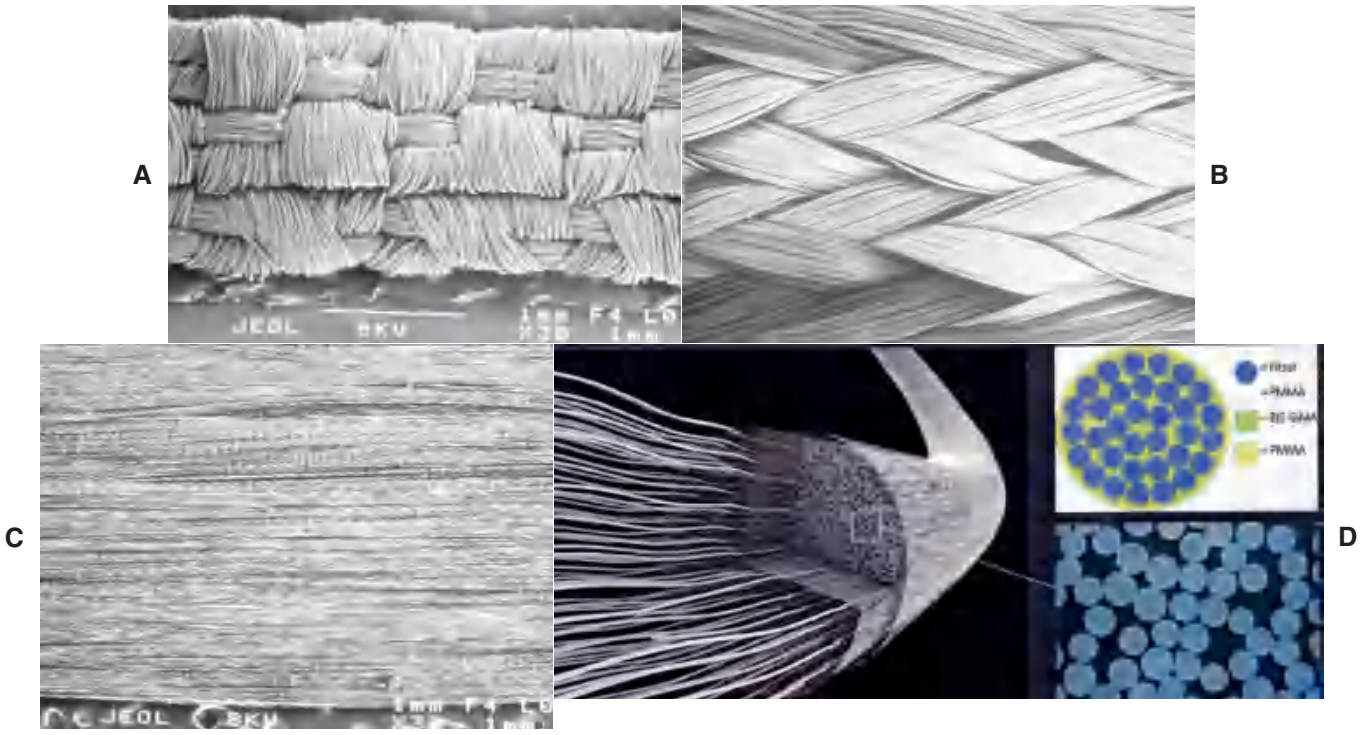


Fig. 27-3
Scanning electron micrographs. **A,** Woven polyethylene fiber-reinforced composite (FRC) (Construct, Kerr Corporation). **B,** Braided polyethylene FRC (Ribbond, Ribbond, Inc.). **C,** Unidirectional long glass fiber FRC (FibreKor, Pentron Clinical Technologies, LLC). **D,** Unidirectional long glass fibers with a polymethylmethacrylate (PMMA) outer membrane (everStick, StickTech).

Table **27-1 FLEXURE PROPERTIES OF COMMERCIAL FIBER-REINFORCED COMPOSITES***

Material	Fiber type	Fiber architecture	Flexural strength (sd) (MPa)	Flexural modulus (sd) (GPa)
FibreKor 2K	Glass	Unidirectional	541 (32)	25.0 (2.0)
FibreKor 16K	Glass	Unidirectional	639 (35)-919† (42)	28.0 (3.0)
everStick	Glass	Unidirectional	739 (47)	24.3 (1.5)
GlasSpan	Glass	Braid	321 (28)	13.9 (1.1)
Construct	Polyethylene	Braid	222 (23)	8.3 (0.5)
Ribbond	Polyethylene	Leno weave	206 (15)	3.9 (0.7)

*Data generated in our laboratory.
†Manufacturer's data.
sd, Standard deviation.

2. The need to decrease wear of the opposing natural dentition.
3. The use of conservative intracoronal abutment tooth preparations.
4. The potential for bonding the prosthesis retainer to the abutment teeth.
5. The desire for a metal-free, nonporcelain prosthesis (this is especially important for individuals with metal allergies).
6. Rapid chairside replacement of a missing tooth as a transitional fixed prosthesis.

These materials can be used anywhere in the mouth where esthetics is important. The lack of metal or opaque materials provides good translucency and a very natural appearance. This natural appearance at the cervical aspect of the prosthesis retainer eliminates the need to hide margins subgingivally, where they may create periodontal problems for the patient. Supragingival margins of this polymer prosthesis blend in easily with the nonprepared tooth structure apical to the tooth preparation finish line, just as the overall prosthesis blends in

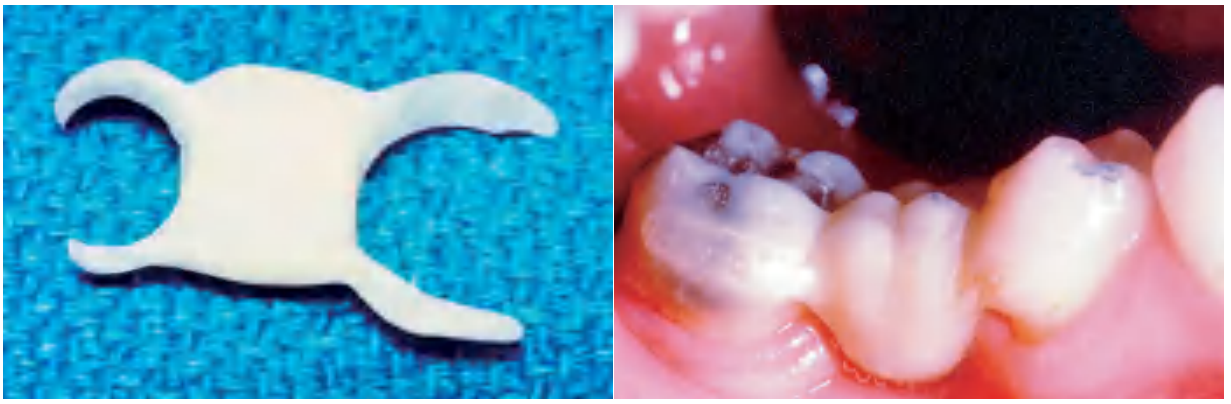


Fig. 27-4
Early prosthodontic application of an experimental thermoplastic unidirectional fiber-reinforced composite (FRC). **A,** A bonded fixed dental prosthesis made with polycarbonate FRC. **B,** The polycarbonate FRC prosthesis after delivery.

with the adjacent natural teeth. Resin composite luting materials that bond to the internal aspect of the polymer prosthesis retainers and to the dentin and enamel of the abutment teeth improve retention of the prosthesis. This feature may provide crucial retention of a polymer prosthesis on abutment teeth that cannot be made to exhibit optimum geometric retention form; however, the bonding process requires careful control of moisture and soft tissues.

An early prosthodontic application of an experimental thermoplastic unidirectional FRC[31-33] was the fabrication of a single tooth replacement bonded fixed dental prosthesis (FDP).[34] These prostheses were formed in the laboratory and then bonded to the teeth (Fig. 27-4).

Box **27-1** **Patient Selection for Fiber-Reinforced Partial Fixed Dental Prostheses**

Indications	Contraindications
Optimal esthetic result	Inability to maintain fluid control
Metal free	Long span needed
Conservative abutment preparation	Patients with parafunctional habits
Decreased wear to opposing teeth	Unglazed opposing porcelain
Use of an adhesive luting technique	Patients who abuse alcohol

CONTRAINDICATIONS

Contraindications to selecting an FRC fixed prosthesis include the following:

1. Inability to maintain good fluid control (e.g., patients with chronic or acute gingival inflammation or when margins would be placed deeply into the sulcus).
2. Long span (i.e., two or more pontics).
3. Patients with parafunctional habits.
4. Patients with unglazed porcelain or metal partial removable dental prosthesis framework components that would oppose the restoration.
5. Patients who abuse alcoholic substances.

Patient selection criteria are summarized in Box 27-1. Composite resin luting materials and an adhesive cementation technique can be used only in situations in which the operator can maintain a contamination-free field. Rubber dam isolation is ideal and should be used whenever possible. At this time, FDPs that replace more than two teeth are not recommended because the material's ability to support longer edentulous spans has not been documented. An increased susceptibility to wear or fracture may occur in patients who brux or clench, and surface degradation of the particulate composite is likely to be a problem in alcoholic patients. Because there are no clinical data to substantiate how the FRC fixed prosthesis would perform when subjected to these conditions, it should not be considered until more information is available.

A number of clinical studies have evaluated FRC full- or partial-coverage fixed prostheses, ranging from 1 to 4 years.[35-41] These have yielded variable results on the basis of the material and fabrication method. Survival rates ranged from 58.8% to 95%,

depending on the criteria used and the type of FRC/particulate resin composite system employed. The FRC frameworks performed well with few fractures. Most of the problems involved the wear, discoloration, degradation, and fracture of the particulate resin composite veneer materials. These veneering resin composite problems were associated with the two types of commercially available FRC systems for laboratory-generated partial fixed dental prostheses—Targis/Vectris (Ivoclar/Vivadent, Inc.) and Sculpture/FibreKor (Pentron, Inc.)—but at a much higher reported rate for the Targis/Vectris system. Ivoclar/Vivadent removed their system from the market because of the frequency of these problems. These data also indicated that the adequacy of tooth preparation (Fig. 27-5) and volume of the FRC framework, particularly in the pontic support area, play crucial roles in the performance of an FRC fixed prosthesis.

EXTRACORONAL COMPLETE-COVERAGE FIXED PROSTHESES

Newer, lighter, heat/vacuum laboratory-polymerized FRC formulations have been developed and tested. They demonstrate excellent esthetics, good handling characteristics, and good flexure properties.[29,42-45] Commercial products have been based on these formulations. The fabrication of a complete-coverage prosthesis with a commercially available, preimpregnated unidirectional FRC (FibreKor, Pentron Clinical Technologies, LLC) and a hand-fabricated technique are shown in Figure 27-6.

INTRACORONAL PARTIAL-COVERAGE FIXED PROSTHESES

The FRC partial-coverage FDP allows a conservative design when the abutment teeth are unrestored or have modest intracoronal restorations. When an implant is not possible, an etched metal resin-retained FDP (see Chapter 26) is the only other conservative fixed treatment alternative. However, these prostheses have problems with retention, graying of abutment teeth (as a result of metal showing through), and overcontoured retainers. The advantages discussed for the complete-coverage FDP (esthetics, metal-free framework, ease of laboratory fabrication, and use of an adhesive cementation technique) also apply to the partial-coverage FDP. The fabrication of a partial-coverage intracoronal prosthesis with a commercially available, preimpregnated unidirectional FRC (FibreKor, Pentron Clinical Technologies, LLC) and a hand-fabricated technique are shown in Figure 27-7.

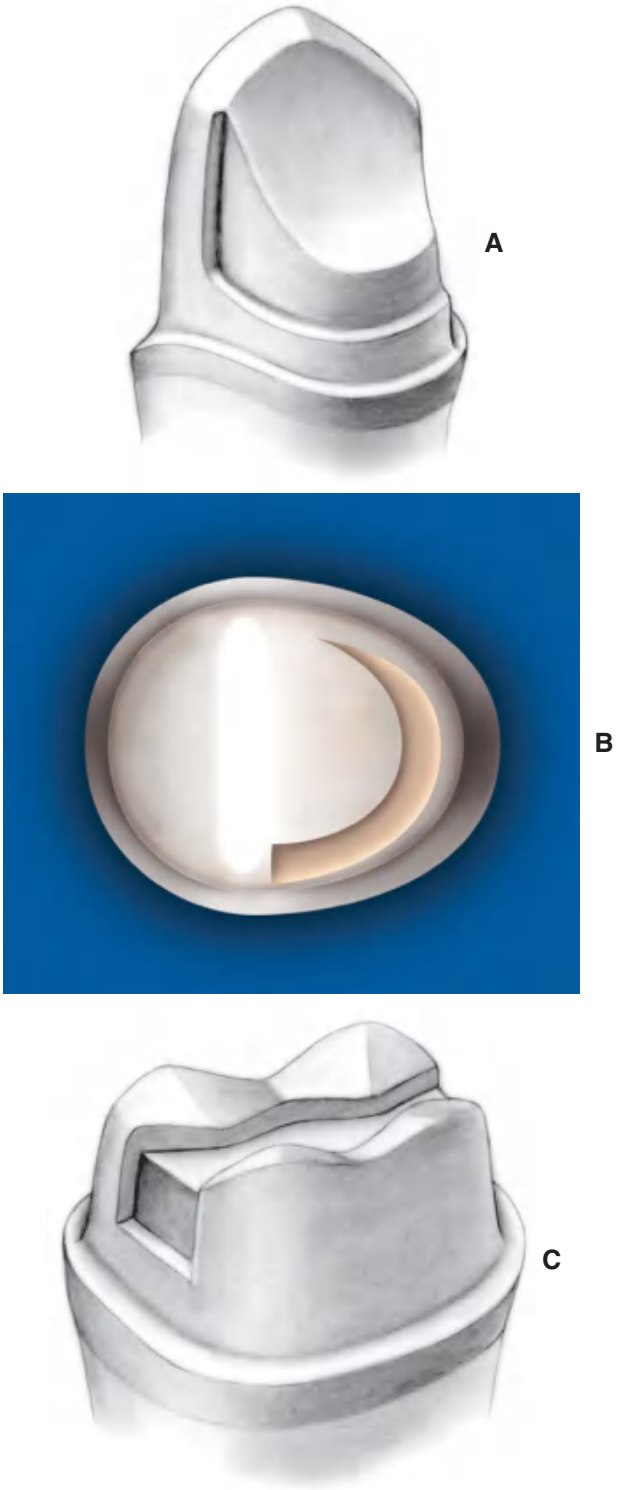


Fig. 27-5
Abutment tooth preparations made for hand-fabricated fiber-reinforced composite (FRC) prostheses. **A,** Anterior proximal view. **B,** Anterior incisal view. **C,** Posterior proximal view.

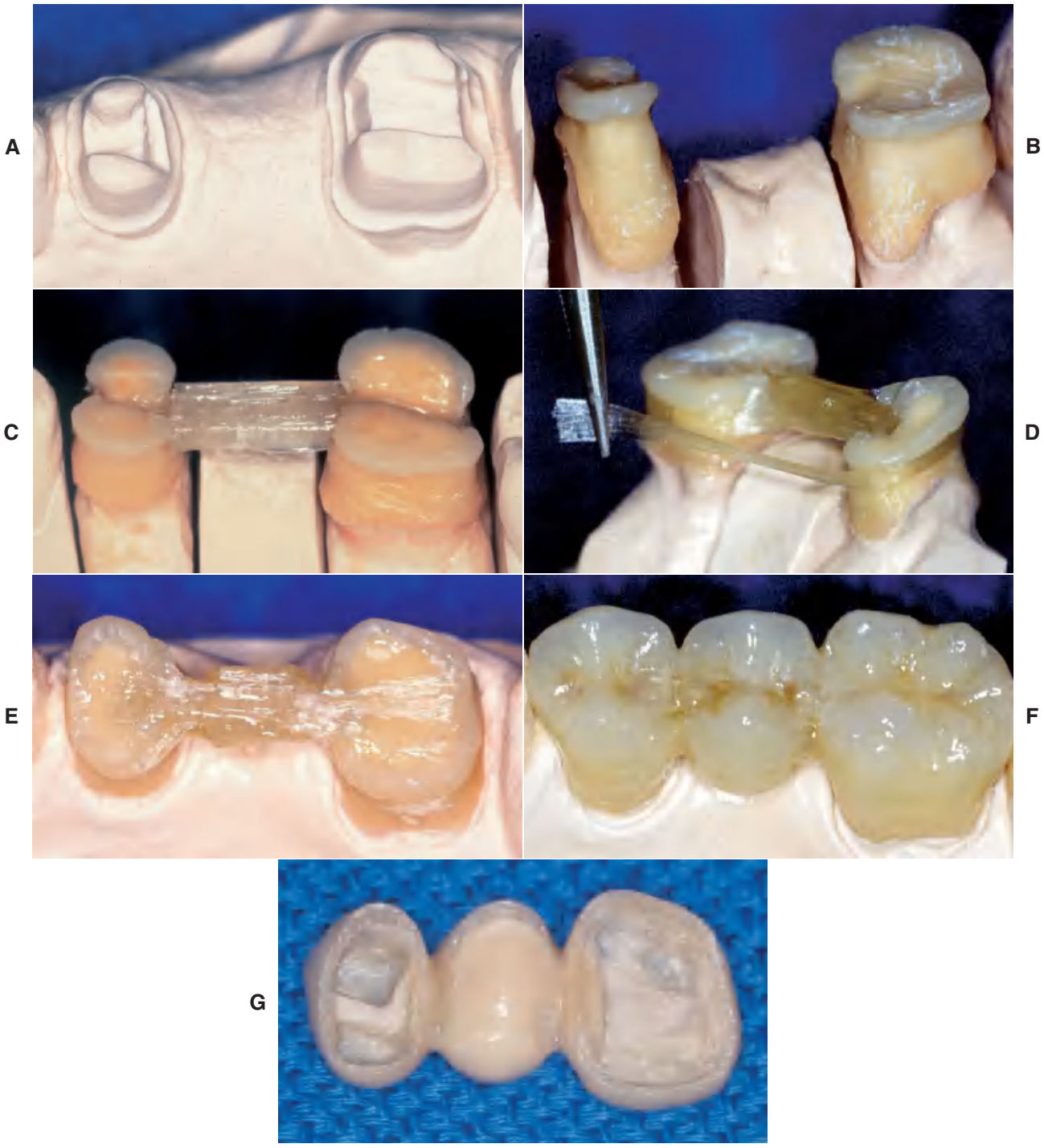


Fig. 27-6

The step-by-step fabrication of a complete-coverage fiber-reinforced composite (FRC) prosthesis with a unidirectional glass material (FibreKor, Pentron Clinical Technologies, LLC), accomplished with a hand-fabricated technique. **A,** Dies showing posterior abutment preparations for an FRC polymer bridge. **B,** Thin coping of opacious body particulate composite adapted to the die. **C,** Bar of multiple layers of FRC spanning the pontic region, bonding the copings together. **D,** Continuous strip of FRC bonded to one end of the pontic bar and then wrapped around the axial surfaces of the copings while being polymerized. **E,** Occlusal view of the completed FRC substructure. **F,** Completed prosthesis with particulate resin veneers on model. **G,** Tissue side view of completed prosthesis, showing the internal adaptation to preparation design of the abutment teeth.

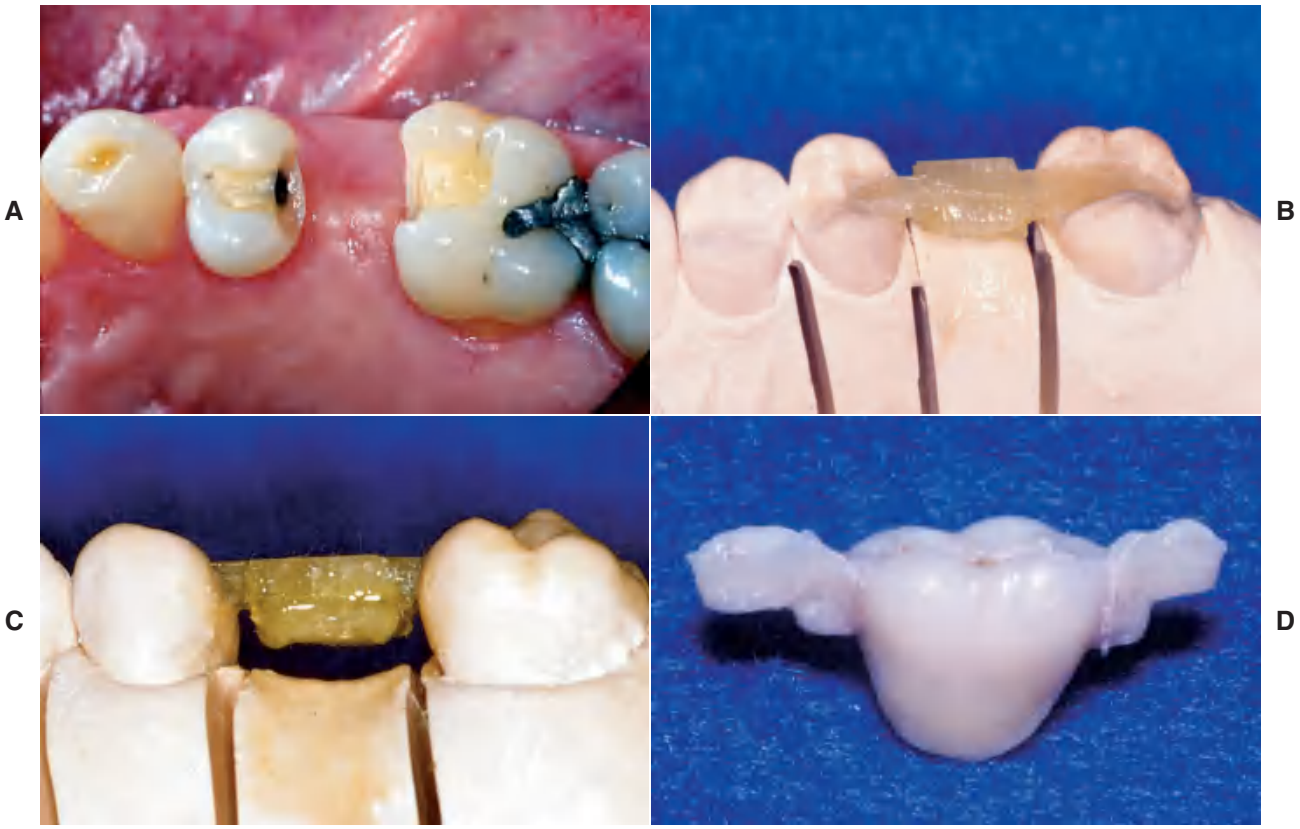


Fig. 27-7
The tooth preparation and step-by-step fabrication of a partial-coverage intracoronal fiber-reinforced composite (FRC) prosthesis with a unidirectional glass material (FibreKor, Pentron Clinical Technologies, LLC) and a hand-fabricated technique. **A,** Intracoronal tooth preparation. **B,** Placement of the unidirectional FRC bar into unpolymerized opacious body particulate composite. **C,** Completed FRC substructure. **D,** Completed prosthesis as viewed from the buccal surface.

CHAIRSIDE PROSTHESES

One of the most exciting and potentially useful applications for preimpregnated FRC technology is its use in replacing missing teeth in a timely and cost-effective manner. The ability to deliver a functional, esthetic tooth replacement with no to minimal tooth preparation of the adjacent abutment teeth in a single visit is now a realistic treatment option with the current adhesive technologies and reinforced composites. The increase in physical properties that fiber reinforcement provides to particulate composites allows for an improved approach versus earlier methods in which denture teeth have been used as pontics.[46,47] This new approach eliminates the disadvantages posed by the incompatibility of the different chemistries between the particulate luting composite and the acrylic resin pontic and also results in a much stronger connector between the pontic and the abutment teeth in comparison with particulate composite alone. This provides the potential for long-term clinical service.[42] Potential clinical applications for chairside-fabricated FRC prostheses include situations in which the abutment teeth may be of questionable prognosis or in place of an interim removable prosthesis immediately after anterior implant placement but before loading. The latter situation is seen in Figure 27-8. In addition, this technology can be used for immediate fixed tooth replacement after extraction, after traumatic loss of a tooth, or for space maintenance in pediatric or adolescent patients, in whom it acts as a transitional prosthesis until a more permanent solution can be delivered.

Methods have been developed whereby preformed substructures can be used to quickly provide a platform for creating a prosthesis at chairside, rather than having to fabricate a chairside prosthesis from scratch by using particulate composite and FRC components.[48-50] This helps reduce time and technique sensitivity in the delivery of chairside prostheses. FRC can be easily manipulated into a pre-



Fig. 27-8
An example of a prefabricated fiber-reinforced composite (FRC) framework used as a fixed interim prosthesis after tooth extraction and before implant placement. **A**, Appearance after lateral incisor has been extracted. **B**, A cantilever prefabricated framework placed. The wing is attached to the central incisor. **C**, Lingual view of completed interim prosthesis, showing the adaptation of the particulate composite veneer. **D**, Facial view of interim FRC prosthesis.

formed (prefabricated) substructure that has both polymerized and nonpolymerized elements. The "wing" element is not yet polymerized and provides an attachment to the adjacent abutment teeth as they are adapted, polymerized, and bonded to the facial or lingual surfaces. The "pontic" element is rigid because it is already polymerized and also consists of unidirectional FRC but in greater bulk. After attaching the wings to the abutment teeth, the dentist veneers the pontic element with light polymerized particulate (restorative) composite.

IMPLANT-SUPPORTED FIXED PROSTHESES

The advantages of using FRC materials to fabricate implant-supported fixed prostheses (see Chapter 13) include good flexure properties of the preimpregnated FRCs, time saving as a result of lack of casting and soldering, and the chemical bond of the resin veneer to substructure. Implant-supported FRC prostheses can either be retained by screws or luted to the implant abutment.[51] In contrast to tooth-supported prostheses, the component of the FRC prosthesis retainer that provides an attachment to the implant abutment can be premanufactured. This is because the implant abutment is generally not custom made but machined by the manufacturer. For luted prostheses, a woven FRC coping can be used to make the underside or foundation of the retainer. The remainder of the FRC substructure can be bonded directly to these copings. An example of a luted FRC framework and a definitive prosthesis can be seen in Figure 27-9. For screw-retained FRC framework, a cylinder with a screw channel that fits directly to the implant abutment becomes an integral component of the substructure. An example of titanium-ceramic cylinders with horizontal grooves on the facial and lingual surfaces and proximal boxes can be seen in Figure 27-10. These design characteristics of the cylinder enable the FRC to be reliably attached. The horizontal grooves provide macromechanical retention, and the proximal boxes provide vertical support to the FRC (Fig. 27-11). The etched and silanated ceramic coating (titanium-ceramic, Vident) provides an opaque mask of the alloy and micromechanical retention for the FRC.

These fixed partial and complete FRC implant prostheses continue to be developed and tested by our research group. The implant prosthesis framework exhibits the "high-volume" design features and external surface air-inhibited layer. An example of a

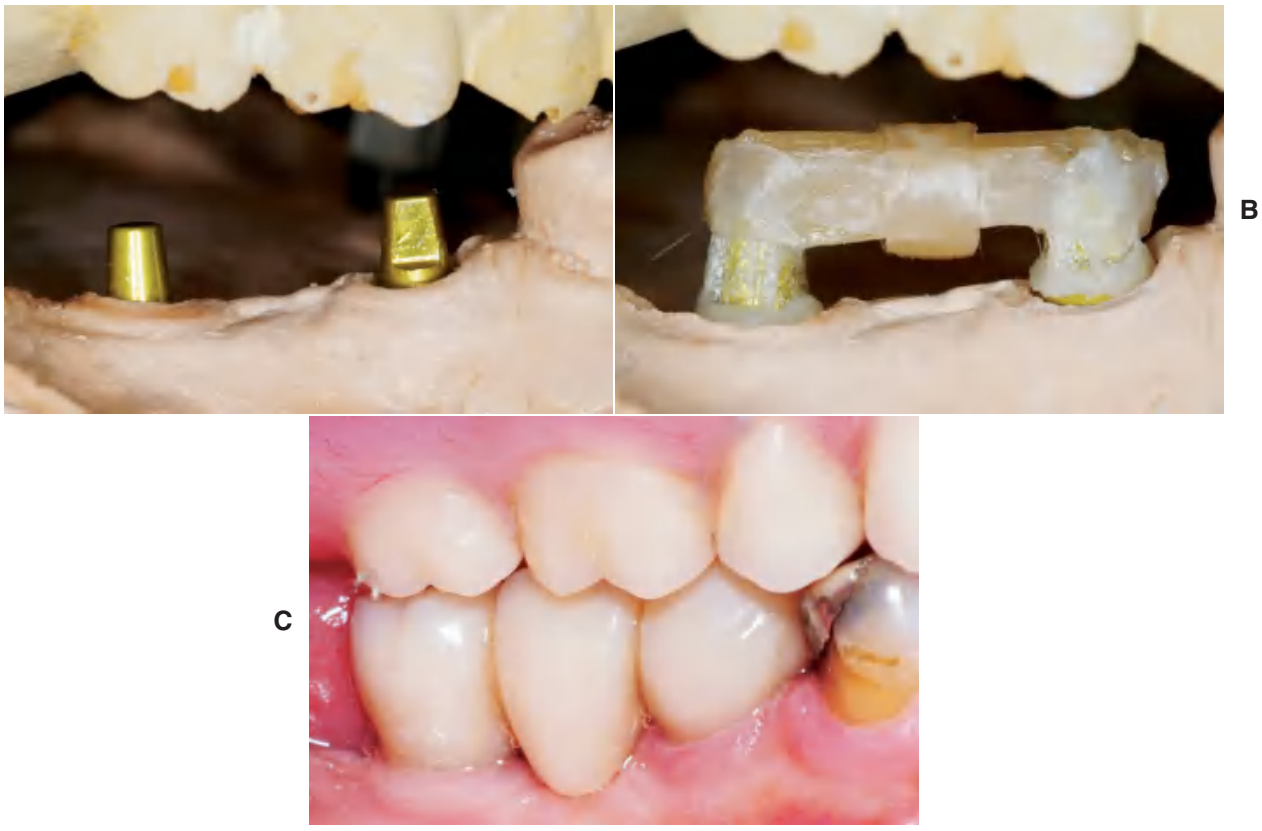


Fig. 27-9
Example of an implant-supported three-unit fiber-reinforced composite (FRC) fixed prosthesis. **A**, Cast with solid analogs for a cemented three-unit FRC polymer prosthesis. **B**, Framework completed, buccal view. **C,** Completed FRC polymer prosthesis.



Fig. 27-10
Examples of titanium-ceramic cylinders used to receive fiber-reinforced composite (FRC) for fixed implant-supported prosthesis. **A**, Titanium-ceramic cylinders on definitive cast in position to receive FRC bundles. **B**, Close-up view of a titanium-ceramic cylinder, showing horizontal groove and proximal box, which act as receptors for FRC bundles/wrap.

complete arch implant-supported prosthesis framework and definitive prosthesis can be seen in Figure 27-12. For the partial prostheses, a light-/heat-/vacuum-polymerized particulate composite veneer is placed over the FRC substructure. For complete, fixed prostheses, polymethylmethacrylate (PMMA) and denture teeth are used to provide final form and occlusal function. These materials are applied through the use of many widely accepted fabrication techniques commonly employed by the dentist and laboratory technician. These include procedures for the verification of the accuracy of the definitive cast, wax evaluation of the denture teeth, and the processing of the PMMA prosthesis suprastructure.[51,52]



Fig. 27-11
Completed fiber-reinforced composite (FRC) framework before polymethylmethacrylate (PMMA) denture base and denture tooth addition.



Fig. 27-12
Completed fiber-reinforced composite (FRC) fixed implant-supported prosthesis in the mouth. **A**, Occlusal view of the completed prosthesis. **B**, Proximal view showing good esthetics with the denture base designed to allow for adequate access to the prosthesis cylinders for oral hygiene.

CEMENTATION

As with porcelain veneers (see Chapter 31), the shade of the complete coverage or inlay prosthesis should be assessed with a water-soluble paste that corresponds to the selected luting composite. Minor adjustments in value can be obtained by selecting darker or lighter luting resins. The translucency of the FRC prosthesis allows the luting composite to play a role in the final shade of the prosthesis. Luting an FRC prosthesis involves the procedures that accompany any bonded restorative procedure: isolation of the abutment teeth, treatment of the inner surface of the FRC retainers, and conditioning of the abutment teeth.

SUMMARY

The natural, esthetic appearance of this metal-free prosthesis and its inherent adhesive nature make the fiber-reinforced prosthesis a successful fixed tooth replacement. Its adhesive qualities may enable the use of abutment teeth that do not exhibit classic geometric retention and resistance form without the need for elective endodontics, surgical crown-lengthening procedures, and the apical placement of finish margins. Furthermore, its favorable strength, esthetics, and adhesive properties make the intracoronal fiber-reinforced prosthesis uniquely qualified for the minimally invasive replacement of a single missing tooth adjacent to unrestored or minimally restored abutment teeth. Multiyear clinical studies are currently in progress to determine the value and efficacy of the FRC prosthesis as a long-term tooth replacement.

STUDY QUESTIONS

1. Compare a FRC fixed prosthesis with a metal-ceramic FDP. Discuss the advantages and disadvantages of each.
2. Discuss tooth preparation designs for FRC fixed prostheses and specify how they differ from conventional preparations.
3. Current fiber-reinforced prostheses involve the use of either glass or polyethylene. Compare the performance and architecture of each.

GLOSSARY*

all-polymer prosthesis: a fixed dental prosthesis fabricated from non-metallic or ceramic components typically composed of an internal glass fiber-reinforced composite framework covered by a particulate composite resin

bond strength \bŏnd strĕngkth, strĕngth\: the force required to break a bonded assembly with failure occurring in or near the adhesive/adherens interface

bond·ing \bŏn′dĭng\ *n* (1976) **1:** joining together securely with an adhesive substance such as cement or glue **2:** the procedure of using an adhesive, cementing material or fusible ingredient to combine, unite, or strengthen **3:** adhesive technique in dentistry involving conditioning of enamel and/or dentin so as to create tags in the tooth structure for mechanical retention of restorative material.

bonding agent \bŏn′dĭng ā′jent\: a material used to promote adhesion or cohesion between two different substances, or between a material and natural tooth structures

resin-bonded splint \rĕz′ĭn bŏn′dĭd splĭnt\: a fixed splint made of heavy wire, fibrous resin materials or/and cast metal that is bonded to the labial or lingual surface of natural teeth with an acid etch technique. It is used to stabilize traumatically displaced or periodontally compromised teeth

REFERENCES

1. Johansson BI, et al: Corrosion of copper, nickel, and gold dental casting alloys: an in vitro and in vivo study. J Biomed Mater Res 23(A3 Suppl):349, 1989.
2. Hani H: Corrosive changes of dental alloys in oral environment–scanning electron microscopic observation and electron probe microanalysis on crown surfaces [in Japanese]. Kokubyo Gakkai Zasshi 60:372, 1993.
3. Ludwig K: Homogeneity and corrosion resistance of cast dental precious metal alloys compared with uncast alloys [in German]. Dtsch Zahnarztl Z 44:905, 1989.
4. American Dental Association, Council on Dental Materials, Instruments and Equipment: Biological effects of nickel-containing dental alloys. J Am Dent Assoc 104:501, 1982.
5. Association Report: Classification system for cast alloys. J Am Dent Assoc 109:838, 1984.
6. American Dental Association, Council on Dental Materials, Instruments, and Equipment: Report on base metal alloys for crown and bridge applications: benefits and risks. J Am Dent Assoc 111:479, 1985.
7. Covington JS, et al: Quantization of nickel and beryllium leakage from base metal casting alloys. J Prosthet Dent 54:127, 1985.
8. Marcusson JA: Contact allergies to nickel sulfate, gold sodium thiosulfate and palladium chloride in patients claiming side-effects from dental alloy components. Contact Dermatitis 34:320, 1996.
9. Moffa JP, et al: Allergic response to nickel containing dental alloys [Abstract no. 107]. J Dent Res 56:1378, 1977.
10. Morris HF: Veterans Administration Cooperative Studies Project No. 147. IV. Biocompatibility of base metal alloys. J Dent 58:1, 1987.
11. Walton JN, et al: A survey of crown and fixed partial denture failures: length of service and reasons for replacement. J Prosthet Dent 56:416, 1986.
12. Libby G, et al: Longevity of fixed partial dentures. J Prosthet Dent 78:127, 1997.
13. Sundh B, Odman P: A study of fixed prosthodontics performed at a university clinic 18 years after insertion. Int J Prosthodont 10:513, 1997.
14. Priest GF: Failure rates of restorations for single-tooth replacement. Int J Prosthodont 9:38, 1996.
15. Robbins JW: Intraoral repair of the fractured porcelain restoration. Oper Dent 23:203,1998.
16. Chung KH, Hwang YC: Bonding strengths of porcelain repair systems with various surface treatments. J Prosthet Dent 78:267, 1997.
17. Kupiec KA, et al: Evaluation of porcelain surface treatments and agents for composite-to-porcelain repair. J Prosthet Dent 76:119, 1996.
18. Pameijer CH, et al: Repairing fractured porcelain: how surface preparation affects shear force resistance. J Am Dent Assoc 127:203, 1996.
19. Monasky GE, Taylor DF: Studies on the wear of porcelain, enamel, and gold. J Prosthet Dent 25:299, 1971.
20. Ekfeldt A, Øilo G: Occlusal contact wear of prosthodontic materials. Acta Odontol Scand 46:159, 1988.
21. Kelly JR, et al: Ceramics in dentistry: historical roots and current perspectives. J Prosthet Dent 75:18, 1996.
22. Hacker CH, et al: An in vitro investigation of the wear of enamel on porcelain and gold in saliva. J Prosthet Dent 75:14, 1996.

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23. Ramp MH, et al: Evaluation of wear: enamel opposing three ceramic materials and a gold alloy. J Prosthet Dent 77:523, 1997.
24. Christensen GJ: The use of porcelain-fused-to-metal restorations in current dental practice: a survey. J Prosthet Dent 56:1, 1986.
25. Kern M, et al: The all-porcelain resin bonded bridge. Quintessence Int 22:257, 1991.
26. Dickerson WG: The Concept bridge. Dent Econ 84:67, 1994.
27. Yang Z, et al: Non-Diluent Dental Composite. Presented at the Fall National American Chemical Society Meeting, Las Vegas, September 7–11, 1997.
28. Karmaker AC, et al: Fiber reinforced composite materials for dental appliances. In ANTEC 1996 Plastics: Plastics—Racing into the Future, Volume 3: Special Areas, pp 2777–2781. Indianapolis, Society of Plastic Engineers, 1996.
29. Freilich MA, et al: Flexure strength of fiber-reinforced composites designed for prosthodontic application [Abstract no. 999]. J Dent Res 76:138, 1997.
30. Freilich MA, et al: Flexure strength and handling characteristics of fiber-reinforced composites used in prosthodontics [Abstract no. 1561]. J Dent Res 76:184, 1997.
31. Goldberg AJ, et al: Flexure properties and fiber architecture of commercial fiber reinforced composites [Abstract no. 967]. J Dent Res 77:226, 1998.
32. Goldberg AJ, et al: Screening of matrices and fibers for reinforced thermoplastics intended for dental applications. J Biomed Mater Res 28:167, 1994.
33. Jancar J, DiBenedetto AT: Thermoplastic fiber reinforced composites for dentistry. II. Effect of moisture on flexural properties of unidirectional composites. J Mater Sci 4:562, 1993.
34. Altieri JV, et al: Longitudinal clinical evaluation of fiber-reinforced composite fixed partial dentures: a pilot study. J Prosthet Dent 71:16, 1994.
35. Gohring TN, et al: Two-year clinical and SEM evaluation of glass-fiber-reinforced inlay fixed partial dentures. Am J Dent 15:35, 2002.
36. Vallittu PK, Sevelius C: Resin-bonded, glass fiber–reinforced composite fixed partial dentures: a clinical study. J Prosthet Dent 84:413, 2000.
37. Freilich MA, et al: Clinical evaluation of fiber-reinforced fixed bridges. J Am Dent Assoc 133:1524, 2002.
38. Behr B, et al: Fiber-reinforced composite crowns and FPDs: a clinical report. Int J Prosthodont 16:239, 2003.
39. Monaco C, et al: Clinical evaluation of fiber-reinforced composite inlay FPDs. Int J Prosthodont 16:319, 2003.
40. Bohlsen F, Kern M: Clinical outcome of glass-fiber-reinforced crowns and fixed partial dentures: a three-year retrospective study. Quintessence Int 34:493, 2003.
41. Vallittu PK: Survival rates of resin-bonded, glass fiber–reinforced composite fixed partial dentures with a mean follow-up of 42 months: a pilot study. J Prosthet Dent 91:241, 2004.
42. Goldberg AJ, Burstone CJ: The use of continuous fiber reinforcement in dentistry. Dent Mater 8:197, 1992.
43. Karmaker AC, et al: Extent of conversion and its effect on the mechanical performance of Bis-GMA/PEGDMA-based resins and their composites with continuous glass fibers. J Mater Sci 8:369, 1997.
44. Freilich MA, et al: Preimpregnated, fiber-reinforced prostheses. I. Basic rationale and complete-coverage and intracoronal fixed partial denture designs. Quintessence Int 29:689, 1998.
45. Freilich MA, et al: Development and clinical applications of a light-polymerized fiber-reinforced composite. J Prosthet Dent 80:311, 1998.
46. Ibsen RL, Neville K: Adhesive Restorative Dentistry, p 139. Philadelphia, WB Saunders, 1974.
47. Littman H, et al: Provisional temporization with acid-etch resin technique. Clin Prev Dent 2:14, 1973.
48. Freilich MA, et al: Fiber-Reinforced Composites in Clinical Dentistry, Chapter 4. Chicago, Quintessence Publishing, 2000.
49. Meiers JC, Freilich MA: Chairside prefabricated fiber-reinforced resin composite fixed partial dentures. Quintessence Int 32:99, 2001.
50. Meiers JC, et al: Direct intra-oral applications of fiber-reinforced composites. The influence of FRC on particulate resin composite to enamel shear bond strengths. In Vallittu PK, ed: The Second International Symposium on Fibre-Reinforced Plastics in Dentistry, Chapter 4. Turku, Finland, Department of Prosthetic Dentistry and Biomaterials Research, Institute of Dentistry, 2002.
51. Freilich MA, et al: The design and fabrication of fiber-reinforced implant prostheses. J Prosthet Dent 88:449, 2002.
52. Freilich MA, et al: Fiber-Reinforced Composites in Clinical Dentistry, Chapter 7. Chicago. Quintessence Publishing, 2000.

28

CONNECTORS FOR PARTIAL FIXED DENTAL PROSTHESES



KEY TERMS

antiflux
cast connector
fineness
index
mortise
nonrigid connectors
soldered connectors
soldering flux
tenon
welding

Connectors are the components of a partial fixed dental prosthesis (FDP) or splint that join the individual retainers and pontics together. Usually this is accomplished with rigid connectors (Fig. 28-1), although **nonrigid connectors** are occasionally used. The latter are usually indicated when it is impossible to prepare a common path of placement for the abutment preparations for a partial FDP (Fig. 28-2*A* and *B*). Their use has been reported to be associated with significantly reduced failure rates.[1]

RIGID CONNECTORS

Rigid connections in metal can be made by casting, soldering, or **welding. Cast connectors** are shaped in wax as part of a multiunit wax pattern. Cast connectors are convenient and minimize the number of steps involved in the laboratory fabrication. However, the fit of the individual retainers may be adversely affected because distortion more easily results when a multiunit wax pattern is removed from the die system. **Soldered connectors** involve the use of an intermediate metal alloy whose melting temperature is lower than that of the parent metal (Fig. 28-3). The parts being joined are not melted during soldering but must be thoroughly wettable by liquefied solder.[2] Dirt or surface oxides on the connector surfaces can reduce wetting and impede successful soldering; for example, the solder may melt but does not flow into the soldering gap. Welding is another method of rigidly joining metal parts. In welding, the connection is created by melting adjacent surfaces with heat or pressure. A filler metal whose melting temperature is about the same as that of the parent metal can be used during welding.



Fig. 28-1
Rigid connectors: A three-unit partial fixed dental prosthesis (FDP) replacing the maxillary second premolar. **A**, The anterior abutment and the pontic are connected with a rigid cast connector. These two partial FDP components are fabricated separately from the posterior abutment, which is cast in gold. **B,** The components are related to one another by a soldering assembly. **C,** The connected components. **D,** The fixed prosthesis in place.

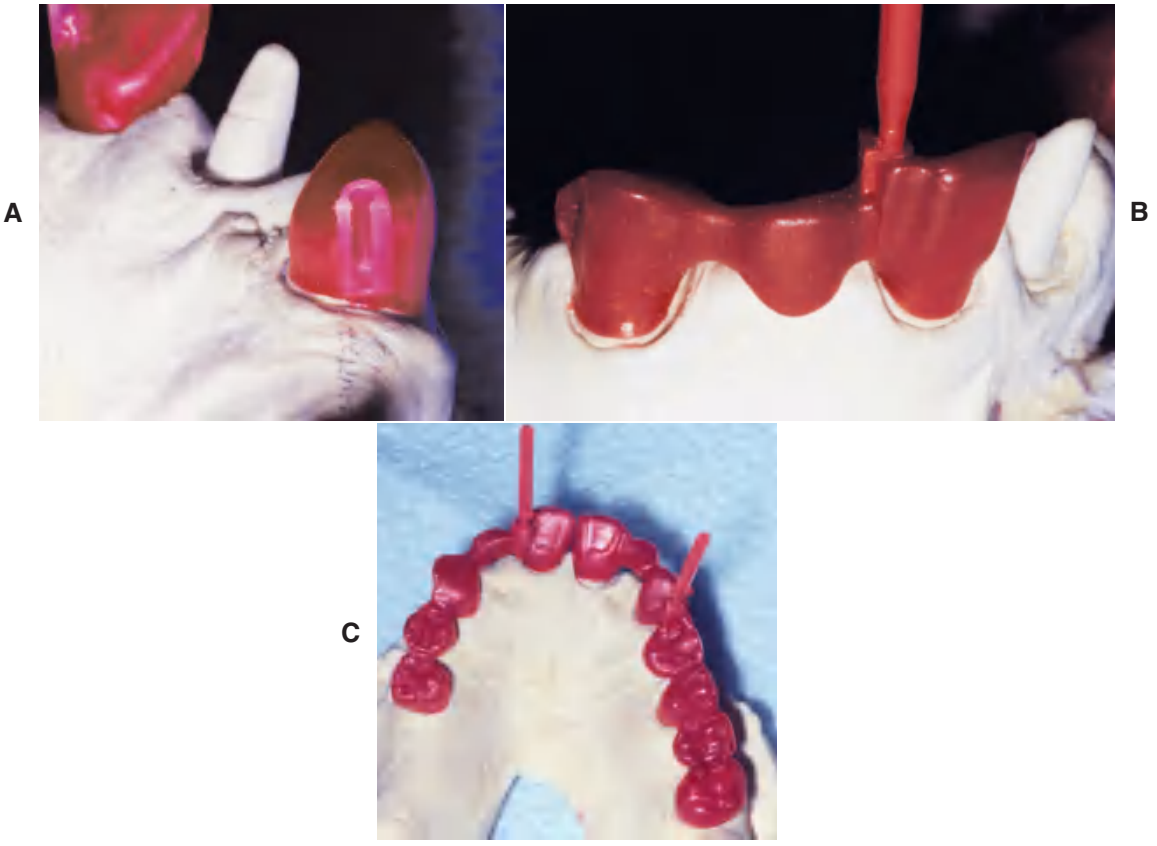


Fig. 28-2
Partial fixed dental prosthesis (FDP) with nonrigid connector. **A,** Mortise pattern (female) positioned on the distal aspect of the canine retainer. **B,** Partial FDP assembled with prefabricated resin tenon (male) on the mesial aspect of the pontic. **C,** Nonrigid connectors used to allow the fabrication of an extensive fixed prosthesis having abutments prepared with divergent paths of placement. *(Courtesy of Dr. M. Chen.)*

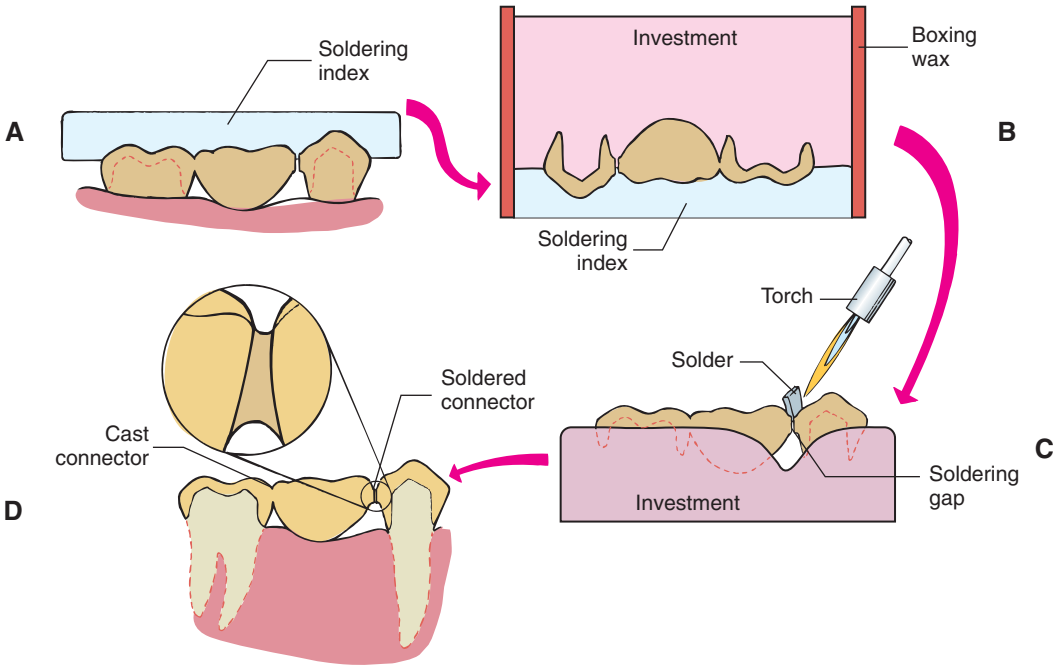


Fig. 28-3
The soldering process. **A,** Occlusal soldering index. **B,** Fixed dental prosthesis components invested. **C,** Torch soldering. **D,** Clinical evaluation.

In industrial metalworking, a distinction is made between *soldering,* in which the filler metal has a melting point below 450°C (842°F), and *brazing,* in which the filler has a melting point above 450°C.[3] Rigid connections in dentistry are generally fabricated above 450°C, but the process has almost always been referred to in the dental literature as *soldering.* However, in a proposed international standard, the term *brazing* is used. With time, the latter term may become more generally accepted. In this text, however, the term *soldering* is used.

NONRIGID CONNECTORS

Nonrigid connectors are indicated when it is not possible to prepare two abutments for a partial FDP with a common path of placement. Segmenting the design of large, complex FDPs into shorter components that are easier to replace or repair individually is advisable. This can be helpful if there is uncertainty about an abutment's prognosis. If the abutment fails, only a portion of the FDP may need to be remade. In the mandibular arch, nonrigid connectors are indicated when a complex FDP consists of anterior and posterior segments. During the mandibular opening and closing stroke, the mandible flexes mediolaterally.[4] Rigid FDPs have been shown to inhibit mandibular flexure, and extensive splints have been shown to flex during forced opening.[5] The associated stresses can cause dislodgment of complex FDPs. Segmenting complex mandibular FDPs can minimize this risk (Fig. 28-4).

Nonrigid connectors are generated through incorporation of prefabricated inserts in the wax pattern or through custom milling procedures after the first casting has been obtained. The second part is then custom-fitted to the milled retainer and cast. They are often made with prefabricated plastic patterns. The retainers are then cast separately and fitted to each other in metal.

CONNECTOR DESIGN

The size, shape, and position of connectors all influence the success of the prosthesis. Connectors must be sufficiently large to prevent distortion or fracture during function but not too large; otherwise, they interfere with effective plaque control and contribute to periodontal breakdown over time. Adequate access (i.e., embrasure space) must be available for oral hygiene aids cervical to the connector. If a connector is too large incisocervically, hygiene is impeded, and over time, periodontal failure will occur (Fig. 28-5*A*). For esthetic FDPs, a large connector or inappropriate shaping of the individual retainers may result in display of the metal connector, which may compromise the appearance of the restoration and lead to patient dissatisfaction (Fig. 28-5*B*).



Fig. 28-4
To accommodate the stresses that potentially result from mandibular flexure, this complex fixed dental prosthesis has been segmented through the use of nonrigid connectors on the distal of the two canines (*arrows*). *(Courtesy of Dr. F. Hsu.)*

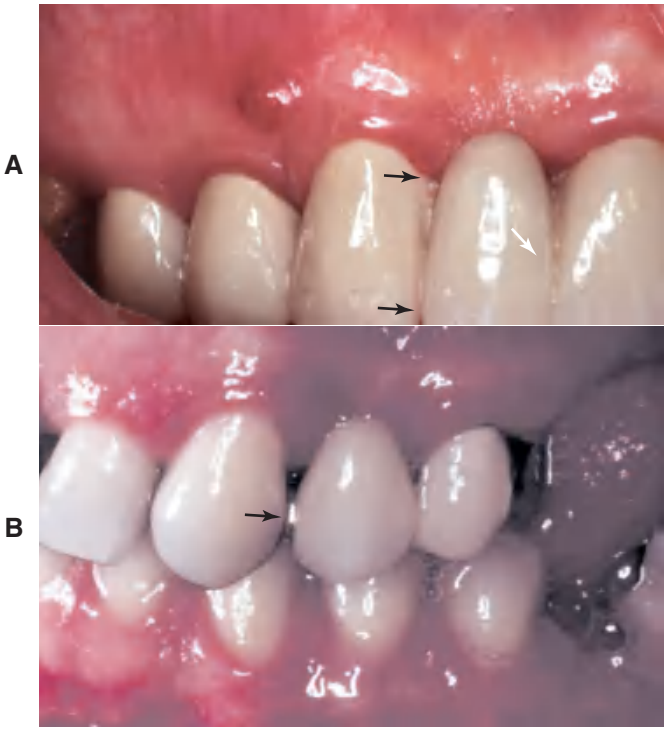


Fig. 28-5
Restorative failure. **A**, Incisocervically an excessively large connector (*arrows*) impedes proper plaque control and has led to periodontal breakdown. **B,** Although it may be acceptable from a biologic and mechanical perspective, a connector (*arrow*) that displays metal can prove to be esthetically unacceptable.

In addition to being highly polished, the tissue surface of connectors is curved faciolingually to facilitate cleansing. Mesiodistally, it is shaped to create a smooth transition from one partial FDP component to the next. A properly shaped connector has a

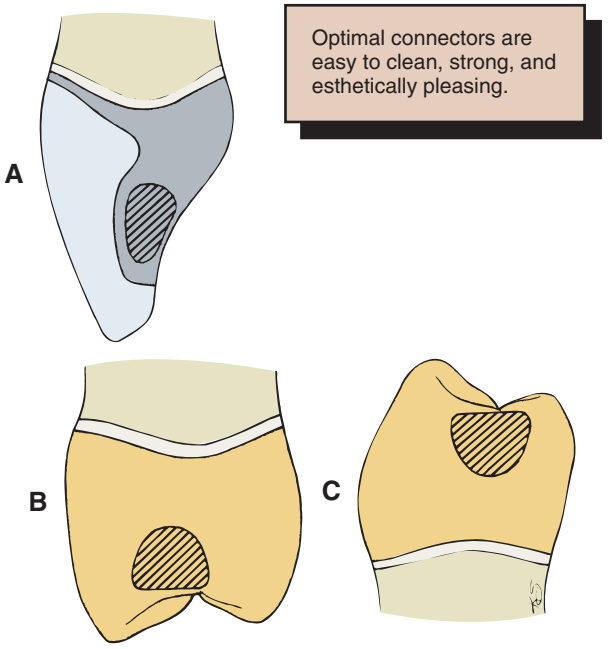


Fig. 28-6
Cross-sections through fixed dental prosthesis connectors. **A,** Maxillary anterior. **B,** Maxillary posterior. **C,** Mandibular posterior. Note the convexity of the gingival aspect of the connectors. To prevent excessive display of metal, anterior connectors should be placed toward the lingual embrasure.

configuration similar to a meniscus formed between the two parts of the prosthesis.

In a buccolingual cross-section, most connectors have a somewhat elliptical shape. Such an elliptical connector is strongest if the major axis of the ellipse parallels the direction of the applied force. Unfortunately, because of anatomic considerations, this cannot always be achieved. In fact, because of space constraints, the greatest dimension of most connectors is perpendicular to the direction of applied force, which tends to result in a weaker connector. For ease of plaque control, the connectors should occupy the normal anatomic interproximal contact areas, because encroaching on the buccal, gingival, or lingual embrasure restricts access. However, to improve appearance without significantly affecting plaque control, anterior connectors are normally placed toward the lingual embrasure. Figure 28-6 depicts typical locations for connectors on selected teeth.

Pulp size and clinical crown height can be limiting factors in the design of nonrigid connectors. Most prefabricated patterns require the preparation of a fairly sizable box. This allows incorporation of the **mortise** (see p. 843; Fig. 28-9*B*) in the cast restoration without overcontouring of the interproximal emergence profile. Short clinical crowns do not

provide adequate occlusocervical space to ensure adequate strength. Most manufacturers recommend 3 to 4 mm of vertical height.

TYPES OF CONNECTORS

Rigid Connectors

Rigid connectors must be shaped and incorporated into the wax pattern after the individual retainers and pontics have been completed to final contour but before reflowing of the margins for investing (see Chapter 18).

Cast connectors

Connectors to be cast are also waxed on the definitive cast before reflowing and investing of the pattern. The presence of a cast connector makes the latter somewhat more awkward. Access to the proximal margin is impeded, and the pattern cannot be held proximally during removal from the die. Restricting cast connectors to complete coverage restorations, which can be gripped buccolingually, is therefore advisable. Partial-coverage wax patterns are easily distorted when they are part of a single-cast partial FDP. One-piece castings often appear to simplify fabrication but tend to create more problems than do soldered connectors, especially as pattern complexity increases.

Soldered connectors

As with cast connectors, connectors to be soldered are waxed to final shape but are then sectioned with a thin ribbon saw (Fig. 28-7*A* and *B*); therefore, when the components are cast, the surfaces to be joined are flat, parallel, and a controlled distance apart. This allows accurate soldering with a minimum of distortion.[6] Molten solder flows toward the location where the temperature is highest. In metal, the two flat surfaces previously created in wax retain heat, ensuring that the highest temperature is in the connector area.

Soldering gap width

As gap width increases, soldering accuracy decreases.[7] Extremely small gap widths can prevent proper solder flow and lead to an incomplete or weak joint.[8] An even soldering gap of about 0.25 mm is recommended. If a connector area has an uneven soldering gap width, obtaining a connector of adequate cross-sectional dimension without resulting distortion is more difficult.

Loop connectors

Although they are rarely used, loop connectors (Fig. 28-8) are sometimes required when an existing diastema is to be maintained in a planned fixed prosthesis. The connector consists of a loop on the lingual aspect of the prosthesis that connects adjacent retainers and/or pontics.

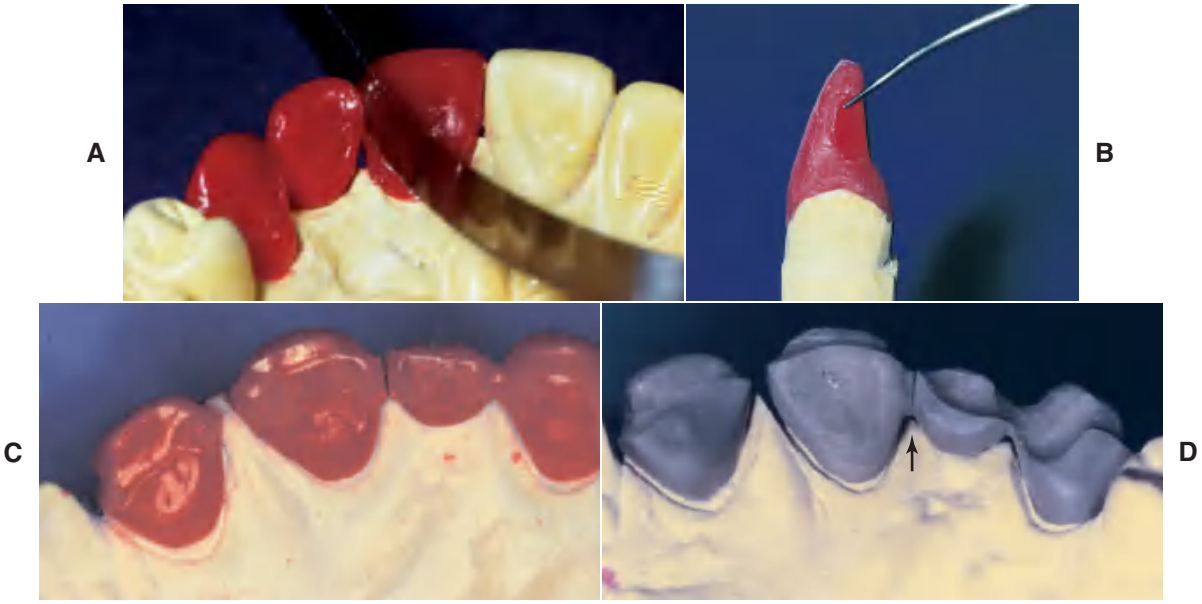


Fig. 28-7

Connector design. **A,** A ribbon saw is used to section the wax pattern. **B**, The sectioned surface should be flat and located sufficiently far incisally and lingually to allow adequate hygiene and esthetics of the completed partial fixed dental prosthesis (FDP). **C,** A three-unit FDP after sectioning. **D,** Framework ready for porcelain application. Note the uniform gap width (*arrow*).



Fig. 28-8
In the presence of a diastema that is to be maintained, a loop connector may be indicated. Incisal (**A**) and labial (**B**) views of a four-unit fixed dental prosthesis with a loop connector. Note that the diastema between the lateral and central incisors is maintained. *(Courtesy of Dr. M. T. Barco.)*

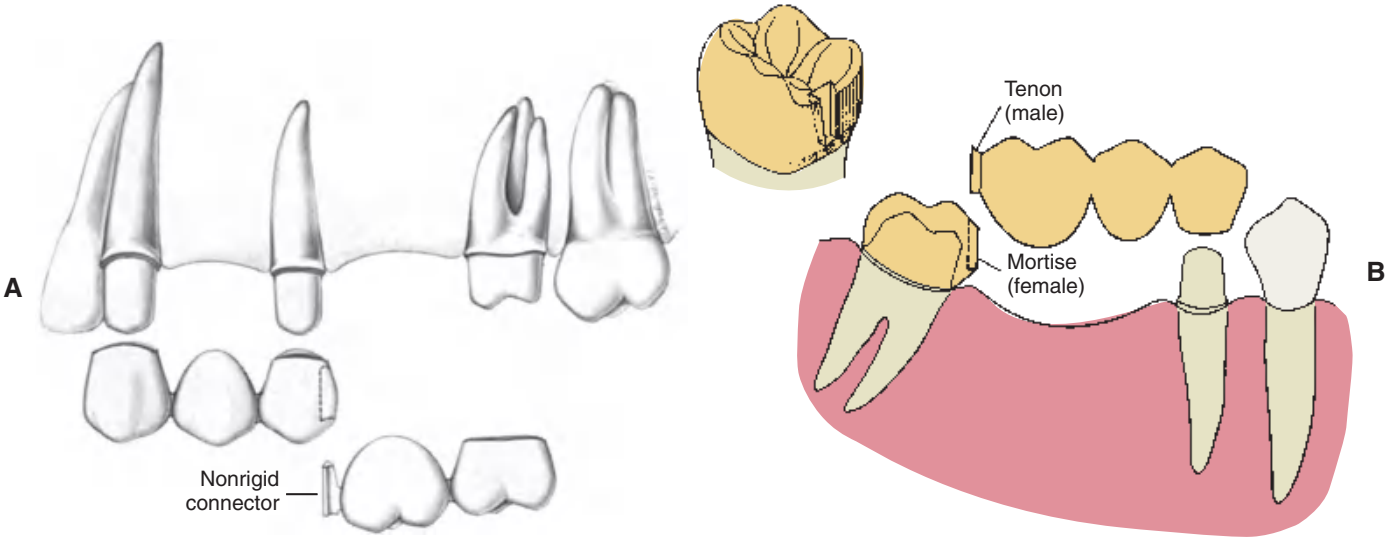


Fig. 28-9
Partial fixed dental prosthesis with nonrigid connectors. This type of connector may be indicated to overcome problems with intermediate or pier abutments (**A**) and abutment alignment (**B**).

The loop may be cast from sprue wax that is circular in cross-section or shaped from a platinum-gold-palladium (Pt-Au-Pd) alloy wire. Meticulous design is important for enabling plaque control.

Nonrigid Connectors

The design of nonrigid connectors that are incorporated in the wax pattern stage consists of a mortise (also referred to as the *female component*) prepared within the contours of the retainer and a **tenon** *(male component)* attached to the pontic (Fig. 28-9). The mortise is usually placed on the distal aspect of the anterior retainer. Accurate alignment of the dovetail or cylindrically shaped mortise is crucial; it must parallel the path of placement of the distal retainer (see Fig. 28-2). Paralleling is normally accomplished with a dental surveyor. When the cast is aligned, the path of placement of the retainer that will be contiguous with the tenon is identified. The mortise in the other retainer is then shaped so that its path of placement allows concurrent seating of the tenon and its corresponding retainer.

The mortise can be prepared freehand in the wax pattern or with a precision milling machine. Another approach is to use prefabricated plastic components for the mortise and tenon of a nonrigid connector (Fig. 28-10). As an alternative, a special mandrel can be embedded in the wax pattern (Fig. 28-11) and the abutment retainer can be cast, with refinement of the female component as necessary; the male key is then fabricated



Fig. 28-10
A, Prefabricated plastic patterns are available for incorporation in the wax pattern. **B,** The metal substructure. **C,** The anterior component of the prosthesis. **D,** The completed prosthesis incorporates bilateral nonrigid connectors (***arrows***). *(Courtesy of Dr. F. Hsu.)*



Fig. 28-11
Ticon mandrels are prefabricated inserts embedded in the wax pattern. The retainer is cast directly onto the mandrel to form the female component of the connector. *(Courtesy of Dr. F. Hsu.)*

with autopolymerizing acrylic resin and attached to the pontic.

MATERIALS SCIENCE

M. H. Reisbick

Solder

Dental gold solders are given a **fineness** designation to indicate the proportion of pure gold contained in 1000 parts of alloy. For example, a 650-fine solder contains 65% gold. In an earlier designation,[9] the solder was assigned a carat number, which indicated the gold content of the castings that were to be joined with the solder; an 18-carat solder could be used to solder castings fabricated of an alloy containing 75% gold. Because numerous alloys other than type IV gold are available today, many of which contain platinum-group metals, the carat designation is of little value.

Modern casting alloys have become so metallurgically complex that most manufacturers now

recommend specifically formulated solders. One manufacturer (Heraeus Kulzer) classifies traditional gold-containing solders as group I and others (termed *special solders*) as group II. Most of these have the brand name with a "pre" or "post" designation to indicate whether the solder is to be used for joining the components before or after porcelain application. The preceramic solders are obviously high-fusing alloys, sometimes fusing only slightly beneath the softening point of the parent alloy to be joined. Ideally, they flow well above the fusion range of the subsequently applied porcelain. Postceramic solders must flow well below the pyroplastic range of the porcelain. For example, one popular silver-palladium (Ag-Pd) casting alloy has a specified melting range between 1232° and 1304°C (2280° to 2384° F). The recommended special presolder melts at 1110°C to 1127°C (2030°F to 2061°F), whereas the postsolder melts at 710°C to 743°C (1310°F to 1369°F). The porcelain fuses at about 982°C (1800°F), depending on time and temperature.

The composition of the solder determines its melting range, among other things. Some typical compositions and melting ranges are given in Table 28-1. Solder's main requirement is to fuse safely below the sag or creep temperature of the casting to be soldered. Newer palladium casting alloys, by virtue of their higher melting ranges, have somewhat increased the reliability of the preceramic application soldering technique.[10]

However, preceramic soldering is relatively difficult and can be structurally hazardous (Fig. 28-12). This may be because of the volatilization of base metal solder constituents that occurs with overheating.[11] Volatilization then results in microporosity or pitting. The melting range of presolders is quite narrow, because silver and copper (the usual modifiers of temperature range) cannot be used in the alloy; these elements discolor porcelain on contact. Another consideration is the oxide necessary for the chemical adherence of porcelain. Porcelain does not chemically bond equally well to all solders.

Other requirements of solders are their ability to resist tarnish and corrosion, to be free flowing, to match the color of the units that will be joined, and to be strong. These factors also depend on the chemical composition of the solder.

Resistance to tarnish and corrosion is determined by a solder's noble or precious metal content and its silver/copper (Ag/Cu) ratio.[12] In addition, if the compositions of the solder and work piece differ, galvanic corrosion may occur.

During the soldering procedure, the solder must flow freely over clean and smooth surfaces. These surfaces should be smoothed with abrasive disks, not with rubber wheels or polishing compounds. The phenomenon of free flow is termed *wetting*, during which remelting or realloying of the surface of the units to be joined must not occur.[13] Solder flow is increased by the addition of silver and decreased by the presence of copper. Figure 28-13 demonstrates a properly made solder joint. Note that the filler metal has joined the surfaces of the two castings without penetrating either one.

Lower-fineness gold solders are often more fluid and are generally chosen for joining castings. If necessary, proximal contacts with a solder of higher fineness can also be added, because this tends to flow less freely. However, the exact minimally acceptable fineness necessary for resisting tarnish and corrosion has not been conclusively established; 615 or

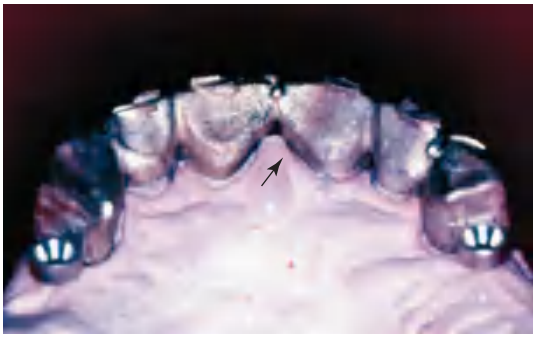


Fig. 28-12
Metal substructure for an anterior prosthesis. The preceramic soldering procedure has led to partial melting of the framework (*arrow*), which can result in distortion and/or premature failure.

Table **28-1 COMPOSITION (%) AND FLOW TEMPERATURES OF DENTAL SOLDERS**

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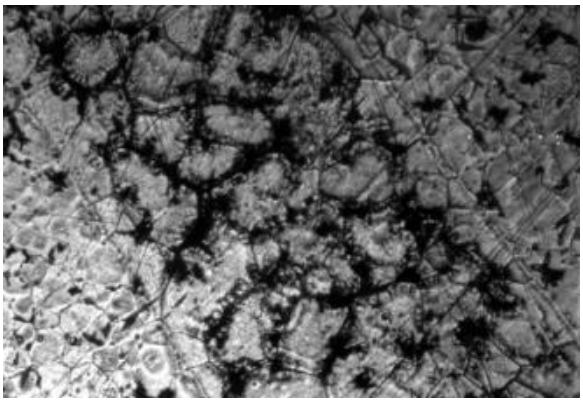


Fig. 28-13
Photomicrograph of a properly made solder joint connecting two castings.



Fig. 28-14
Simulated base metal-to-base metal postceramic soldering procedure. Excessive oxide formation has prevented wetting by the solder. *(From Sloan RH, et al: Post-ceramic soldering of various alloys. J Prosthet Dent 48:686, 1982.)*

580 fineness is probably the lower limit of clinical acceptability.

The last requirement, strength, is easily satisfied by most solders and is usually greater than that of the soldered parent metal, provided that the procedure is followed carefully.[8] In addition, most solders harden during cooling because of the "order-disorder" transformation and the formation of other intermetallic phases, which occur at grain boundaries. Brittleness is frequently encountered with gold-based copper-containing solders. As with type III and type IV gold casting alloys, the gold-copper order-disorder (or discontinuous phase-hardening) mechanism causes similar changes in the solder's microstructure.[14] Simply stated, with these solders, cooling to room temperature results in a brittle joint. The joints are strong but have no ductility. Some solder joints are weakened by notches.[15] This means that soldered connectors should be well-polished to prevent fracture.

Partial FDPs fabricated with type III gold alloys and joined interproximally with traditional gold-based solders are usually water quenched 4 to 5 minutes after soldering is complete. Quenching immediately after soldering causes the partial FDP to warp; failure to quench leads to creation of a joint with little or no ductility. A brittle joint may easily fracture. Thus, a disadvantage of postceramic soldering is the loss of joint ductility. Because the components are partially porcelain, quenching is not done, because porcelain fracture will occur.

Soldering Flux and Antiflux

Soldering flux

This substance is applied to a metal surface to remove oxides or prevent their formation. When the oxides are removed, the solder is free to wet the clean metal surface.

Borax glass ($Na_2B_4O_7$) is frequently used with gold alloys because of its affinity for copper oxides. An often-cited **soldering flux** formula[16] is borax glass (55 parts), boric acid (35 parts), and silica (10 parts). These ingredients are fused together and then ground into a powder.

Fluxes are available in powder, liquid, or paste form. The paste is popular because it can be easily placed and confined. Pastes are made by mixing the flux powder with petrolatum. The petrolatum excludes oxygen during heating and eventually carbonizes and then vaporizes.

New fluxes are available for use with non-gold-based alloys. Their formulas are not generally published. At present, none of the new fluxes are totally capable of preventing oxide formation during heating of the base metal or nonnoble alloys. An example of a rapidly forming oxide on a base metal occurring during a simulated postceramic application soldering can be seen in Figure 28-14. Soldering of base metal alloys is still unpredictable.[17]

All fluxes should be kept from contacting porcelain-veneered surfaces. The contact causes pitting and porcelain discoloration.

Soldering antiflux

Antiflux is used to limit the spreading of solder. It is placed on a casting before the flux application to limit the flow of molten solder. When the metal surfaces are clean, any excess solder introduced into the work gap tends to flow into undesirable areas. The antiflux helps prevent this.

Graphite (from a pencil) is often used as an antiflux. However, the carbon easily evaporates at higher temperature, leaving the work piece unprotected. A more reliable antiflux is iron oxide (rouge) in a suitable solvent such as turpentine, which can be painted on the casting with a small brush.

Soldering Investment

Soldering investments are similar in composition to casting investments (see Chapter 22). Casting investments, both gypsum and phosphate bonded, mixed with water only, have been used for soldering. However, the refractory component in casting investments usually creates unwanted thermal expansion and therefore excessively separates the units to be joined. Soldering investments ideally contain fused quartz (the lowest thermally expanding form of silica) as their refractory component.

Invested units expand during heating, and they should do so at the same rate as the castings. The units must be correctly gapped so that they do not touch. When the work units are allowed to touch, distortion and porous inadequate joints result.[9] Alternatively, excessive gap spaces cause undersized mesiodistal partial FDP widths because of solder solidification shrinkage. However, Ryge[9] showed that the gap space closes somewhat during heating, and so it is doubtful that the alloy and investment truly expand equally or at the same rates. Several commercial soldering investments are available; these should be used whenever possible. A list of reliable investments appears in Appendix A.

Joining Base Metals

Titanium and titanium alloys

The advent of titanium and its alloys, as with cobalt-chromium-nickel, has brought a new challenge to joining cast units. Titanium also responds to high heat with an increased oxide formation, which results in a poor union between components to be joined. A reasonable solution has proved to be welding, by either laser or plasma. Advantages include less heat distortion and a compositionally uniform joint. Thus, joining with the same chemical element or elements minimizes detrimental galvanic degradation. Figure 28-15 shows a "stepped" laser weld. Much work yet remains to render titanium a suitable replacement for noble casting alloys.

• • •



Fig. 28-15
Stepped weld on left, parent metal on right.

SELECTION OF SOLDERING TECHNIQUE

When partial FDPs are assembled by soldering, the relative position of the components is recorded with a soldering **index** on the definitive cast or intraorally. If pontics are made individually, they can be difficult to position properly in relation to the abutment teeth. Although a positioning index made previously upon completion of the wax pattern can be helpful (Fig. 28-16), the pontics should be connected to one of the retainers with a cast connector because this stabilizes them and makes accurate positioning in relation to the other retainer much easier. To understand the selection of soldering technique, a thorough knowledge of the fusing ranges of all materials involved in the FDP is essential (Fig. 28-17).

Soldering of all-metal FDPs consisting of type III or IV gold units requires the use of a low-fusing solder. The procedure is referred to as *conventional soldering*. Through the use of the same low-fusing solder, regular gold retainers can also be connected with metal-ceramic components. A gas-air torch is used for either of these procedures.

For FDPs consisting of metal-ceramic units, the soldered connectors may be made either before the ceramic application with high-fusing solder (approximately 1100°C [2012°F]) or after the ceramic application with lower-fusing solder (750°C [1382°F]). Soldering before ceramic application is called *pre-ceramic application soldering* or *pre-soldering*. Soldering of metal-ceramic crowns after their completion is referred to as *post-soldering*. Many alloys can be combined by using either pre-ceramic or post-ceramic soldering. However, pre-soldering has been found to be less reliable,[8] with a number of apparently sound connectors exhibiting negligible tensile strength. Considerable variation in solder joint strength has also been recorded after laboratory testing,[18] which emphasizes the special care needed to avoid defective connectors.

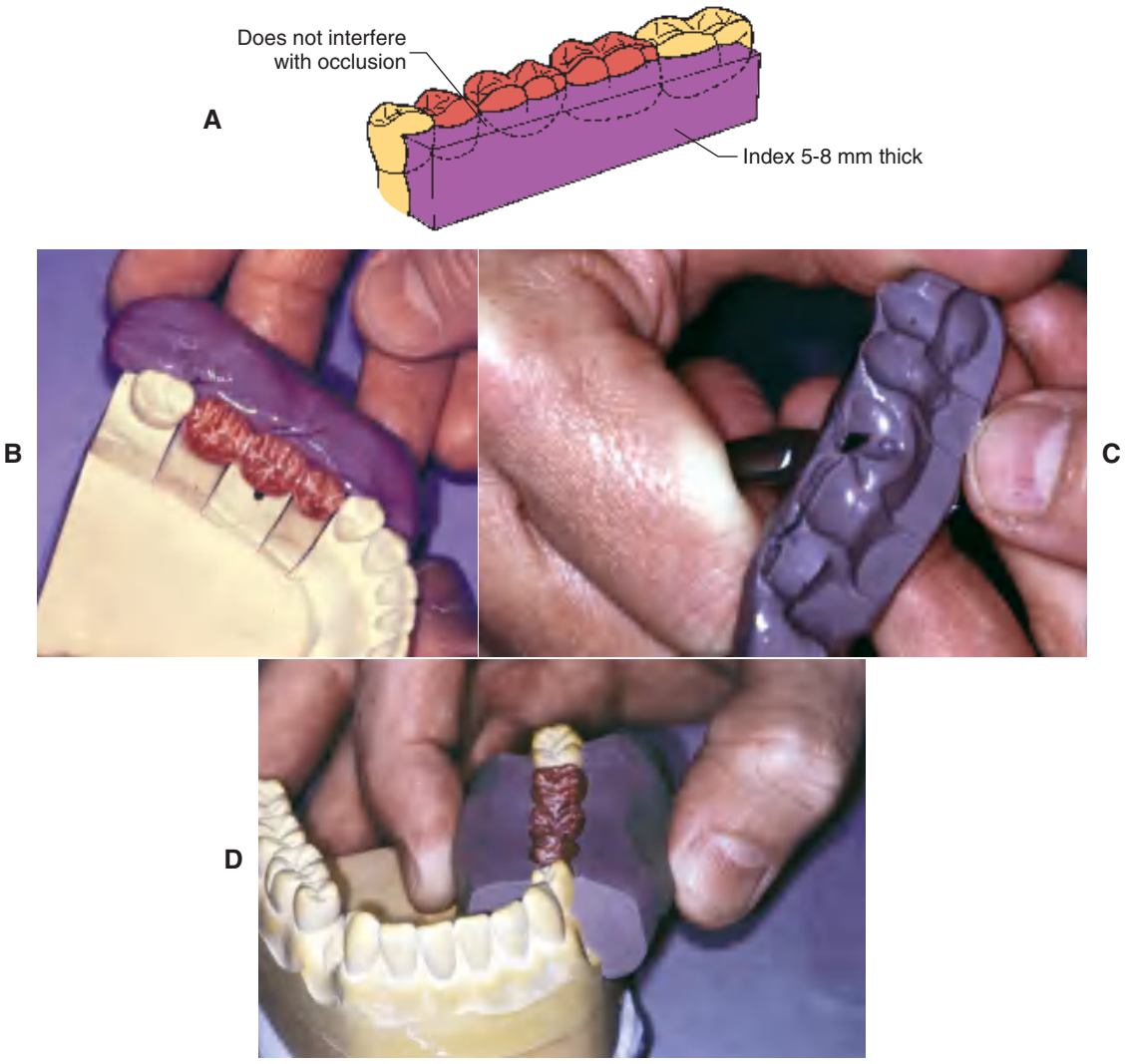


Fig. 28-16
Once the fixed dental prosthesis has been waxed to anatomic contour, a silicone putty buccal index (**A**) can be made. This can be helpful when relating the castings. **B,** Putty is applied to the buccal aspect of the completed waxing. **C,** Excess is trimmed away with a scalpel blade. **D,** The flat surface makes verification of accurate reseating of the index much easier.

Base metal alloys can be difficult to solder because they oxidize; oxidation must be controlled with special fluxes, although excessive fluxing can lead to undesirable inclusions and weak connectors. In one study,[19] investigators found that 20% of post-ceramic soldered joints involving base metal alloys had to be resoldered because they were so weak that they broke with finger pressure. Another study[20] showed great variability in solder joint quality with these alloys, with no consistent relationship of strength to gap width. Those authors found that most failures occurred through the solder and were attributable to voids caused by gas entrapment or localized shrinkage. With experience and careful adherence to the manufacturer's recommended techniques and materials, reliable base metal alloy soldered connectors are possible.[21] However, because of the problems of soldering base metal alloys, various alternative procedures have been advocated. These include making the soldered joint through the center of the pontic to increase the area soldered[22] and connecting the parts by a second casting procedure, with the molten metal flowing into undercuts in the sectioned pontic.[23]

Soldering All-Metal Partial Fixed Dental Prostheses

Type III and type IV gold retainers of partial FDPs are soldered with gold solder ranging from 615 to

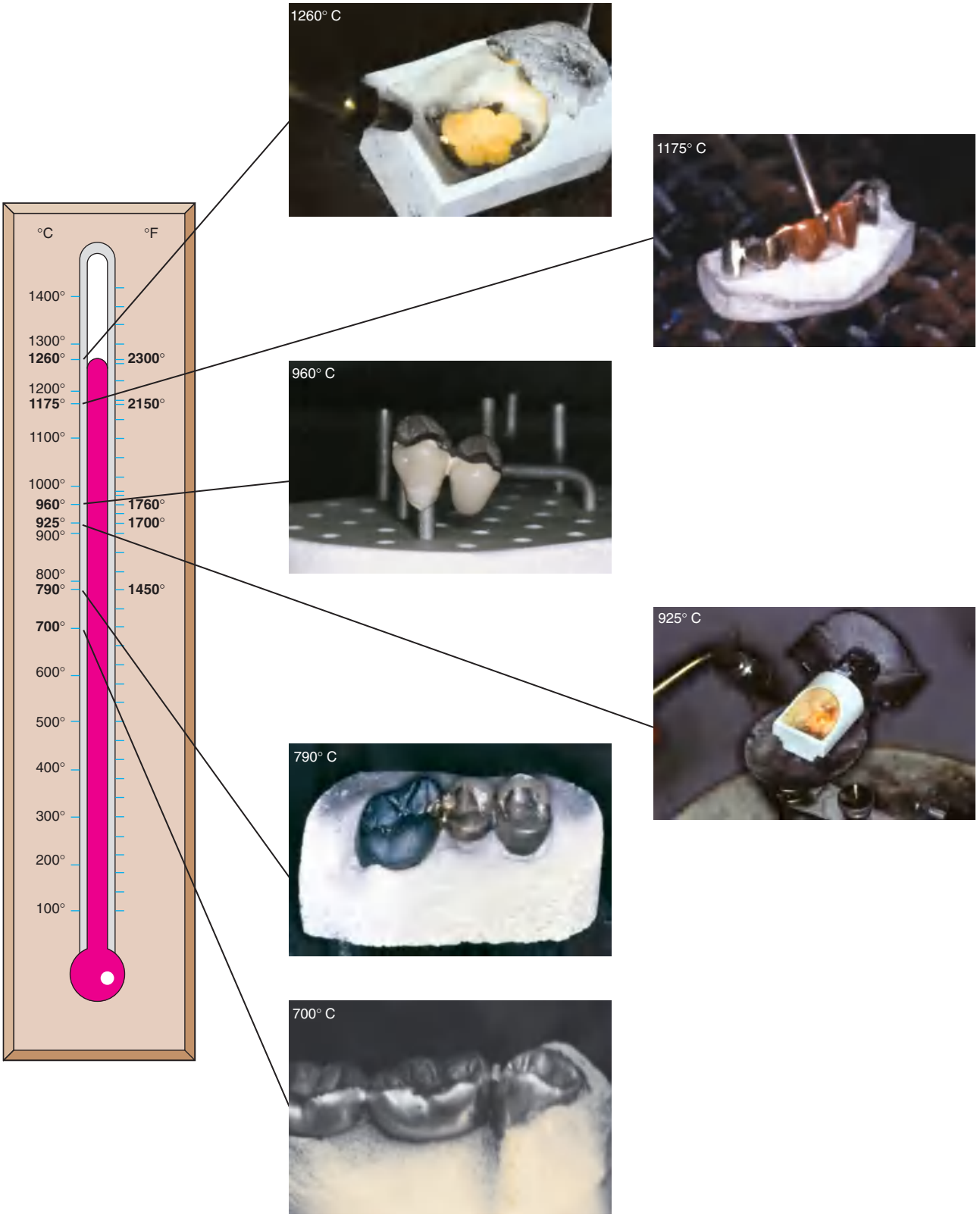


Fig. 28-17

A, Casting metal-ceramic alloys. **B,** Presoldering. **C,** Porcelain firing. **D,** Casting type III and type IV gold alloy. **E,** Postceramic soldering. **F,** Conventional soldering.

650 fineness. An occlusal plaster index or autopolymerizing resin index is fabricated intraorally or in the dental laboratory; after investing, a gas-air torch can be used to solder the components. A disadvantage of the soldering procedure is that it requires an additional step, in comparison with a one-piece casting. However, soldering simplifies the manipulation of wax patterns. For instance, when a three-abutment FDP with two splinted abutments (e.g., two premolars) is fabricated, access to the interproximal margins of the two splinted abutments is often very difficult during the reflowing and finishing steps. Soldering such retainers enables the retainers to be shaped and adjusted individually with improved access for finishing procedures. Conventional soldering requires a gas-air torch; soldering can also be performed in a furnace.

Soldering Metal-Ceramic Partial Fixed Dental Prostheses

Pre-ceramic soldering

Once a metal-ceramic framework has been assembled by pre-ceramic application soldering, the subsequent procedures are the same as if it had been cast in one piece. This has the advantage of allowing the connected prosthesis to be tried in the mouth in the unglazed state. Any necessary adjustments can be made to the porcelain, which fuses at a lower temperature than does the pre-ceramic soldered connector. However, with pre-ceramic soldering, contouring the proximal embrasures so that the units resemble natural teeth may be more difficult. A very thin diamond disk is helpful for this.

A disadvantage results from having to apply the porcelain to a longer structure, which needs support during firing to prevent high-temperature deformation or sag. Sag can be a particular problem with the high-gold content ceramic alloys because they have a lower melting range. High–palladium content or base metal alloys exhibit little sag during firing. Presoldering requires a gas-oxygen torch.

Post-ceramic soldering

Post-ceramic soldering is necessary when regular gold and metal-ceramic units are being combined in a partial FDP. The regular gold melts if it is subjected to the high temperatures needed for porcelain application; therefore, all porcelain adjustment and firing, including that for the final characterization and glazing, must be completed before the soldering. If further corrective adjustment is needed after soldering, the porcelain must be polished, or the joint must be separated, after which additional porcelain can be added as needed, the restorations can be reglazed, a new index can be made, and the FDP resoldered.



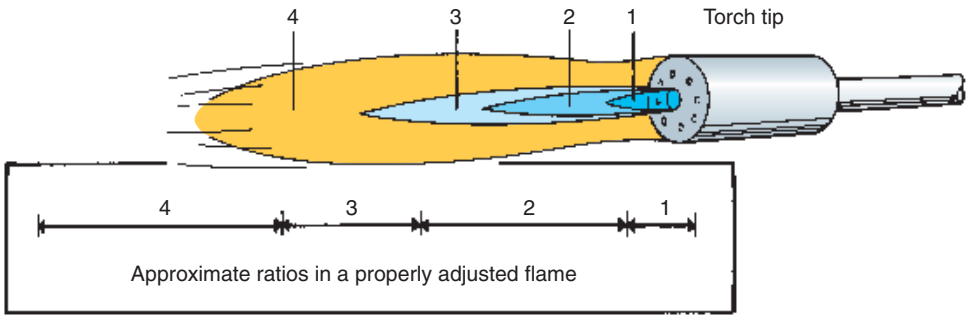
Fig. 28-18
A, This anterior fixed prosthesis was connected by post-ceramic soldering. **B,** Note the connector placed sufficiently lingually for good facial embrasure form. **C,** The assembled fixed dental prosthesis.

Because the proximal areas are shaped before soldering, a postsoldered connector can often be made to look more natural than a presoldered or cast connector (Fig. 28-18). In addition, customized firing supports are not needed because sag is not a problem (the lengths of the individual components are shorter). Postsoldering is performed either in a porcelain furnace or with a gas-air torch.

HEAT SOURCES

Torch Soldering

When a gas-air torch is used as the heat source to melt the solder, metal-ceramic restorations are preheated in an oven to minimize the risk of cracking of the porcelain veneer. Oxidization of the joint surfaces is prevented by using the reducing portion of the flame (Fig. 28-19) and by applying an appropriate flux (some soldering fluxes are unsuitable



Zones:
1. Mixing zone
2. Combustion zone
3. Reducing zone
4. Oxidizing zone

Fig. 28-19
Gas-air torch adjusted for soldering.

because they discolor the porcelain). To prevent uneven heat distribution, which could result in fracture, the flame is never concentrated in one area but is kept in constant motion.

Some dentists believe that the flow of solder is more controllable during torch soldering because a slight temperature differential can be created and the solder always flows toward the hotter point. This makes torch soldering useful when the connector has not been well designed in wax, and a minor temperature difference can deliberately be created in the assembly to help direct the flow of the molten solder to ensure an adequate connector.

Oven Soldering

Furnace or oven soldering is performed under vacuum or in air. A piece of solder is placed at the joint space, and the casting and solder are heated simultaneously.

Criticism of this technique has been based on earlier observations[24] that less porosity resulted when castings were brought to soldering temperature before the solder was applied. The method does not allow the moment of solder fusion to be observed.* This may be important, because the longer the solder remains molten, the more it dissolves the parent metal and consequently weakens the joint.[9] Nevertheless, joints with strength similar or superior to that of the parent metal have been demonstrated[8] when oven soldering was used.

A different technique may be appropriate if the porcelain furnace has a horizontal muffle with a fixed floor. The soldering assembly is heated above the fusion point of the solder, the muffle door is opened, and the solder is fed into the joint space (Fig. 28-20).



Fig. 28-20
Oven soldering a three-unit fixed dental prosthesis. *(Courtesy of Dr. A. G. Gegauff.)*

Laser Welding

Laser energy is extensively used for welding (Fig. 28-21) in many industries and has been described in dentistry since the 1970s.[25,26] Interest has continued in laser assembly of fixed prostheses with reportedly higher strength[27] and reduced corrosion[28] compared with conventional soldering, although laser-welded connectors seem as susceptible to fatigue failure.[29] Laser welding may be a practical way to join cast titanium components (e.g., if these are to be used for implant-supported prosthesis frameworks[30,31]).

*Some porcelain furnaces have an observation window for post-soldering.



Fig. 28-21
Laser welding. Individual titanium components are carefully aligned in the laser welding unit. The joining procedure is monitored with high-magnification video. *(Courtesy of Crafford-LaserStar Technologies, Riverside, Rhode Island.)*

SOLDERING ACCURACY

Controversy exists as to the relative accuracy of partial FDPs that are cast in one piece, preceramic soldered, or postceramic soldered. Individual laboratory technicians often obtain consistently better results with one particular technique, but scientific evidence is conflicting.[32,33] In evaluating clinical work to determine whether cast or soldered connectors provide better results, the determining factor should be the fit of the individual retainers. This should be optimized through the investing and casting process (see Chapter 22) to minimize the risks of incomplete seating or excessive luting agent space. In some situations, it may be impossible to cast a long-span FDP with ideal retainer dimensions and ideal interabutment dimensions; the challenge lies in obtaining enough interabutment expansion without making the retainers too loose. In such circumstances, a soldered connector may provide better accuracy. The situation is reversed for fabricating frameworks for implant-supported prostheses (see Chapter 13). Here the fit of the individual units is determined by the implant manufacturer. Only the overall abutment-to-abutment fit is under the control of the technician. However, an accurate, passively fitting implant-supported framework is crucial for avoiding damaging forces. It is not yet clear whether accurate implant-supported frameworks are most effectively made with one-piece castings or as sectioned and soldered units.[34]

SOLDERING TECHNIQUE

Armamentarium

- Autopolymerizing acrylic resin
- Zinc oxide–eugenol (ZOE) paste
- Impression plaster
- Mixing bowl
- Spatula
- Small brush
- Waxing instrument
- Sticky wax
- Baseplate wax
- Sprue wax
- Soldering investment
- Glass slab
- Soldering tripod
- Flux
- Solder
- Tongs
- Pickling solution

Step-by-Step Procedure

Occlusal soldering index

An intraoral plaster or ZOE impression is made of the occlusal surfaces of the partial FDP to capture the relative relationship of the individual FDP components and transfer this to the laboratory. This procedure can also be performed in the laboratory if the technician is satisfied that the individual components are seated completely on an accurate definitive cast. An advantage of an occlusal index (Fig. 28-22; see Fig. 28-3) is that after the soldering procedure has been completed, the FDP can be reseated in the index and soldering accuracy can be verified (sometimes a small amount of plaster must be removed in the area where the solder has been added, to ensure seating).

1. Grind the connector surfaces of the finished castings with a stone or disk to remove surface oxides. Then fully seat the castings on the definitive cast or in the mouth. Post-ceramic connectors are best indexed intraorally after the contour and appearance have been perfected. If necessary, the soldering gap can be adjusted at this time (gap distance, 0.25 mm). The castings can be seated intraorally with a small quantity of low-viscosity impression material to ensure they are not disturbed during the indexing.[35]
2. Make an impression plaster registration in a small tray or on a sheet of baseplate wax for the occlusal index. As an alternative, an index can be made with ZOE paste, a technique that has



Fig. 28-22
Soldering index (plaster) for posterior fixed dental prostheses. **A,** A suitable carrier (e.g., baseplate wax) is trimmed to proper shape before a registration is made with impression plaster (**B**). **C,** The plaster occlusal registration.

shown[36] consistent and accurate recordings. The index should not cover the margins of regular gold retainers because these are to be embedded in the investment to prevent their accidental melting during soldering.

3. Trim the index to fully expose the margins before investing (Fig. 28-23).

Investing

4. Seat each casting into the index, and lute it to place with sticky wax.
5. Flow wax into the connector area to prevent the investment from entering.
6. To create a space that will help the solder spread, adapt sprue wax gingival to the solder joint. Burying the units completely in the investment makes soldering difficult because the unnecessary bulk of the investment prevents rapid heating of the castings.
7. Protect any glazed porcelain from contacting the investment by coating it with wax before investing. To protect regular gold margins from the soldering flame, they should be embedded in the investment; otherwise, they may become overheated and melt. For the same reason, all margins should be embedded in the investment before preceramic application soldering.
8. Box the assembly with a suitable sheet wax.
9. Mix the investment carefully, and flow it into the castings without trapping any air. Only slight vibration is used so that the castings are not displaced from the index.
10. Allow the invested block to bench set before removing the wax and preheating.

Autopolymerizing resin soldering index

A plaster or ZOE occlusal index is less suitable for the registration of anterior restorations. The thinness of the incisal edges of these units makes them less stable, and accurate repositioning is more difficult. For this reason, autopolymerizing resin (Fig. 28-24) is recommended, although the resin burns off during the procedure. Therefore, the accuracy of the soldering procedure can be verified only intraorally.

1. Join the completed units together with autopolymerizing resin. The resin will later burn out, leaving no residue that could interfere with the casting.
2. Apply the resin with a bead technique. This minimizes the distortion from polymerization shrinkage. Excessive bulk of resin reduces the accuracy of the technique,[37] but sufficient material must be present to ensure that the components do not break (because they cannot then be accurately reseated in the index). The resin should extend onto the incisal edges of the retainers.
3. When the resin has fully hardened, carefully loosen the prosthesis from the abutments. Then replace it and check whether distortion has occurred. This is done in the same way as the evaluation of a finished FDP. It must be stable with no marginal discrepancies (see Fig. 28-24C). The prosthesis should be invested without delay; otherwise, the resin index will distort.[38]

Investing (Fig. 28-25)

4. Warm a sheet of wax, and push the cervical aspect of the restorations through it. Then seal it



Fig. 28-23
Investing procedure (occlusal index). **A,** The index is trimmed to ensure complete seating of the castings. **B** and **C,** The connector area is ground with a noncontaminating stone. **D,** The restorations are steam cleaned. (Alternatively, an ultrasonic can be used.) **E,** The castings are seated firmly and luted to place with sticky wax. **F,** Glazed porcelain is damaged by contact with the investment; the porcelain is therefore protected with a layer of wax. **G,** The wax is flowed into the connector areas and is adapted below each connector to create an airway. **H,** The soldering assembly is boxed. **I** and **J,** When the assembly is filled with soldering investment, great care is taken to ensure that there are no air bubbles in the investment.



Fig. 28-24
Soldering index (autopolymerizing resin). **A,** Armamentarium. **B,** A small brush dipped in resin monomer is touched to the polymer powder. This forms a bead. **C,** The restorations are thus connected, with resin extending onto the incisal edges of all the retainers.

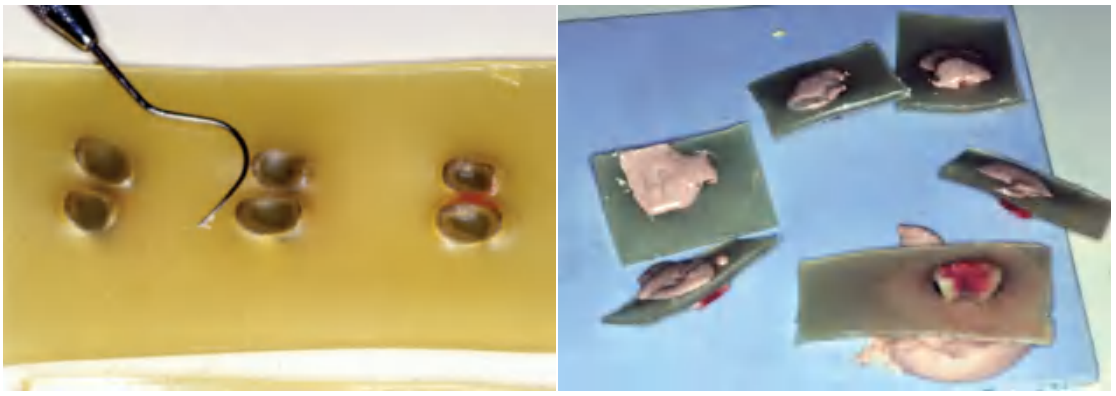


Fig. 28-25
Investing procedure (autopolymerizing resin). **A,** The castings pressed firmly into a softened sheet of wax. Note that the internal walls of the castings are exposed; the wax seals them. **B,** Castings filled with soldering investment and then inverted onto a patty of investment.

along the axial wall with a warmed instrument. This protects the porcelain from contact with the soldering investment.
5. Fill the castings with soldering investment, and blot excess water from the remaining investment, forming it into a patty on a slab or tile.
6. Seat the restorations on the patty. When a joint is to be oven-soldered, the restoration should be angled forward so that the solder can be placed above the joint before the block is set inside the furnace.

Wax removal and preheating (Fig. 28-26).

1. If a plaster or ZOE index was used, remove it after the investment has fully set. This separation is most effectively accomplished after the wax is removed with boiling water. The joint space must be free of investment. Flowing a little flux into the joint space while the soldering block is still warm from wax removal is recommended. This prevents small particles from inadvertently falling into the gap. Be aware that many special soldering investments have low strength, and the assembly is easily broken at this stage.
2. Preheat the investment in a burnout furnace to 650°C (1202°F) for low-heat soldering or 850°C (1562°F) for preceramic soldering. Acrylic resin indexes are removed by heating slowly to 300°C (572°F), at which time most of the resin will have burned away.
3. Heat the block to 650°C (1202°F) until all traces of wax and resin have vaporized, and then transfer it to the soldering stand or porcelain furnace.

Torch soldering (low heat) (Fig. 28-27)

1. Transfer the assembly to a soldering stand with a Bunsen flame underneath, and place a piece of solder above the gap. Adjust the gas-air torch to give a sharp blue cone (as for casting), and then reduce the air for a softer "brush" flame. The reducing zone of the flame is used to heat the investment block. The flame is directed at the lingual aspect of the block rather than at the casting.
2. Heat evenly and slowly, moving the tip of the flame constantly. This is particularly important in post-ceramic application soldering because the porcelain may easily crack. When the metal glows brightly, the solder melts and flows into the joint space.
3. Quickly move the flame to the facial aspect. When the solder "spins" in the joint, remove the flame.
4. Extinguish the flame, and let the soldered prosthesis cool for 4 or 5 minutes before quenching (unless there is porcelain on the restoration, in which case it should cool to room temperature). Earlier quenching may lead to distortion, whereas prolonged bench cooling increases the brittleness of the joint.

Torch soldering (high heat) (Fig. 28-28)

1. Wear dark glasses for eye protection (Fig. 28-29). Gas-oxygen torches for high-heat pre-ceramic soldering have a miniature needle tip so that the flame can be pinpointed on the joint space.
2. Place the solder above the gap, and concentrate the reducing zone of the flame on the joint space.
3. When the solder melts, draw it into the joint and quickly "chase" it around with the flame (Fig. 28-30). The pre-ceramic solder may have a melting point close to that of the parent metal, and there is danger of melting a thin framework unless the flame is concentrated on the joint space (see Fig. 28-12).



Fig. 28-26

Wax removal and preheating. **A** and **B,** Boxing material removed and the wax residue flushed out with boiling water. **C,** The connector area must be free of contaminants. **D,** A small amount of soldering flux is applied while the assembly is still warm. **E,** The flux is carried into the connector area by capillary action. Then the assembly is placed in the burnout furnace. **F** and **G,** Autopolymerizing resin indexes. These are burned off directly in the furnace after wax elimination. **H,** The soldered restorations.

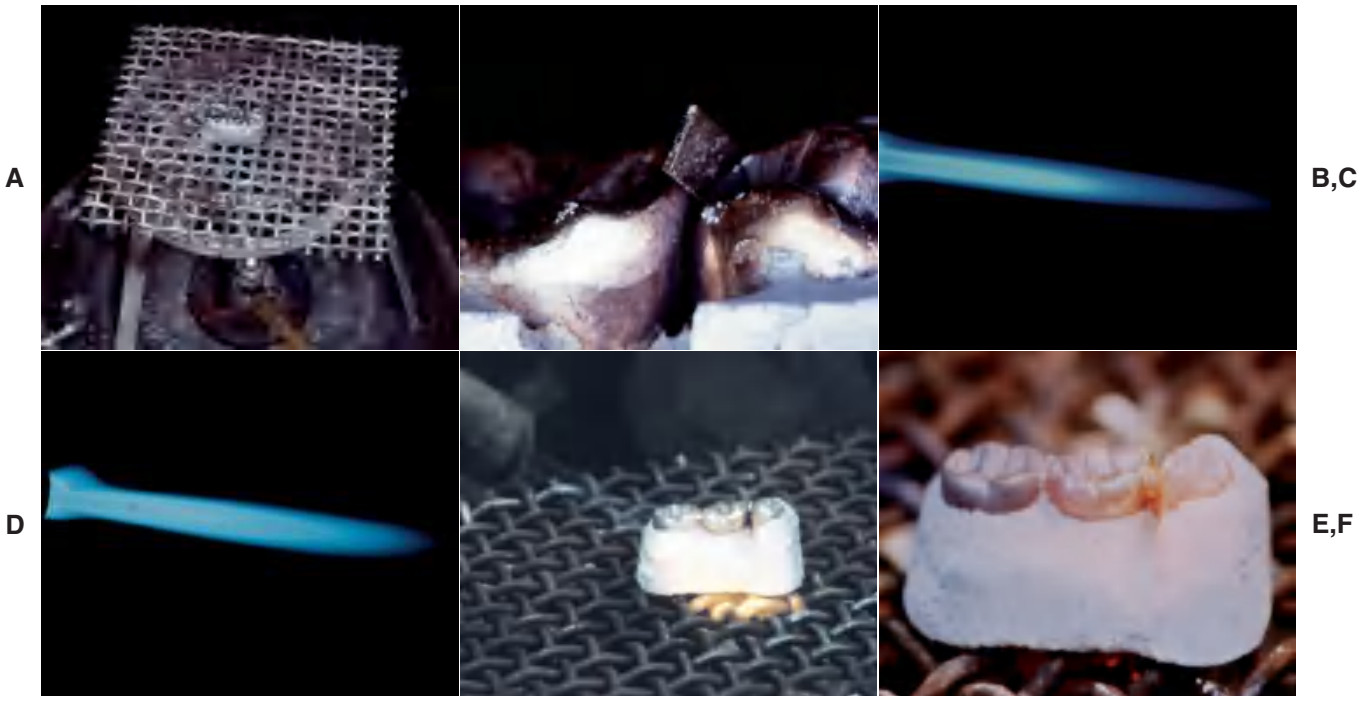


Fig. 28-27
Low-heat torch soldering. **A,** The assembly positioned on a wire mesh over a Bunsen burner. **B,** A flexed piece of solder placed into the connector area. **C,** A sharply defined flame is preferable for casting procedures. **D,** A brush flame is more suitable for soldering. This can be obtained by slightly reducing the amount of air. **E,** The assembly is heated evenly until the solder melts. The solder must "spin" in the connector area to form a complete connection (**F**).

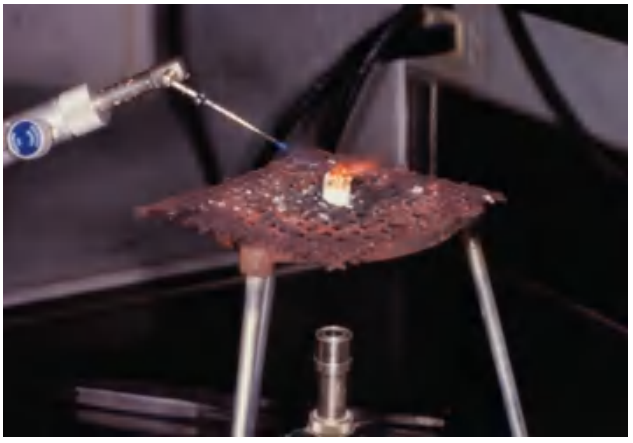


Fig. 28-28
High-heat (pre-ceramic application) torch soldering with a gas-oxygen torch and a miniature needle tip.



Fig. 28-29
Eye protection is essential for high-heat soldering and the casting of high-fusing alloys.

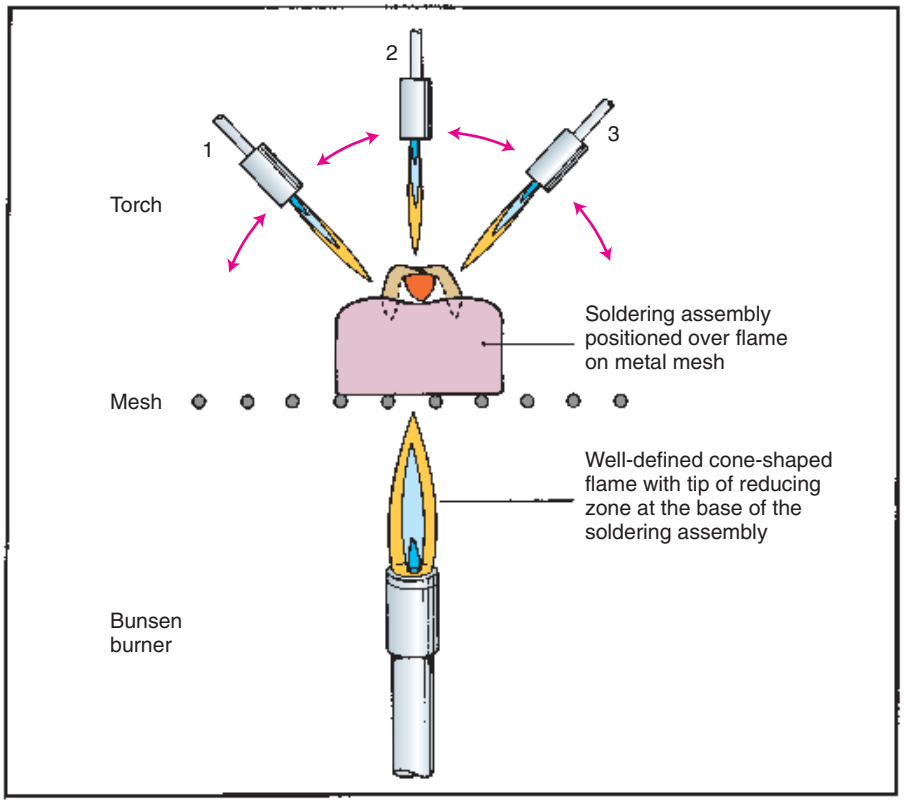


Fig. 28-30
The flame is directed at the connector immediately when the solder melts and is moved around from position 1 to positions 2 and 3. This ensures that a complete meniscus is formed.

Oven soldering (Fig. 28-31)

1. Prepare a piece of solder by dipping it in liquid flux and melting it in a Bunsen flame to form a ball. The size of the ball is determined by the connector size and the joint gap.
2. Leave a short tail attached to the ball to help position it above the joint space. As an alternative, the solder can be fed into the joint area as shown in Figure 28-20.
3. Put the assembly in the furnace, and increase the temperature to melt the solder. A vacuum is not needed for oven soldering of noble metal alloys. Air firing is preferred by some technicians because in a vacuum, there is always the chance of drawing entrapped gases to the surface of glazed porcelain, causing localized swelling or bloating.

Evaluation

If the solder fails to flow during torch soldering but forms a ball above the joint area, heating should be discontinued. The solder has oxidized, and further heating will melt the castings. If the solder has flowed properly, the completed joint can be evaluated for size before removal of the investment and, if necessary, reheated while still hot, with additional solder added. Excessive solder must be ground away during the finishing procedure (Fig. 28-32).

If the connector has been designed properly and the solder has been properly positioned, no solder should run onto the occlusal surface or cover the margins. To prevent stray flow, a small amount of antiflux (rouge dissolved in turpentine) can be painted on critical areas before the assembly is heated. After bench cooling for about 5 minutes, the assembly is quenched (not porcelain) and the investment broken away (Fig. 28-33). The connector is then carefully inspected. If signs of an incomplete joint are evident (e.g., visible porosity in the solder), they are removed by grinding with a fine disk; the units are then reinvested and resoldered.

The joints must be tested for strength (Fig. 28-34). Any connector that can be broken by force of hand will not serve adequately in the mouth. Because broken connectors cannot be easily repaired intraorally once the prosthesis has been cemented, the entire restoration usually must be remade.

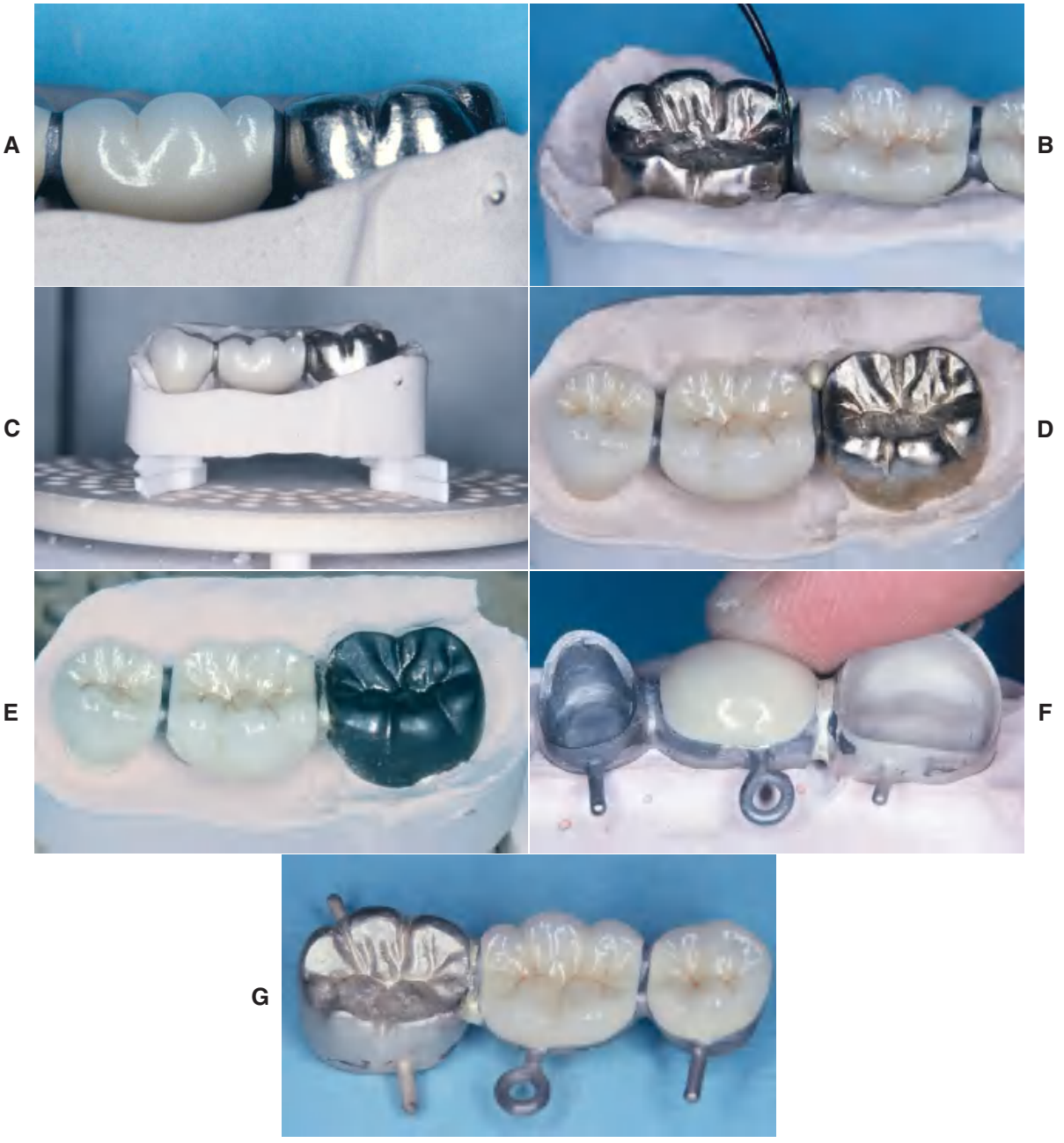


Fig. 28-31
Oven soldering procedure. **A,** The invested partial fixed dental prosthesis (FDP) before soldering. **B,** A small amount of flux is added to the clean joint area. **C** and **D,** Solder is added, and the assembly placed in the oven. **E,** The soldered FDP. **F,** The soldering index is used to assess soldering accuracy. **G,** Oven-soldered connector before finishing.



Fig. 28-32

A, A fixed splint was indicated for this patient to prevent drifting of teeth with compromised periodontal support. **B** and **C,** Plaster soldering index. **D** and **E,** Splint before investing. **F,** The soldering assembly. **G,** The assembled prosthesis after soldering. **H,** Note that the connectors have been considerably reduced in size during the finishing procedure. Splinted teeth do not require as large connectors as do fixed dental prostheses. **I,** The completed prosthesis.



Fig. 28-33

A, The assembly is quenched after bench cooling for approximately 5 minutes. **B,** Investment removed from the castings. **C,** Surface oxides dissolved in a pickling solution.



Fig. 28-34
Solder joints should always be tested for strength.

REVIEW OF TECHNIQUE

Figure 28-35 summarizes the steps involved in partial FDP connector fabrication and should be referred to when the material is reviewed.

1. The design of connectors is determined in the wax pattern (Fig. 28-35*A* and *B*).
2. All soldered connections require clean parallel surfaces. Gap width should be 0.25 mm.
3. The units are indexed either from the definitive cast or in the mouth (Fig. 28-35*C*).
4. Wax is added to the indexed restorations to shape the soldering assembly. For metal-ceramic restorations, it is added to protect the porcelain (Fig. 28-35*D*).



Fig. 28-35
Technique review. **A,** The design of connectors is determined in the wax pattern. **B,** All soldered connections require clean parallel surfaces. Gap width should be 0.25 mm. **C,** The units are indexed either from the definitive cast or in the mouth. **D,** Wax is added to the indexed restorations to shape the soldering assembly. For metal-ceramic restorations, it is added to protect the porcelain. **E,** The units are invested, and the investment is allowed to bench set. **F,** If a plaster or zinc oxide-eugenol index is used, wax is eliminated with boiling water, the joint is fluxed, and the assembly is preheated in a burnout furnace. **G,** If a resin index has been used, it is placed directly in the burnout furnace. **H,** The connectors are soldered with a torch or in a porcelain furnace.

STUDY QUESTIONS

1. Contrast soldering, brazing, and welding.
2. Discuss how biologic, mechanical, and esthetic considerations affect connector size and position for each of the following classes of teeth: incisors, premolars, and molars.
3. When and why would a nonrigid connector be used? A loop connector?
4. Discuss fineness and carat. What is their importance in dental soldering?
5. How do soldering investments differ from conventional casting investments? Why?
6. What is flux? Antiflux? How do they work? Give several examples of each.
7. What are the fundamental differences among conventional soldering, post-ceramic soldering, and pre-ceramic soldering? When contrasting the last two techniques, identify the advantages and limitations associated with their use.
8. Describe the step-by-step procedures for two techniques to make a soldering index for a partial FDP. What are the respective advantages and limitations?

5. The units are invested, and the investment is allowed to bench set (see Fig. 28-35*E*).
6. If a plaster or ZOE index is used, wax is eliminated with boiling water or chloroform, the joint is fluxed, and the assembly is preheated in a burnout furnace (see Fig. 28-35*F*).
7. If a resin index has been used, it is placed directly in the burnout furnace (see Fig. 28-35*G*).
8. The connectors are soldered with a torch or in a porcelain furnace (see Fig. 28-35*H*).

SUMMARY

Connectors join individual retainers and pontics. Rigid or nonrigid connectors can be used. Connector size, shape, and position influence the success of a partial FDP. The use of soldered connectors can simplify the fabrication of larger fixed prostheses, which may be cast separately in groups of one or two units and assembled after their individual fit has been verified. The technical procedures involved in soldering are not difficult. If the joint surfaces have been correctly designed and soldering gap width has been carefully controlled, the procedures are routine. All debris must be removed from the connector area because it interferes with surface wetting.

Conventional soldering involves the assembly of type II, III, or IV gold castings. Pre-soldering is the assembly of metal ceramic substructures before porcelain application. Post-soldering is the assembly of metal ceramic units after porcelain application. Heat sources used for soldering procedures include gas-air torches, gas-oxygen torches, furnaces, and laser units.

If the basic principles are understood and the technique has been mastered, these procedures are entirely reliable.

GLOSSARY*

[1]abra·sive \uh-brā′ siv, -ziv\ *n* (1853): a substance used for abrading, smoothing, or polishing

airborne-particle abrasion \âr′bôrn′ pär′tĭ-kal a-brā′zhun\: the process of altering the surface of a material through the use of abrasive particles propelled by compressed air or other gases

antiflux \ăn′tē-flŭks′\ *n*: materials that prevent or confines solder attachment or flow

bees' wax *n* (1676): a low-melting wax obtained from honeycomb and used as an ingredient of many dental impression waxes

brazing investment \brā′zing ĭn-vĕst′ment\: an investment having a binding system consisting of acidic phosphate such as monoammonium phosphate and a basic oxide such as magnesium oxide

brazing material \brā′zing ma-tîr′ē-al\: an alloy suitable for use as a filler material in operations with which dental alloy(s) is/are joined to form a dental restoration

cast connector: a cast metal union between the retainer(s) and pontic(s) in a fixed dental prosthesis

[1]con·nec·tor \ka-nĕk′tor\ *n* (15c): in removable denture prosthodontics, the portion of a removable dental prosthesis that unites its components—*usage:* see BAR C., CONTINUOUS BAR C., MAJOR C., MINOR C.

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di·a·ste·ma \dī′a-stē′ma\ *n, pl* **-ma·ta** \-ma-ta\ (1854)**:** a space between two adjacent teeth in the same dental arch

fine \fīn\ *adj* (13c) **1:** free from impurities **2:** of a metal: having a stated proportion of pure metal in its composition, expressed in parts per thousand > a gold coin 0.9265

fine·ness \fīn′nĕs′\ *n***:** the proportion of pure gold in a gold alloy; the parts per 1000 of gold

flux \flŭks\ *n* (14c) **1:** in physics, the rate of flow of a liquid, particles or energy **2:** in ceramics, an agent that lowers the fusion temperature of porcelain **3:** in metallurgy, a substance used to increase fluidity and to prevent or reduce oxidation of a molten metal **4:** any substance applied to surfaces to be joined by brazing, soldering or welding to clean and free them from oxides and promote union

in·dex \ĭn′dĕks′\ *n* (1571)**:** a core or mold used to record or maintain the relative position of a tooth or teeth to one another, to a cast, or to some other structure

infrared radiation \ĭn′fra-rĕd**:** electromagnetic radiation of wavelengths between 760 nm and 1000 nm

laser welding \lā′zer wĕl′dĭng**:** the joining of metal components through the use of heat generated with a laser beam

nonrigid connector \nŏn-rĭj′ĭd ka-nĕk′tor**:** any connector that permits limited movement between otherwise independent members of a fixed dental prosthesis

rigid connector \rĭj′ĭd ka-nĕk′tar**:** a cast, soldered, or fused union between the retainer(s) and pontic(s)

[1]**sol·der** \sŏd′ar\ *n* (15c)**:** a fusible metal alloy used to unite the edges or surfaces of two pieces of metal; something that unites or cements

[2]**sol·der** \sŏd′ar\ *v,* **sol·der·ed** \sŏd′ard\ **sol·der·ing** \sŏd′ar-ĭng\ **sol·der·a·bil·i·ty** \sŏd′ar-ă-bĭl′ĭ-tē\ *n*— **sol·der·er** \sŏd′ar-er\ *n***:** to unite, bring into, or restore to a firm union; the act of uniting two pieces of metal by the proper alloy of metals

soldering antiflux: a material, such as iron oxide (rouge) dissolved in a suitable solvent such as turpentine placed on a metal surface to confine the flow of molten solder

sta·b·i·li·za·tion \stā′ba-lĭ-zā′shun\ *n, obs***:** the seating of a fixed or removable denture so that it will not tilt or be displaced under pressure (GPT-1)

stab·il·ize \stā′ba-līz′\ *vb* **-liz·ed** \līzd\ **-liz·ing** \lī-zĭng\ *vt,* **stabilization** \stā′ba-lĭ-zā′shun\ *v* (1861) **1:** to make firm, steadfast, stable **2:** to hold steady, as to maintain the stability of any object by means of a stabilizer

subocclusal connector \sŭb′a-klōō′zal ka-nĕk′tar**:** an interproximal nonrigid connector positioned apical to and not in communication with the occlusal plane

[2]**weld** \wĕld\ *vb***:** to unite or fuse two pieces by hammering, compression, or by rendering soft by heat with the addition of a fusible material

REFERENCES

1. Walton TR: An up to 15-year longitudinal study of 515 metal-ceramic FPDs: Part 2. Modes of failure and influence of various clinical characteristics. Int J Prosthodont 16:177, 2003.
2. Anusavice KJ: Phillips' Science of Dental Materials, 11th ed, p. 608. Philadelphia, WB Saunders, 2003.
3. British Standard Institute: British Standard Glossary of Dental Terms. London, British Standard Institute, 1983.
4. Goodkind RJ, Heringlake CB: Mandibular flexure in opening and closing movements. J Prosthet Dent 30:134, 1973.
5. Fischman BM: The influence of fixed splints on mandibular flexure. J Prosthet Dent 35:643, 1976.
6. Steinman RR: Warpage produced by soldering with dental solders and gold alloys. J Prosthet Dent 4:384, 1954.
7. Willis LM, Nicholls JI: Distortion in dental soldering as affected by gap distance. J Prosthet Dent 43:272, 1980.
8. Stade EH, et al: Preceramic and postceramic solder joints. J Prosthet Dent 34:527, 1975.
9. Ryge G: Dental soldering procedures. Dent Clin North Am 2:747, 1958.
10. Rasmussen EJ, et al: An investigation of tensile strength of dental solder joints. J Prosthet Dent 41:418, 1979.
11. Craig RG, Powers J: Restorative Dental Materials, 11th ed. St. Louis, Mosby, 2002.
12. Tucillo JJ: Compositional and functional characteristics of precious metal alloys for dental restorations. In Valega TM, ed: Alternatives to Gold Alloys in Dentistry [U.S. DHEW Publication No. (NIH) 77-1227], p 40. Washington, DC, Deptartment of Health, Education, and Welfare, Public Health Service, National Institutes of Health, 1977.
13. El-Ebrashi MK, et al: Electron microscopy of gold soldered joints. J Dent Res 47:5, 1968.
14. Leinfelder KF, et al: Hardening of dental gold-copper alloys. Dent Res 51:900, 1972.
15. Chaves M, et al: Effects of three soldering techniques on the strength of high-palladium alloy solder. J Prosthet Dent 79:677, 1998.

16. Phillips RW: Skinner's Science of Dental Materials, 8th ed. Philadelphia, WB Saunders, 1982.
17. Sloan RM, et al: Postceramic soldering of various alloys. J Prosthet Dent 48:686, 1982.
18. Beck DA, et al: A quantitative study of preporcelain soldered connector strength with palladium-based porcelain bonding alloys. J Prosthet Dent 56:301, 1986.
19. Staffanou RS, et al: Strength properties of soldered joints from various ceramic-metal combinations. J Prosthet Dent 43:31, 1980.
20. Anusavice KJ, et al: Flexure test evaluation of presoldered base metal alloys. J Prosthet Dent 54:507, 1985.
21. Sobieralski JA, et al: Torch versus oven precer-amic soldering of a nickel-chromium alloy. Quintessence Int 21:753, 1990.
22. Ferencz JL: Tensile strength analysis of midpontic soldering. J Prosthet Dent 57:696, 1987.
23. Fehling AW, et al: Cast connectors: an alternative to soldering base metal alloys. J Prosthet Dent 55:195, 1986.
24. Saxton PL: Post-soldering of nonprecious alloys. J Prosthet Dent 43:592, 1980.
25. Gordon TE, Smith DL: Laser welding of prostheses—an initial report. J Prosthet Dent 24:472, 1970.
26. Preston JD, Reisbick MH: Laser fusion of selected dental casting alloys. J Dent Res 54:232, 1975.
27. Kasenbacher A, Dielert E: Tests on laser-welded or laser-soldered gold and Co/Cr/Mo dental alloys. Dtsch Zahnarztl Z 43:400, 1988.
28. Van Benthem H, Vahl J: Corrosion behavior of laser-welded dental alloys. Dtsch Zahnarztl Z 43:569, 1988.
29. Wiskott HW, et al: Mechanical and elemental characterization of solder joints and welds using a gold-palladium alloy. J Prosthet Dent 77:607, 1997.
30. Sjögren G, et al: Laser welding of titanium in dentistry. Acta Odontol Scand 46:247, 1988.
31. Ortorp A, et al: Clinical experiences with laser-welded titanium frameworks supported by implants in the edentulous mandible: a 5-year follow-up study. Int J Prosthodont 12:65, 1999.
32. Gegauff AG, Rosenstiel SF: The seating of one-piece and soldered fixed partial dentures. J Prosthet Dent 62:292, 1989.
33. Sarfati E, Harter J-C: Comparative accuracy of fixed partial dentures made as one-piece castings or joined by solder. Int J Prosthodont 5:377, 1992.
34. Wee AG, et al: Strategies to achieve fit in implant prosthodontics: a review of the literature. Int J Prosthodont 12:167, 1999.
35. Lynch CD, McConnell RJ: Accurately locating the components of a fixed partial denture prior to soldering the connector: an intraoral technique. J Prosthet Dent 87:460, 2002.
36. Harper RJ, Nicholls JI: Distortions in indexing methods and investing media for soldering and remount procedures. J Prosthet Dent 42:172, 1979.
37. Moon PC, et al: Comparison of accuracy of soldering indices for fixed prostheses. J Prosthet Dent 40:35, 1978.
38. McDonnell T, et al: The effect of time lapse on the accuracy of two acrylic resins used to assemble an implant framework for soldering. J Prosthet Dent 91:538, 2004.

29

FINISHING THE CAST RESTORATION



KEY TERMS

airborne particle abrasion
axial walls
external margin
finishing
intaglio
internal margin
internal surface
marking agent
polishing
proximal contact
rouge
sprue

A cast metal restoration is not ready for evaluation and cementation merely because it has been stripped of its investment. The unpolished surface is relatively rough, and a series of **finishing** procedures are needed to produce highly polished axial surfaces. Such surfaces limit the accumulation[1,2] and retention[3] of plaque and facilitate maintenance of health of the supporting periodontal tissues. The **sprue** needs to be removed, and the area of its attachment needs to be recontoured. Any nodules or other minor irregularities remaining on the cast surface must be eliminated.

Metal finishing for metal-ceramic restorations is similar to that for cast metal. The discussion in this chapter is applicable to both restoration types. In practice, the final **polishing** of metal-ceramic restorations is not done until after characterization and glazing (see Chapter 30).

OBJECTIVES AND PROCEDURES

The objectives and procedures for finishing are different for each part of the cast restoration. The following discussion is sequentially divided into corresponding phases; each is identified as a zone (Fig. 29-1).

Zone 1: Internal Margin

Objective

To minimize any dissolution of the luting agent, a 1-mm-wide band of metal must be obtained that is closely adapted to the tooth surface.[4] A defect within this zone can significantly reduce a restoration's longevity. Good adaptation is obtained by carefully reflowing the wax pattern (Fig. 29-2). With careful standardization of technique, the dentist can achieve predictable and consistent results.

Procedure

If a defect occurs in the marginal area, the restoration must be remade. This may require an additional patient visit to make the new impression. Defects can be prevented or minimized by paying particular attention to reflowing the margins of the wax pattern and through careful investing (see Chapter 22).

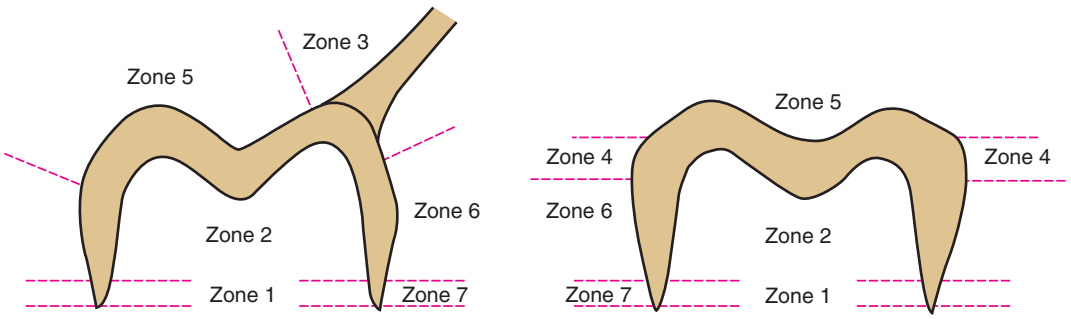


Fig. 29-1
Recommended sequence for finishing of a cast restoration. All procedures for a zone should be completed before the next zone is started. *Zone 1* is the internal margin; *Zone 2*, the internal surface; *Zone 3*, the sprue; *Zone 4*, the proximal contacts; *Zone 5*, the occlusal surface; *Zone 6*, the axial walls; and *Zone 7*, the external margins.

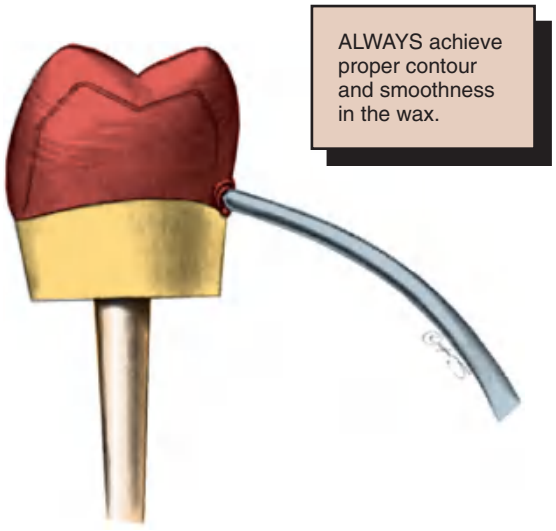


Fig. 29-2
Reflowing the wax pattern. The objective is to create a well-adapted 1-mm zone to prevent cement dissolution. Proper reflowing before investing is a prerequisite to accomplish this.



Fig. 29-3
Nodules on a casting have resulted from improper investing. To enable complete seating of the casting, even small ones such as these must be removed entirely.

Even small nodules can prevent a casting from seating completely. Careful examination under ample magnification helps identify interferences. Small nodules, if far enough away from the margin itself, can be removed under a binocular microscope with exceptionally cautious use of very small rotary instruments (e.g., a No. ¼ round bur). However, great care is needed to avoid damage to the margin and annoying remakes.

Zone 2: Internal Surface (Intaglio)

Objective

No contact should exist between the die and the internal surface (**intaglio**) of the casting. A uniform space of 25 to 35 μm is necessary for the luting agent to spread evenly. Any contacts must be identified and relieved by careful selective grinding of the internal surface.

Procedure

Under normal circumstances, a casting's internal surface does not require finishing. It should, however, be examined for nodules (Fig. 29-3) before the restoration is seated on the die. Nodules can be removed with a small round carbide bur, which can be time consuming because it may need to be repeated several times. If the internal surface needs to be adjusted more than occasionally, the investing procedure should be reexamined for flaws.

Even a very small nodule can result in significant increase of the marginal gap width (Fig. 29-4). A binocular microscope is especially helpful in identifying nodules. High-quality loupes can also be used. Great care should be exercised when seating a casting on its die. Any significant force will abrade or chip the die so that the casting will seat on the die but will not seat fully on the prepared tooth. Over-

NEVER force the casting onto the die; use great caution when fitting the casting.

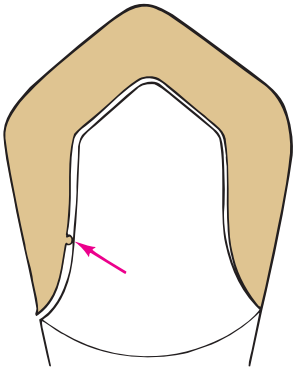


Fig. 29-4
A relatively small nodule (*arrow*) results in a substantial open margin.



Fig. 29-5
A, Internal surface of a casting. Note the stone (*arrow*) adhering where the die has been abraded by the casting. **B**, A suitable marking agent (e.g., rouge and turpentine) can be used to detect areas that must be relieved to allow complete seating.

looking this at the cementation appointment will result in a restoration with open margins and a poor prognosis. If a casting does not seat, a nodule may have been overlooked and may have scratched the die, or a little stone may have been picked up in the process. Close examination of the internal surface of the casting or the **axial walls** of the die (Fig. 29-5) will reveal this. Corrective action is often relatively simple, and the casting may be acceptable. Care must be taken not to seat a faulty casting repeatedly, thereby abrading the die. After a die has been abraded by a casting, it should not be used for rewaxing a restoration. If rewaxing is necessary, a new impression is required.

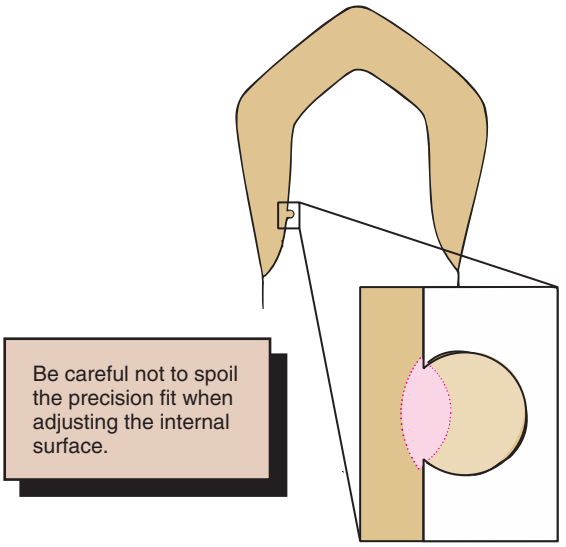


Fig. 29-6
When removing a nodule, remove slightly more than the defect to ensure complete seating of the restoration.

When a nodule is removed from the internal aspect of a casting, deliberately removing a slightly greater amount of alloy in the area is recommended. Once the casting has been adjusted, determining the exact location of the nodule is no longer possible. Therefore, the nodule should be removed entirely in one step, rather than through sequential relief of the internal surface (Fig. 29-6).

Indiscriminately removing material from the internal aspect of any casting is not an acceptable alternative. This results in excessive loss of retention and resistance form, and the restoration must be remade.

Marking agents

Several agents are commercially available to facilitate identification of the seating interference between the casting and the die. These include water-soluble dies (e.g., Liqua-Mark*), solvent-based dies (e.g., AccuFilm IV†), and powdered sprays (e.g., Occlude‡). A suspension of **rouge** in turpentine or an elastomeric detection paste (e.g., Fit Checker, Fit Checker II§) can also be used as an alternative.[5,6] These agents should be applied as a thin film to the internal surface of the casting. High magnification of the casting after seating reveals initial contact for grinding (Fig. 29-7). Regardless of the method used, the internal surface of the casting should always be thoroughly cleaned before the luting procedure (see Chapter 31).

*Leach & Dillon Products, Cranston, Rhode Island.
†Parkell, Inc., Farmingdale, New York.
‡Pascal Company, Inc., Bellevue, Washington.
§GC America, Inc., Alsip, Illinois.



Fig. 29-7
Liquid marking agents can be helpful if the internal surface of a casting has a nodule. **A**, Incomplete seating. **B**, Liquid marking agent. **C**, A thin coat is applied to the internal surface and air dried. **D**, Casting gently returned to the die. **E**, Area of interference identified. **F**, Nodules are best removed with a small round bur. **G**, Seated casting.

Zone 3: The Sprue

Objective

To reestablish proper coronal structure and function, the sprue must be sectioned, and the casting must be recontoured in the area of its attachment.

Procedure

Once the fit of the casting has been verified on the die and it has been found to be acceptable, the sprue is sectioned, and the area of its attachment to the casting (Fig. 29-8) is reshaped.

A carborundum separating disk is used to cut through the sprue. Cutting should be performed circumferentially, with a small area maintained in the center of the sprue. This last connection is broken by twisting and separating it from the casting. Wire cutters are not recommended, because they may lead to distortion of the casting. Any excess in the area of the sprue attachment is removed with the disk, and the area is refined with stones and sandpaper disks.

Zone 4: Proximal Contacts

Objective

The proximal contact areas are adjusted in the laboratory so that they will be correct (or slightly too tight) when the casting is evaluated in the mouth.

Procedure

Special care is needed to prevent the finishing procedures from producing an overreduced and, consequently, inadequate proximal contact. Although this can be corrected with solder (see p. 889), it is a time-consuming and unnecessary procedure.

A slightly excessive contact, however, may be corrected easily during clinical evaluation. The proximal contacts on the stone cast can be minimally relieved by careful scraping with a scalpel (Fig. 29-9). The casting is then adjusted until it just seats. When adjacent castings are made, they should not be simultaneously adjusted to seat on the definitive cast. Under these circumstances, the proximal contacts should be left slightly too tight in the dental laboratory. For such multiple castings, clinical evaluation is done sequentially and on an individual basis. Adjustments are made for each casting independently.

When proximal contacts are adjusted, placing a thin Mylar articulating film between adjacent castings or between the casting and the adjacent tooth is helpful (Fig. 29-10). Doing this allows the areas where binding contact occurs to be adjusted through selective adjustment where markings result.

Connectors

When a partial fixed dental prosthesis is being finished, the connectors require special attention.



Fig. 29-8
A, The button is most effectively removed by cutting around the sprue and then twisting it off (**B**). **C**, With multiple castings made simultaneously, access is more difficult. When it is necessary to sever a sprue completely, care must be taken not to damage the margin inadvertently. **D**, Disks and stones are used for gross recontouring.



Fig. 29-9
Rather than risk a deficient proximal contact at evaluation, the technician may reduce the cast slightly by scraping the adjacent teeth with a blade.

Unless they are properly contoured and highly polished, periodontal health is invariably adversely affected, even in the presence of the most meticulous oral hygiene. Mesiodistally, a properly finished connector has a parabolic configuration (Fig. 29-11). Rotary instruments such as rubber wheels, which allow access to the cervical aspect of the connector for finishing while not jeopardizing the margin, are essential in these situations. In cases of root proximity between adjacent teeth, this can be quite problematic. After preliminary finishing with rubber wheels, a piece of twine can be used to impart the final polish to the cervical aspect of the connector (Fig. 29-12).

Zone 5: Occlusal Surface

Objective

Occlusal contacts are reestablished in static and dynamic relationships to the opposing arch. Obtaining accurate and stable contacts does not require highly polished metal occlusal surfaces. A satin finish is acceptable. Occlusal structure must ensure positional stability and satisfy all functional requirements (see Chapter 4).

Procedure

The occlusal contacts are checked with thin Mylar articulating film (Fig. 29-13) to ensure that they match the design in the waxing stage. If they do not, the occlusion must be adjusted. Wax is subject to elastic recovery. If an occlusal contact is heavy in wax, it springs back slightly when the articulator is opened and produces an occlusal prematurity in the casting (Fig. 29-14). If "pinpoint" contacts are established carefully during the waxing phase, significant occlusal adjustment should not be necessary.

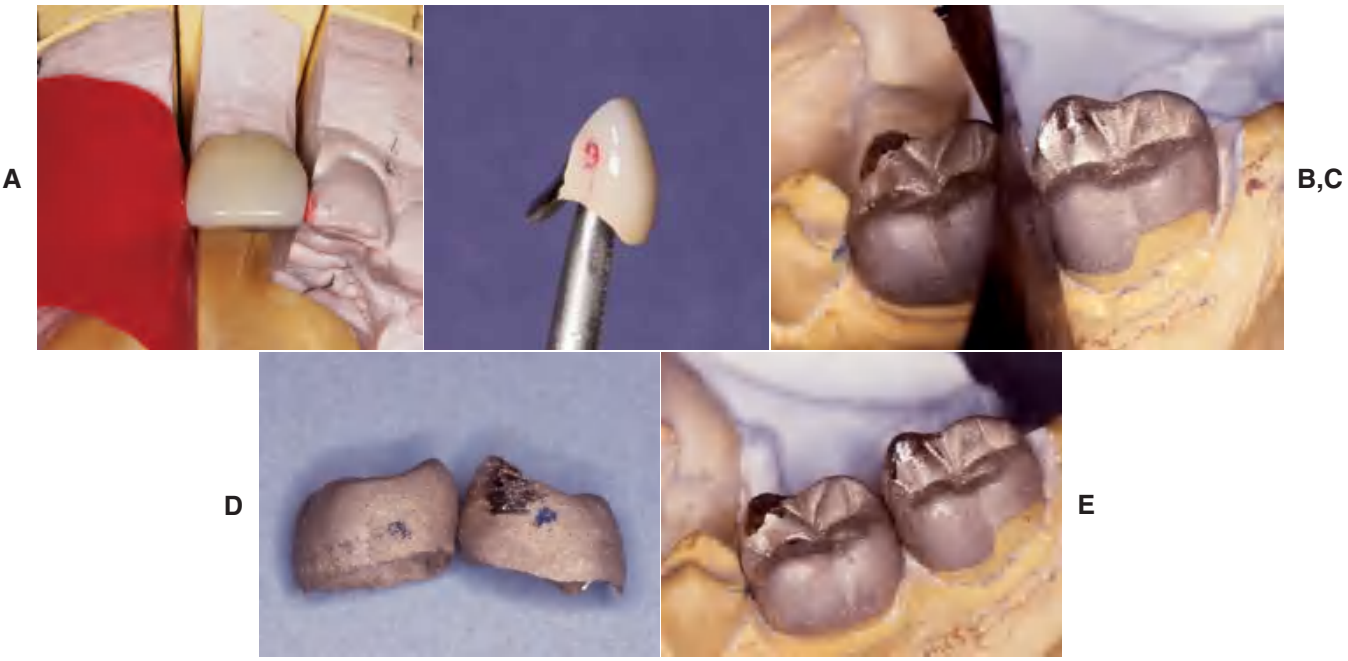


Fig. 29-10
A, Thin articulating film interposed between a metal-ceramic restoration and the adjacent tooth. **B,** The area of contact that prevents complete seating is readily apparent. **C** to **E,** Articulating film is used to detect the location of an excessive proximal contact on cast metal.

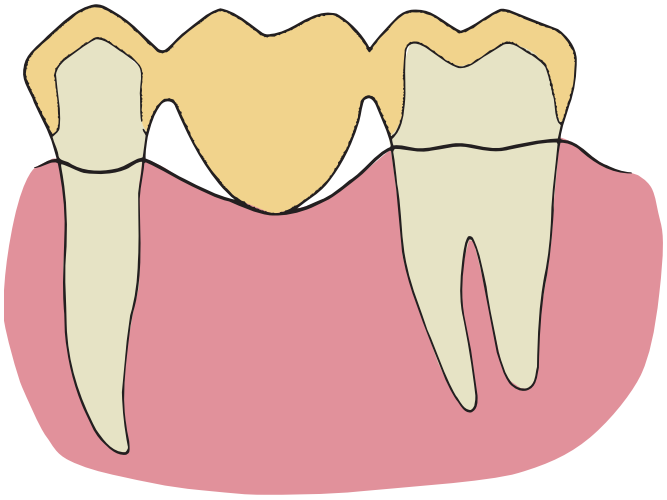


Fig. 29-11
Cross-section depicting properly finished connectors.



Fig. 29-12
Polishing connector areas. **A** and **B,** Twine impregnated with polishing compound is an efficient way to polish this hard-to-reach area.



Fig. 29-13
After complete seating is verified, the initial point of contact is marked.



A and **B,** Occlusal prematurities are generally the result of excessively heavy contact on the wax pattern.

Occlusal adjustments can be performed with flame-shaped finishing burs or diamonds (Fig. 29-15). A large stone creates unwanted concavities in the occlusal surface. The correct technique for occlusal adjustment is to redevelop the anatomy of the entire ridge or cusp rather than grinding only the point of interference. Simultaneously, any nodules can be removed, and grooves can be defined with a finishing bur or a small round bur.

Before starting any adjustment, the practitioner should use a thickness gauge on the metal. If only minimum clearance was established at the tooth-preparation stage, indiscriminate adjustment leads

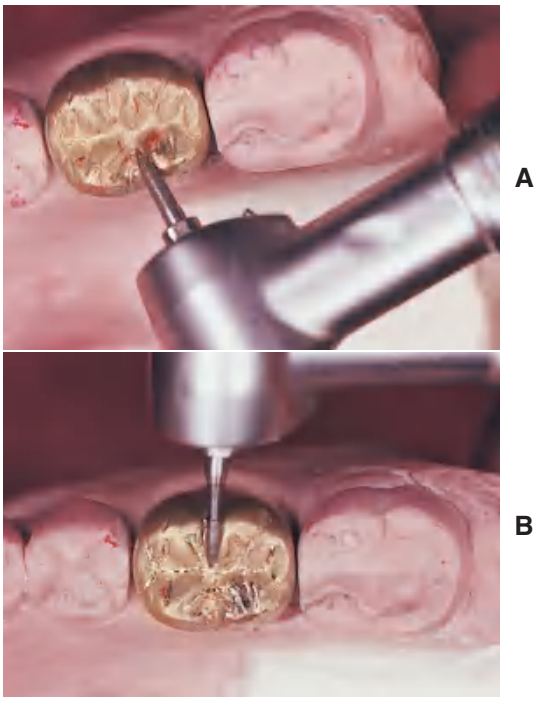


Fig. 29-15
A, Occlusal adjustment is readily accomplished with a pointed diamond or carbide bur. **B,** The grooves and fissures are concurrently refined.

to inadequate thickness of the casting (Fig. 29-16) and possible perforation. Although soldering such a hole in a casting is possible, the occurrence of this complication usually indicates an earlier error that requires correction (e.g., inadequate clearance necessitates additional reduction of the tooth preparation).

After the occlusal contacts have been refined, they must not be altered by extensive polishing. A high polish may be essential for plaque control on axial surfaces (Zones 6 and 7), but its benefit is questionable on the occlusal surface of metal castings. In fact, an accurate occlusion so painstakingly established in wax can be rapidly destroyed by overzealousness to make a casting "look pretty."

If the wax pattern has been carefully finished, a smooth casting results, and removing surface oxides with a soft wire brush wheel is sufficient. The surface can then be polished with rouge on a soft brush wheel (which removes only 5 μm from the surface of the casting[7]) (see Fig. 29-19).

Some authorities[8] recommend producing a matte finish on the occlusal surfaces to aid in the initial identification of wear facets during function, which show up as shiny marks on an otherwise dull surface. This type of finish is usually achieved with an **airborne particle abrasion** unit and 25- to 50-

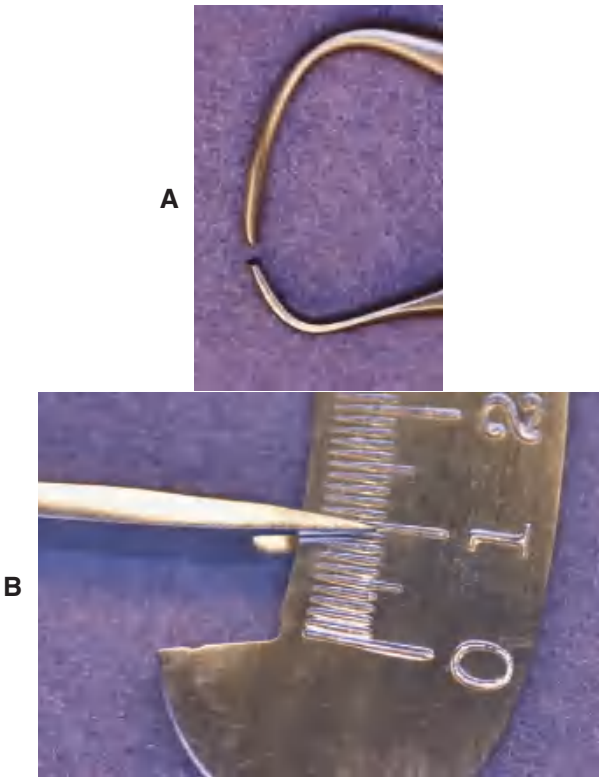


Fig. 29-16
As occlusal adjustments are made (**A**), the residual thickness is continually monitored with an appropriately designed thickness gauge (**B**). For structural durability, less than 1.0 mm is inadequate metal thickness and is the result of insufficient occlusal reduction.

μm Al_2O_3 (alumina) particles. However, a 5-second blast with 50-μm alumina at 0.5 MPa (73 psi) pressure removes about 20 μm of metal from the air-abraded surfaces[9]; therefore, the margins should be protected.[10] An exposure of about 1 second usually produces a smooth satin finish. If this cannot be accomplished, it is likely that the preparation before this step was deficient, and further refinement is necessary.

Zone 6: Axial Walls

Objective

When axial wall finishing is completed, the walls should be smoothly contoured and highly polished, enabling the patient to carry out optimum plaque control.

Procedure

Surface defects are removed by grinding with abrasive particles bound into a grinding stone or rubber wheel, on a paper disk, or applied as an abrasive paste (Fig. 29-17). Each particle acts as a cutting tool on the metal surface.

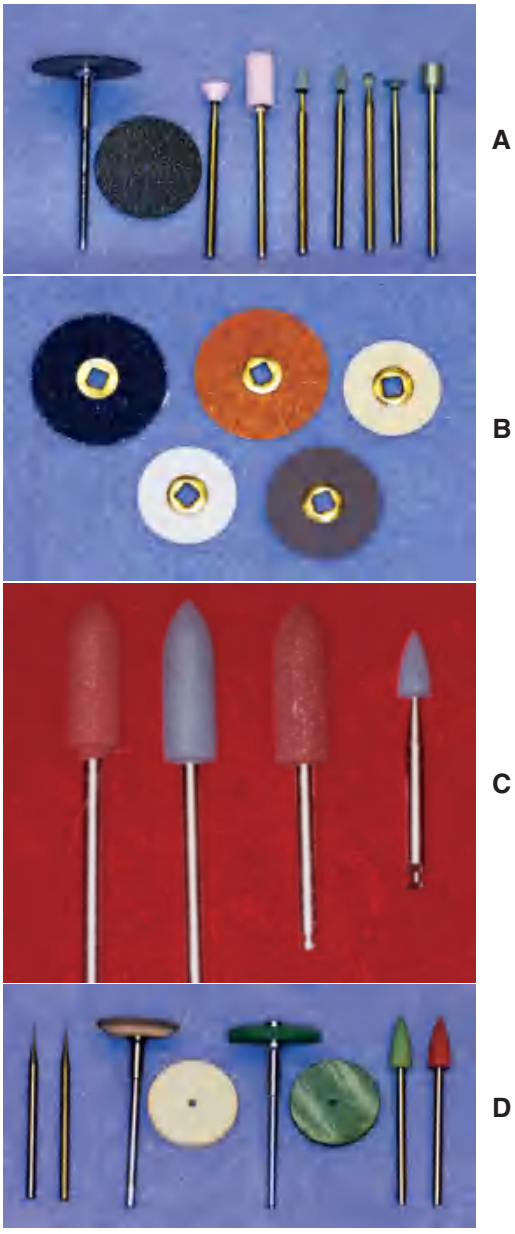


Fig. 29-17
Abrasives for finishing. A sequence of progressively finer grades is used to attain the desired surface. Carborundum disks and stones of varying degrees of coarseness (**A**) are typically used first; these are followed by garnet paper and sandpaper disks (**B**), rubber points and white Arkansas stones (**C**), and rubber wheels and points along with small carbide burs for removing nodules (**D**).

The most efficient method of polishing[11] is a sequence of progressively finer abrasives (Fig. 29-18), each removing the scratches made by the previous grade. Time is wasted if the progression to



Fig. 29-18

Finishing armamentarium. **A,** Assorted abrasives, sandpaper disks, rubber points, and polishing wheels. **B,** Instruments used range from small carbides (for removing nodules) and a steel wire brush (for occlusal surface smoothing) to buffing wheels and compounds. **C,** A coarse wheel is used to true and thin the edge of a rubber wheel. **D,** Buffing compounds applied on a felt wheel or bristle brush.

a finer grade abrasive is too rapid, because the coarser grits remove material much more efficiently.

Light pressure is applied when abrasives are used, and the instrument must be kept rotating; otherwise, the surface of the casting is ground into a series of facets that ultimately impede plaque control. When all surface irregularities have been removed and the progression through the series of abrasives has left a finish with only minute scratches, the axial surfaces of the restoration are polished. Jeweler's rouge rapidly produces a high polish on a well-prepared surface of a dense casting (Fig. 29-19*K*). This is carried on a wheel or brush, with heavier pressures and higher rotational speeds than were used in finishing (see Fig. 29-19).

Zone 7: External Margins

Objective

Margin finishing is crucial for a restoration's longevity and therefore merits special attention. The objective of all cast restoration finishing is a highly polished metal surface without ledges or steps as the transition is made from restoration to unprepared tooth. Failure to accomplish this leads to compromised plaque control.

Procedure

Where access allows, cavosurface margins should be finished directly on the tooth (see Fig. 30-10). Unfortunately, the areas where access for finishing is restricted (e.g., proximally or subgingivally) are precisely where plaque control presents the most problems. Therefore, only the least crucial areas can be finished intraorally. An advantage of partial-coverage restorations over complete crowns is that they allow better access for finishing margins and for subsequent plaque control.

The parts of the margin that cannot be finished on the tooth are finished on the die (Fig. 29-20). Care must be taken not to remove more metal than is strictly necessary. Excessive finishing creates problems similar to those caused by incomplete polishing. This raises the issue of how much material can be removed from the surface of a casting without compromising the ultimate fit and emergence profile of the finished restoration.



Fig. 29-19

Finishing and polishing. **A,** Initially a wire brush is used on the occlusal surfaces. **B,** A fine-grit sandpaper disk is applied for removing pits and irregularities from the axial walls. Note that the margin is not touched at this time. **C** and **D,** Rubber points and small carbides for selective finishing of the occlusal structure. **E,** A rubber wheel is then used on the axial walls. **F,** Castings, after polishing with buffing compound, immediately before clinical evaluation. **G,** When the fit has been verified clinically, the margins are polished. **H** and **I,** The completed castings immediately before cementation. **J,** Scanning electron micrograph of a gold alloy in the "as-cast" state. **K,** The same casting after finishing and polishing with a series of abrasives culminating in rouge. *(**J** and **K,** Courtesy of Dr. J. L. Sandrik.)*

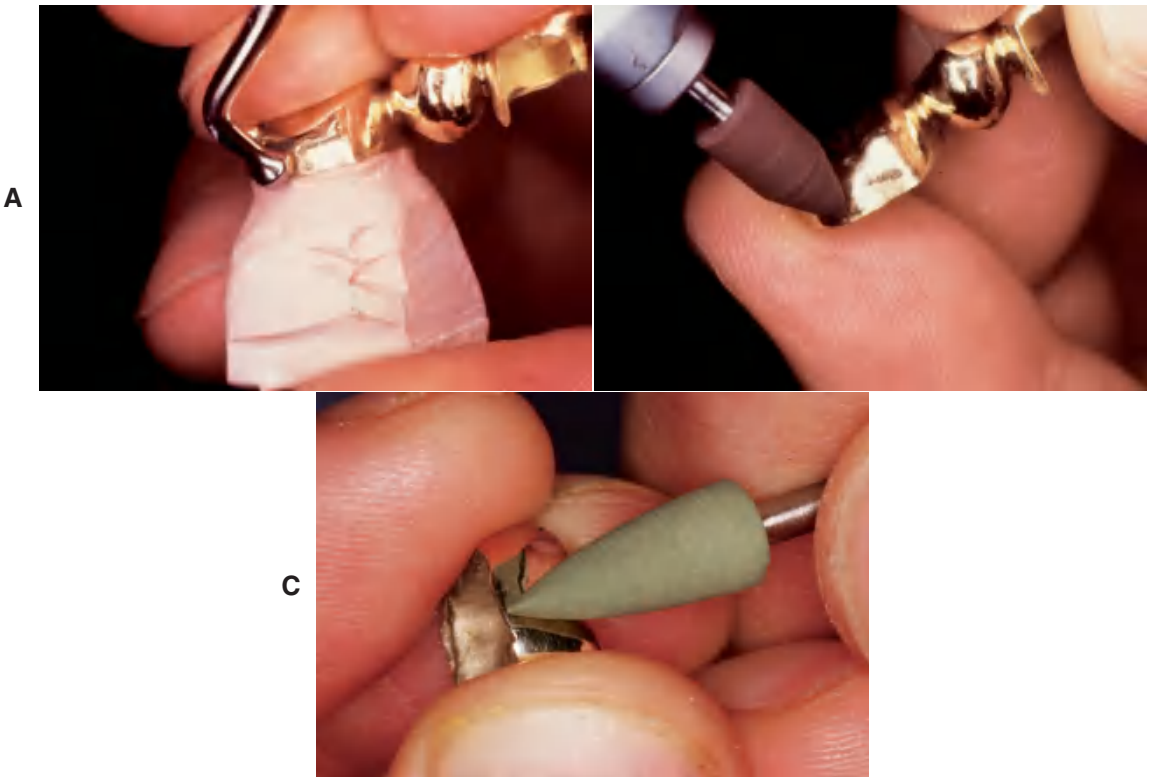


Fig. 29-20
When subgingival margins do not allow access, final finishing is performed on the die. **A** to **C,** During final polishing, the margin is carefully supported with a finger.

A stone die from a polysulfide impression is approximately 25 μm wider than the tooth because of polymerization and thermal shrinkage of the impression material and expansion of the gypsum.[12] In theory, therefore, if 12.5 μm is removed during finishing, the casting will be flush with the tooth surface. Although these values cannot be measured on a day-to-day basis in a dental office, they illustrate the tolerances of, and restrictions imposed by, the materials that are currently in use.

The edge of the margin must not be distorted during finishing, although carefully rubbing a smooth instrument along the length of the margin (burnishing) (see Fig. 29-20*A*) may improve the margin,[13,14]* but only when softer alloys are used.[15]

Finishing should be performed by gently brushing a fine-grit stone over the surface to remove casting roughness (see Fig. 29-20*B*). This is followed by a soft rubber wheel or point (see Fig. 29-20*C*) and finally by rouge on a brush. The margin should be supported with a finger during final polishing.

When the casting is smooth on all critical surfaces, any remaining polishing compound can be removed with a soft toothbrush, by ultrasonic cleaning in an appropriate solution, or by steam cleaning.

*Unfortunately, burnishing does not make a poorly fitting margin acceptable.

REVIEW OF TECHNIQUE

Figure 29-21 presents the steps involved in finishing a restoration and should be consulted when techniques are reviewed.

1. The internal margin is inspected to confirm that the casting accurately reproduces the prepared tooth and is intimately adapted to the prepared surfaces adjacent to the margin (see Fig. 29-21*A*).
2. The internal surface is inspected under magnification and adjusted as necessary with small stones and carbide burs. Adjustments are restricted to areas where binding contacts occur (see Fig. 29-21*B*).
3. The casting should seat completely without force and without noticeable rocking or instability (see Fig. 29-21*C*).
4. The sprue is removed (see Fig. 29-21*D*).
5. The area of its attachment is reshaped (see Fig. 29-21*E*).
6. The proximal contact areas are adjusted (see Fig. 29-21*F*).

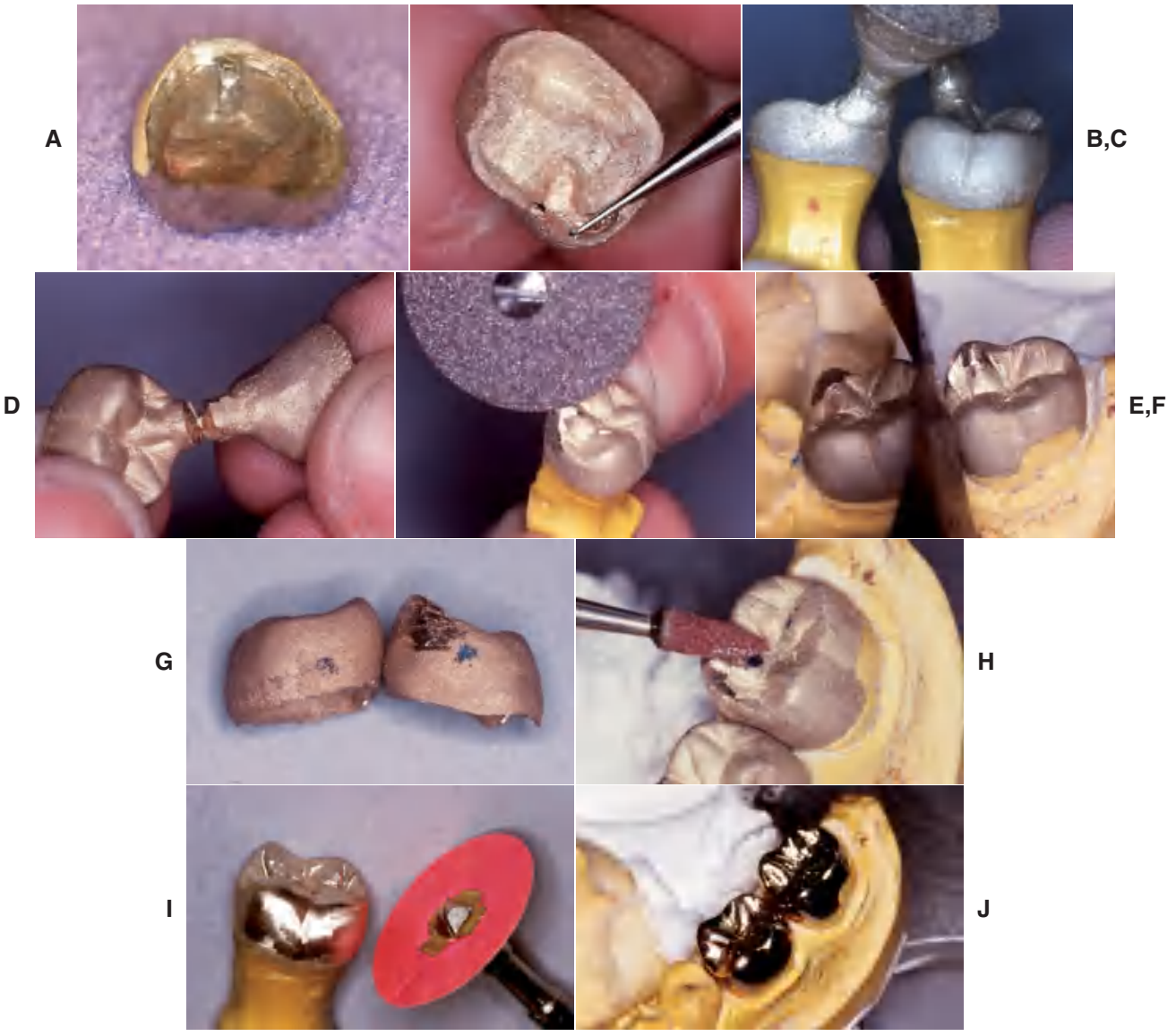


Fig. 29-21

Technique review. **A,** The internal margin is inspected to confirm that the casting accurately reproduces the prepared tooth and is intimately adapted to the prepared surfaces adjacent to the margin. **B,** The internal surface is inspected under magnification and adjusted as necessary with small stones and carbide burs. **C,** The casting should seat completely without force and without noticeable rocking or instability. **D,** The sprue is removed. **E,** The area of its attachment is reshaped. **F,** The proximal contact areas are adjusted. **G,** On the cast, proximal contacts can be left slightly tight before the clinical evaluation appointment. **H,** The occlusal surfaces are evaluated and adjusted. **I,** The axial surfaces are finished and polished. **J,** The polished restoration is cleaned.

7. On the cast, proximal contacts can be left slightly tight before the clinical evaluation appointment (see Fig. 29-21*G*).
8. The occlusal surfaces are evaluated and adjusted. No centric or excursive interferences should remain (see Fig. 29-21*H*).
9. The axial surfaces are finished and polished. Finishing the cervical aspect of axial walls on metal-ceramic restorations is postponed until after final glazing and characterization. In addition, if a soldering procedure is anticipated, the marginal area is left unfinished until the soldering has been completed and the fit of the assembled prosthesis is acceptable (see Fig. 29-21*I*).
10. The polished restoration is cleaned. A steam cleaner or ultrasonic cleaner (with the appropriate solutions) can be used. The cleaned castings are seated on the definitive cast (see Fig. 29-21*J*).

STUDY QUESTIONS

1. What is the purpose of finishing and polishing the margin of a cast restoration? The occlusal surface? The proximal contact area?
2. What is the recommended procedure for severing a sprue?
3. What is the recommended procedure for removing a nodule?
4. What is the recommended procedure for shaping and finishing a connector for a partial fixed dental prosthesis?
5. Discuss the uses and limitations of air particle abrasion in finishing cast restorations (gold and metal-ceramic).

GLOSSARY*

adaptation \ăd′ăp-tā′shun\ *n* (1610) **1:** the act or process of adapting; the state of being adapted **2:** the act of purposefully adapting two surfaces to provide intimate contact **3:** the progressive adjustive changes in sensitivity that regularly accompany continuous sensory stimulation or lack of stimulation **4:** in dentistry, (**a**) the degree of fit between a prosthesis and supporting structures, (**b**) the degree of proximity of a restorative material to a tooth preparation, (**c**) the adjustment of orthodontic bands to teeth

airborne-particle abrasion \âr′bôrn′ pär′tĭ-kal a-brā′zhun**:** the process of altering the surface of a material through the use of abrasive particles propelled by compressed air or other gases

aluminum oxide \a-lōō′mi-num ŏk′sīd′\ **1:** a metallic oxide constituent of dental porcelain that increases hardness and viscosity **2:** a high strength ceramic crystal dispersed throughout a glassy phase to increase its strength as in aluminous dental porcelain used to fabricate aluminous porcelain crowns **3:** a finely ground ceramic particle (frequently 50 um) often used in conjunction with air-borne particle abrasion of metal castings before the application of porcelain as with metal ceramic restorations

articulating paper \är-tĭk′ya-lāt′ing pā′per**:** ink-coated paper strips used to locate and mark occlusal contacts

Beilby layer [Sir George Thomas Beilby, British chemist, 1850-1924]: *eponym* for the molecular disorganized surface layer of a highly polished metal. A relatively scratch-free microcrystalline surface produced by a series of abrasives of decreasing coarseness.

Beilby GT. Aggregation and flow of solids, 1921.

bur·nish \bûr′nĭsh\ *vt* (14c)**:** to make shiny or lustrous by rubbing; also to facilitate marginal adaptation of restorations by rubbing the margin with an instrument

de·vest \dĭ-vĕst\ *vb***:** the retrieval of a casting or prosthesis from an investing medium

finish \fĭn′ĭsh\ *n* (1779)**:** to put a final coat or surface on; the refinement of form prior to polishing

in·tagl·io \ĭn-tăl′yō, -täl′-\ *n, pl* **-ios** \-yōs\ (1644) **1:** an incised or engraved figure in stone or any hard material depressed below the surface of the material such that an impression from the design would yield an image in relief **2:** something carved in intaglio

intaglio surface \ĭn-tăl′yō, täl′- sûr′fas**:** the portion of the denture or other restoration surface that has its contour determined by the impression; the interior or reversal surface of an object

man·drel \măn′dral\ also **man·dril** \măn′dral\ *n* (1790) **Ia:** usually a tapered or cylindrical axle, spindle, or arbor placed in a hole to support it during machining **Ib:** a metal bar which serves as a core about which material may be cast, molded, compressed, forged, bent or shaped **2:** the shaft and bearings on which a tool is mounted

pol·ish·ing \pŏl′ĭsh-ĭng\ *v, obs* **1:** to make smooth and glossy, usually by friction; to give luster to (GPT-1) **2:** *obs:* the act or process of making a denture or casting smooth and glossy (GPT-1)

polishing agents \pŏl′ĭsh-ĭng ā′jants**:** any material used to impart luster to a surface

rouge \rōōzh\ *n* (1753)**:** a compound composed of ferric oxide and binders used for imparting a high luster to a polished surface, glass, metal, or gems

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REFERENCES

1. Gildenhuys RR, Stallard RE: Comparison of plaque accumulation on metal restorative surfaces. Dent Surv 51:56, 1975.
2. Shafagh I: Plaque accumulation on cast gold complete crowns polished by a conventional and an experimental method. J Prosthet Dent 55:339, 1986.
3. Keenan MP, et al: Effects of cast gold surface finishing on plaque retention. J Prosthet Dent 43:168, 1980.

4. Mesu FP: Degradation of luting cements measured in vitro. J Dent Res 61:665, 1982.
5. White SN, et al: Improved marginal seating of cast restorations using a silicone-disclosing medium. Int J Prosthodont 4:323, 1991.
6. Troendle GR, Troendle KB: Polyvinyl siloxane as a disclosing medium. J Prosthet Dent 68:983, 1992.
7. Phillips RW: Skinner's Science of Dental Materials, 7th ed, p. 632. Philadelphia, WB Saunders, 1973.
8. Shillingburg HT, et al: Fundamentals of Fixed Prosthodontics, 2nd ed. Chicago, Quintessence Publishing, 1981.
9. Adams HF: Effect of abrasive blasting on castings of gold alloys. Op Dent 6:11, 1981.
10. Felton DA, et al: Effect of air abrasives on marginal configurations of porcelain-fused-to-metal alloys: an SEM analysis. J Prosthet Dent 65:38, 1991.
11. Troxell RR: The polishing of gold castings. J Prosthet Dent 9:668, 1959.
12. Rosenstiel SF: The marginal reproduction of two elastomeric impression materials. Master's thesis, Indiana University, 1977.
13. Eames WB, Little RM: Movement of gold at cavo-surface margins with finishing instruments. J Am Dent Assoc 75:147, 1967.
14. Goretti A, et al: A microscopic evaluation of the marginal adaptation of onlays in gold. Schweiz Monatsschr Zahnmed 102:679, 1992.
15. Sarrett DC, et al: Scanning electron microscopy evaluation of four finishing techniques on margins of gold castings. J Prosthet Dent 50:784, 1983.
16. Beilby GT: Aggregation and Flow of Solids; Being the Records of an Experimental Study of the Microstructure and Physical Properties of Solids in Various States of Aggregation, 1900-1921. London, Macmillan, 1921.

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30



EVALUATION, CHARACTERIZATION, AND GLAZING

KEY TERMS

castings
characterization
emergence profile
external color modification
glaze
glazing
internal color modification
overglaze
pigment
remount procedure
stains

EVALUATION

When the laboratory procedures have been completed, the restoration is ready to be evaluated in the patient's mouth before final finishing and cementation. The completed prosthesis is cleaned either ultrasonically or with a steam cleaner to remove any residual polishing compound and then disinfected. Metal **castings** need to be evaluated in terms of proximal contacts, margin integrity, stability, internal fit, external contours, occlusion, and surface finish.

Metal-ceramic restorations often require two evaluations: a metal evaluation stage, followed by reevaluation after the esthetic veneer has been applied. At the metal evaluation appointment, the margin integrity, stability, occlusion, and substructure design are evaluated. Especially important at this appointment is the assessment of the cut-back area. Minor adjustments can be made: for instance, by extending the veneering surface slightly interproximally to enhance the appearance of the completed prosthesis. During the subsequent bisque evaluation, marginal integrity and stability are reassessed to determine whether any distortion has occurred during porcelain firing. Proximal contacts are also evaluated during this stage, as are porcelain contours, stability, and the shade, texture, and **glaze.** For fixed dental prostheses (FDPs), tissue contact of the pontics and the location and shape of connectors need careful assessment; otherwise, tissue irritation may occur. Primarily because of the inevitable inaccuracies that result during the indirect technique and the high degree of precision needed for a successful fixed prosthesis, only rarely does the restoration not require some chairside adjustment.

Interim Restoration and Luting Agent

The interim restoration is removed by gently positioning hemostats or a Backhaus towel clamp on the buccal and lingual surfaces and rocking it gently in a buccolingual direction to break the seal of the interim luting agent. Special band removers (Fig. 30-1) may also be used. Most of the luting agent or interim cement adheres to the interim restoration when it is taken out of the mouth. Any remaining

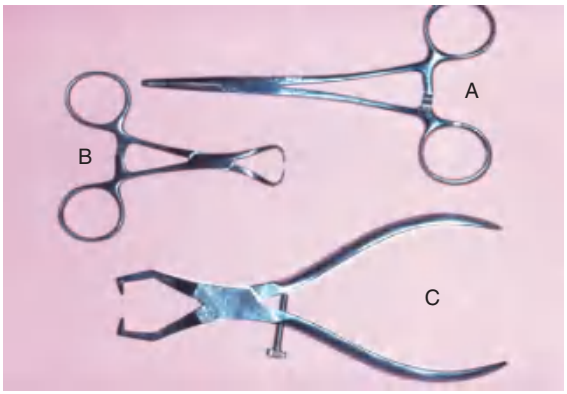


Fig. 30-1
Hemostat (*A*), Backhaus towel clamp forceps (*B*), and Baade-type band remover (*C*).

cement should be loosened from the prepared tooth surface with an explorer, followed by careful application of a water-pumice mixture* in a prophylaxis cup. Slow speed and relatively light pressure are essential. Polishing the preparation is undesirable because it may lessen retention. The preparations are rinsed with water and air spray, and after drying, the area is inspected. All residual luting agent must have been removed, because even a very small particle of interim cement can prevent a casting from seating completely.

Evaluation Sequence

Following a logical sequence during the evaluation procedures is important if mistakes are to be avoided. The recommended sequence is as follows:

1. Proximal contacts.
2. Marginal integrity.
3. Stability.
4. Occlusion.
5. **Characterization** and **glazing**.

The proximal contacts are evaluated first because excessive contact there prevents the restoration from seating, leading to a marginal discrepancy. Obviously, if a restoration is not seating completely, assessing stability and sectioning, or adjusting the occlusion, is premature.

Proximal Contacts

The location, size, and tightness of a restoration's proximal contacts should resemble those of the natural teeth. Typically, textbooks refer to contacts

*As an alternative, the pumice can be mixed with an antimicrobial such as Consepsis (Ultradent Products, Inc., South Jordan, Utah), which may reduce postcementation sensitivity.



Fig. 30-2
Deficient mesial contact, which could allow food to become impacted.

that allow unwaxed floss to "snap" through "relatively easily." Although this is not a very scientific definition, the use of floss is a convenient method for comparing the contacts with other contacts between adjacent teeth in the arch. If the floss does not pass, the contact is excessively tight; if it goes through too easily, food impaction may result (Fig. 30-2). The use of shim stock (thin Mylar film) is probably a more reliable indicator of proximal contact. The ideal contact should allow for positional stability of the abutments and adjacent teeth, as well as easy maintenance of the supporting structures. Most patients give reliable information as to a tight proximal contact when asked whether they "feel as though they have a seed between their teeth," provided that a local anesthetic has not been administered. A deficient contact is easily overlooked but invariably results in discomfort as food becomes impacted.

Excessive tightness

All-metal restorations

If a tight contact prevents the seating of an all-metal restoration, adjustments are readily made with a rubber wheel. The satin finish produced helps identify where binding occurs, because a shiny spot (Fig. 30-3) appears where adjustment is necessary.

When a contact is too tight, the restoration is removed from the mouth, adjusted, and then reevaluated intraorally. The dentist must remember to allow a small degree of excessive tightness for polishing. When both proximal contacts of a crown are excessively tight, the dentist should make adjustments on an alternating basis, verifying whether additional material needs to be removed before proceeding with further adjustments.

Porcelain restorations

A tight proximal contact in unglazed porcelain is easily adjusted with a cylindrical stone. The area of contact (Fig. 30-4) can be identified with red pencil or thin marking tape.



Fig. 30-3
Identifying the location of a tight proximal contact. The metal is given a matte finish by grinding with a rubber wheel. A shiny mark is formed where the contact is excessive.



Fig. 30-4
The location of tight porcelain contacts can be identified with thin marking tape.

After glazing, a slight change in the contact may be observed because of the pyroplastic surface flow that occurs during firing. If adjustment of a glazed restoration is needed, it can be repolished with diamond-impregnated silicone points, pumice, or diamond-polishing paste.

Deficiency

All-metal restorations

A gold casting with a deficient proximal contact can usually be corrected by soldering (Fig. 30-5). The procedure is simple and can be performed in the dental office in a matter of minutes. However, soldering a proximal contact should not be routinely necessary. After soldering, the restoration requires repolishing.

Armamentarium (see Fig. 30-5A)

- Soldering tweezers
- Gold solder
- Paste flux
- Bunsen burner
- Antiflux
- Polishing armamentarium

Step-by-step procedure

1. Roughen the deficient area with a disk (see Fig. 30-5*B*).
2. Protect the margin of the casting with a graphite pencil (or another suitable antiflux) (see Fig. 30-5*C*).
3. Coat a small piece of solder with flux and position it on the previously roughened surface (see Fig. 30-5*D*).
4. Hold the casting with the soldering tweezers in a properly adjusted flame of the Bunsen burner to position the solder at the height of the reducing portion of the flame (see Fig. 30-5*E*).
5. Observe the solder carefully as it heats up. As the solder starts to fuse, it rapidly spreads. With a little practice, the casting can be tipped to help the solder flow in the desired direction. The casting is then immediately removed from the flame.
6. Pickle the casting, and adjust the proximal contours with disks (see Fig. 30-5*F*) before repolishing and cleaning.

Porcelain restorations

A deficient proximal contact in porcelain requires additional firing. At the bisque stage, this is time consuming, but adding additional porcelain is not a problem. However, if a restoration has been completely finished, glazed, and characterized at the time the deficient contact is discovered, a lower fusing "add-on" or correction porcelain can be used to solve the problem (Fig. 30-6).

These correction porcelains are a mixture of body porcelain and **overglaze** with additional modifiers to produce a maturation temperature as low as 850° C (1562° F). Minor corrections can thus be made with little risk of dimensional change in any other part of the restoration. Major corrections should be made by performing an additional firing with the conventional body and incisal powders, although there are limits to the number of times a restoration can be fired if devitrification is to be avoided (see Fig. 24-36*B*).

Margin Integrity

The completed restoration should go into place without binding of its internal aspect against the occlusal surface or the axial walls of the tooth preparation; in other words, the best adaptation should be at the margins. If the indirect procedure is handled properly, there should be no noticeable difference between the fit of a restoration on the die and that in the mouth.

Several techniques have been used to detect where a casting binds against an occlusal or axial wall, including disclosing waxes, a suspension of

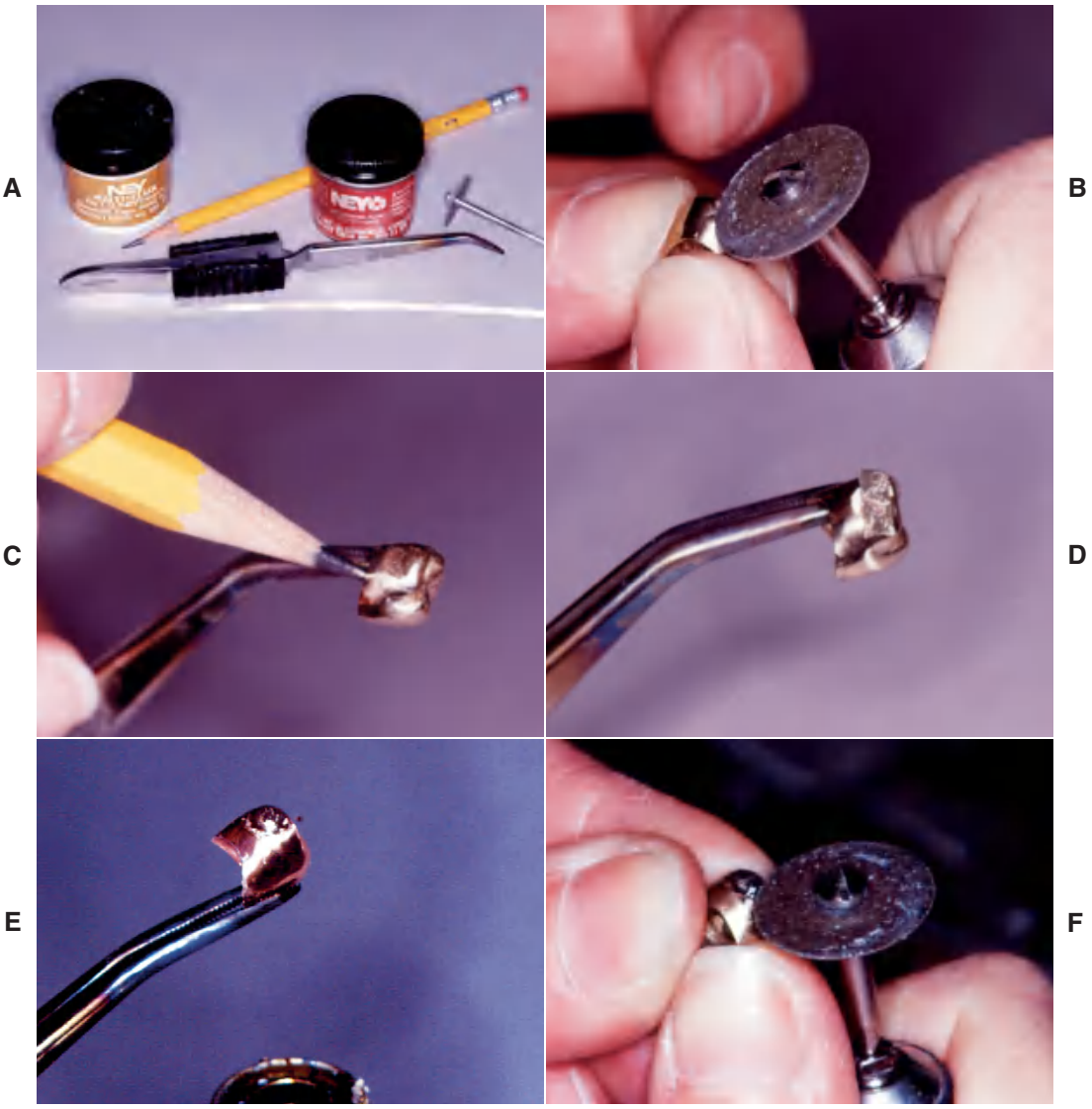


Fig. 30-5
Adding a proximal contact with gold solder. **A,** Armamentarium. **B,** Roughening the deficient proximal surface. **C,** Adding antiflux (graphite or rouge/turpentine) to the margin. **D,** Segment of solder positioned with paste flux. **E,** Heated over a Bunsen burner flame until the solder just melts. **F,** Proximal contact readjusted.

rouge in turpentine or acetic acid, air abrasion to form a matte finish surface, powdered sprays, water-soluble marking agents (Fig. 30-7), and special elastomeric detection pastes. However, none has proved to be entirely satisfactory. Most techniques are rather messy and time consuming and should not be needed on a routine basis.

Nevertheless, elastomeric paste (Fig. 30-8) has some advantages. The material is similar to a silicone impression material and is obtained as a two-paste system. Its viscosity is similar to that of the final luting agents, and so it can be used not only to identify unwanted internal contacts but also to assess adequate marginal fit. The degree of clinically acceptable marginal opening (i.e., the discrepancy unlikely to have an adverse effect on the prognosis) is hard to define. Margin integrity has been the subject of many laboratory and clinical evaluations. Obviously, to limit dissolution of the luting agent, the thickness of the cement film at the margins should be kept minimal. Through careful technique, a marginal gap width of less than 30 μm can be obtained consistently.[1,2]

Assessment

Figure 30-9 illustrates some of the possibilities that may be encountered in verifying margin integrity. The presence of a small ledge does not necessarily



Fig. 30-6
Correction of a defective proximal contour with low-fusing, add-on porcelain (**A**). **B,** Applying the porcelain. **C,** Corrected proximal contours. **D,** Fired restoration.



Fig. 30-7
Water-soluble marking agent.

mean that the restoration must be remade. It may merely require additional finishing where accessibility allows.

A sharp explorer moved from restoration to tooth and from tooth to restoration can be used in evaluating the marginal adaptation. If resistance is encountered in both directions, a gap or open margin exists, and its cause must be determined. If the gap is the result of an excessive proximal contact or of residual interim luting agent that prevents the casting from being seated, corrective action can be easily taken and the situation remedied. However, an obviously inaccurate restoration should be quickly rejected. Trying to "make it fit" should be avoided, because a new impression is a better use of time.

Finishing

Subgingival margins are not accessible for finishing in the mouth. They must be finished on the die. Because clinical examination of subgingival margins is not always easy, a precementation radiograph may be justified.

Supragingival margins are generally finished with the casting seated on the tooth. White stones and cuttle disks rotating from restoration to tooth structure should result in a suitably finished margin (Fig. 30-10), which, if the casting is properly adapted, is virtually undetectable with the tip of a sharp explorer.[3]

Accessible margins can also be burnished during the cementation procedure before initial setting of the cement.[4] However, the less accessible proximal margins are the critical ones in terms of prognosis. They are the most common site of recurring caries and periodontal disease, and they can neither be evaluated readily nor finished easily. It has also been demonstrated[5,6] that correcting a poorly fitting cast restoration with finishing procedures is not possible.

Stability

The restoration should then be assessed for stability on the prepared tooth. It should not rock or rotate when force is applied. Any degree of instability is likely to cause failure during function. If instability



Fig. 30-8
A, Elastomeric detection paste, recommended for evaluating the internal surface of a restoration. **B,** The interference is seen as a perforation in the film of silicone material, which can be marked with a colored pencil. Note: The residual film of silicone should be thoroughly removed before cementing the restoration. (***B,*** *Courtesy of Dr. J. H. Bailey.*)

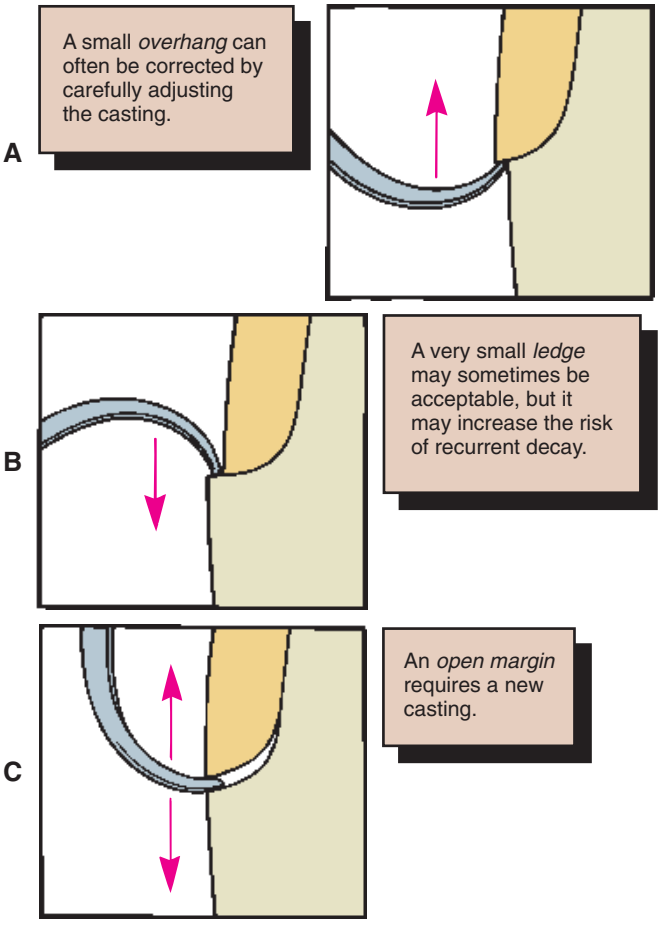


Fig. 30-9
Assessing margin integrity with an explorer. **A**, An overhang. **B**, A ledge. **C**, An open margin.

is caused by a small positive nodule, this can usually be corrected; however, if it is caused by distortion, a new casting is necessary.

Occlusion

After the restoration has been seated and the margin integrity and stability are acceptable, the occlusal contact with the opposing teeth is carefully checked. The criteria for these relationships, both static and dynamic, have been discussed in Chapters 4 and 18. Any undesirable eccentric contacts as well as centric interferences must be identified. Minor adjustment of eccentric contacts may be needed if a semiadjustable (as opposed to a fully adjustable) articulator is used.

Evaluation and adjustment

Armamentarium

- Hemostats
- Miller forceps
- Marking ribbon or tape
- Thin Mylar shim stock
- Diamond rotary instruments
- White stones

Only restorations in supraocclusion can be adjusted. For those that are out of occlusion, there is no satisfactory solution other than remaking (if in metal) or adding porcelain and refiring (if a metal-ceramic restoration).

Step-by-step procedure (Fig. 30-11)

1. Before seating the casting, assess the contact relationship between maxillary and mandibular teeth. The most convenient way to do this is to cut a narrow strip of Mylar shim stock, hold it in hemostats or forceps, and have the patient open

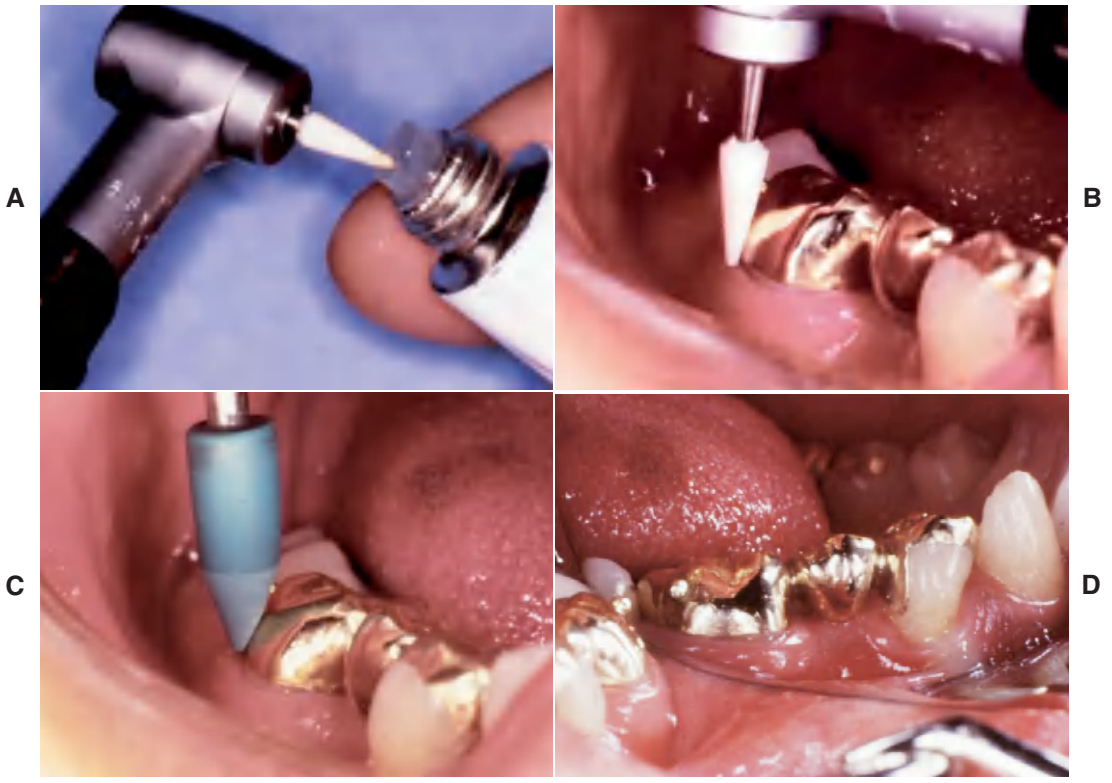


Fig. 30-10
Supragingival margins allow access for finishing the restoration directly on the tooth. **A** and **B,** Fine-grit white stone lubricated with petroleum jelly. **C,** Rubber point. **D,** Completed restoration.



Fig. 30-11
Evaluating and adjusting the occlusion. **A,** Refinement on the articulator before evaluation. **B,** Testing the occlusal relationship with shim stock and marking with tape. Typically, some adjustment is needed, especially in more complex treatments, but this should not be extensive unless an error has been made. **C,** After adjustment, the occlusal contacts should always be verified with shim stock because ribbon markings can be misinterpreted.

and close with the strip between opposing teeth. A "tug" can be felt on the strip, indicating occlusal contact (Fig. 30-12). Ideally, contact should be as evenly distributed as possible, but it is not uncommon to find one or more areas of relatively light contact between opposing teeth.

2. Seat the restoration, have the patient close, and reassess the contacts. The new restoration should hold the shim stock and yet not alter the existing tooth relationships. If a discrepancy is detected, a decision must be made whether this can be adjusted intraorally or whether a **remount procedure** is necessary.
3. Mark any interferences that are detected. Have the patient close on articulating ribbon or tape.
4. Adjust the marked interferences with the diamond rotary instrument or white stone, always checking the thickness of the casting with calipers before an adjustment is made. On occasion, adjusting an opposing cusp rather than cementing a restoration that is too thin may be the preferred method, although performing such adjustment at the tooth preparation stage is recommended. Explaining the procedure and its rationale to the patient before grinding an opposing tooth is essential. Options, such as increasing occlusal clearance by repreparing the tooth, should be presented to the patient before proceeding.
5. Be careful not to misinterpret occlusal markings. Note that a true interocclusal contact leaves a mark with a clean center (like a bull's-eye), but a false contact leaves a smudge. Marking ribbon or tape is useful for helping determine the location of an interference. Shim stock, however, is a more reliable indicator than ribbon or tape for confirming the presence or absence of an occlusal contact and should be used to evaluate the result when the end point is reached.
6. Use two colors of ribbon for the different types of movement. Excursive movements and interferences are first marked in one color (e.g., green). Then a different color (e.g., red) is inserted for centric contacts. Any excursive interferences (i.e., green marks not covered by red) are adjusted with the diamond or white stone.

An alternative technique requires the use of an airborne particle abrasion unit with aluminum oxide (Fig. 30-13). A matte finish is obtained on the occlusal surfaces of the casting in question, and the patient is asked to close. Where shiny marks appear, an adjustment is made. This technique, however, presents the following disadvantages:

1. Differentiating between centric and excursive contacts is not possible.
2. The technique is more time consuming.
3. It is applicable only to cast-metal occlusal surfaces.

Gross occlusal adjustment involving dental porcelain is better done in the bisque stage, because interferences are more easily marked on a bisque surface than on glazed porcelain. Minor adjustments are needed after glazing because of the pyroplastic flow of the porcelain.[7] After adjustment, the porcelain can be polished with silicone wheels or diamond-polishing paste.

Remount

If there is a need for significant occlusal adjustment, a remount procedure[8] may be recommended. It is typically used when extensive restorative dentistry has been performed, and it serves to convey the relationships of the restorations and teeth to the dental laboratory (Fig. 30-14). Detailed adjustments can then be made in an organized manner. Any inaccuracy (e.g., slight tooth movement, previous mounting discrepancies, or small dimensional change inherent with the indirect process) can be



Fig. 30-12

A, Use Mylar shim stock to identify presence or absence of occlusal contacts. **B,** Use articulating tape to identify the location of occlusal contact.



Fig. 30-13
Occlusal prematurities can be identified by giving the casting a matte finish with an air-abrasion unit. A and B, The prematurities appear as shiny areas. *(Courtesy of Dr. M. T. Padilla.)*



Fig. 30-14
A and B, Accurate transmission of occlusal relationships to the laboratory should be the rule when a careful technique has been followed. If discrepancies occur, they are often better corrected by a remount procedure in the laboratory.

compensated for relatively easily, thus reducing the amount of chair time needed for precementation adjustment.

Intraoral occlusal refinement is limited because of visibility and access difficulties. Laboratory adjustments offer optimum access and visibility and the opportunity to evaluate lingual contact relationships.

The remount procedure consists of making an impression of the castings in the patient's mouth, with an occlusal index in place. The index is made with reinforced resin or impression plaster and provides the opportunity to accurately reposition the castings back into the impression after it has been removed from the patient's mouth. A new definitive cast can then be fabricated. To enable easy removal of the castings from the newly fabricated definitive cast, resin is usually poured into the castings, after which the rest of the impression is poured in conventional type IV stone (Fig. 30-15). The cast can then be articulated with a conventional facebow transfer and occlusal registration techniques (see Chapter 2).

Armamentarium (Fig. 30-16)

- Impression trays (A)
- Irreversible hydrocolloid (B)
- Rubber bowl and spatula (C)
- Interim luting agent (D)
- Petrolatum (E)
- Autopolymerizing resin (F)
- Stiff wire (e.g., coat hanger wire) (G)
- Zinc oxide-eugenol (ZOE) occlusal registration paste (H)
- Inlay wax or light-bodied reversible hydrocolloid (I)
- Facebow transfer equipment
- Centric relation recording

Step-by-step procedure (Fig. 30-17)

1. Use autopolymerizing resin (e.g., custom tray resin) to make an occlusal index of the restorations on the definitive cast. Reinforce the index with stiff wire. The index should not extend beyond the occlusal table of the restored teeth, and its thickness must not be greater than 5 mm. It should fit the cast passively.
2. Grind the occlusal aspect of the index until only shallow indentations of the cusp tips remain.

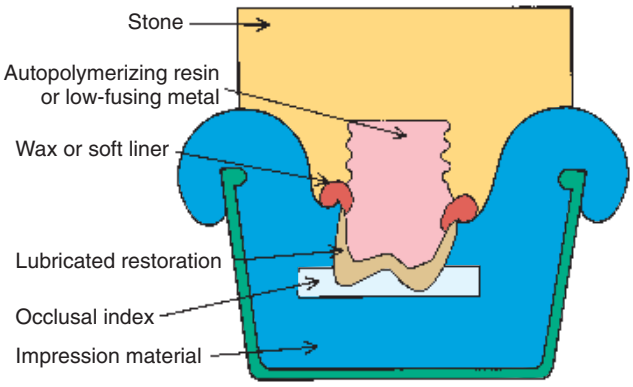


Fig. 30-15
Cross-sectional schematic of the remount procedure.



Fig. 30-16
Armamentarium for a remount procedure.

3. Seat the restorations on the prepared teeth (see Fig. 30-17*B*). To prevent dislodgment, use a small amount of interim luting agent mixed with petrolatum. FDPs that have yet to be assembled can be stabilized with autopolymerizing resin applied by the brush-bead technique (see Fig. 28-24).
4. After the fit of the index has been verified, cover the surfaces of the restorations with a thin coating of petrolatum, and apply ZOE registration paste to the occlusal aspect of the index. Then seat it in the patient's mouth. As an alternative, impression plaster can be used (see Fig. 30-17*C*).
5. Make an orientation impression over the index and the restorations with an elastomeric impression material in a stock tray, making sure the index is not displaced (see Fig. 30-17*D*).
6. Make a conventional opposing impression if no restorations were made for that arch. If restorations have been made for both arches, repeat the procedure described previously.
7. Remove the restorations from the mouth, replace the interim restorations, and reschedule the patient.
8. Clean the internal aspects of the restoration of any residual cement or debris, reseat the restoration in the index, and apply a thin coating of petrolatum.
9. Cover the margins of the restoration with wax or soft lining resin. As an alternative, reversible hydrocolloid impression material can be applied around them with a syringe. Note: Crowns with long retentive axial walls can be partially filled with reversible hydrocolloid to aid in their subsequent removal.
10. Pour the internal surface of the casting with autopolymerizing resin or low-fusing metal, adding retention (see Fig. 30-17*E*). American Dental Association type IV stone can be used, but the casting must be lubricated carefully; special care must be taken to prevent fracture when the casting is removed.
11. Complete the maxillary cast (see Fig. 30-17*F*).
12. Make a new centric relation record at the occlusal vertical dimension and articulate the cast (see Fig. 30-17*G*).
13. Save the index to confirm accuracy after the occlused remount is poured.

This completes the remount procedure. The restoration can now be reassessed and adjusted in the dental laboratory. Although a remount procedure is not routinely needed, it may be advantageous with an extensive restoration to reduce the amount of chair time required for occlusal adjustment.

Ceramic Restorations

Ceramic restorations need certain additional steps during evaluation to satisfy esthetic, biologic, and mechanical requirements. Achieving an esthetic result depends on the contour of the restoration, surface characterization, and color match.

Contouring

Armamentarium (Fig. 30-18)
- Flexible diamond disk
- Porcelain grinding wheel
- Ceramic-bound stones
- Diamonds



Fig. 30-17

Remount technique. A, A maxillary arch is prepared for metal-ceramic crowns and fixed dental prostheses. **B,** The metal framework is evaluated clinically; a remount procedure is needed. **C,** Impression plaster is used to register the location of each unit. **D,** The registration is picked up with an elastomeric material. **E,** Restorations are lubricated, and soft lining resin is painted around them. Their internal surfaces are filled with hard resin. Acrylic chips provide retention for the soft resin. Small wood screws are inserted into the hard acrylic, which are also for retention. **F** and **G,** The remainder of the cast is poured and articulated in the usual way. *(Courtesy of Dr. J. H. Bailey.)*

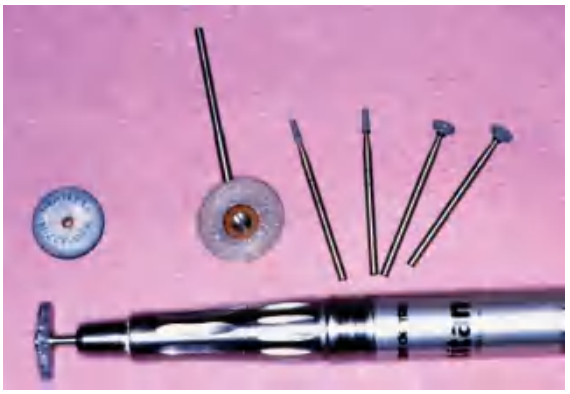


Fig. 30-18
Armamentarium for porcelain adjustment.

When contouring a restoration that is to be evaluated during the bisque stage, it should be moistened first with water or saliva. The moist surface reflects light in the same manner as the glazed restoration.

Step-by-step procedure

1. Check the proximal contact relationship (adjust as necessary), and verify the marginal fit of the restoration.
2. Verify the contour of the gingival third, and make any necessary adjustments. Excessive bulk in this area is a common fault and is often associated with periodontal disease (Fig. 30-19). When adjustment of porcelain is needed, the porcelain and metal should not be ground simultaneously, because small metal particles may be transferred to the porcelain, causing discoloration and a black spotty appearance after the restoration has been glazed. If grinding both porcelain and metal simultaneously is absolutely necessary, the direction of grinding should be parallel to the metal-ceramic junction (Fig. 30-20). A thin, flexible disk provides good access to reduce any overcontoured interproximal area (Fig. 30-21).
3. Identify and adjust any occlusal interferences on the posterior teeth. As mentioned, porcelain occlusal contacts need readjustment after glazing because of the pyroplastic flow of porcelain.
4. On anterior teeth, establish the proper position and shape of the incisal edge. This is a key step in achieving good esthetics and function. Unfortunately, it is hard to obtain in the laboratory because the soft tissues of the patient's lips and cheeks are not present on the articulator. A stone cast of a well-adjusted interim restoration (made from the diagnostic cast or waxing procedure) helps the technician because it can be duplicated when the porcelain is applied. However, as a general rule, the restoration should be tried in the patient's mouth with the incisal edges slightly longer than intended; their shape should be refined in the mouth.

   If too much adjustment is made, the incisal porcelain layer will be ground away, and the esthetic effect will be spoiled. Incisal edge position is important in obtaining good esthetics and function. Specific criteria for what constitutes "normal" are hard to define, but an average of 1 to 2 mm of the clinical crown should be visible on maxillary central and lateral incisors when the upper lip is relaxed. Additional help in contouring the incisal edges can be obtained by looking at the patient's smile and listening to speech characteristics. Ideally, the incisal edges of the maxillary anterior teeth follow the curvature of the lower lip when the patient smiles.[9] Ordinarily, the incisal edges of the lateral incisors (Fig. 30-22) are 1 to 2 mm shorter than the central incisors, which may touch the internal aspect of the lower lip when it is relaxed.
5. Evaluate the *negative space*, the name given to the shape of the incisal embrasures[10] (see Chapter 1). Proper embrasures (Fig. 30-23) significantly enhance the apparent separation between restorations, whereas their absence draws attention to the prosthesis and reveals its artificial nature (see Fig. 30-23C). Similarly, when viewed from the incisal aspect, interproximal embrasures should be as narrow and deep as possible to enhance the shadows between components of the fixed prosthesis. If these are absent, even the casual observer will recognize the teeth as artificial.
6. Have the patient enunciate the consonants. *F* sounds are particularly helpful because they are made with the incisal edge of the maxillary central incisors touching at the junction of the moist and dry surfaces of the vermilion border of the lower lip ("wet-dry line").[11]
7. Mark the line angles directly on the porcelain restoration in the bisque stage with a colored pencil, and compare these to the line angles of adjacent and contralateral teeth. Red pencil is preferred because blue or black pencil may discolor the porcelain. The position of the line angles is probably one of the more critical procedures for achieving good esthetics because the line angles delineate the shape of the tooth to an observer. (Line angles on wax patterns are discussed in Chapter 18.) By superimposing normal line angle distribution over teeth that are otherwise too large or too narrow,[12] creating the impression that



Fig. 30-19
A, Periodontal disease associated with excessively contoured restorations. **B** and **C**, Teeth reprepared to allow appropriate facial contours. **D**, Correct emergence profile established in restoration. **E**, Clinical adaptation verified. **F**, Note tissue response to new restorations. **G**, Appropriate embrasure form allows plaque control.

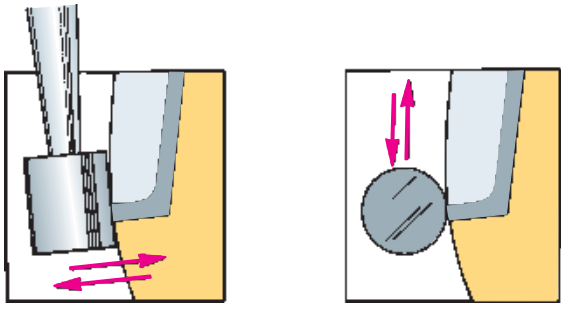


Fig. 30-20
If it is necessary to grind at the metal-porcelain junction, the stone should be held perpendicular to the junction. Otherwise, metal particles may contaminate the porcelain.



Fig. 30-21
Adjusting the axial contour.



Fig. 30-22
Typical incisal edge position. *(From Monteith BD: A cephalometric method to determine the angulation of the occlusal plane in edentulous patients. J Prosthet Dent 54:81, 1985.)*

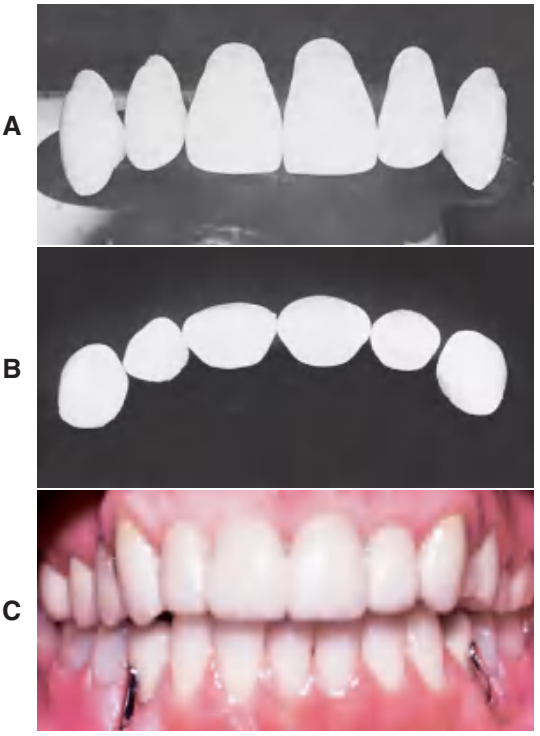


Fig. 30-23
A and **B,** Properly shaped incisal embrasures. **C,** Inadequate embrasures. Note the unnatural look.

the left and right sides are identical is possible (Fig. 30-24) (see Chapter 23).

8. Evaluate the overall contour to see that it matches the shape of the adjacent teeth. With experience, most operators quickly develop an appreciation for evaluating "normal" contours and detecting areas that need correction. Moistening the teeth and observing light reflections may help. It also helps to have the patient stand up to be checked at normal conversational distance, as opposed to the extreme closeup of a dental examination.



Fig. 30-24
Insufficient mesiodistal space is available for the right maxillary lateral incisor. By creation of an apparent overlap, the pontic is given the illusion of normal anatomic proportions.

Surface texture characterization

When the contour of the restoration has been finalized, the next goal is to duplicate the surface detail of the patient's natural teeth.

Armamentarium

- Diamond disk
- Carborundum stones
- Diamond stones

Step-by-step procedure

1. Dry the teeth, and examine their surfaces carefully. Perikymata and defects can be simulated by grinding the porcelain with a diamond stone of appropriate texture. (Be careful not to overemphasize such details.) Flat or concave areas reflect light in a characteristic manner, producing highlights (Fig. 30-25).
2. Copy the details and carefully blend them with the adjacent area. In general, the effort should aim at generating textures that follow the principal curvatures of the normal anatomic form of the

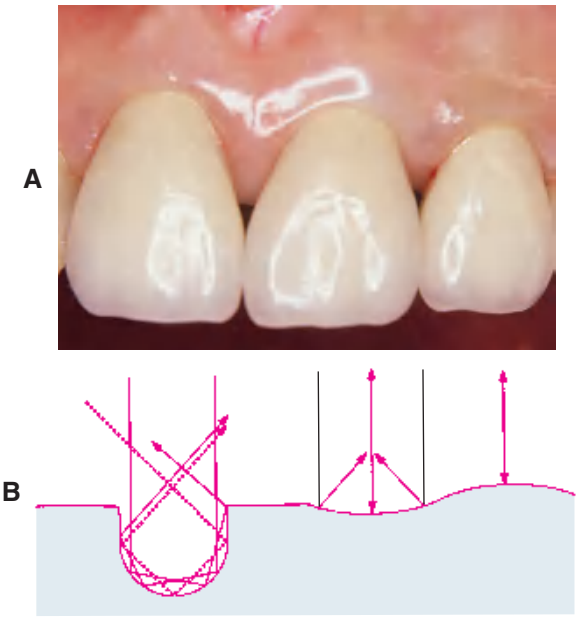


Fig. 30-25
A, Restoration texture should closely match natural enamel. **B,** Sharp grooves should not be cut into the ceramic surface because these "trap" light. A curved surface looks more natural and results in either converging or diverging reflections.



Fig. 30-26
The texture of these metal-ceramic units has been overemphasized, which has led to an artificial appearance.

tooth, in order to result in optimal perception of the **characterized** surface.

3. Similarly, mimic any vertical defects with careful grinding.
4. Be careful to avoid "overcharacterizing" restorations, which is a common error (Fig. 30-26).

On occasion, altering the apparent size of a restoration by these techniques may be possible. A smooth tooth appears larger than one that is identical in size but has intensive surface texture characterization.

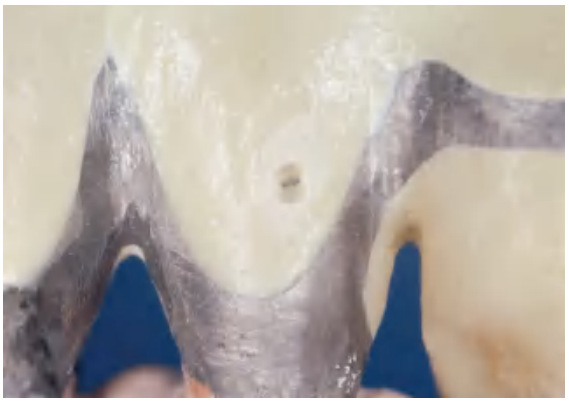


Fig. 30-27
A bubble that surfaced immediately before the evaluation stage. These types of defects must be addressed before delivery of the prosthesis.

CHARACTERIZATION AND GLAZING

The surface luster or degree of gloss of a porcelain restoration depends on the autoglazing procedure (see Chapter 24). Both time and temperature must be carefully controlled. During a glazing firing, the surface layers of porcelain melt slightly, coalescing the particles and filling in surface defects.

The restoration should not be glazed in a vacuum, because included air may be drawn to the surface and result in bubbling (Fig. 30-27). Because air-fired glazing furnaces are relatively compact and inexpensive, some dentists prefer to glaze porcelain restorations in the operatory. This is particularly convenient if surface **stains** are to be used. The glazing step is straightforward; the degree of glaze depends on furnace temperature and how long the restoration is held at that temperature. Excessively glazed anterior teeth look unnatural. The patient should moisten the restoration because saliva affects its appearance. A dry crown looks misleadingly underglazed. Underglazing and refiring a restoration is better than overglazing it. If a restoration is not sufficiently glazed, it will retain more plaque and may be more liable to fracture. After glazing, the metal surfaces of the restoration are polished.

An alternative to glazing is to polish the porcelain surfaces of the restoration.[13] This provides greater control of the surface luster and distribution than glazing.[14] For example, having a higher gloss on the cervical area and a lower gloss on the incisal area is possible. This is not possible with glazing because the entire crown is subjected to the same time-temperature combination.

Polishing dental ceramics has long been advocated as an expedient way of restoring luster after

adjusting by grinding. A number of commercially available polishing kits are available for this purpose. If used correctly (i.e., without omitting the successively finer grits), most are capable of producing smooth porcelain surfaces.[15,16] As an alternative, the use of finishing wheels followed by pumice is satisfactory.[17] More recently, ceramists have advocated polishing as a way to improve luster control. To achieve the precise degree and distribution of luster required, the porcelain is polished rather than glazed.

Despite the esthetic advantages of polishing, there is concern whether the strength of a polished restoration might be reduced or its abrasiveness increased. Glazing has been cited as strengthening a dental restoration,[18] presumably because it causes a reduction of the flaws that initiate fracture. However, polishing also reduces flaws, and in laboratory studies, polishing has not been found to result in reduced physical properties, in comparison with glazing.[19-23] Laboratory studies have shown that polished porcelain is no more abrasive than glazed porcelain.[24] However, unpolished porcelain is much more abrasive on opposing enamel and is more plaque retentive than is polished or glazed porcelain.

External Color Modification and Characterization

Stuart H. Jacobs

The accomplishment of a perfect color match by using the basic shades supplied in the porcelain kits, without the need for chairside modification, is the goal of all dental ceramists. However, there are difficulties and inaccuracies inherent in the technique. There are also difficulties in duplicating the appearance of a patient's tooth without the patient's actually being present in the dental laboratory. These problems make perfect shade matching very difficult to achieve routinely. In many situations, a restoration that does not blend well with the adjacent teeth can be improved by simple chairside color modification or characterization procedures.[25] These are done concurrently with final glazing, and it is therefore recommended that restorations be tried in the patient's mouth contoured but unglazed (bisque stage).

Armamentarium

- Porcelain furnace (a small air-fired furnace is suitable for the operatory) (Fig. 30-28).
- Clean glass slab
- Sable hair brush



Fig. 30-28
Ney Miniglaze/2 glazing furnace.

- Distilled water
- Tissue
- Stain kit

A number of stain kits are available from porcelain manufacturers, and most contain a fairly wide range of colors. The stains themselves are highly **pigmented** surface colorants that contain a small amount of glass, allowing the color to fuse into the porcelain surface.

Available characterization kits are illustrated in Figure 30-29. They come in various colors. Additional colors can be made by mixing the stains with each other; the color intensity can also be toned down with a colorless porcelain.

Step-by-step procedure

The application of stain has advantages and disadvantages. One advantage is that the dentist or technician can modify the shade after a restoration is completed with the patient present. The greatest disadvantage is that the color can be applied only to the surface, and so it is ineffective in producing characterizations that look realistic (i.e., deep within the tooth). Also, if surface characterization is applied excessively,[26] it can cause a loss of fluorescence in the finished restoration, as well as an increase in the metameric effect (shade mismatch is more apparent under some lighting conditions). Furthermore, a characterized crown is slightly rougher than an autoglazed one,[27] and the stain will eventually wear away under normal toothbrushing[28,29] (10 to 12 years).



Fig. 30-29
A, The IPS Stain and Shade kits. **B,** The Akzent Stain Kit. (***A,*** *Ivoclar Vivadent, Amherst, New York;* ***B,*** *Courtesy of Vident, Brea, California.)*

Three aspects of characterization may be used singly or in combination to achieve a natural appearance: shade modification (increasing the chroma, changing the hue, or reducing the value); specific characterization (e.g., hypocalcified areas or cracks); and special illusions of form or position (Fig. 30-30).

1. Mix the stain with the liquid provided in the kit (normally a glycerin-water mixture) to a creamy, stiff consistency (see Fig. 30-30*A*). If the mixture is too thin, it runs over the restorations and pools in certain areas. An even coat is essential for producing the best results.
2. Before applying the stain, thoroughly clean the restoration with steam. Apply stain to the restorations with the clean moist sable brush (see Fig. 30-30*B*). When moist, the brush becomes easier to draw to a point, and application of the stain is greatly facilitated.
3. When the effect has been created, make a note of which stain was used and where. This procedure usually must be duplicated because absolute cleanliness is essential; in addition, placing a unit in the mouth without some contamination is difficult. Removing the restorations without smudging is also difficult.
4. Take the restorations out of the mouth, wash them, and re-create the characterization (see Fig. 30-30*C* to *E*).
5. After the characterization is complete, transfer the restorations to a firing tray, and place it in front of the muffle of the furnace until the stain is dry and the surface appears chalky white (see Fig. 30-30*F* and *G*).
6. Remove the prosthesis, and examine it to ensure that no stain has run inside.
7. Remove any excess with a dry brush, and place the crown in the furnace.
8. Increase the heat to the maturation temperature of the porcelain, and hold it there according to the degree of glaze required (see Fig. 30-30*H*).
9. Remove the restorations, allow them to cool, and retry them in the patient's mouth.

Shade modification (see Chapter 23)

When a porcelain shade is being altered with external stain, certain limitations must be considered, particularly because surface characterization causes a loss of fluorescence and increases the effect of metamerism. It cannot be used to make major corrections or compensate for gross errors.

When the correctness of shade is assessed, simulating the appearance of glazed porcelain is necessary. This can be done by painting on some of the liquid provided in the stain kit. It may also help to paint the adjacent natural tooth to prevent dehydration during the characterization procedure, which would increase the value of the tooth.

Chroma and hue adjustment

Increasing the chroma (saturation) is one of the simplest shade alterations to achieve.[30] The addition of yellow stain increases the chroma of a basically yellow shade, whereas adding orange has the same effect on a yellow-red shade. When an alteration in hue is necessary, pink-purple moves yellow toward yellow-red, whereas yellow decreases the red content of a yellow-red shade. These are the only two modifications that should be necessary, because the hue of a natural tooth always lies in the yellow-red to yellow range.

A metal-ceramic restoration that has too high a chroma is difficult to modify. Choosing a shade with



Fig. 30-30

Characterization and glazing technique. **A,** The colored stains are mixed to a stiff consistency on a suitable palette. **B,** Applying the stain. Often the procedure is repeated, or modifications are made after removal from the mouth. **C,** White stain is used to mimic hypocalcification. **D,** Stain with increased chroma is used for proximal coloration. **E,** A thin brown check line is made by painting a line of stain on the porcelain. This is reduced to the desired width by wiping a clean brush on each side of it. **F** and **G,** Stain is dried to a chalky consistency in front of the furnace muffle. **H,** Characterized and glazed restorations after firing. (**A,** *Courtesy of Dr. G. W. Sheen.*)

a lower chroma is always better, because a lower chroma can be altered easily. Using the complementary color of a restoration reduces its chroma: Yellow requires purple-blue and orange requires blue or blue-green. However, the addition of these stains lowers the value of the restoration and increases the metameric effect; it is rarely successful in practice.

Value adjustment

Value can be reduced by adding a complementary color (see Fig. 23-1). Violet is used on yellow restorations and has the added effect of increasing the translucency. Gray is not encouraged because it tends to reduce translucency and makes the surface cloudy.

Attempting to increase the value is generally less successful, although value can be increased if the dominant color added has a higher lightness ranking. For example, a crown can be stained with white, but opacity will be greatly increased.

Characterization

Characterization is the art of reproducing natural defects, and it can be particularly successful in making a crown blend with the adjacent natural teeth. In general, defects should be reproduced to a slightly lesser extent on the restoration than as they appear on the natural teeth. The temptation to overcharacterize is strong but must be resisted.

Characterization looks slightly more natural and is more permanent if applied intrinsically during the buildup of the restoration (see Chapter 24) rather than by subsequent extrinsic application.[31] However, communicating the exact characterization needed to

the laboratory may be difficult; therefore, copying natural defects at chairside may be more practical.

Hypocalcified areas

These are produced with white stain and may be some of the easiest and most commonly made modifications.

Proximal coloration

Many natural teeth exhibit proximal characterization. By reproducing this in the restoration, the dentist is able to create the illusion of depth and separation and is also able to tone down excessive opacity at the cervical area. The stains used are brown and orange. They are applied lightly to the proximal area and extended slightly onto the buccal surface apical to the contact. Proximal coloring is particularly useful in creating the illusion of separate units of an FDP.

Enamel cracks

This characterization is better if done intrinsically, although it can be added extrinsically. A linear vertical crack interrupts the light transmission across the tooth surface, causing a shadow. Thus, both the highlight and the shadow of the crack must be simulated for an authentic result.

The highlight is developed with white and yellow mixed in the ratio of 4 : 1, and gray stain is used for the shadow. A thin line is drawn with a brush in the desired area with the white and yellow stains. Then a thin line of gray is placed distal to the first line to create the illusion of a shadow.

Stained crack line (Fig. 30-31)

Cracked enamel stains quickly on natural teeth. An orange-brown mixture applied in as thin a line as possible will effectively simulate a crack.

Exposed incisal dentin

This is usually seen on the mandibular incisors of older patients and is caused by enamel wear. The incisal edge should be "cupped out," with orange and brown colorants used to reproduce the dentinoenamel junction.



Fig. 30-31

Thin brown check lines have been added to enhance the appearance of this prosthesis.

Incisal halo

Translucent incisal edges are more common on the incisors of younger patients. Often, although the incisal area is translucent, the edge is totally opaque. This may be difficult to reproduce internally. A mixture of white and yellow stains in the ratio of 4 : 1 is placed in the linguoincisal area, with an extension just onto the labial area, to produce the halo effect.

Translucency

Translucency can be mimicked with violet stain, although the results are usually disappointing in comparison with those achieved with correct application of the incisal porcelain. For optimum results, both labial and lingual surfaces should be coated. Decreasing the translucency is accomplished by adding the dominant hue over the labiolingual surface.

Special illusions

Form and position are undoubtedly the most important factors in achieving an attractive result. However, restoring the original form may not always be possible. Loss of supporting tissue, the size of a pontic space, or a poor occlusal position may impede the attempt.

An FDP pontic may be very long because of loss of supporting bone. Simulating a root surface can partially improve the appearance. The root extension is contoured for length and width, and then an orange-brown mixture is placed over the extension. Pink stain can be used to simulate gingival tissue, but results are better with pink body porcelain.

Recommended characterization procedures are summarized in Table 30-1.

SUMMARY

When a restoration is evaluated in the mouth, the proximal contacts are assessed first, followed by margin integrity, stability, and occlusion. Minor occlusal discrepancies can usually be adjusted intraorally. For extensive prosthodontic treatment, a remount procedure may be needed, which will reduce the chair time needed to achieve an optimum occlusal scheme in the restoration.

With a metal-ceramic restoration, proper contouring of the porcelain in the cervical third is crucial for facilitating maintenance of health of the supporting structures. Proper shaping of the gingival and incisal embrasures, along with contouring and characterization, significantly improves the esthetic result. Small corrections and subtle changes can be made with surface stains.

Table **30-1 CHARACTERIZATION PROCEDURES**

	Basic colors	Ivoclar IPS stain	VITA Akzent stain No.
Chroma increase	Yellow and yellow-red	Caramel brown, orange	See Fig. 30-30A
Chroma decrease	Violet and blue-green	Sky blue + basic red, sky blue	See Fig. 30-30A
Hue adjustment	Pink-purple or yellow	Basic red + basic blue, basic yellow	12 (Redwood) + 17 (Niagara), 03 (Sun Kiss)
Value adjustment	Violet and (white)*	Sky blue + basic red, white	See Fig. 30-30A
Hypocalcification	White	White	01 (Birch)
Proximal coloration	Brown and orange	Cork brown, orange	Use increased chroma (see Fig. 30-30A)
Enamel cracks	White-yellow and gray	Bamboo beige	01 (Birch) + 03 (Sun Kiss)
Stained crack line	Orange-brown	Cork brown + orange	01 (Birch) with 13 (Shak)
Exposed incisal dentin	Orange and brown	Orange, cork brown	Use increased chroma (see Fig. 30-30A)
Incisal halo	White-yellow	Bamboo beige	02 (Mellow Yellow)
Translucency	(Violet)*	Sky blue + basic red	13 (Shak)
Cervical staining			
A shades	Orange-browns	A1, A2/3, A4†	Use increased chroma (see Fig. 30-30A)
B shades	Greenish-browns	B1, B2/B3/B4†	Use increased chroma (see Fig. 30-30A)
C shades	Greenish-browns	C1/C2, C3/C4†	Use increased chroma (see Fig. 30-30A)
D shades	Greenish-browns	D2/D3, D4†	Use increased chroma (see Fig. 30-30A)

*Modification may not be successful.
†IPS Shade V.

STUDY QUESTIONS

1. What is the recommended sequence for the clinical evaluation of a gold crown? Why? Which additional steps are necessary for a metal-ceramic restoration?
2. How is a tight proximal contact most effectively identified and corrected?
3. Discuss the addition of a proximal contact for a gold crown and a metal-ceramic crown.
4. What is a remount procedure? Discuss the steps involved.
5. What is the "negative space"?
6. When shade modification is desired, how is chroma increased? What hue adjustments are feasible? How is value adjusted?

GLOSSARY*

antiflux \ăn′tē-flŭks′\ *n*: materials that prevent or confines solder attachment or flow

[1]cast·ing \kăs′tĭng\ *n* (14c): something that has been cast in a mold; an object formed by the solidification of a fluid that has been poured or injected into a mold

[2]cast·ing \kăs′tĭng\ *vt*: the act of forming an object in a mold–see VACUUM C.

characterization: to characterize by application of unique markings, indentations, coloration and similar custom means of deliniation on a tooth or dental prosthesis thus enhancing natural appearance

char·ac·ter·ize \kăr′ak-ta-rīz\: to distinguish, individualize, mark, qualify, singularize, or differentiate something

emergence profile \ĭ-mûr′jens prō′fīl\: the contour of a tooth or restoration, such as a crown on a natural tooth or dental implant abutment, as it relates to the adjacent tissues

extrinsic coloring \ĭk-strĭn′sĭk kŭl′or-ĭng\: coloring from without; applying color to the external surface of a prosthesis

glaze \glāz\ *vb* **glazed** \glāzd\; **glaz·ing** \glā′zĭng\ *vt* (14c) **1:** to cover with a glossy, smooth surface or coating **2:** the attainment of a smooth and reflective surface **3:** the final firing of porcelain in which the surface is vitrified and a high gloss is imparted to the material **4:** a ceramic veneer on a dental porcelain restoration after it has been fired, producing a nonporous, glossy or semi-glossy surface–see NATURAL G., OVERGLAZE

intrinsic coloring \ĭn-trĭn′zĭk, -sĭk kŭl′ar-ĭng\: coloring from within; the incorporation of a colorant within the material of a prosthesis or restoration

line angle \līn ang′gal\: the point of convergence of two planes in a cavity preparation

natural glaze \năch-ar-al, năch′ral glāz\: the production of a glazed surface by the vitrification of the material itself and without addition of other fluxes or glasses

o·ver·glaze \ō′var-glāz\ *adj* (1879): the production of a glazed surface by the addition of a fluxed glass that usually vitrifies at a lower temperature

pig·ment \pĭg′mant\ *n* (14c): finely ground, natural or synthetic, inorganic or organic, insoluble dispersed particles (powder), which, when dispersed in a liquid vehicle, may provide, in addition to color, many other essential properties such as opacity, hardness, durability, and corrosion resistance. The term is used to include an extender, white or color pigments. The distinction between powders that are pigments and those that are dyes is generally considered on the basis of solubility–pigments being insoluble and dispersed in the material, dyes being soluble or in solution as used

primary colors (additive) \prī′mĕr′ē, -ma-rē kŭl′erz ăd′ĭ-tĭv\: three colored lights from which all other colors can be matched by additive mixture. The three must be selected so that no one of them can be matched by mixture of the other two. Generally, red, green, and blue are used. Additive primaries are the complements of the subtractive primaries

primary colors (subtractive) \prī′mĕr′ē, -ma-rē kŭl′erz sab-trăk′tĭv\: colors of three colorants or colored materials which, when mixed together subtract from one another, resulting in black or a very dark neutral color. Subtractive primaries are generally cyan, magenta, and yellow

remount cast \rē-mount′\: a cast formed of a prosthesis for the purpose of mounting the prosthesis on an articulator

remount procedure \rē-mount′ pra-sē′jur\: any method used to relate restorations to an articulator for analysis and/or to assist in development of a plan for occlusal equilibration or reshaping

remount record index \rē-mount′ rĕk′ard ĭn′dĕks′\: a record of maxillary structures affixed to the mandibular member of an articulator useful in facilitating subsequent transfers

speaking space \spē′kĭng spās\: the space that occurs between the incisal or/and occlusal surfaces of the maxillary and mandibular teeth during speech

[1]stain \stān\ *n* (1583) **1:** a soiled or discolored spot; a spot of color in contrast to the surrounding area **2:** a preparation used in staining **3:** in dentistry, the discoloration of a tooth surface or surfaces as a result of ingested materials, bacterial action, tobacco, and/or other substances. This may be intrinsic, extrinsic, acquired, or developmental

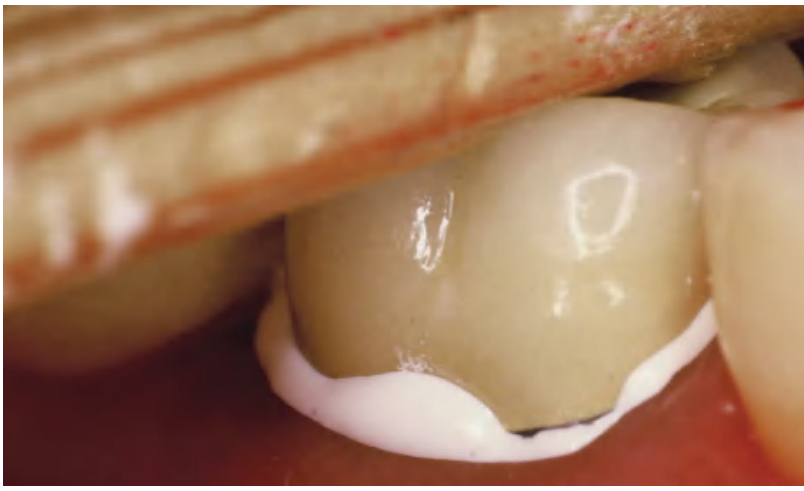
[2]stain \stān\ *vb* (14c) **1:** to suffuse with color **2:** to color by processes affecting chemically or otherwise the material itself **3:** in dentistry, to intentionally alter restorations through the application of intrinsic or extrinsic colorants to achieve a desired effect, best termed *characterization* or to *characterize* a restoration

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REFERENCES

1. Byrne G, et al: Casting accuracy of high-palladium alloys. J Prosthet Dent 55:297, 1986.
2. Schilling ER, et al: Marginal gap of crowns made with a phosphate-bonded investment and accelerated casting method. J Prosthet Dent 81:129, 1999.
3. Christensen GJ: Marginal fit of gold inlay castings. J Prosthet Dent 16:297, 1966.
4. Goretti A, et al: A microscopic evaluation of the marginal adaptation of onlays in gold. Schweiz Monatsschr Zahnmed 102:679, 1992.
5. Lofstrom LH, Asgar K: Scanning electron microscopic evaluation of techniques to extend deficient cast gold margins. J Prosthet Dent 55:416, 1986.
6. Eames WB: Movement of gold at cavosurface margins with finishing instruments [Letter]. J Prosthet Dent 56:516, 1986.
7. Hobo S: Distortion of occlusal porcelain during glazing. J Prosthet Dent 47:154, 1982.
8. Huffman RW, Regenos JW: Principles of Occlusion, 4th ed. London, Ohio, H & R Press, 1973.
9. Monteith BD: A cephalometric method to determine the angulation of the occlusal plane in edentulous patients. J Prosthet Dent 54:81, 1985.
10. Matthews TG: The anatomy of a smile. J Prosthet Dent 39:128, 1978.
11. Rahn AO, Heartwell CM: Textbook of Complete Dentures, 5th ed. Philadelphia, BC Decker, 1993.
12. Blancheri RL: Optical illusion and restorative dentistry. Rev Asoc Dent Mex 8:103, 1950.
13. al-Wahadni A, Martin DM: Glazing and finishing dental porcelain: a literature review. J Can Dent Assoc 64:580, 1998.
14. Hubbard JR: Natural texture and lustre in ceramics. In Preston JD, ed: Perspectives in Dental Ceramics. Chicago, Quintessence Publishing, 1988.
15. Goldstein GR, et al: Profilometer, SEM, and visual assessment of porcelain polishing methods. J Prosthet Dent 65:627, 1991.
16. Fuzzi M, et al: Scanning electron microscopy and profilometer evaluation of glazed and polished dental porcelain. Int J Prosthodont 9:452, 1996.
17. Newitter DA, et al: An evaluation of adjustment and postadjustment finishing techniques on the surface of porcelain-bonded-to-metal crowns. J Prosthet Dent 48:388, 1982.
18. Binns DB: The physical and chemical properties of dental porcelain. In Yamada HN, ed: Dental Porcelain: The State of the Art 1977. A Compendium of the Colloquium Held at the University of Southern California School of Dentistry on Feb. 24-26, 1977, pp 25. Los Angeles, University of Southern California, 1977.
19. Levy H: Effect of laboratory finishing technics and the mechanical properties of dental ceramic. Inf Dent 69:1039, 1987.
20. Rosenstiel SF, et al: Comparison of glazed and polished dental porcelain. Int J Prosthodont 2:524, 1989.
21. Brackett SE, et al: An evaluation of porcelain strength and the effect of surface treatment. J Prosthet Dent 61:446, 1989.
22. Fairhurst CW, et al: The effect of glaze on porcelain strength. Dent Mater 8:203, 1992.
23. Giordano R, et al: Effect of surface finish on the flexural strength of feldspathic and aluminous dental ceramics. Int J Prosthodont 8:311, 1995.
24. al-Hiyasat AS, et al: The abrasive effect of glazed, unglazed, and polished porcelain on the wear of human enamel, and the influence of carbonated soft drinks on the rate of wear. Int J Prosthodont 10:269, 1997.
25. Abadie FR: Porcelain surface characterization and staining in the office. J Prosthet Dent 51:181, 1984.
26. Weiner S: Staining porcelain veneer restorations. J Prosthet Dent 44:670, 1980.
27. Cook PA, et al: The effect of superficial colorant and glaze on the surface texture of vacuum-fired porcelain. J Prosthet Dent 51:476, 1984.
28. Aker DA, et al: Toothbrush abrasion of color-corrective porcelain stains applied to porcelain-fused-to-metal restorations. J Prosthet Dent 44:161, 1980.
29. Bativala F, et al: The microscopic appearance and effect of toothbrushing on extrinsically stained metal-ceramic restorations. J Prosthet Dent 57:47, 1987.
30. Lund TW, et al: Spectrophotometric study of the relationship between body porcelain color and applied metallic oxide pigments. J Prosthet Dent 53:790, 1985.
31. Winings JR: A method of making decalcifications in the porcelain build up. J Dent Technol 15:13, 1998.

31



LUTING AGENTS AND CEMENTATION PROCEDURES

KEY TERMS

cement
compressive strength
crown retention
film thickness
luting agents
microleakage
solubility

INTERIM CEMENTATION

On many occasions, cementing a restoration on an interim basis is advised so that the patient and dentist can assess its appearance and function over a time longer than a single visit. However, these trial cementations should be managed cautiously. On one hand, removing the restoration for definitive cementation may be difficult, even when temporary zinc oxide–eugenol (ZOE) **cement** is used. To avoid this problem, the interim cement can be mixed with a little petrolatum or silicone grease. The modified luting agent is applied only to the margins of the restoration to seal them and yet allow subsequent removal without difficulty. On the other hand, an interim cemented restoration may come loose during function. If a single unit is displaced, it can be embarrassing or uncomfortable for the patient. If one abutment of a partial fixed dental prosthesis (FDP) becomes loose, the consequences can be more severe. If the patient does not return promptly for recementation, caries may develop very rapidly. Interim cementation should not be undertaken unless the patient is given clear instructions about the objectives of the procedure, the intended duration of the trial cementation, and the importance of returning if an abutment loosens. If removing an interim cemented fixed prosthesis is difficult, the use of a crown-removal device such as the CORONAflex* (see Chapter 32) is recommended.

DEFINITIVE CEMENTATION

Conventional Cast Restorations

Definitive cementation often does not receive the same attention to detail as do other aspects of restorative dentistry. Careless luting agent selection can result in margin discrepancies and improper

*KaVo Dental Corporation, Lake Zurich, Illinois.

occlusion and may even necessitate cutting the restoration from the patient's mouth and making a new one. The choice of cement depends first on whether a conventional casting or an adhesively bonded restoration, such as a ceramic inlay or resin-bonded partial FDP, is to be cemented. Traditional dental cements can be used for cast crowns and FDPs, but not where adhesion is needed. Adhesive resins are necessary for some restorations, but they can be difficult to use; in addition, there are no long-term data to justify more general use with conventional castings.

Dental Cements

Most **luting agents** traditionally used for cast restorations are dental cements (Fig. 31-1). These consist of an acid combined with a metal oxide base to form a salt and water. The setting mechanism results from the binding of unreacted powder particles by a matrix of salt to harden the mass. However, because they are ionic, these agents are susceptible to acid attack and are therefore somewhat soluble in oral fluids.[1-4] Traditionally, the success of restorations cemented with these luting agents has been attributed to excellent adaptation between the casting and the prepared tooth. In vitro, however, cement dissolution is independent of the marginal width up to a certain critical value. After that, it increases only slightly, which is explained by Fick's first law of diffusion.*[5]

This study and others identify dissolution (rather than physical disintegration) as the mechanism for cement erosion.[6] They explain the success of cast restorations, despite the prevalence of relatively large subgingival marginal discrepancies, which are difficult to detect even at 0.1 mm.[7]



Fig. 31-1
Representative cement-based luting agents.

Zinc phosphate cement

This traditional luting agent continues to be popular for cast restorations. It has adequate strength, a **film thickness** (thickness of the layer) of about 25 μm (Fig. 31-2) (which is within the tolerance limits required for making cast restorations),[8] and a rea-

*According to Fick's first law, the flux of a component of concentration across a membrane of unit area, in a predefined plane, is proportional to the concentration differential across that plane.

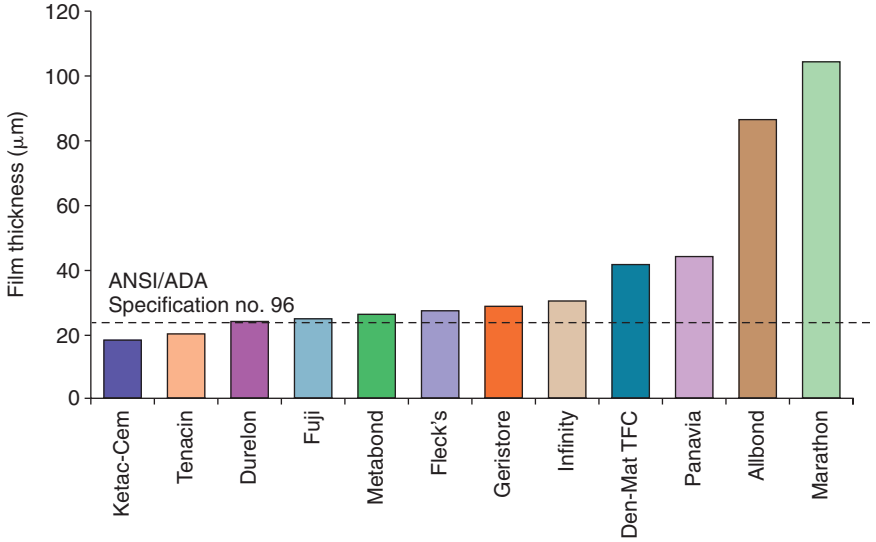


Fig. 31-2
The film thickness of a range of luting agents was tested according to American Dental Association (ADA) specification No. 8 for zinc phosphate cement (now American National Standards Institute [ANSI]/ADA specification No. 96) by White and Yu.[64] Some of the adhesive materials possessed unacceptably high film thicknesses, which may translate into clinical problems for complete restoration seating. *(From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)*

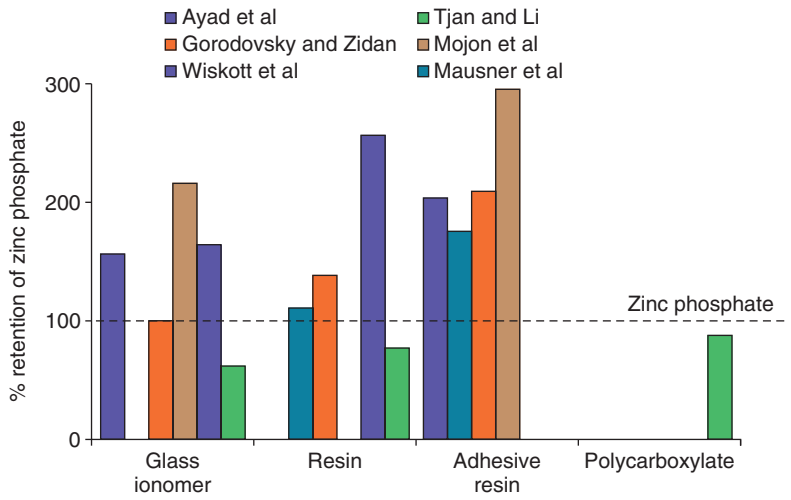


Fig. 31-3

Crown retention studies. Effect of luting agent. These six in vitro studies evaluated the effect of luting agent on crown retention. The data were normalized as a percentage of the retention value with zinc phosphate cement. Adhesive resins had consistently greater retention than zinc phosphate. Conventional resins and glass ionomers yielded less consistent results. *(From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)*

sonable working time. Excess material can be easily removed.

The toxic effects of zinc phosphate, or, more specifically, phosphoric acid, are well documented.[9] However, the success of the use of this material over many years suggests that its effect on the dental pulp is clinically acceptable as long as normal precautions are taken and the preparation is not too close to the pulp.

Zinc polycarboxylate cement

One advantage of this luting agent is its relative biocompatibility,[10] which may stem from the fact that the polyacrylic acid molecule is large and therefore does not penetrate into the dentinal tubule.

Zinc polycarboxylate cement also exhibits specific adhesion to tooth structure because it chelates the calcium (although it has no adhesion to gold castings). Because of its high viscosity, zinc polycarboxylate cement can be difficult to mix, but this problem can be overcome by using encapsulated products.*

In clinical trials, polycarboxylate performs as well as or slightly better than zinc phosphate.[11,12] However, dentists have reported varying success rates, and claims of inferior long-term retention have been made. These problems may be related to the powder/liquid ratio. At manufacturers' recommended powder/liquid ratios, mixed polycarboxylate cement is very viscous. Some dentists may prefer a more fluid working consistency for reliable seating during cementation. However, polycarboxylate cements have different rheologic or flow properties than zinc phosphate, exhibiting thinning with increased shear rate.[13] This means that they are capable of forming low film thicknesses despite their viscous appearance. When the dentist unnecessarily reduces the powder/liquid ratio, the **solubility** (how susceptible something is to being dissolved) of the cement increases dramatically (as much as threefold).[14] This may be the cause of increased clinical failures. By fabricating luting agents, including polycarboxylate in encapsulated form, manufacturers have reduced problems arising from manipulative variables.

The working time of polycarboxylate is much shorter than that of zinc phosphate (about 2.5 minutes, in comparison with 5 minutes). This may be a problem when multiple units are being cemented. Residual zinc polycarboxylate is more difficult to remove than zinc phosphate, and there is some evidence[15,16] that it provides less **crown retention** than zinc phosphate (Fig. 31-3). Its selection therefore should probably be limited to restorations with good retention and resistance form where minimum pulp irritation is wanted. Its use as a base material and to block out minor undercuts in preparations on vital teeth may also be worth considering.

Glass ionomer cement

This cement adheres to enamel and dentin and exhibits good biocompatibility. In addition, because it releases fluoride,[17,18] it may have an anticariogenic effect, although this has not been documented clinically.[19] The set cement is somewhat translucent,

*Durelon Maxicap, 3M ESPE United States, Inc., Norristown, Pennsylvania.

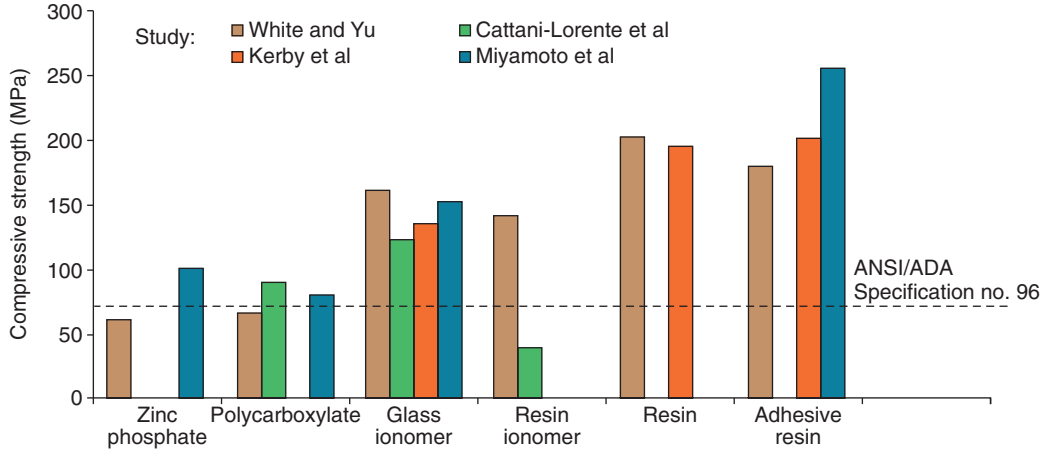


Fig. 31-4

Compressive strength of luting agents. Higher strength values were reported in these studies with the resin cements and glass ionomers than with zinc phosphate or polycarboxylate. Resin-modified glass ionomer exhibited greater variation than did other cements. *(From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)*

which is an advantage when it is used with the porcelain labial margin technique (see Chapter 24).

The mechanical properties of glass ionomer cement are generally superior compared with zinc phosphate or polycarboxylate cements (Fig. 31-4). A disadvantage is that during setting, glass ionomer appears particularly susceptible to moisture contamination[20] and should be protected with a foil or resin coat or by leaving a band of cement undisturbed for 10 minutes.[21] The water changes the setting reaction of the glass ionomer as cement-forming cations are flushed away and water is absorbed, which leads to erosion.[22] Nevertheless, zinc phosphate has also demonstrated significant early erosion when exposed to moisture.[18] Glass ionomers should not be allowed to desiccate during this critical initial setting period. The newer resin-modified glass ionomers are less susceptible to early moisture.[23]

Although glass ionomers have been reported to cause sensitivity,[24] there appears to be little pulpal response at the histologic level,[25] particularly if the remaining dentin thickness exceeds 1 mm.[26] Side effects such as posttreatment sensitivity thought to result from a lack of biocompatibility may actually be a result of desiccation or bacterial contamination[27] of the dentin rather than irritation by the cement. The anecdotal reports that glass ionomer causes more post-treatment sensitivity have not been replicated in clinical trials. Authors have reported little association between the choice of zinc phosphate or glass ionomer cement and increased pulpal sensitivity, provided that manufacturers' recommendations were followed[28-30] (Fig. 31-5). If postcementation sensitivity becomes a problem, dentists should carefully evaluate their technique, particularly avoiding

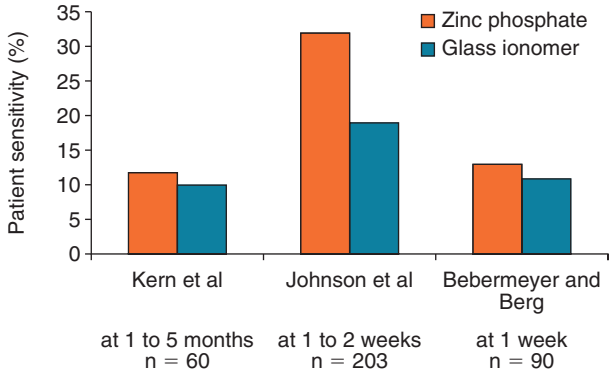


Fig. 31-5

Clinical trials[28-30] that evaluated postcementation sensitivity of patients with crowns cemented with zinc phosphate or glass ionomer cement. Contrary to anecdotal evidence, those with glass ionomer cemented crowns did not exhibit increased postcementation sensitivity. *(From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)*

desiccation of the prepared dentin surface.[31] Resin-modified glass ionomer materials have been reported to provoke less posttreatment sensitivity. Again, this information is anecdotal and has not been confirmed by clinical research.[32] A desensitizing agent may prevent sensitivity, although it may also reduce retention, at least with some luting cements.[16,33] Some formulations of glass ionomer and resin cements are radiolucent (Fig. 31-6), which may prevent the practitioner from distinguishing between a cement line and recurrent caries, as well as detecting cement overhangs.[34] The use of a glass ionomer luting agent in general practice has been favorable[35]; however, any reduction in caries activity that might be anticipated by the fluoride content has not been demonstrated by clinical research.[36]

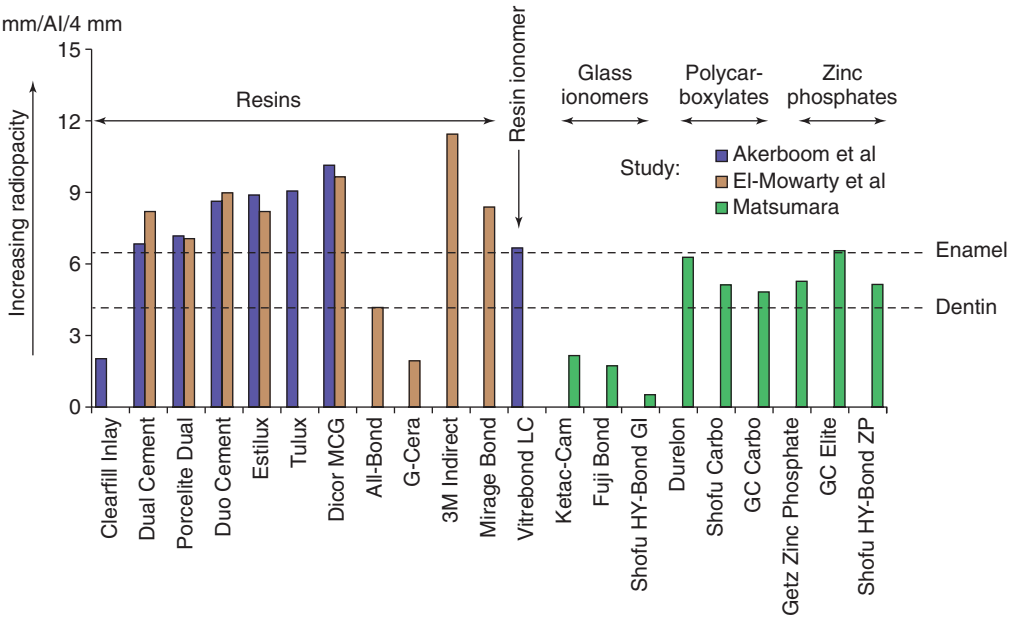


Fig. 31-6

Radiopacity of luting agents. In three in vitro studies, investigators compared the radiographic appearance of various luting agents to aluminum. The data were normalized to account for different specimen thicknesses used by the investigators. Excess luting agent is more difficult to detect if materials with lower values are chosen. In addition, margin gaps and recurrent caries are more difficult to diagnose. *(From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)*

Zinc oxide–eugenol with and without ethoxybenzoic acid

Reinforced ZOE cement is extremely biocompatible and provides an excellent seal. However, its physical properties are generally inferior to those of other cements, which limits its use.[37] In terms of **compressive strength,** solubility, and film thickness, another luting agent (e.g., zinc phosphate) should be used. The ethoxybenzoic acid (EBA) modifier replaces a portion of the eugenol in conventional ZOE cement, although the change improves compressive strength without affecting its resistance to deformation; the cement should be used only in restorations with good inherent retention form in which emphasis is on biocompatibility and pulpal protection. The EBA cement has a relatively short working time, and excess material is difficult to remove.

Resin-modified glass ionomer luting agents

Resin-modified glass ionomers* were introduced in the 1990s in an attempt to combine some of the desirable properties of glass ionomer (i.e., fluoride release and adhesion) with the higher strength and low solubility of resins. These materials are less susceptible to early moisture exposure[38] than is glass ionomer and are currently among the most popular materials in general practice. The materials exhibit higher strength than the conventional cements; values are similar to the resin luting agents.[39] Resin-modified glass ionomers should be avoided with all-ceramic restorations because some brands have been associated with fracture,[40,41] which is probably caused by their water absorption and expansion.[42]

Resin luting agents

Unfilled resins have been used for cementation since the 1950s. Because of their high polymerization shrinkage and poor biocompatibility, these early products were unsuccessful, although they had very low solubility. Composite resin cements with greatly improved properties were developed for resin-bonded prostheses (see Chapter 26) and are used extensively for the bonded ceramic technique (see Chapter 25). Resin cements are available with adhesive properties (i.e., they are capable of bonding chemically to dentin).[43] Bonding is usually achieved with organophosphonates, hydroxyethyl methacrylate (HEMA), or 4-methacryloxyethyl-trimellitic anhydride (4-META).[44] These developments, and their lack of solubility, have rekindled an interest in

*The terminology for some of the newer glass ionomer/resin combinations is rather confusing. In this textbook, the term *resin-modified glass ionomer* has been used. Other terms used for luting agents and restorative materials with a combination of glass ionomer and resin chemistries include *compomer* (mostly composite with some glass ionomer chemistry), *hybrid ionomer* (now considered obsolete), and *resin-reinforced glass ionomer.*

the use of resin cements for crowns and conventional fixed prostheses (Fig. 31-7). Resin luting agents are less biocompatible than cements such as glass ionomer, especially if they are not fully polymerized. They also tend to have greater film thickness.[45]

Choice of Luting Agent

An ideal luting agent has a long working time, adheres well to both tooth structure and cast alloys, provides a good seal, is nontoxic to the pulp, has adequate strength properties, is compressible into thin layers, has low viscosity and solubility, and exhibits good working and setting characteristics. In addition, any excess can be easily removed. Unfortunately, no such product exists (Tables 31-1 and 31-2).

Zinc phosphate cement

Despite its limited biocompatibility in terms of pulp irritation, zinc phosphate has a long history, and its limitations are well documented. This factor is important for cast restorations, which should be designed for long-term service. Zinc phosphate cement is probably still the luting agent of choice for otherwise normal, conservatively prepared teeth. Cavity varnish can be used to protect against pulp irritation from phosphoric acid and appears to have little effect on the amount of retention of the cemented restorations.[46] In addition, crowns cemented with zinc phosphate displayed increased resistance to dislodgment on preparations lacking resistance form.[31]

Zinc polycarboxylate cement

This agent is recommended on retentive preparations when minimal pulp irritation is important (e.g., in children with large pulp chambers).

Glass ionomer cement

This has become a popular cement for luting cast restorations. It has good working properties, and is more translucent than zinc phosphate.

Resin-modified glass ionomer luting agents

Currently among the most popular luting agents, resin-modified glass ionomer luting agents have low solubility, adhesion, and low **microleakage*** (Fig. 31-8). The popularity of these materials is derived

*The seepage of fluids and microorganisms at the interface between a restoration and the walls of a cavity preparation.



Fig. 31-7
Representative resin luting agents. **A,** All-Bond. **B,** Panavia 21. **C,** C and B Metabond.

Table 31-1 COMPARISON OF AVAILABLE LUTING AGENTS

Property	Ideal material	Zinc phosphate	Poly-carboxylate	Glass ionomer	Resin ionomer	Composite resin	Adhesive resin
Film thickness (μm)*	Low	≤25	<25	<25	>25	>25	>25
Working time (min)	Long	1.5-5	1.75-2.5	2.3-5	2-4	3-10	0.5-5
Setting time (min)	Short	5-14	6-9	6-9	2	3-7	1-15
Compressive strength (MPa) (see Fig. 31-4)	High	62-101	67-91	122-162	40-141	194-200	179-255
Elastic modules (GPa)†	Dentin = 13.7 Enamel = 84-130‡	13.2	Not tested	11.2	Not tested	17	4.5-9.8
Pulp irritation	Low	Moderate	Low	High	High	High	High
Solubility	Very low	High	High	Low	Very low	High to very high	Very low to low
Microleakage (see Fig. 31-8)	Very low	High	High to very high	Low to very low	Very low	High to very high	Very low to low
Removal of excess	Easy	Easy	Medium	Medium	Medium	Medium	Difficult
Retention (see Fig. 31-3)	High	Moderate	Low/ moderate	Moderate to high	High§	Moderate	High

*From White SN, Yu Z: Film thickness of new adhesive luting agents. J Prosthet Dent 67:782, 1992; see also Figure 31-2.
†From Rosenstiel SF, et al: Strength of dental ceramics with adhesive cement coatings. J Dent Res 71:320, 1992.
‡From O'Brien WJ: Dental Materials and Their Selection, 2nd ed, p 351. Chicago, Quintessence, Publishing, 1997.
§From Cheylan JM, et al: In vitro push-out strength of seven luting agents to dentin. Int J Prosthodont 15:365, 2002.

mainly from the perceived benefit of reduced postcementation sensitivity, although this benefit has not been confirmed in clinical studies.[47]

Adhesive resins

Long-term evaluations of these materials are not yet available, and so they cannot be recommended for routine use; however, they are indicated for all-ceramic and laboratory-processed composite restorations. Laboratory testing yields high retention strength values,[48] but there is concern that stresses caused by polymerization shrinkage, magnified in thin films,[49] lead to marginal leakage. Adhesive resin may be indicated when a casting has become displaced through lack of retention, and is recommended for all-ceramic restorations.[50]

Preparation of the Restoration and Tooth Surface for Cementation

The performance of all luting agents is degraded if the material is contaminated with water, blood, or saliva. Therefore, the restoration and tooth must be carefully cleaned and dried after the evaluation procedure, although excessive drying of the tooth must

Table **31-2 INDICATIONS AND CONTRAINDICATIONS FOR LUTING AGENT TYPES**

Restoration	Indication	Contraindication
Cast crown, metal-ceramic crown, partial FDP	1, 2, 3, 4, 5, 6, 7	–
Crown or partial FDP with poor retention	1	2, 3, 4, 5, 6, 7
MCC with porcelain margin	1, 2, 3, 4, 5, 6, 7	–
Casting on patient with history of post-treatment sensitivity	Consider 4 or 7	2
Pressed, high-leucite, ceramic crown	1, 2	3, 4, 5, 6, 7
Slip-cast alumina crown	1, 2, 3, 4, 6, 7	5
Ceramic inlay	1, 2	3, 4, 5, 6, 7
Ceramic veneer	1, 2	3, 4, 5, 6, 7
Resin-retained partial FDP	1, 2	3, 4, 5, 6, 7
Cast post-and-core	1, 2, 3, 5, 6	4, 7

KEY:

Luting agent type	Chief advantages	Chief concerns	Precautions
1. Adhesive resin	Adhesive, low solubility	Film thickness, history of use	Moisture control
2. Composite resin	Low solubility	Film thickness, irritation	Use bonding resin, moisture control
3. Glass ionomer	Translucency	Solubility, leakage	Avoid early moisture exposure
4. Reinforced ZOE	Biocompatible	Low strength	Only for very retentive restorations
5. Resin ionomer	Low solubility, low microleakage	Water sorption, history of use	Avoid with ceramic restorations
6. Zinc phosphate	History of use	Solubility, leakage	Use for "traditional" cast restorations
7. Zinc polycarboxylate	Biocompatible	Low strength, solubility	Do not reduce powder/liquid ratio

FDP, fixed dental prosthesis; MCC, metal-ceramic crown; ZOE, zinc oxide–eugenol.

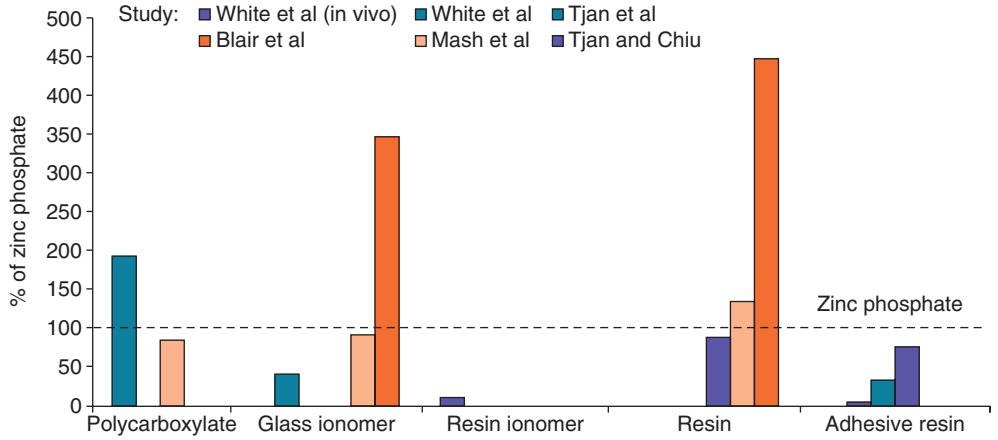


Fig. 31-8

Microleakage of luting agent. A comparison of data from one clinical study and five laboratory studies, expressed as a percentage of the value obtained for zinc phosphate cement. Considerable variation was reported, with adhesive resins and resin-modified glass ionomer exhibiting low microleakage values. *(From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)*



Fig. 31-9
Teeth and restorations must be carefully prepared immediately before cementation. **A,** These preparations need to be cleaned of interim luting agent and dried but not excessively desiccated. **B** and **C,** A steam cleaner is convenient for removing traces of polishing compound from the restorations. **D** and **E,** Airborne particle abrasion of internal restoration surface.

be avoided to prevent damage to the odontoblasts (Fig. 31-9). The casting is best prepared by airborne particle abrading the fitting surface with 50-µm alumina. This should be done carefully to avoid abrading the polished surfaces or margins. Air abrasion has increased the in vitro retention of castings by 64%.[51] Alternative cleaning methods include steam cleaning, the use of ultrasonics, and the use of organic solvents.

Before the initiation of cement mixing, isolating the area of cementation and cleaning and drying the tooth is mandatory. However, the tooth should never be excessively desiccated. Overdrying the prepared tooth leads to postoperative sensitivity. (The techniques for moisture control, essential to proper cementation, are described in Chapter 14.) If a nonadhesive cement (zinc phosphate) is to be used, the tooth should be cleaned,* gently dried, and coated with cavity varnish or dentin-bonding resin.

*Pumice and/or a chlorhexidine preparation such as Consepsis (Ultradent, South Jordan, Utah) is recommended.

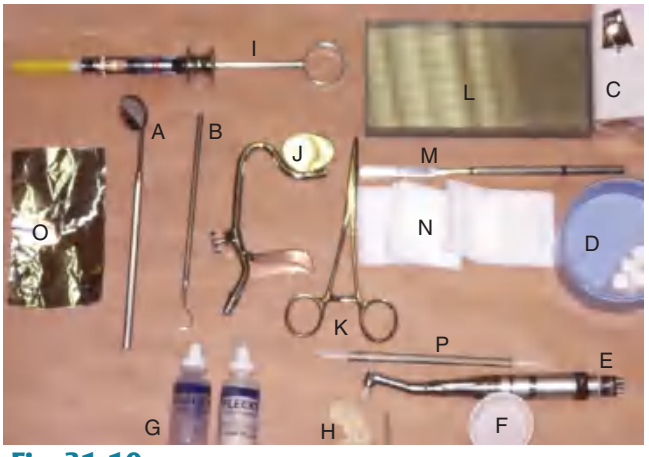


Fig. 31-10
Armamentarium for permanent cementation.

Armamentarium (Fig. 31-10)

- Mirror (A)
- Explorer (B)
- Dental floss (C)
- Cotton rolls (D)

- Prophylaxis cup (E)
- Flour of pumice (F)
- Cement (powder and liquid) (G)
- White stones (H)
- Cuttle disks (H)
- Local anesthetic (if needed) (I)
- Saliva evacuator (J)
- Forceps (K)
- Thick glass slab (chilled) (L)
- Cement spatula (M)
- Gauze squares (N)
- Adhesive foil (O)
- Plastic instrument (P)

Step-by-step procedure

Zinc phosphate cement is used to illustrate a typical procedure, but the steps may vary slightly, depending on the cement chosen (Fig. 31-11). The differences with glass ionomer are pointed out in the description.



Fig. 31-11

Cementation technique with zinc phosphate. **A,** Armamentarium. **B,** The powder is divided into small increments and mixed with liquid on a cool slab over a large surface area. **C,** The consistency of the mix is evaluated by pulling out a "thread" of cement. The thread should break at about 20 mm (¾ inch). **D** and **E,** The internal surface of the restoration is coated. **F,** The restoration is seated. **G** and **H,** Applying an orangewood stick with a rocking motion against the restoration ensures that all excess cement is expressed. **I,** Complete seating is immediately verified with an explorer. **J,** When set, the excess cement is removed from around the margins. A length of dental floss with a knot tied in it is useful for removing excess interproximally. **K,** Cemented restoration. (***A*** *to* ***C,*** *Courtesy of Dr. J. H. Bailey; G, Reprinted from Campagni WV: The final touch in the delivery of a fixed prosthesis. CDA J 12(2):21, 1984.)*

1. Immediately before cementation, inspect all preparation surfaces for cleanliness. Remove any interim luting agent with a pumice wash or hydrogen peroxide (see Fig. 31-9*A*). Because the casting-cement interface is where failure occurs when a crown is displaced, the casting should be airborne particle abraded, steam cleaned, or cleaned ultrasonically and washed with alcohol to remove any remaining polishing compound that might interfere with retention of the finished restoration (see Fig. 31-9*B* to *E*).
2. Isolate the area with cotton rolls and place the saliva evacuator. On occasion, a rubber dam can be used, but only rarely for extracoronal restorations. Avoid using cavity cleaners to aid in drying the preparation, because they may adversely affect pulpal health.
3. Apply cavity varnish to reduce pulp irritation from the zinc phosphate cement. Obviously, a varnish should not be applied when an adhesive material, such as resin, glass ionomer, or polycarboxylate, is used, because it would prevent the material's adhesion to dentin.
4. Cool the glass slab under running water, dry it, and dispense the proper amount of powder and liquid. The cooled slab retards setting and allows additional powder to be incorporated in the liquid. This results in higher compressive strength and reduced solubility of the set cement.

A paper mixing pad is generally used with glass ionomer or polycarboxylate cements.

Frozen slab technique

This technique is a practical way to increase the working time and reduce the setting time of zinc phosphate cement.[52,53] The technique entails the use of a 50% increased powder/liquid ratio, and mixing is performed on a frozen glass slab. There is no adverse effect on compressive strength, solubility, or retention,[54,55] and the pH rise in the cement may be accelerated.[56] The frozen slab technique is reliable and is particularly effective when multiple castings are to be cemented. An incidental advantage of this technique is that the condensation that forms on the glass slab facilitates cleanup of excess cement. Reduced-temperature mixing has also been applied to glass ionomer cements as a way of increasing working time and increasing powder/liquid ratio. Film thickness measurements suggest that the procedure is beneficial.[57]

5. Divide the powder into small quantities (each about one sixth of the total mix), and add them one at a time to the liquid (see Fig. 31-11*B*). After the first increment of powder has been incorporated for 15 to 20 seconds, a second is added, and so on. During mixing, a large surface area (e.g., 60% of the slab) should be used so that the heat of the exothermic setting reaction is dissipated. The mixing continues until all powder has been incorporated (about 90 seconds). For glass ionomer cement, the measured powder is divided into two equal parts and mixed with a plastic spatula. The first increment is rapidly incorporated in 10 seconds, and the second increment is incorporated and mixed for an additional 10 seconds.
6. When the mixing procedure is completed, check the consistency by lifting some cement off the slab with the spatula (see Fig. 31-11*C*). The cement is of proper consistency if it pulls into a thread of about 20 mm (¾ inch) in length before "snapping" back onto the slab.

The consistency of properly mixed glass ionomer is noticeably more viscous than zinc phosphate, but the material thins out with seating pressure.

7. Apply a thin coat of cement to the clean internal surface of the restoration (see Fig. 31-11*D* and *E*). To extend working time, the cement should be applied to a cool restoration rather than to a warm tooth.
8. Dry the tooth again with a light blast of air and push the restoration into place (see Fig. 31-11*F*). Final seating is achieved by rocking with an orangewood stick until all excess cement has escaped (see Fig. 31-11*G*). Seating the restoration firmly with a rocking, dynamic seating force is important (see Fig. 31-11*H*). Using a static load may cause binding of the restoration and lead to incomplete seating. Without rocking the casting, increasing the load only seems to increase the binding reaction.[58] Excessive force during seating should be avoided, especially with metal-ceramic or all-ceramic restorations, which may fracture.
9. After the casting is seated, check the margins to verify that the restoration is fully in place (see Fig. 31-11*I*). Protect the setting cement from moisture by covering it with an adhesive foil (e.g., Dryfoil*).
10. When it is fully set, remove excess cement with an explorer. Early cement removal may lead to early moisture exposure at the margins with increased solubility. Some cements, such as polycarboxylate or resin, tend to pull away from the margins if excess removal is performed too early and the integrity of many contemporary cements is disturbed if finished in the first 24 hours.[59] Dental floss with a small knot in it can

*Burlew-Jelenko Dryfoil, Heraeus Kulzer, Armonk, New York.



Fig. 31-12
Cementation with C&B-MetaBond resin cement. **A,** The brush-on separating film is applied to the prosthesis, the proximal teeth, in order to prevent the adhesive from bonding where it is not wanted. **B,** The recommended dentin conditioner is applied for 10 seconds and rinsed off, and the tooth is dried. **C** and **D,** Four drops of base and 1 drop of catalyst are mixed for each crown. **E,** After the preparation and interior of the crown are wetted with this mixed liquid, the powder is added (**F**). **G,** The casting is painted, and the crown is seated. **H,** Excess resin is removed after it has completely set. Cleanup is greatly facilitated when the separating film is used. It is important not to remove resin before it has fully set, because the rubbery material will pull away from the margins. *(Courtesy of Parkell Products, Farmingdale, New York.)*

be used to remove any irritating residual cement interproximally and from the gingival sulcus (see Fig. 31-11*J*). The sulcus should contain no cement. After the excess has been removed, the occlusion can be checked once more with Mylar shim stock.

11. Cements take at least 24 hours to develop their final strength. Therefore, the patient should be cautioned to chew carefully for a day or two.

Resin luting agents

Resin luting agents are available in a wide range of formulations. These can be categorized on the basis of polymerization method (chemical-cure, light-cure, or dual-cure) and the presence of dentin-bonding mechanisms. Metal restorations require a chemically cured system, whereas a light- or dual-cure system is appropriate with ceramics. Resins formulated for cementing conventional castings must have lower film thickness than materials designed for ceramics or orthodontic brackets. However, this may be achieved at the expense of filler particle content and will adversely affect other properties such as polymerization shrinkage.

Manipulative techniques vary widely, depending on the brand of resin cement. For example, Panavia EX* sets very rapidly when air is excluded. The directions call for the material to be spatulated in a thin film. It sets rapidly if piled up on the mixing pad. Another material, C&B-MetaBond,† is mixed in a ceramic well that must be chilled to prevent premature setting. Mixing techniques for these materials are illustrated in Figures 31-12 and 31-13.

*Kuraray America, Inc., New York, New York.
†Parkell Products, Farmingdale, New York.



Fig. 31-13
A, Panavia resin cement. **B,** Measured powder and liquid are spatulated for 60 to 90 seconds. The mix becomes creamier as it is mixed. The cement sets if oxygen is excluded, and so it should not be piled up. Instead, it should be spread out over a large surface area. **C,** A thin coat of the cement is applied, the restoration is seated, and excess cement is removed. **D,** The cement is coated with oxygen-inhibiting gel to promote polymerization. *(Courtesy of J. Morita USA, Inc., Irvine, California.)*

CEMENTATION PROCEDURES FOR CERAMIC VENEERS AND INLAYS

These restorations rely on resin bonding for retention and strength. The cementation steps are critical to the restoration's success; careless handling of the resin luting agent may be a key factor in their prognosis. Bonding is achieved by performing the following steps:

1. Etching the fitting surface of the ceramic with hydrofluoric acid.
2. Applying a silane coupling agent to the ceramic material.
3. Etching the enamel with phosphoric acid.
4. Applying a resin-bonding agent to etched enamel and silane.[60]
5. Seating the restoration with a composite resin luting agent (Fig. 31-14).

The etching and silanating steps are presented in Chapter 25.

Selection of Resin Luting Agent

Composite resin luting agents are available in a range of formulations. For veneers, a light-cured

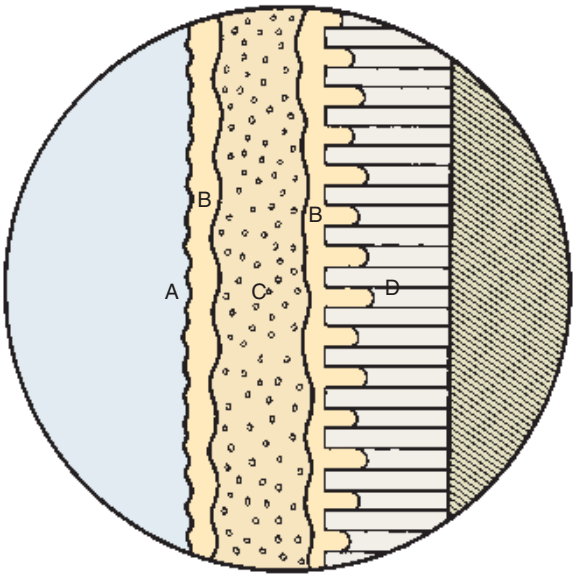


Fig. 31-14
Schematic of resin-bonding technique. *A,* Ceramic surface (etched and silanated); *B,* unfilled resin; *C,* resin luting agent; *D,* etched enamel.



Fig. 31-15
Armamentarium for bonding procedure.

material can be used. For inlays, a chemical-cure material is preferred, to ensure maximum polymerization of the resin in the less accessible proximal areas. In clinical testing, restorations luted with chemically cured materials have performed better than dual-cured luted restorations.[61]

The shade of veneers can be modified by the shade of the luting agent. To facilitate shade selection, color-matched try-in pastes are available from some manufacturers (e.g., Nexus*).

Bonding the Restoration

Armamentarium (Fig. 31-15)

- Mirror
- Explorer
- Rubber dam kit
- Local anesthetic
- Saliva evacuator
- Forceps
- Scalpel
- Curette
- Plastic instrument
- Dental tape
- Mylar strips
- Cotton rolls
- Prophylaxis cup
- Flour of pumice
- Acid etchant
- Porcelain etchant
- Silane coupling agent
- Acetone
- Glycerin or try-in paste
- Bonding agent
- Brush
- Resin luting agent
- Curing light
- Fine grit diamonds
- Porcelain polishing kit

Step-by-step procedure (Fig. 31-16)

1. Clean the teeth with pumice and water (or a chlorhexidine preparation). Isolate them with the rubber dam or displacement cord. A luting agent that contains ZOE should be avoided for cementing interim restorations before resin bonding, because eugenol inhibits the polymerization of the resin. Cleansing with pumice leaves a ZOE residue mixed with pumice, which can inhibit bonding.[62] Etching with 37% phosphoric acid after cleaning with pumice may be the best way to remove ZOE.[63]
2. Evaluate the restorations with glycerin or a try-in paste (see Fig. 31-16*A*). Verify fit, shade, and insertion sequence.
3. Clean the restorations thoroughly in water with ultrasonic agitation. Use acetone if luting resin was used to verify the shade at evaluation.* Dry the restorations.
4. Etch and silanate the restorations as described in Chapter 25.
5. Acid etch the enamel; 37% phosphoric acid is generally used and is applied for 20 seconds. Rinse thoroughly and dry.
6. Apply a thin layer of bonding resin to the preparation. Brush, rather than air thin, the bonding resin, because air thinning might inhibit polymerization. Do not polymerize this layer, because it might interfere with complete seating.
7. For veneers, place a Mylar matrix strip at the mesial and distal surfaces of the prepared tooth (see Fig. 31-16*B*).
8. Apply composite resin luting agent to the restoration; be especially careful to avoid trapping air. (Dual cure is recommended for inlay and onlays; light cure is recommended for veneers) (see Fig. 31-16*C*).
9. Position the restoration gently, removing excess luting agent with an instrument (see Fig. 31-16*D*).
10. Hold the restoration in place while light-curing the resin. Do not press on the center of veneers; they may flex and break (see Fig. 31-16*E*).
11. Use dental tape to remove resin flash from the interproximal margins of inlays and onlays before curing these areas.

*Kerr Corporation, Orange, California.

*This technique requires care. The restoration should not be exposed to the unit light; otherwise, the resin polymerizes prematurely.

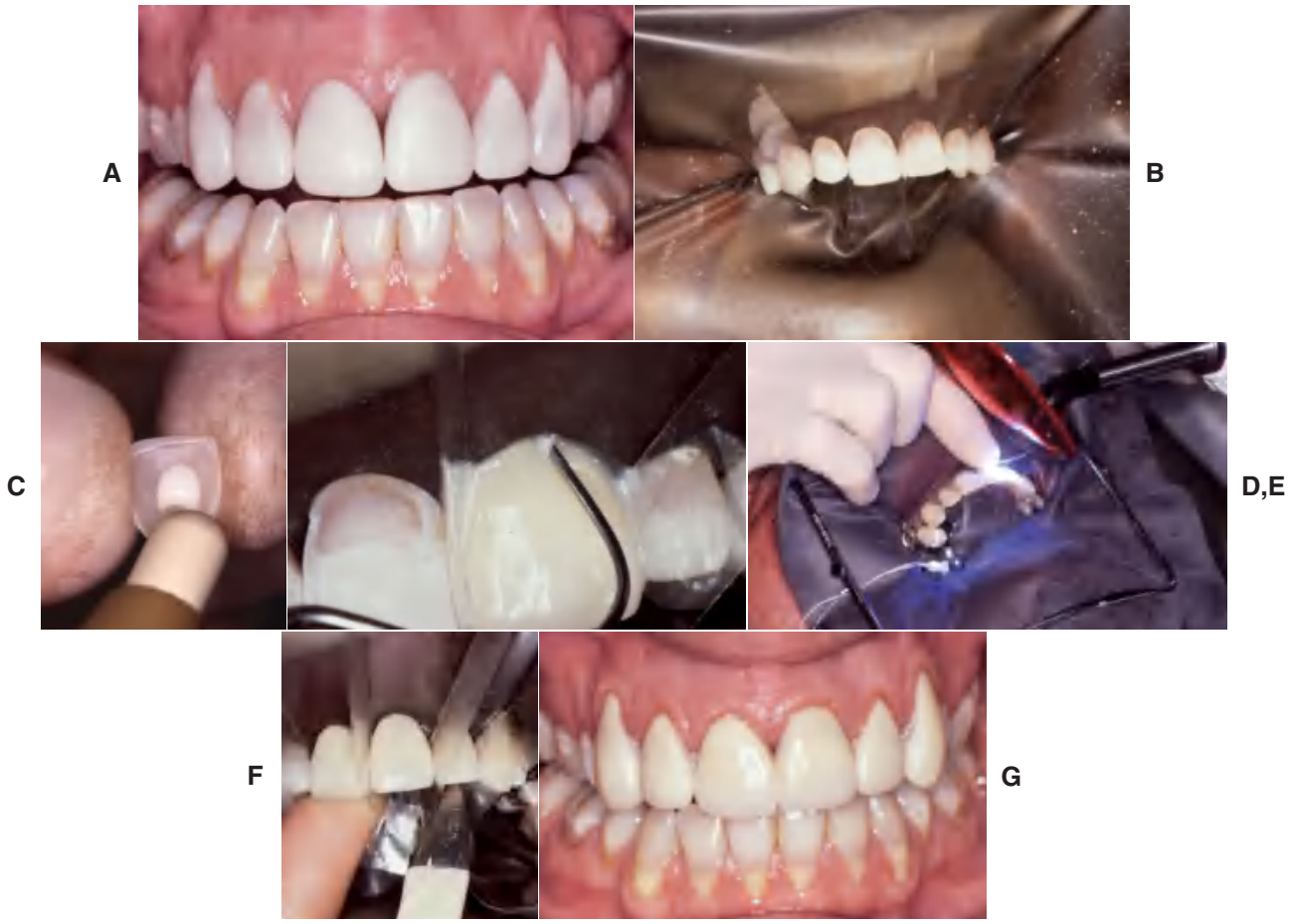


Fig. 31-16
Evaluation and bonding procedure. **A,** The veneers are evaluated very carefully. A drop of glycerin on the fitting surface aids in shade assessment and provides retention. If necessary, the shade can be modified slightly with colored luting agents. The luting agent must not polymerize during evaluation; in particular, the unit light must not shine directly on the restoration. The veneers are thoroughly cleaned in acetone and are silanated according to the manufacturer's recommendations. **B,** The teeth are isolated, pumiced, and etched. Mylar strips are placed between adjacent teeth. **C,** The veneers are filled with resin luting agent and gently seated. **D,** Excess resin is removed with an explorer. **E,** The resin is polymerized. **F,** Gross excess resin is trimmed with a scalpel, and the margins are finished with fine-grit diamonds and diamond polishing paste. **G,** The completed restorations.

12. Do not undercure the resin cement. Allow at least 40 seconds for each area.
13. Remove resin flash with a scalpel or sharp curette (see Fig. 31-16*F*).
14. Finish accessible margins and occlusion with fine diamonds, using water spray. Use finishing strips for the interproximal margins.
15. Polish adjusted areas with rubber wheels or points and then with diamond polishing paste.

REVIEW OF TECHNIQUE

Figure 31-17 illustrates the cementation of six maxillary anterior metal-ceramic crowns.

1. The preparations are thoroughly cleaned; the clinician makes sure all interim luting agent is removed (see Fig. 31-17*A*).
2. The restorations are seated, and a readily accessible area of the margin is examined with an explorer (see Fig. 31-17*B*); this evaluation provides a reference for complete seating during cementation.
3. The restorations are thoroughly cleaned with air abrasion, steam cleaning, or ultrasonics (see Fig. 31-17*C*).
4. The luting agent is mixed according to the manufacturer's recommendations (see Fig. 31-17*D*).
5. The restorations are seated to place with a firm rocking pressure (see Fig. 31-17*E*).
6. The accessible margin area is quickly reexamined to ensure complete seating (see Fig. 31-17*F*).
7. Once the luting agent has completely set, all excess is removed (see Figs. 31-17*G* and *H*).



Fig. 31-17
Technique review. **A,** The preparations are thoroughly cleaned; all interim luting agent should be removed. **B,** The restorations are seated, and a readily accessible area of the margin is examined with an explorer. **C,** The restorations are thoroughly cleaned with airborne particle abrasion, steam cleaning, or ultrasonics. **D,** The luting agent is mixed according to the manufacturer's recommendations. **E,** The restorations are seated to place with a firm rocking pressure. **F,** The accessible margin area is quickly reexamined to ensure complete seating. **G** and **H,** Once the luting agent has completely set, all excess is removed.

SUMMARY

Proper moisture control is essential for the cementation step. The restoration must be carefully prepared for cementation, including the removal of all polishing compounds. Airborne particle abrading the fitting surface is recommended. The luting agent of choice is mixed according to the manufacturer's recommendations, and the restoration is seated, with the use of a rocking action. The luting agent must be protected from moisture during its initial set. Removal of excess luting agent from the gingival sulcus is crucial for continued periodontal health.

Additional steps are necessary for adhesively bonded restorations. These steps must be carefully sequenced according to the manufacturer's directions.

STUDY QUESTIONS

1. Discuss the principal differences in chemistry, physical properties, and manipulative variables for three different types of luting agents. How do the differences affect their clinically indicated use?
2. What are properties of the "ideal" luting agent?
3. Compare the recommended techniques for mixing zinc phosphate cement and Panavia EX.
4. Describe how the tooth and the restoration are prepared before a metal-ceramic crown is cemented with glass ionomer cement. How does this change when a different luting agent is selected?
5. Discuss the steps involved in cementation of two laminate veneers on the maxillary central incisors.

GLOSSARY*

ac·cel·er·a·tor \ăk-sĕl′a-rā′ter\ *n* (1611) **1:** a substance that speeds a chemical reaction **2:** in physiology, a nerve, muscle, or substance that quickens movement or response

ad·her·ence \ăd-hîr′ens, -enz\ *n* (1531)**:** the act, quality, or action of adhering; persistent attachment

ad·he·sion \ăd-hē′zhun\ *n* (1624) **1:** the property of remaining in close proximity, as that resulting from the physical attraction of molecules to a substance or molecular attraction existing between the surfaces of bodies in contact **2:** the stable joining of parts to each other, which may occur abnormally **3:** a fibrous band or structure by which parts abnormally adhere—*comp* CAPSULAR FIBROSIS, FIBROUS A., INTRACAPSULAR A., MYOFIBROTIC CAPSULAR CONTRACTURE

[1]ce·ment \sĭ-mĕnt\ *n* (14c) **1:** a binding element or agent used as a substance to make objects adhere to each other, or something serving to firmly unite **2:** a material that, on hardening, will fill a space or bind adjacent objects- syn *luting agent*

ce·men·ta·tion \sē′mĕn-tā′shun**: 1:** the process of attaching parts by means of cement **2:** attaching a restoration to natural teeth by means of a cement (GPT-4)

com·po·mer \kŏm′pō-mĕr\ *n* (1998)**:** a poly-acid modified composite resin, composed of glass filler, acid-modified dimethacrylate resin, and a *photo initiator*

hybrid ionomer \hī′brĭd ī′a-nō′mĕr**:** a conventional glass ionomer that has been modified to include methacrylate groups in the liquid component. It may contain photo-initiators. Setting is by an acid-base reaction with light and dual cure polymerization ***syn***—RESIN-MODIFIED GLASS IONOMER

[1]lute \lōōt\ *n* (15c)**:** a substance, such as cement or clay, used for placing a joint or coating a porous surface to make it impervious to liquid or gas—see CEMENT

luting agent: any material used to attach or cement indirect restorations to prepared teeth

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REFERENCES

1. Swartz ML, et al: In vitro degradation of cements: a comparison of three test methods. J Prosthet Dent 62:17, 1989.
2. Stannard JG, Sornkul E: Demineralization resistance and tensile bond strength of four luting agents after acid attack. Int J Prosthodont 2:467, 1989.
3. Dewald JP, et al: Evaluation of the interactions between amalgam, cement and gold castings. J Dent 20:121, 1992.
4. Knibbs PJ, Walls AW: A laboratory and clinical evaluation of three dental luting cements. J Oral Rehabil 16:467, 1989.
5. Jacobs MS, Windeler AS: An investigation of dental luting cement solubility as a function of the marginal gap. J Prosthet Dent 65:436, 1991.
6. Dupuis V, et al: Solubility and disintegration of zinc phosphate cement. Biomaterials 13:467, 1992.
7. Dedmon HW: Ability to evaluate nonvisible margins with an explorer. Oper Dent 10:6, 1985.
8. Phillips RW: Skinner's Science of Dental Materials, 9th ed, p. 491. Philadelphia, WB Saunders, 1991.
9. Langeland K, Langeland LK: Pulp reactions to crown preparation, impression, temporary crown fixation, and permanent cementation. J Prosthet Dent 15:129, 1965.
10. Going RE, Mitchem JC: Cements for permanent luting: a summarizing review. J Am Dent Assoc 91:107, 1975.
11. Dahl BL, et al: Clinical study of two luting cements used on student-treated patients: final report. Dent Mater 2:269, 1986.
12. Black SM, Charlton G: Survival of crowns and bridges related to luting cements. Restorative Dent 6:26, 1990.

13. Phillips RW: Skinner's Science of Dental Materials, 9th ed, p. 490. Philadelphia, WB Saunders, 1991.
14. Osborne JW, Wolff MS: The effect of powder/liquid ratio on the in vivo solubility of polycarboxylate cement. J Prosthet Dent 66:49, 1991.
15. Øilo G, Jørgensen KD: The influence of surface roughness on the retentive ability of two dental luting cements. J Oral Rehabil 5:377, 1978.
16. Mausner IK, et al: Effect of two dentinal desensitizing agents on retention of complete cast coping using four cements. J Prosthet Dent 75:129, 1996.
17. Swartz ML, et al: Long term F release from glass ionomer cements. J Dent Res 63:158, 1984.
18. Muzynski BL, et al: Fluoride release from glass ionomers used as luting agents. J Prosthet Dent 60:41, 1988.
19. Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.
20. Um CM, Øilo G: The effect of early water contact on glass-ionomer cements. Quintessence Int 23: 209, 1992.
21. Curtis SR, et al: Early erosion of glass-ionomer cement at crown margins. Int J Prosthodont 6:553, 1993.
22. McLean JW: Glass-ionomer cements. Br Dent J 164:293, 1988.
23. Cho E, et al: Moisture susceptibility of resin-modified glass-ionomer materials. Quintessence Int 26:351, 1995.
24. Council on Dental Materials, Instruments, and Equipment, American Dental Association: Reported sensitivity to glass ionomer luting cements. J Am Dent Assoc 109:476, 1984.
25. Heys RJ, et al: An evaluation of a glass ionomer luting agent: pulpal histological response. J Am Dent Assoc 114:607, 1987.
26. Pameijer CH, et al: Biocompatibility of a glass ionomer luting agent. II. Crown cementation. Am J Dent 4:134, 1991.
27. Torstenson B: Pulpal reaction to a dental adhesive in deep human cavities. Endod Dent Traumatol 11:172, 1995.
28. Johnson GH, et al: Evaluation and control of post-cementation pulpal sensitivity: zinc phosphate and glass ionomer luting cements. J Am Dent Assoc 124:38, 1993.
29. Bebermeyer RD, Berg JH: Comparison of patient-perceived postcementation sensitivity with glass-ionomer and zinc phosphate cements. Quintessence Int 25:209, 1994.
30. Kern M, et al: Clinical comparison of postoperative sensitivity for a glass ionomer and a zinc phosphate luting cement. J Prosthet Dent 75:159, 1996.
31. Rosenstiel SF, Rashid RG: Postcementation hypersensitivity: scientific data versus dentists' perceptions. J Prosthodont 12:73, 2003.
32. Proussaefs P: Crowns cemented on crown preparations lacking geometric resistance form. Part II: effect of cement. J Prosthodont 13:36, 2004.
33. Pameijer CH, et al: Influence of low-viscosity liners on the retention of three luting materials. Int J Periodontics Restorative Dent 12:195, 1992.
34. Goshima T, Goshima Y: Radiographic detection of recurrent carious lesions associated with composite restorations. Oral Surg 70:236, 1990.
35. Brackett WW, Metz JE: Performance of a glass ionomer luting cement over 5 years in a general practice. J Prosthet Dent 67:59, 1992.
36. Moura JS, et al: Effect of luting cement on dental biofilm composition and secondary caries around metallic restorations in situ. Oper Dent 29: 509, 2004.
37. Silvey RG, Myers GE: Clinical study of dental cements. VI. A study of zinc phosphate, EBA-reinforced zinc oxide eugenol and polyacrylic acid cements as luting agents in fixed prostheses. J Dent Res 56:1215, 1977.
38. Cho E, et al: Moisture susceptibility of resin-modified glass-ionomer materials. Quintessence Int 26:351, 1995.
39. Piwowarczyk A, et al: Laboratory strength of glass ionomer cement, compomers, and resin composites. J Prosthodont 11:86, 2002.
40. Letters to the editor. Quintessence Int 27:655, 1996.
41. Leevailoj C, et al: In vitro study of fracture incidence and compressive fracture load of all-ceramic crowns cemented with resin-modified glass ionomer and other luting agents. J Prosthet Dent 80:699, 1998.
42. Knobloch L, et al: Solubility and sorption of resin-based luting cements. Oper Dent 25:434, 2000.
43. Cheylan J-M, et al: In vitro push-out strength of seven luting agents to dentin. Int J Prosthodont 15: 365, 2002.
44. Anusavice KJ: Phillips' Science of Dental Materials, 11th ed, p. 456. Philadelphia, WB Saunders, 2003.
45. Caughman WF, et al: Glass ionomer and composite resin cements: effects on oral cells. J Prosthet Dent 63:513, 1990.
46. Felton DA, et al: Effect of cavity varnish on retention of cemented cast crowns. J Prosthet Dent 57:411, 1987.
47. Hilton T, et al: A clinical comparison of two cements for levels of post-operative sensitivity in a practice-based setting. Oper Dent 29:241, 2004.

48. Tjan AHL, Tao L: Seating and retention of complete crowns with a new adhesive resin cement. J Prosthet Dent 67:478, 1992.
49. Feilzer AJ, et al: Setting stress in composite resin in relation to configuration of the restoration. J Dent Res 66:636, 1987.
50. Malament KA, Socransky SS: Survival of Dicor glass-ceramic dental restorations over 16 years. Part III: effect of luting agent and tooth or tooth-substitute core structure. J Prosthet Dent 86:511, 2001.
51. O'Connor RP, et al: Effect of internal microblasting on retention of cemented cast crowns. J Prosthet Dent 64:557, 1990.
52. Henschel CJ: The effect of mixing surface temperatures upon dental cementation. J Am Dent Assoc 30:1583, 1943.
53. Kendzior GM, Leinfelder KF: Characteristics of zinc phosphate cements mixed at sub-zero temperatures [Abstract no. 134]. J Dent Res 55(Special Issue B):B95, 1976.
54. Myers CL, et al: A comparison of properties for zinc phosphate cements mixed on room temperature and frozen slabs. J Prosthet Dent 40:409, 1978.
55. Rosenstiel SF, Gegauff AG: Mixing variables of zinc phosphate cement and their influence on the seating and retention of complete crowns. Int J Prosthodont 2:138, 1989.
56. Fakiha ZA, et al: Rapid mixing of zinc phosphate cement for fixed prosthodontic procedures. J Prosthet Dent 67:52, 1992.
57. Brackett WW, Vickery JM: The influence of mixing temperature and powder/liquid ratio on the film thickness of three glass-ionomer cements. Int J Prosthodont 7:13, 1994.
58. Rosenstiel SF, Gegauff AG: Improving the cementation of complete cast crowns: a comparison of static and dynamic seating methods. J Am Dent Assoc 117:845, 1988.
59. Irie M, et al: Marginal and flexural integrity of three classes of luting cement, with early finishing and water storage. Dent Mater 20:3, 2004.
60. Della Bona A, et al: Effect of ceramic surface treatment on tensile bond strength to a resin cemen. Int J Prosthodont 15: 248, 2002.
61. Sjögren G, et al: A 10-year prospective evaluation of CAD/CAM-manufactured (Cerec) ceramic inlays cemented with a chemically cured or dual-cured resin composite. Int J Prosthodont 17: 241, 2004.
62. Mojon P, et al: A comparison of two methods for removing zinc oxide–eugenol provisional cement. Int J Prosthodont 5:78, 1992.
63. Schwartz R, et al: Effect of a ZOE temporary cement on the bond strength of a resin luting cement. Am J Dent 3:28, 1990.
64. White SN, Yu Z: Physical properties of fixed prosthodontic, resin composite luting agents. Int J Prosthodont 6:384, 1993.

32

POSTOPERATIVE CARE



KEY TERMS

fractured connectors
loose retainer
occlusal adjustment
plaque control
porcelain repair
recall
root caries

After placement and cementation of a fixed dental prosthesis (FDP), patient treatment continues with a carefully structured sequence of postoperative appointments designed to monitor the patient's dental health (Fig. 32-1), stimulate meticulous **plaque control** habits, identify any incipient disease, and introduce whatever corrective treatment may be needed before irreversible damage occurs.

Patients should be instructed in special plaque-control measures, especially around pontics and connectors, and the use of special oral hygiene aids such as floss threaders (Fig. 32-2). If the pontics are properly designed (see Chapter 20), floss can be looped through the embrasure spaces on each side, and the loop can be pulled tightly against the convex pontic tissue surface. A sliding motion is then used to remove dental plaque (Fig. 32-3). Flossing under pontics is essential for improving prosthesis longevity. When dental floss is used, the mucosa beneath pontics remains healthy; without it, mild or moderate inflammation results.[1] Tissue response has been shown to be independent of the pontic material.[2]

Recall examinations are especially important for patients with extensive restorations and should be carried out by the dentist. Responsibility for follow-up care should not be delegated to auxiliary personnel (although good cooperation with a dental hygienist will prove beneficial for success).

Detecting disease around an FDP can be extremely difficult at a stage when corrective treatment is still relatively simple. For instance, partial dissolution of the luting agent may be difficult to diagnose with a subgingival margin. Caries is often detected only after irreversible pulp involvement has resulted. Caries under a crown is more difficult to detect radiographically, although bitewing images provide some information interproximally. Follow-up studies on patients with FDPs reveal that identifying risk factors and predicting the development of caries in any particular patient are complicated. However, there is no indication that caries is more likely in association with prostheses than on unrestored teeth.[3]

If caries is overlooked, disease may rapidly progress to the point at which the fabrication of a new prosthesis becomes inevitable or, even worse, tooth loss results.

POSTCEMENTATION APPOINTMENTS

To enable the dentist to monitor the function and comfort of the prosthesis and to verify that proper plaque control has been mastered by the patient



Fig. 32-1
Treatment after placement of multiple restorations. To ensure tissue health and long-term success, proper oral hygiene is mandatory.



Fig. 32-3
The patient should be instructed in the use of floss to clean partial fixed dental prostheses.



Fig. 32-2
Oral hygiene aids designed to maintain partial fixed dental prostheses.



Fig. 32-4
Postcementation monitoring of plaque control is necessary around recently cemented restorations. Poor oral hygiene has led to gingival inflammation (*arrows*).

(Fig. 32-4), an appointment is generally scheduled within a week to 10 days after the cementation of an FDP. The dentist should check carefully that the gingival sulcus remains clear of any residual luting agent that may have been overlooked previously and that all aspects of the occlusion remain satisfactory.

Radiolucent cements should be avoided because detecting excess luting agent radiographically is impossible if that material is effectively radiolucent. As luting agent radiopacity increases, excess cement is spotted more easily on routine radiographs; therefore, the dentist should choose a luting agent that is as radiopaque as possible. In practice, luting agents are available in a wide range of radiopacities.[4-6] Figure 32-5 summarizes data from these studies.

The presence of fremitus (see Chapter 1) or "polished" facets on the occluding surfaces of cast restorations at the postcementation appointment should prompt a careful reassessment and correction of the occlusion. If any minor shift in tooth position has occurred, some **occlusal adjustment** may be necessary. If so, the patient is rescheduled to visit the following week to ensure that no further correction is needed.

PERIODIC RECALL

Patients with cast restorations should attend recall visits at least every 6 months. Less frequent recall may lead to oversight of recurrent caries or the development of periodontal disease. Patients who have been provided with extensive fixed prostheses (Fig. 32-6) need more frequent recall appointments, particularly when advanced periodontal disease was present. The appointments can be coordinated by the restorative dentist or the periodontist. To ensure treatment continuity, it is imperative to establish in advance who will assume primary responsibility for coordinating recall appointments.

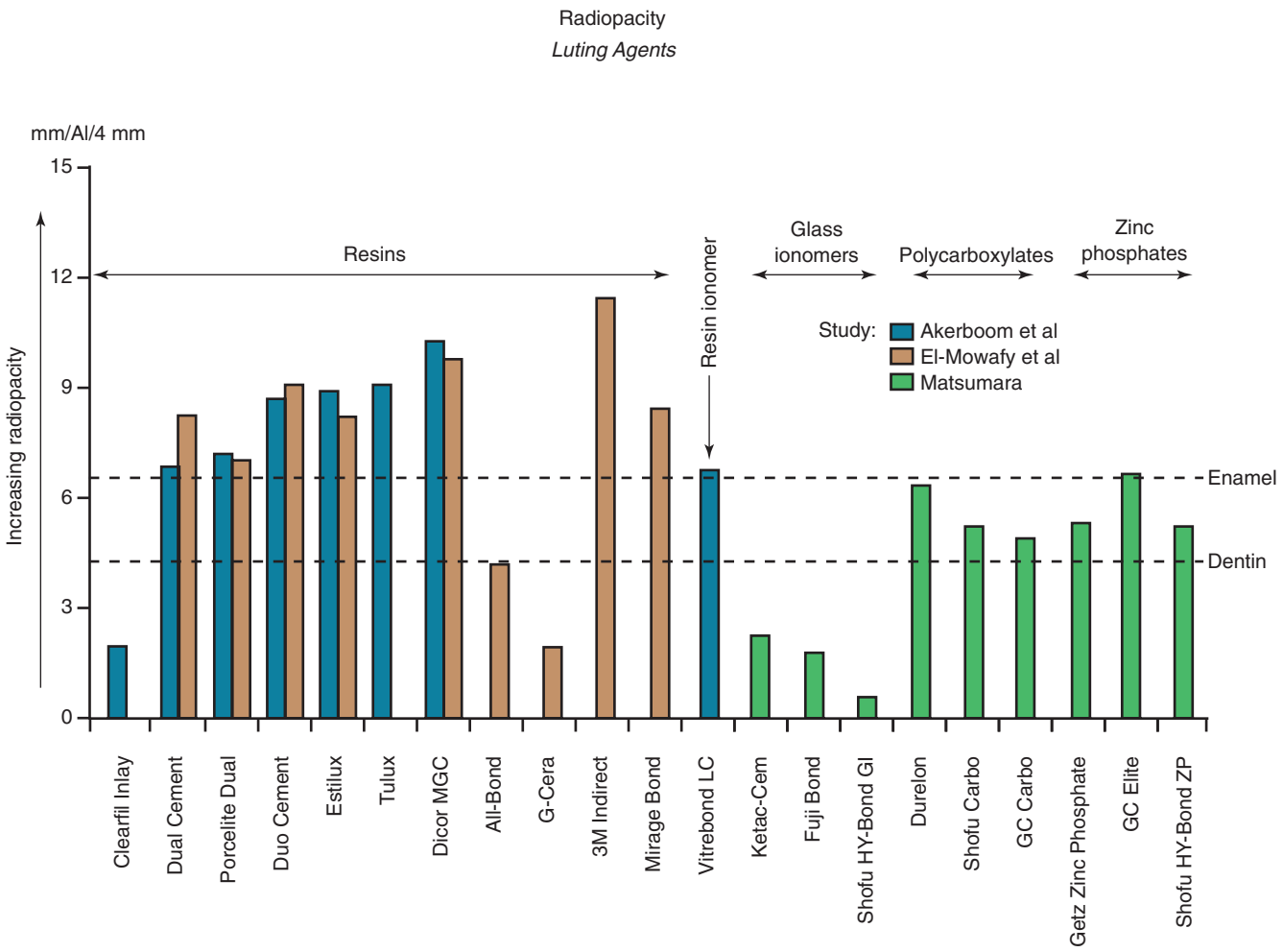


Fig. 32-5
Radiopacity of luting agents. In three in vitro studies,[4-6] investigators compared the radiographic appearance of various luting agents to aluminum. The data were normalized to account for different specimen thicknesses used by the investigators. Excess luting agent is more difficult to detect if materials with lower values are chosen. In addition, margin gaps and recurrent caries are more difficult to diagnose.



Fig. 32-6
Patients who have received extensive treatment of this nature require more frequent follow-up care.

History and General Examination

The patient's medical history should be reviewed and updated at least annually. The patient should be examined according to the principles introduced in Chapter 1. Particular attention is paid to the soft tissues, because early signs of oral cancer may be detected at a recall appointment.

Oral Hygiene, Diet, and Saliva

Patients tend to become somewhat less diligent in their plaque control efforts when the active phase of their treatment is completed. The dentist should look carefully for any signs of deterioration in oral hygiene and assess the general effectiveness of plaque control at every recall with an objective index (Fig. 32-7). Deficiencies must be identified early, and

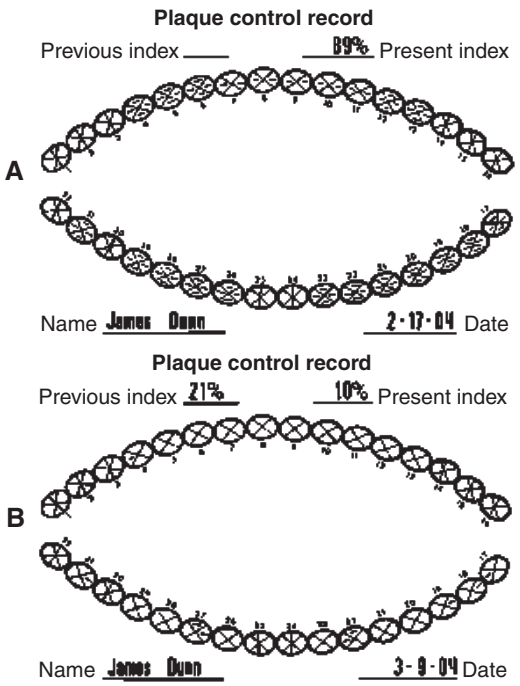


Fig. 32-7

A, Plaque control record filled out at the first appointment for teaching proper oral hygiene measures. **B,** Plaque control record after four sessions of instruction. This patient's plaque level is such that definitive treatment can begin. This level of plaque control needs to be maintained during the postoperative phase of treatment. *(Modified from Goldman HM, Cohen DW: Periodontal Therapy, 5th ed. St. Louis, Mosby, 1973.)*



Fig. 32-8

Undetected caries beneath this partial fixed dental prosthesis resulted in serious complications.



Fig. 32-9

Drying the teeth facilitates assessment of the margin integrity of a cemented prosthesis.

corrective therapy should be initiated. The dentist should ask about changes in diet, particularly increased sugar consumption or "fad" diets. Excessive weight loss or gain should also be investigated. For instance, a patient who has recently stopped smoking may start ingesting large amounts of candy, which can result in an increase in dental caries.

Saliva plays an important role in caries development. Patients with xerostomia can rapidly develop extensive carious lesions.[7] Diagnosing the cause of reduced saliva is imperative; the origin is often a drug side effect.[8]

Dental Caries

Dental caries (Fig. 32-8) is the most common cause of failure of a cast restoration.[9-12] Detection can be very difficult,[13] particularly where complete coverage is used. At each appointment, the teeth should be thoroughly dried and visually inspected (Fig. 32-9). The explorer must be used very carefully when early enamel lesions are assessed, because a heavy-handed examination may damage the fragile demineralized enamel matrix. An intact enamel matrix is essential for procedures that induce remineralization[14] (e.g., improved plaque control, dietary changes, topical fluoride applications).

Conservative treatment of caries at the cavosurface margin is especially problematic. The lesion can spread rapidly, particularly if the restoration has a less than optimal marginal fit. Correcting the problem with a small amalgam, composite resin, or glass ionomer restoration is sometimes possible (Fig. 32-10). If the cast restoration is supported by an amalgam or composite resin core, the extent of the caries may be difficult to determine. When there is



Fig. 32-10
Occasionally, cervical glass ionomer or amalgam restorations (*arrows*) can extend the useful life of a previously placed cast restoration and postpone complicated replacement of the prosthesis.

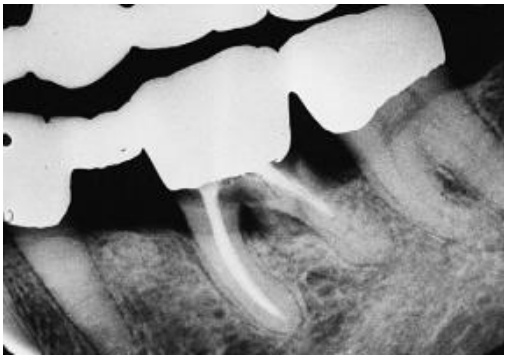


Fig. 32-11
Extensive root caries beneath a cemented partial fixed dental prosthesis. *(Courtesy of Dr. J. Keene.)*

doubt that all carious dentin has been removed, replacing the entire restoration is recommended.

Root caries

Caries of exposed root surfaces (Fig. 32-11) can be a severe problem in the age group commonly seeking fixed prosthodontic care.[15-17] In the classic Vipeholm study,[18] **root caries** accounted for more than 50% of new lesions in patients in the 50-year-old age group. Root caries incidence increased considerably with age.[19] In the caries examination from phase 1 of the Third National Health and Nutrition Examination Survey, root caries affected 22.5% of the dentate population.[20] Root surface caries seems to be associated with individual dental plaque scores and high counts of salivary *Streptococcus mutans*.[21] Xerostomia that is age-related or caused by medication or radiation treatment has been implicated in the etiology of rampant caries.[22-24] Other factors include the patient's economic status, diet, oral hygiene, and ethnic background.[25] Only a most vigorous effort on the part of the dentist and patient leads to resolution of the problem. Prevention is focused on diet counseling and fluoride treatment. Treatment often requires the placement of large cervical glass ionomer or amalgam restorations that wrap around the periphery of previously placed cast restorations. Such restorations are difficult to place. However, in view of the constraints, they are a preferred alternative to comprehensive re-treatment with elaborate fixed prostheses.

Periodontal Disease

Unfortunately, periodontal disease often occurs after placement of fixed prostheses,[26] especially where the cavosurface margin has been placed subgingivally[27-29] or the prosthesis is overcontoured.[30] Inflammation is more severe with poorly fitting restorations[31] (Fig. 32-12), but even "perfect" margins have been associated with periodontitis.[32] At recall appointments, particular attention is given to sulcular hemorrhage, furcation involvement, and calculus formation as early signs of periodontal disease. Improperly contoured restorations should be recontoured or replaced.

Occlusal Dysfunction

The patient is examined for signs of occlusal dysfunction at each recall appointment. The patient should be asked about any noxious habits such as bruxism. An examination of the occlusal surfaces may reveal abnormal wear facets (Fig. 32-13). In particular, the canines should be inspected, because wear in this area soon leads to other excursive interferences. If a patient engages in parafunctional activity that causes tooth wear, the progression of facet formation often begins on the canines. In a slightly more advanced state of wear, additional facets can be observed on the incisor teeth, after which excursive interfering contacts result in wear facets on the posterior teeth. Abnormal tooth mobility is investigated, as is muscle and joint pain. A standardized muscle-and-joint palpation technique (see Chapter 1) is helpful. Articulated diagnostic casts should be periodically remade (Fig. 32-14) and compared with previous records so that any occlusal changes can be monitored and corrective treatment initiated.

A small number of patients may not have responded well to previous occlusal treatment or may resume parafunctional activity some time after completion of the active phase of fixed prosthodontic treatment. Although resolving the underlying etiology is preferable, a nightguard can occasionally be prescribed (Fig. 32-15). Its design is identical to that of the occlusal device described in Chapter 4 for treating neuromuscular symptoms resulting from



Fig. 32-12
Periodontal failure resulting from defective fixed prostheses. **A,** Inadequate margins and contour. **B,** Appearance before surgery. **C,** Flap reflected. **D,** Appearance after surgical recontouring. **E,** Radiograph of new cast restorations. **F,** Replacement restorations. *(Courtesy of Dr. C. L. Politis.)*



Fig. 32-13
If a cast restoration is not designed according to neuromuscular and temporomandibular controls, extensive wear can result after a relatively short time.

malocclusion. However, the device is worn only at night. If the patient primarily clenches, the dentist should consider a slightly flatter anterior ramp than is ordinarily incorporated in the conventional device.

Pulp and Periapical Health

At the recall appointment, the patient may describe one or more episodes of pain during the previous months. This could indicate the loss of vitality of an abutment tooth and should be investigated. Appropriate corrective measures can then be taken.

One advantage of partial-coverage restorations is that pulp health can be monitored with an electric pulp tester (Fig. 32-16), although the vitality of any tooth with a complete crown can still be assessed by thermal means. Correlating the histologic condition

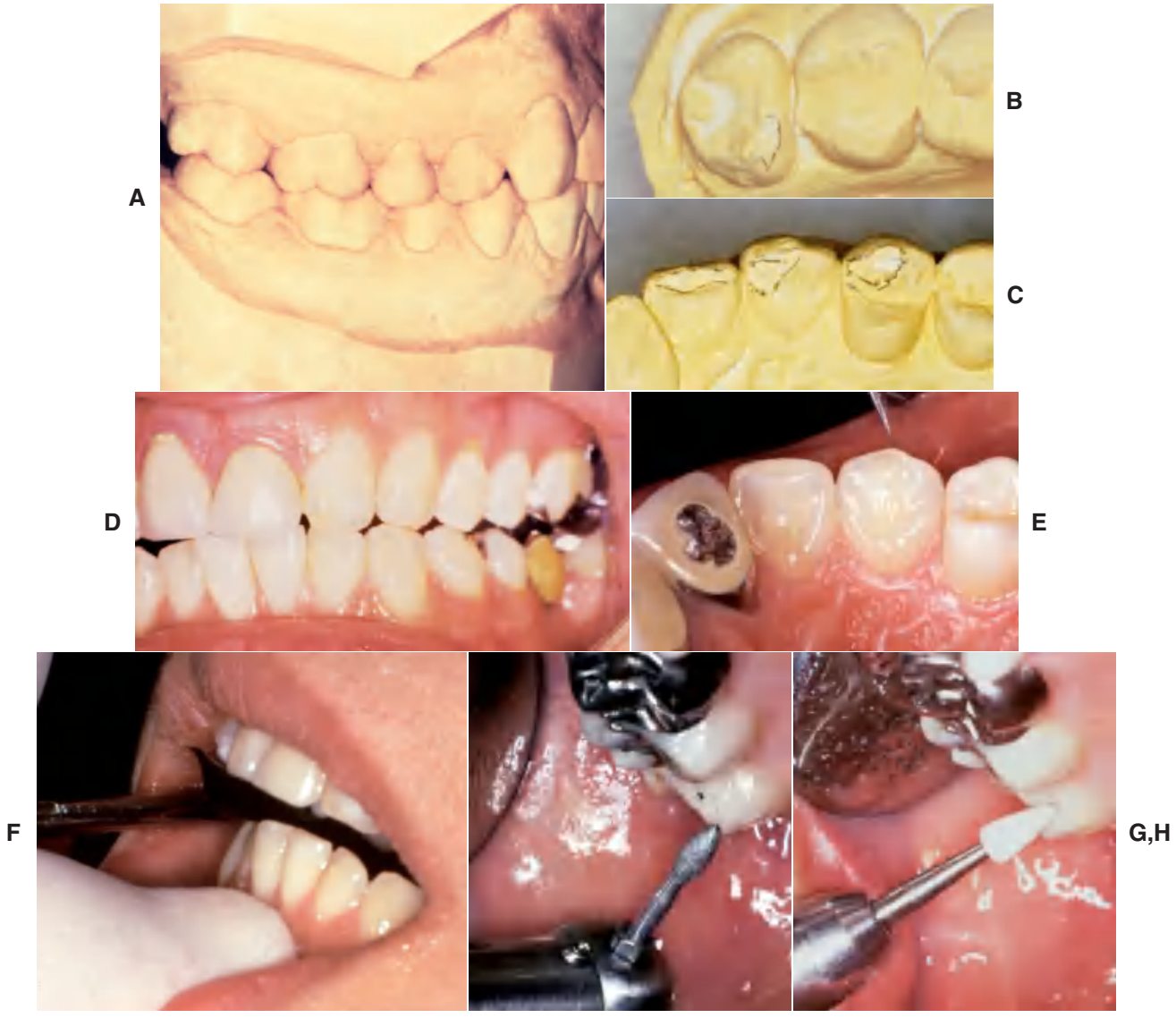


Fig. 32-14

Posttreatment occlusal analysis. **A,** Diagnostic casts should be articulated periodically. **B** and **C,** Non-working wear facets on the maxillary molar correspond with wear on the premolar, canine, and lateral incisor. **D** and **E,** Mandibular excursion corresponding to the observed wear patterns. **F** and **G,** After marking, the newly detected interferences can be easily removed. **H,** The adjusted surfaces are polished.



Fig. 32-15

A and **B,** It may be essential to prescribe an occlusal device after extensive fixed prosthodontics treatment has been provided, especially where occlusal porcelain is used or the patient has a bruxing habit.



Fig. 32-16
A and **B,** Partial-coverage restorations offer the advantage of convenient vitality assessment with an electric pulp tester.



Fig. 32-17
Endodontic treatment after crown cementation. **A,** Symptomatic maxillary molar with a metal-ceramic crown. **B,** Access cavity prepared through the crown. **C,** Endodontic therapy in progress. *(Courtesy of Dr. D. A. Miller.)*

of a pulp directly with the patient's response to pulp testing is difficult.[33] Therefore, such results should be combined with other clinical data that result from careful patient history documentation and examination. Seeking the opinion of an endodontist is often advisable (Fig. 32-17). Radiographs provide useful information about the presence of periapical pathosis. Teeth with fixed restorations should be reviewed radiographically every few years. The use of a standardized technique enables the dentist to make an objective comparison with previous films. Although some studies have shown a high incidence of periapical disease associated with fixed prostheses,[34,35] other studies have shown a low incidence of this complication.[29,36,37]

EMERGENCY APPOINTMENTS

On occasion, patients have an emergency between routine recall visits. With carefully planned and executed treatment, however, these should be rare (although problems can still develop even with the best treatment). Patients should be taught to notice small changes in their oral health and to report them without delay. For instance, the porcelain veneer of a metal-ceramic restoration may be shielded from further fracture when a small chip is promptly rounded off and the occlusion adjusted immediately after it is first noticed. Postponement of corrective treatment can be especially costly, necessitating a remake of a complex prosthesis that could have been saved with prompt attention.

Pain

A patient presenting with pain should be asked about its location, character, severity, timing, and onset. Factors that precipitate, relieve, or change the pain should be investigated, and appropriate treatment measures should be initiated (see Chapter 3).

Although most oral pain is of pulpal origin, such an origin should never be assumed. A detailed investigation is always recommended. In difficult or questionable situations, the diagnosis should be confirmed by an appropriate specialist.

If the patient has several endodontically treated teeth that have been restored with posts and cores and with fixed prostheses, the possibility of root fracture should be considered, especially for teeth that were internally weakened as a result of endodontic

treatment in conjunction with oversized posts of suboptimal length. If a fracture has occurred, the tooth is almost invariably lost, which can significantly complicate follow-up treatment, especially if it involves an abutment tooth for an FDP (Fig. 32-18).

Loose Abutment Retainer

A **loose retainer** (Fig. 32-19) may not be easily perceived by the patient, especially if it is part of a fixed prosthesis supported by several abutment teeth. The patient may have noticed a bad taste or smell rather than detecting movement.

Unless appropriate instrumentation is available, removing the prosthesis intact for recementation is often difficult or impossible. The more recently developed devices shown in Figures 32-20 to 32-22 have been successful, but they are expensive. The devices shown in Figure 32-23 are less reliable and can be quite intimidating and uncomfortable for the patient. On occasion, a direct pull with hemostat forceps succeeds. (Metal-ceramic crowns should first be coated with autopolymerizing acrylic resin to prevent chipping or cracking.) Applying the tip of an ultrasonic scaler to the restoration is recommended because prolonged ultrasonic vibration can decrease crown retention.[38] A procedure for removing crowns and FDPs with a strongly adhesive resin[39] has been used successfully in certain cases[40] (Fig. 32-24). When trying to remove a permanently cemented prosthesis, the dentist must use great caution. Unless force is applied in the path of withdrawal, an abutment tooth may fracture, and tooth loss may result.

A loose retainer usually indicates inadequate tooth preparation, poor cementation technique, or caries. In this case, the tooth requires repreparation and a new prosthesis. Sectioning the prosthesis rather than attempting to remove it intact is often the best policy (Fig. 32-25).

Fractured Connector

An improperly fabricated connector may fracture under functional loading (Fig. 32-26). Depending on the design and location of the FDP, the patient may complain of varying degrees of pain. Extra force is typically transmitted to the abutment teeth, and discomfort from overloading the periodontal ligament may draw attention away from the location of the actual problem. If the abutment teeth have good bone support and minimal mobility, **fractured connectors** can be very difficult to detect clinically.

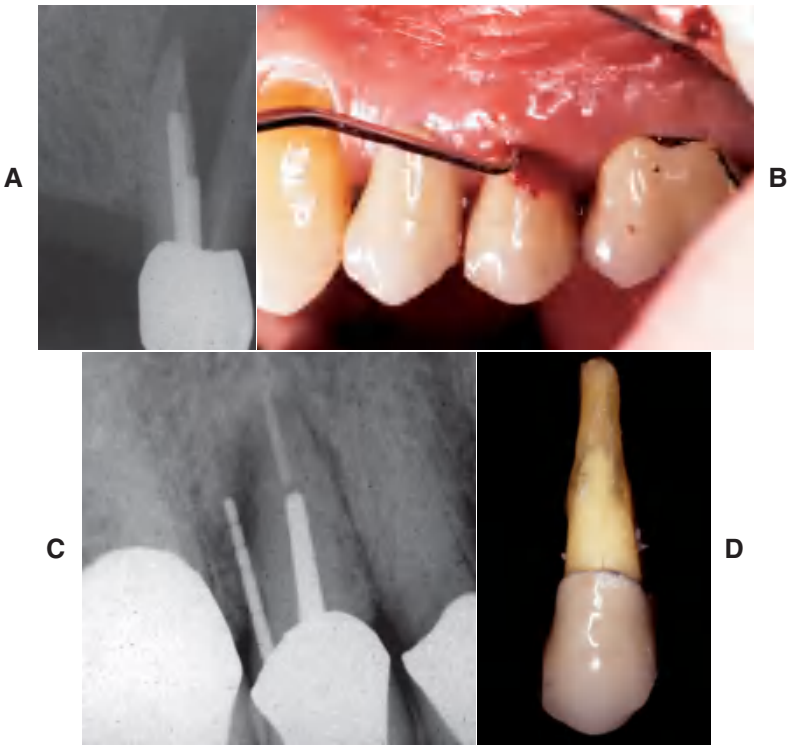


Fig. 32-18

A, Longitudinal root fracture of partial removable dental prosthesis abutment necessitated tooth removal. **B** and **C,** Longitudinal fracture with resulting periodontal defect. **D,** Fracture is clearly visible after removal. *(Courtesy of Dr. D. A. Miller.)*



Fig. 32-19

A, Severe tooth destruction may result when a loose retainer goes undetected. **B,** Looseness of one retainer can occasionally be observed directly (*arrow*) when force is exerted in an occlusal direction. **C,** Water is then applied to the cervical area, and the diagnosis is confirmed if bubbles appear when pressure is exerted (**D**).

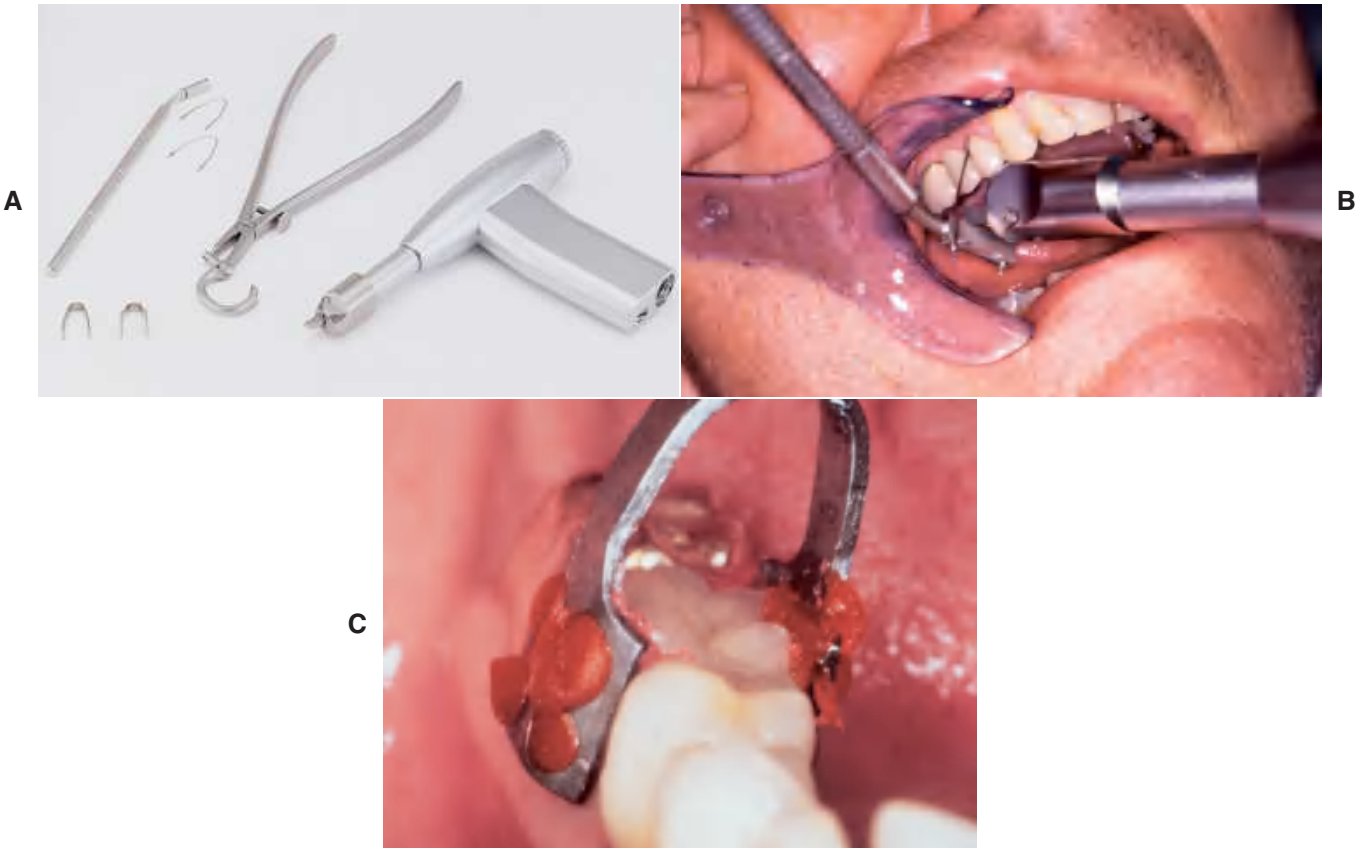


Fig. 32-20

CORONAflex crown remover. This is an air-driven device that connects to standard dental handpiece hoses via KaVo's MULTIflex coupler. The crown remover delivers a controlled low-amplitude impact at its tip. The device works well on partial fixed dental prostheses (FDPs) and is well tolerated by patients. **A,** The kit includes loops to thread under FDP connectors that attach to a holder, calipers, and an adhesive clamp to obtain a purchase on single crowns. The goal is to deliver the impact in the long axis of the abutment tooth. **B,** The loop is threaded under the connector. The tip of the crown remover is placed on the bar, and the impact is activated by releasing the index finger from the air valve. **C,** The adhesive clamp is attached with autopolymerizing resin used to remove a single crown. (***A*** *and* ***C,*** *Courtesy of KaVo Dental Corporation, Lake Zurich, Illinois.)*

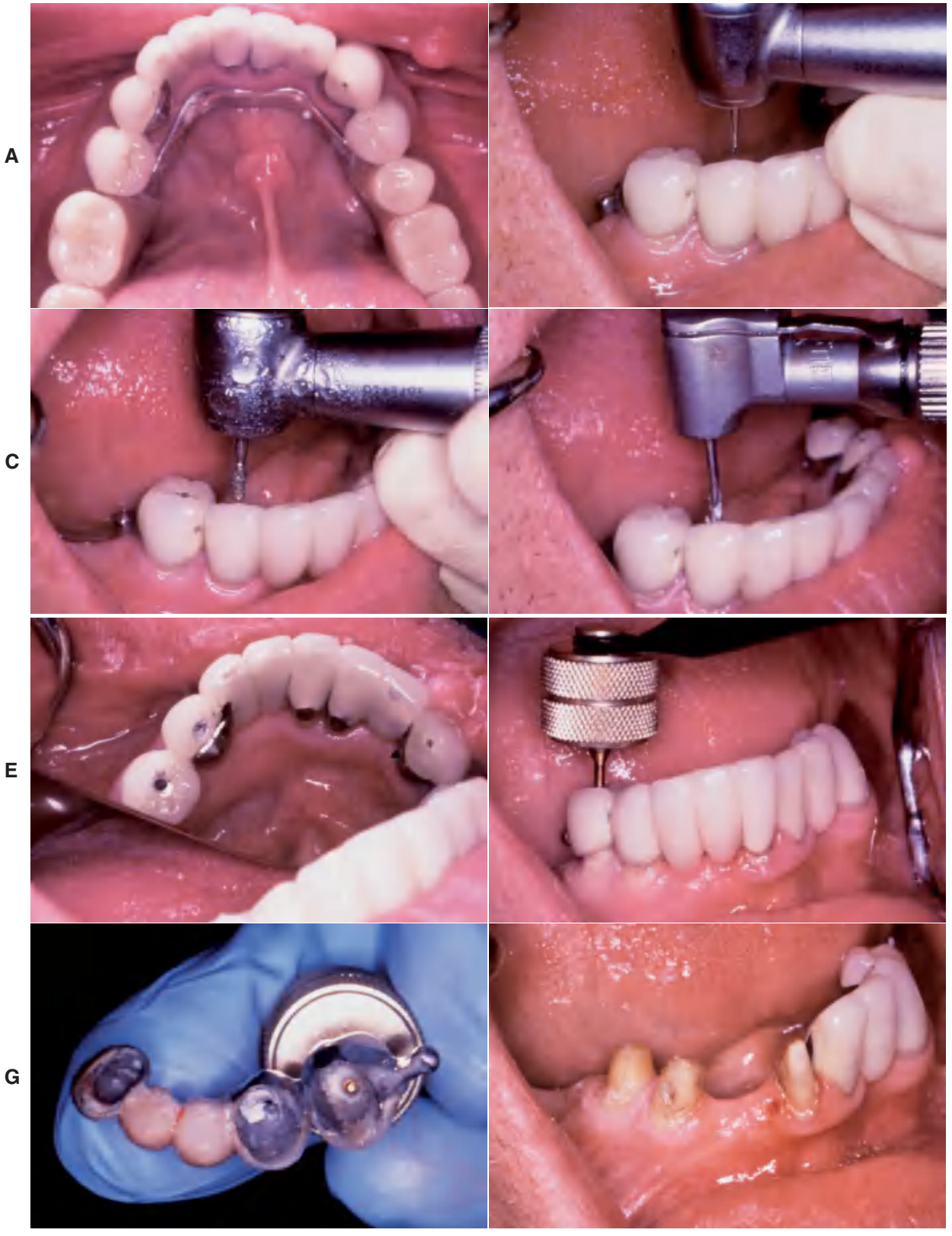


Fig. 32-21

The Metalift Crown and Bridge Removal System (Classic Practice Resources, Baton Rouge, Louisiana). **A,** Five-unit partial fixed dental prosthesis (FDP) supporting a partial removable dental prosthesis. The anterior abutment (right mandibular central incisor) is loose; the posterior abutments (both right mandibular premolars) are firmly cemented. **B,** Access to the metal on each abutment is provided by preparing through the porcelain with a diamond. **C,** The metal is penetrated with a No. 1 round bur to create a pilot channel in each abutment. **D,** The pilot hole is followed by the special drill. **E,** The holes should just penetrate the metal, as indicated by the visible cement. **F,** The Metalift instrument is threaded into both crowns, breaking the cement seal. **G,** The partial FDP is removed, and if the abutments are satisfactory as seen here (**H**), it can be recemented for further service. The manufacturer supplies threaded keys that can be used to seal the occlusal holes. To facilitate recovery, they can also be incorporated in crowns before cementation. *(Courtesy of Dr. R. D. Westerman.)*



Fig. 32-22

Removal devices. A, K.Y. Pliers. This device has specially rasped finish with small sharp pins and is designed to grip a crown or partial fixed dental prosthesis and to deliver a removal force along the long axis. Grip can be enhanced with emery powder. B, Easy Pneumatic C&B Remover II. This device uses compressed air to deliver a controlled, adjustable force to remove the restoration. *(**A,** Courtesy of GC America, Alsip, Illinois. **B,** Courtesy of Dent Corp Research and Development, White Plains, New York.)*

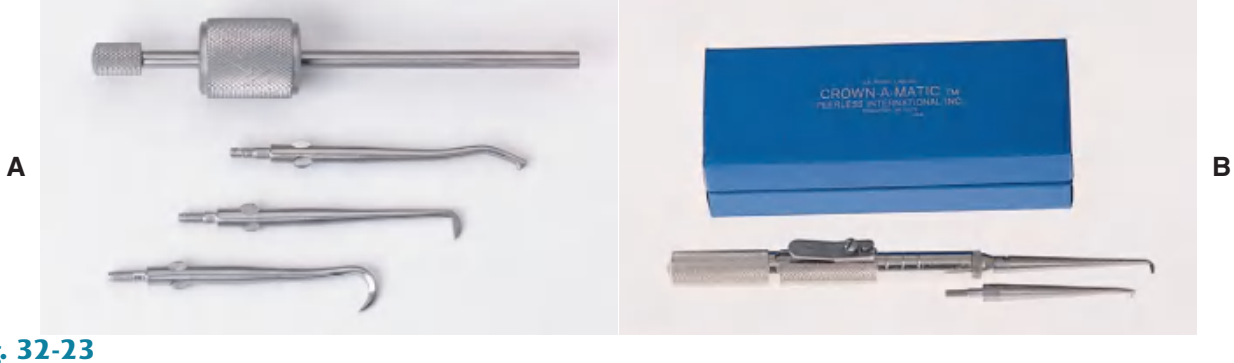


Fig. 32-23

Crown removers. A, Back-action. B, Spring-activated. *(**A,** Courtesy of Henry Schein Inc., Melville, New York. **B,** Courtesy of Peerless International Inc., North Easton, Massachusetts.)*



Fig. 32-24

Richwil Crown and Bridge Remover (Almore International, Inc., Portland, Oregon). This adhesive resin tablet is softened in warm water for 1 to 2 minutes, and the patient is instructed to occlude into it (A) (the manufacturer recommends tying a length of floss to the tablet to prevent aspiration). The resin is cooled with water. A sharp opening action should remove the crown (B). Care is needed to avoid removing a restoration in the opposing jaw.

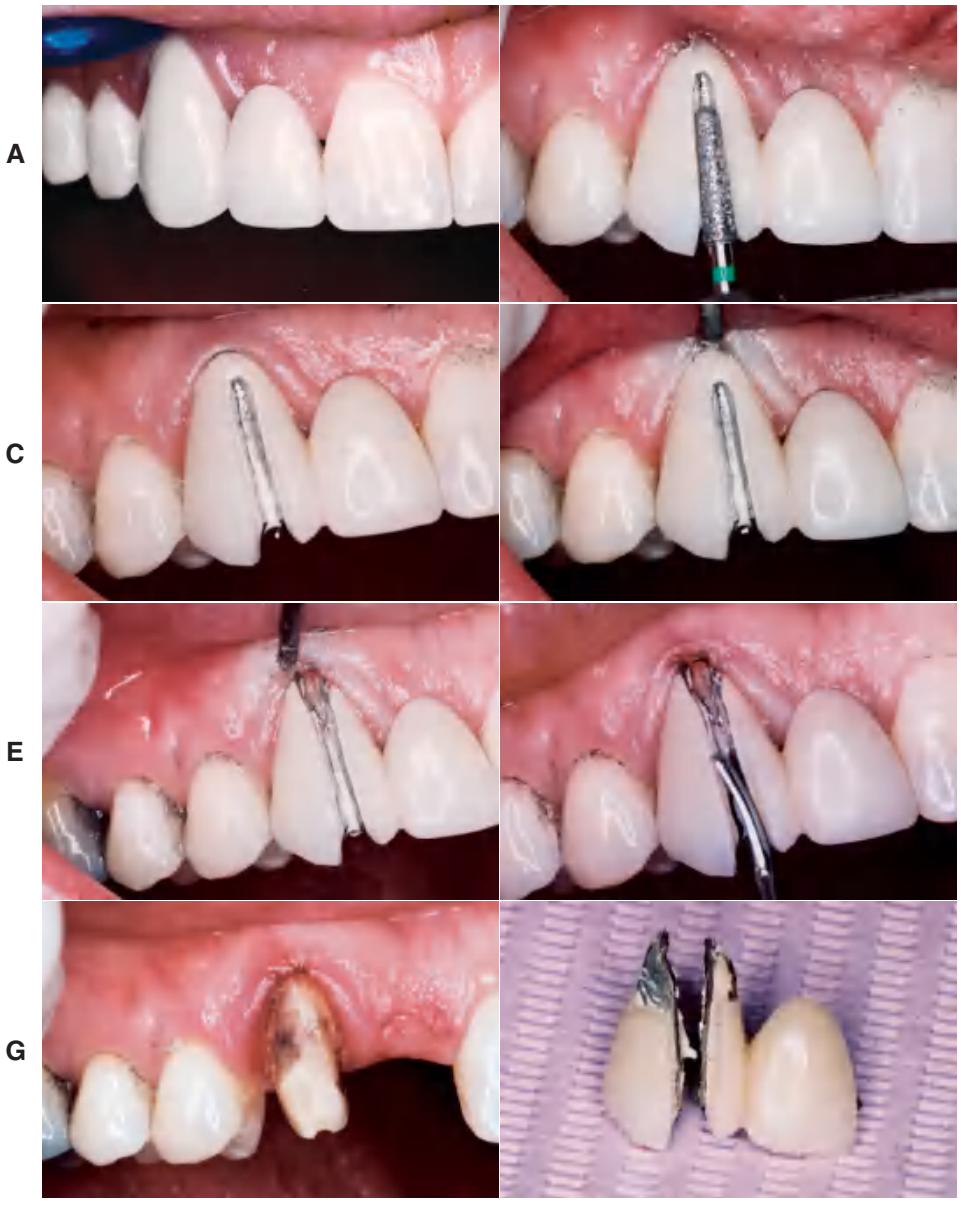


Fig. 32-25

Removal of an existing crown by sectioning. **A,** This cantilevered partial fixed dental prosthesis required replacement for esthetic and periodontal reasons. **B,** The restoration is carefully sectioned, with the initial cut through the ceramic just to the metal. It is easiest to do this on the facial and incisal surfaces. **C,** The goal is to cut through the metal just to the cement and follow the cement toward the gingival margin. **D,** The gingiva is displaced with an instrument and the crown carefully sectioned to the gingival margin (**E**). **F,** A suitable instrument (e.g., a cement spatula or sterilized screwdriver) is placed in the cut and gently rotated to force the halves of the crown apart. It may be necessary to section part of the lingual surface to facilitate this step. **G,** The abutment. Additional incisal reduction was necessary; the notch in the incisal edge is of no concern. **H,** Removed prosthesis. *(Courtesy of Dr. D. H. Ward.)*



Fig. 32-26
A and **B,** The soldered connector of a four-unit partial fixed dental prosthesis fractured during function. The patient's chief complaint was molar pain, although the fracture was between the premolars.

Wedges can sometimes be positioned to separate the individual FDP components enough to confirm the correct diagnosis.

Fractured Porcelain Veneer

Mechanical failure of a metal-ceramic restoration (Fig. 32-27) is not uncommon. It is usually related to faults in framework design, improper laboratory procedures, excessive occlusal function, or trauma (e.g., an automobile or sports accident).

If the porcelain has fractured on an otherwise satisfactory multiunit prosthesis, an attempt at repair rather than a remake may be justified to save the patient additional discomfort, time, and expense. When the fractured porcelain is not missing and there is little or no functional loading on the fracture site, it can sometimes be bonded in place with a **porcelain repair** system (Fig. 32-28) with the use of silane coupling agents or 4-methacryloxyethyltrimellitic anhydride (4-META) to promote bonding with acrylic or composite resin.[41-44] Unfortunately, the strength of joints made this way seems to diminish with changes in temperature[45] and with prolonged water storage.[46] Benefits from such repair are considered temporary, but it may be preferable to dismantling and remaking a complex FDP. In other circumstances, the fractured area may be repaired with composite resin retained by means of mechanical undercuts in the metal framework.[47] The use of a silane coupling agent is also recommended for these repairs.

A more permanent repair can sometimes be effected by making a metal-ceramic restoration to fit over the fractured original. This technique is appropriate when the pontic rather than an abutment retainer has fractured. A little ingenuity is needed to produce a suitable design.[48,49] The most common difficulty encountered when such a repair is attempted is weakening of the connectors during the preparation, with the associated risk of subsequent prosthesis fracture (Fig. 32-29).



Fig. 32-27
Fractured metal-ceramic veneer.



Fig. 32-28
On occasion, repairing a fractured metal-ceramic veneer rather than replacing the entire fixed dental prosthesis is advantageous. In this example, the porcelain surface has been etched; a resin repair system has been used.

RE-TREATMENT

Fixed prostheses do not last forever; however, with good plaque removal, patient motivation, and average or above-average resistance to disease, a



Fig. 32-29

Repair of a fractured metal-ceramic pontic. **A,** Pretreatment appearance. **B,** The ceramic veneer is removed with diamond rotary instruments. **C,** Appearance after porcelain removal. **D,** Special impression tray. **E,** Pinholes are placed in the substructure. **F,** Cast of the substructure. **G** and **H,** Waxed overlay. Note the plastic pins used (**H**). **I,** Cast overlay. **J,** Facial aspect. **K,** Proximal aspect. **L,** Facial aspect after the porcelain application. **M,** Lingual aspect after firing (cast relieved). **N,** Appearance after cementation. **O** and **P,** The finished repair. *(Courtesy of Dr. A. G. Gegauff.)*

well-designed and well-fabricated restoration can provide many years of service. With poor care and neglect, even the "perfect" prosthesis or restoration can fail rapidly (Fig. 32-30). Because of exceptional host resistance, long-term success is sometimes possible with obviously defective restorations (Fig. 32-31).

Nevertheless, at some stage, the decision about re-treatment must be made. Much depends on whether the re-treatment is part of an ongoing program of comprehensive care or whether the existing prosthesis has been subjected to years of neglect.

Planned Re-treatment

At the original treatment planning stage, re-treatment should be considered. This consideration may need to be general rather than specific because of difficulties in accurately predicting the pattern of future dental disease. On occasion, however, a prosthesis is designed to accommodate the eventual failure of a doubtful abutment (Fig. 32-32). With a little foresight, survey contours can already be incorporated in the retainers of an FDP to accommodate a future partial removable dental prosthesis in the event of a terminal abutment loss. Similarly, accommodations can be made for future occlusal rests by deliberately increasing occlusal reduction during tooth preparation and using metal occlusal surfaces. Furthermore, proximal boxes can be incorporated if it is anticipated that a nonrigid (dovetail) rest could simplify future re-treatment (see Fig. 32-32).

When tooth preparations are conservative, when margins are supragingival, and when complicated FDP designs are avoided, replacement dentistry can be performed in an orderly manner, as long as plaque control and follow-up care are maintained.

The key to successful fixed prosthodontic treatment planning lies in anticipating potential areas of future failure. Ideally, the design of a prosthesis should incorporate an escape mechanism to allow simple and convenient alteration to accommodate future treatment needs.

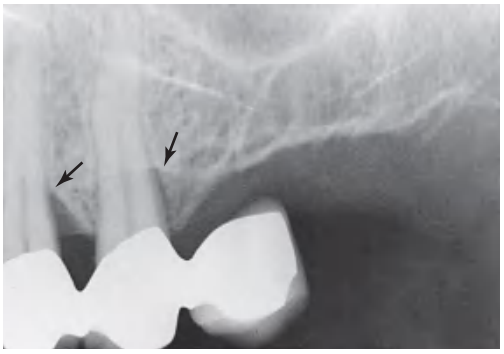


Fig. 32-30
Osseous defects (*arrows*) within 2 years of the placement of this partial fixed dental prosthesis. *(Courtesy of Dr. J. Keene.)*

Neglect

An extensive fixed prosthesis that has been neglected is much more difficult to treat. Considerable expertise is needed to successfully perform the lengthy and demanding procedures. Specialized treatment is almost always necessary and usually includes controlling mobility of the abutment teeth, improving support for removable appliances in the edentulous area, and creating a more favorable load distribution.

TREATMENT PRESENTATIONS

Several treatment results are presented, including follow-up documentation as appropriate, in some cases over many years. The treatments demonstrate successful treatment approaches that are consistent with the principles discussed throughout this text.

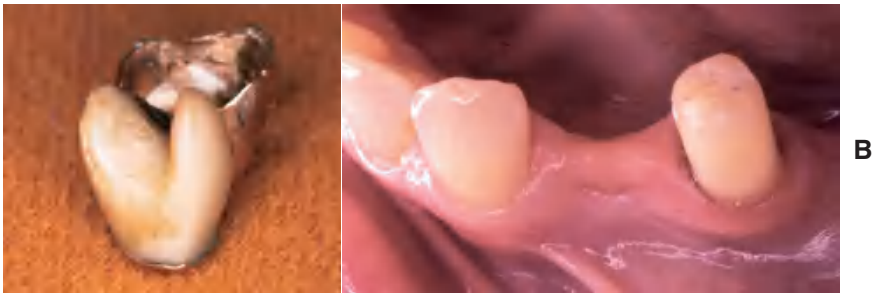


Fig. 32-31
A "saddle" pontic should not be fabricated, because it makes plaque control impossible. **A**, However, this particular partial fixed dental prosthesis was replaced after 35 years of service. **B,** Despite poor pontic design, there are no significant signs of ulceration. This example illustrates the variability of tissue response as a result of differences in host resistance.

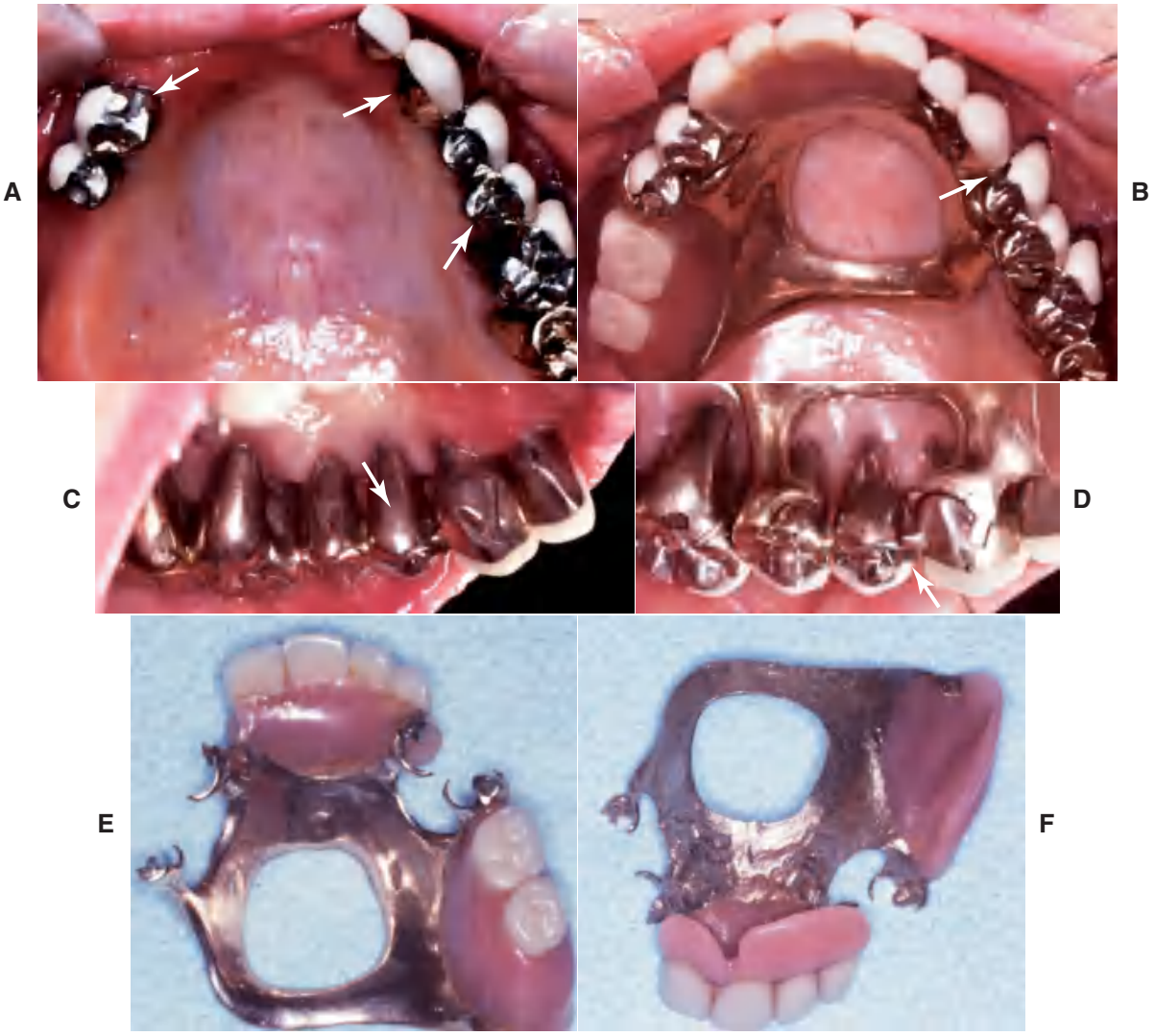


Fig. 32-32

Anticipation of future needs. **A,** Appearance 4 years after the restoration of an arch with periodontally compromised teeth. Three intracoronal rests (*arrows*) were fabricated to support a partial removable dental prosthesis (RDP). **B,** An additional rest (*arrow*) was included as a nonrigid connector for splinting the prostheses in the maxillary left quadrant. This rest is parallel to the others, and so it is available (if needed) for future support of a modified or new RDP. **C,** The lingual aspect of the premolar incorporates the appropriate survey contour (*arrow*) to accommodate such a prosthesis. **D,** The RDP in place. Note the third intracoronal rest (*arrow*). **E** and **F,** External and internal aspects of the RDP. This was cast in type IV gold, which allows the relatively easy addition of a new minor connector with conventional soldering techniques.

- Treatment I (Fig. 32-33): simple cast restorations
- Treatment II (Fig. 32-34): single cast restorations
- Treatment III (Fig. 32-35): simple partial FDPs
- Treatment IV (Fig. 32-36): partial-coverage retainers
- Treatment V (Fig. 32-37): pinledge splint
- Treatment VI (Fig. 32-38): full-mouth rehabilitation with fixed and removable prostheses
- Treatment VII (Fig. 32-39): extensive fixed prosthodontics
- Treatment VIII (Fig. 32-40): extensive fixed and removable prosthodontics
- Treatment IX (Fig. 32-41): anticipation of future needs
- Treatment X (Fig. 32-42): long-term evaluation of comprehensive rehabilitation with fixed and removable prostheses
- Treatment XI (Fig. 32-43): long-term evaluation of comprehensive rehabilitation with fixed prostheses
- Treatment XII (Fig. 32-44): long-term evaluation of comprehensive rehabilitation of a periodontally compromised dentition
- Treatment XIII (Fig. 32-45): long-term evaluation of FDPs

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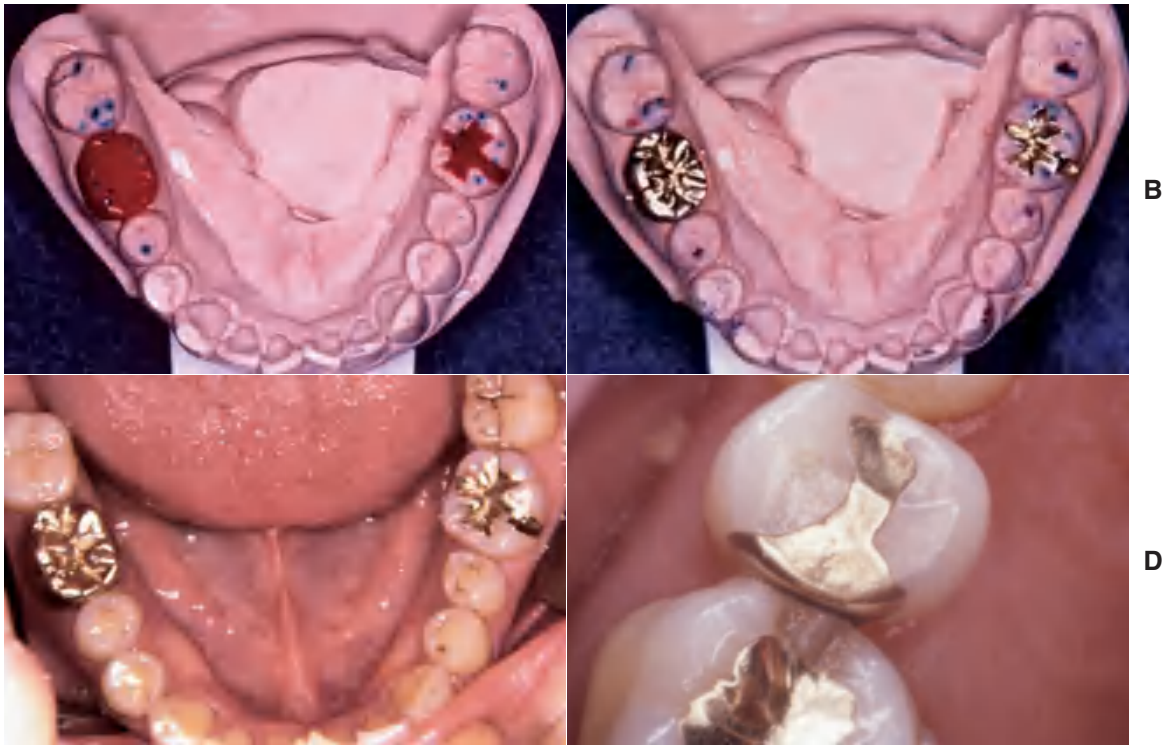


Fig. 32-33
Simple cast restorations (Treatment I). A complete cast crown and inlay used to restore the first molars. **A,** Wax patterns. **B,** Castings seated and adjusted for clinical evaluation. **C,** Cemented restorations. **D,** This two-surface intracoronal cast restoration served for 66 years.

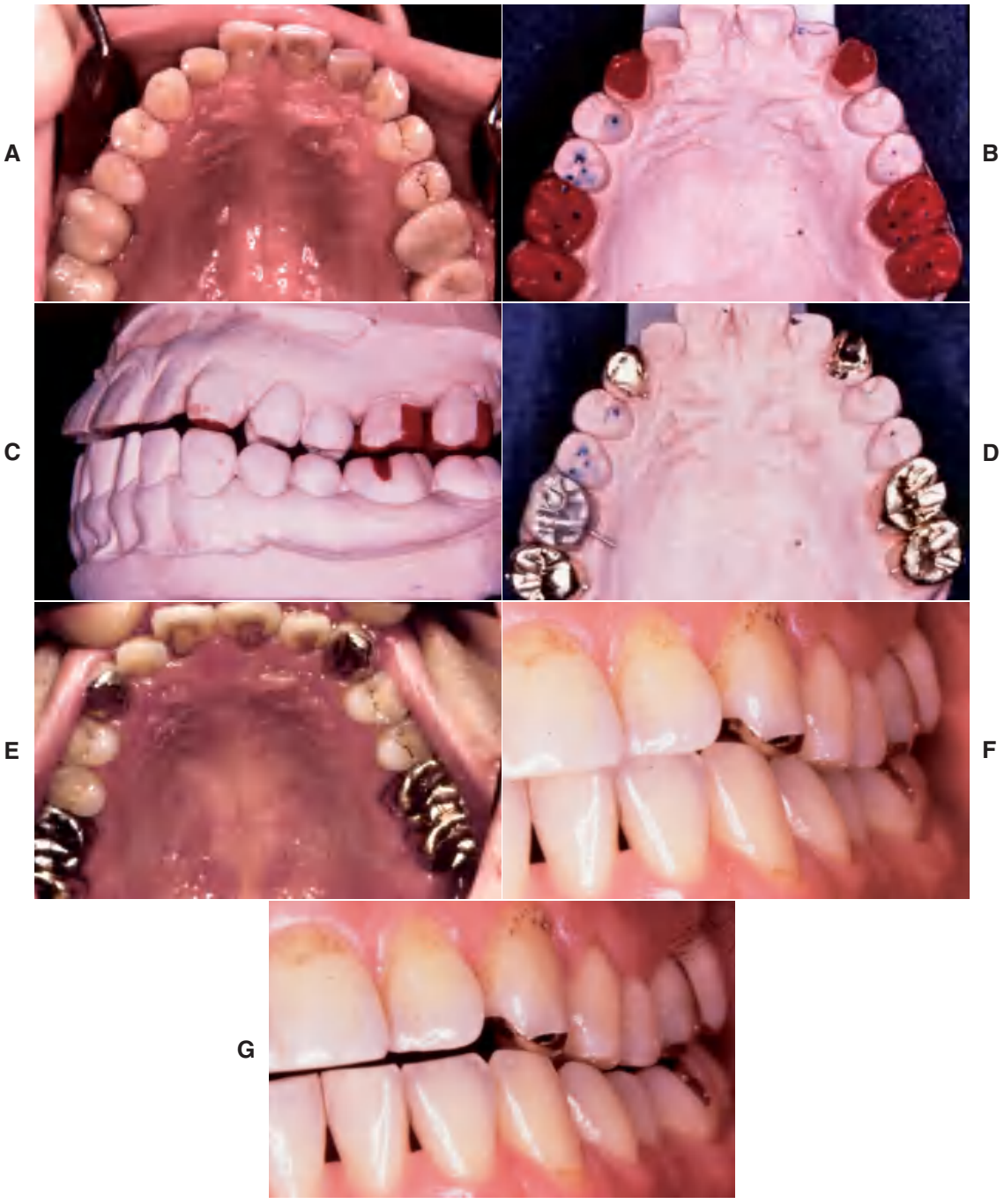


Fig. 32-34

Single cast restorations reestablish canine guidance and functional occlusion (Treatment II). **A,** Extensive anterior wear caused by prolonged parafunctional activity that resulted from malocclusion. **B,** Anterior pinledges are waxed concurrently with the molar castings. **C,** Anterior guidance and posterior occlusion are reestablished. **D** and **E,** Castings seated and adjusted and at clinical evaluation. **F,** A normal canine-to-canine relationship has been reestablished. **G,** Working-side excursion.



Fig. 32-35
Simple partial fixed dental prostheses (FDPs) (Treatment III). Long-term follow-up: These small FDPs remain serviceable after 7 and 13 years. **A** and **B,** Seven-year follow-up. **C** and **D,** Thirteen-year follow-up.



Fig. 32-36
Partial-coverage retainers used to support a partial fixed dental prosthesis (FDP) replacing the maxillary premolar (Treatment IV). **A** and **B**, Tooth preparations. **C**, Preparations on definitive cast. **D** and **E**, Occlusal and buccal views of cemented FDP.



Fig. 32-37
Pinledge splint (Treatment V). **A** and **B,** Periodontally involved anterior teeth prepared for pinledges. **C** and **D,** Completed restorations. Some metal is displayed as a result of the long clinical crown length and opened embrasures resulting from periodontal surgery. However, this treatment approach is preferred because it is much more conservative of tooth structure than is splinting with metal-ceramic crowns.



Fig. 32-38

Full-mouth rehabilitation with fixed, implant-supported, and removable partial prosthodontics (Treatment VI). Before treatment: Note the reverse smile line and discrepancy in the maxillary central incisor gingival tissue levels. The maxillary first molars had furcation involvement and poor prognosis as a result of periodontal bone loss. **A** and **B,** Occlusal views. **C,** Frontal view. **D** and **E,** Right and left views in maximum intercuspation. **F,** Diagnostic waxing. **G,** Dental implants were placed to restore the mandibular arch and provide retention and support for a maxillary partial removable dental prosthesis (RDP). **H,** The gingival tissue levels were corrected with periodontal surgery. **I** and **J,** Anterior teeth prepared for fixed restorations.



Fig. 32-38, cont'd

After treatment: **K** and **L,** Occlusal views of maxillary arch with and without partial RDP. **M,** Occlusal view of restored mandibular arch. **N** and **O,** Right and left mirror views in maximum intercuspation. **P,** Frontal view. *(Courtesy of Dr. B. A. Purcell.)*



Fig. 32-39

Extensive fixed prosthodontics (Treatment VII). Teeth with advanced periodontal disease restored with fixed prosthodontics. **A,** Initial presentation. The patient required extraction of the right maxillary incisor and surgical correction of the periodontal defects. **B,** Maxillary teeth prepared for metal-ceramic restorations. **C,** Reversible hydrocolloid impression. **D,** Interim restorations. **E,** Definitive casts. **F,** Anatomic contour wax patterns.

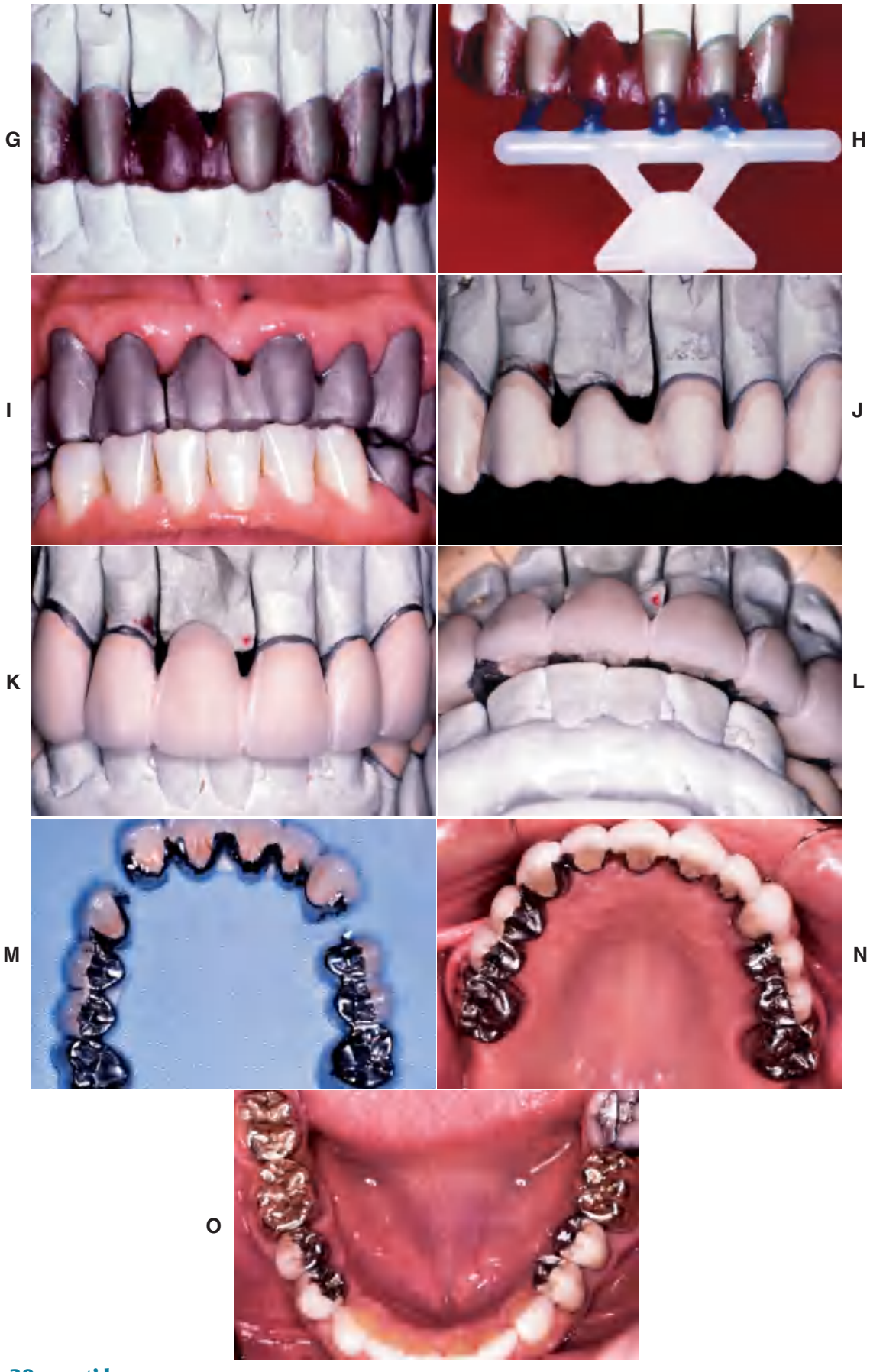


Fig. 32-39, cont'd

G, Patterns cut back for porcelain application. **H,** Sprued patterns. **I,** Metal framework evaluation. **J,** Opaque porcelain applied. **K,** Bisque porcelain. **L,** Centric contacts are on metal. **M,** Finished restorations before cementation. The extensive prosthesis is segmented with intracoronal rests. **N** and **O,** Cemented prostheses. *(Courtesy of Dr. M. T. Padilla.)*

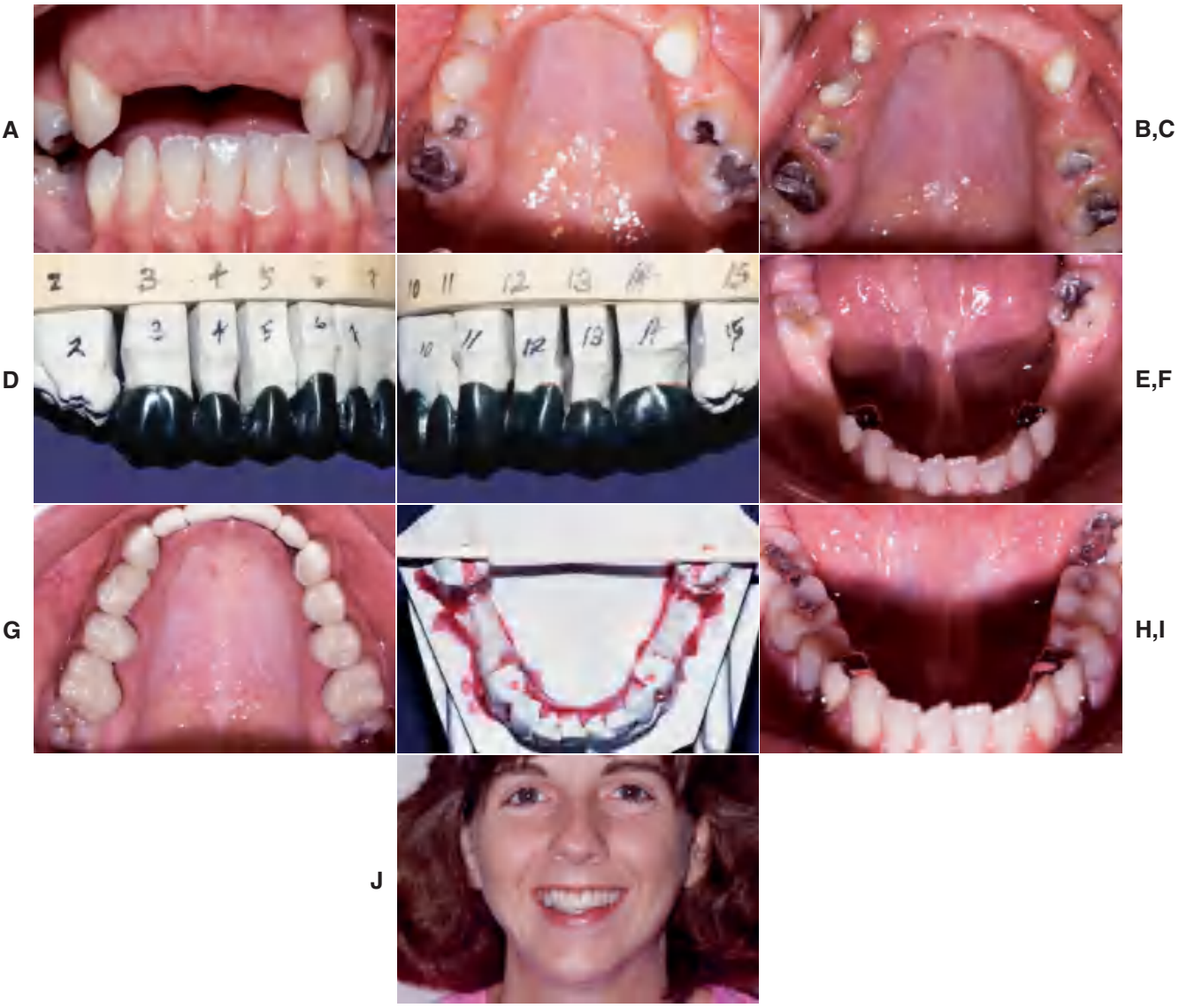


Fig. 32-40

Extensive fixed and removable prostheses (Treatment VIII). **A** and **B,** The patient presented with missing maxillary anterior teeth and mandibular posterior teeth. There was a significant slide from centric relation to maximum intercuspation. The patient was treated with a combination of fixed and removable prostheses. **C,** Maxillary teeth prepared and foundation restorations placed. **D** and **E,** Maxillary teeth waxed to anatomic contour. **F** and **G,** Completed fixed restorations. **H,** Definitive cast for mandibular partial removable dental prosthesis (RDP) framework before duplication. A rotational path of placement was used to engage mesial undercuts in second molars. **I,** Completed mandibular RDP. Amalgam stops were placed in the first molars to prevent premature wear of the denture teeth. **J,** Completed treatment.



Fig. 32-40, cont'd
K to O, Appearance 13 years after treatment. *(Courtesy of Dr. J. A. Holloway.)*



Fig. 32-41

Anticipation of future needs (Treatment IX). **A** and **B,** Pretreatment photographs. **C** to **E,** Buccal/labial view of bisque bake. **F** and **G,** Occlusal view before and at clinical evaluation. Note the location of the occlusal rests to anticipate various future partial removable dental prosthesis designs. An intracoronal rest (dovetail) was incorporated in the left lateral incisor. It is filled with composite resin, which is easily removed if the need arises. **H,** Completed treatment.



Fig. 32-42
This patient presented with multiple failing restorations and severely compromised function (Treatment X). **A** to **E,** Preoperative photographs. **F** to **J,** Posttreatment photographs. Where possible, I-bars were used to minimize clasp visibility. Also note the extensive use of metal occlusal surfaces. When prostheses are designed for dentitions with compromised crown/root ratios, precise adjustment of the occlusion and anterior guidance components is critical.



Fig. 32-42, cont'd

K to **Q,** Seventeen-year follow-up photographs. Note that the maxillary canine was lost and the existing retainer was modified into a pontic through the addition of composite resin. Additional endodontic treatment was needed as time passed.

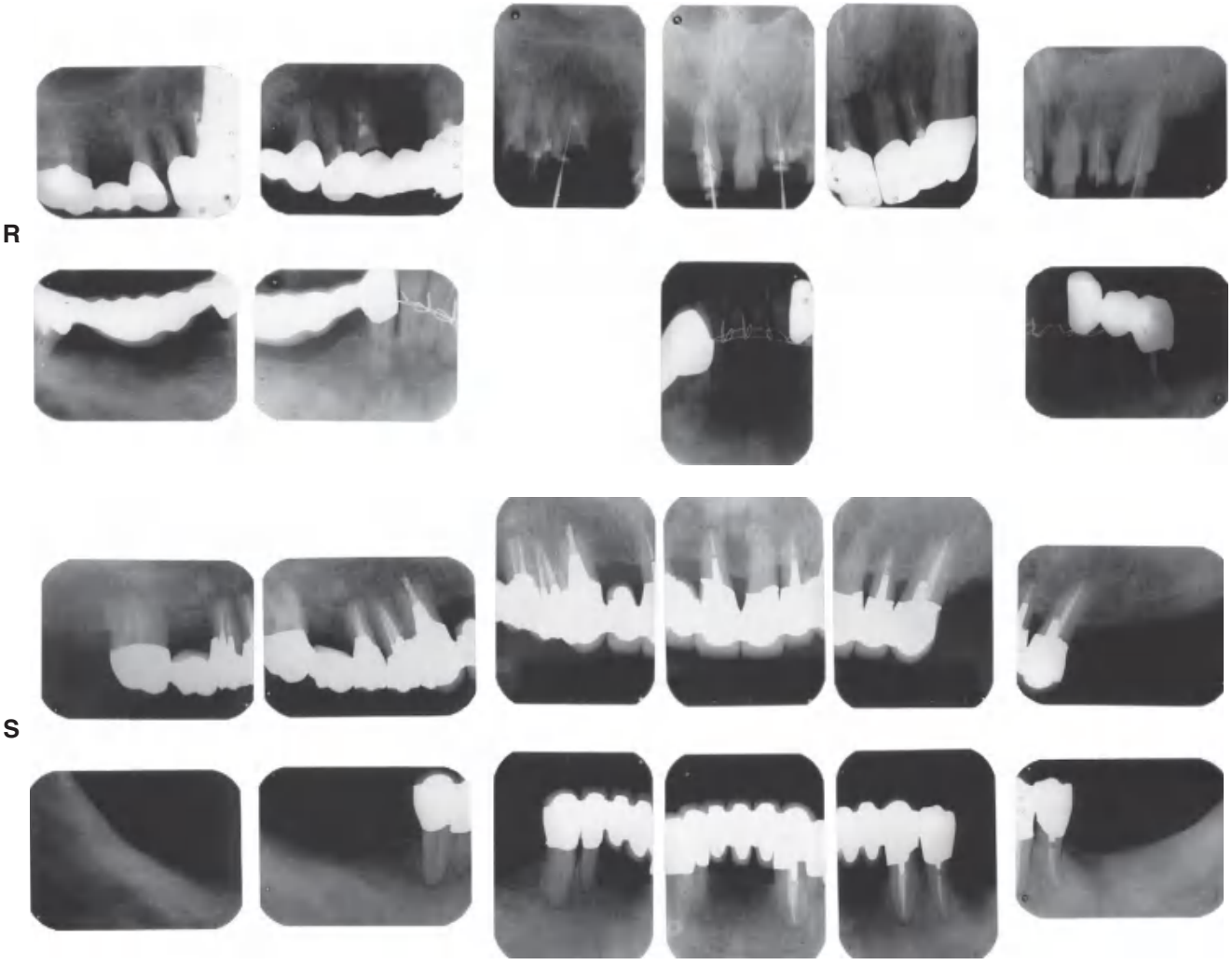


Fig. 32-42, cont'd
R, Preoperative radiographs. **S,** Postoperative radiographs.

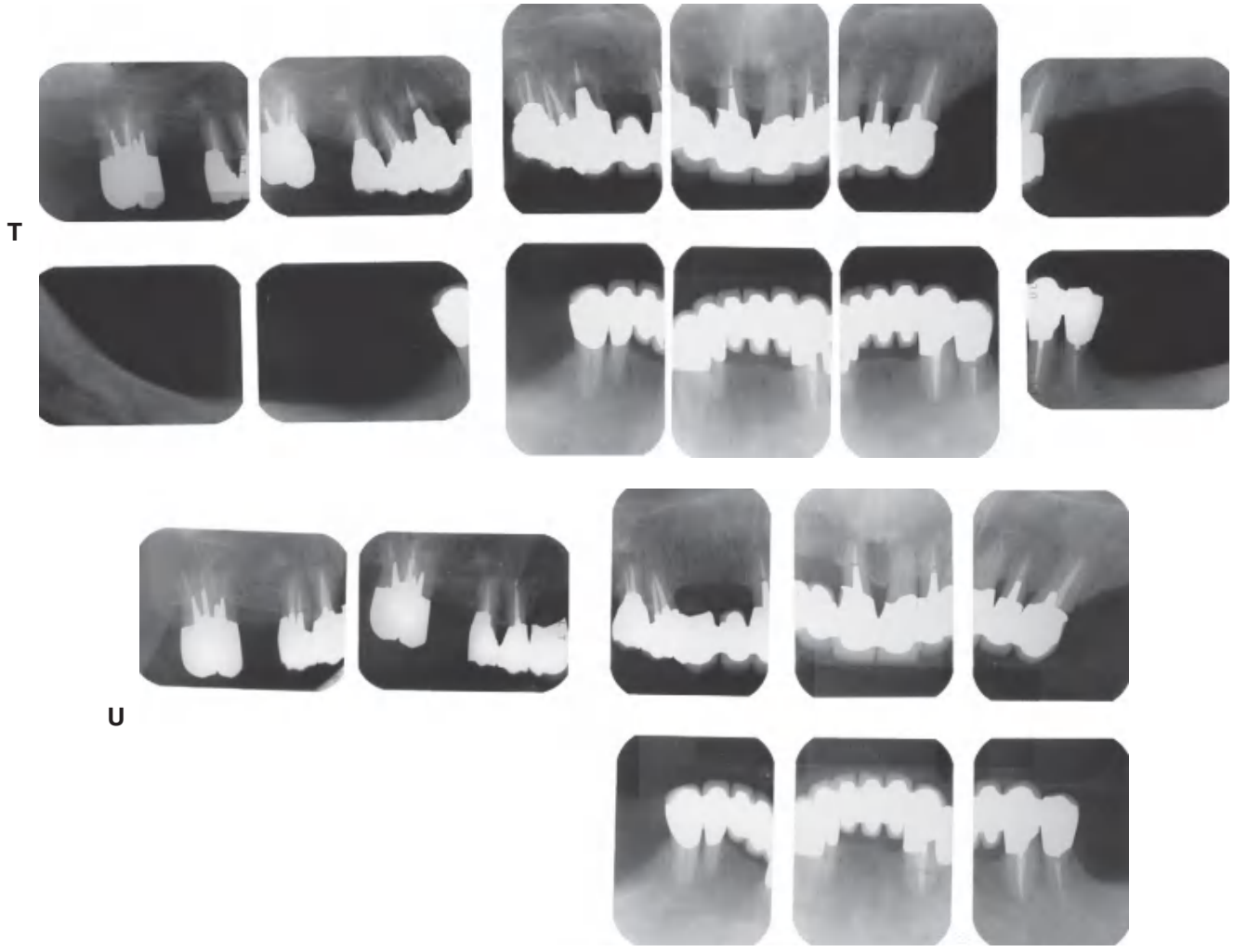


Fig. 32-42, cont'd

T, Eight-year postoperative radiographs. **U,** Seventeen-year postoperative radiographs. A fixed dental prosthesis (FDP) was fabricated, replacing the missing tooth #3 with teeth #5, #4, and #2 as abutments. The teeth were prepared with minimal taper, and the castings exhibited good retention. After 10 years, the FDP failed when tooth #2 became dislodged, possibly as a result of the additional loading by the removable dental prosthesis (RDP). Tooth #2 and the pontic were removed, endodontic treatment was performed, a new crown was fabricated, and the #3 pontic was incorporated in a new RDP. Tooth #6 was lost as a result of internal resorption and caries. Initially, the tooth was discolored, but the lesion was inactive, and the attempt to save it failed after 8 years. Its guarded prognosis was discussed as a significant risk factor before treatment initiation. This suggests that teeth with a guarded prognosis can be maintained if attention is paid to the principles of casting adaptation and occlusion.



Fig. 32-43
Long-term follow-up after comprehensive treatment with fixed prostheses of the patient in Fig. 32-41 (Treatment XI). **A** to **E,** Preoperative photographs. **F** to **J,** Postoperative photographs.

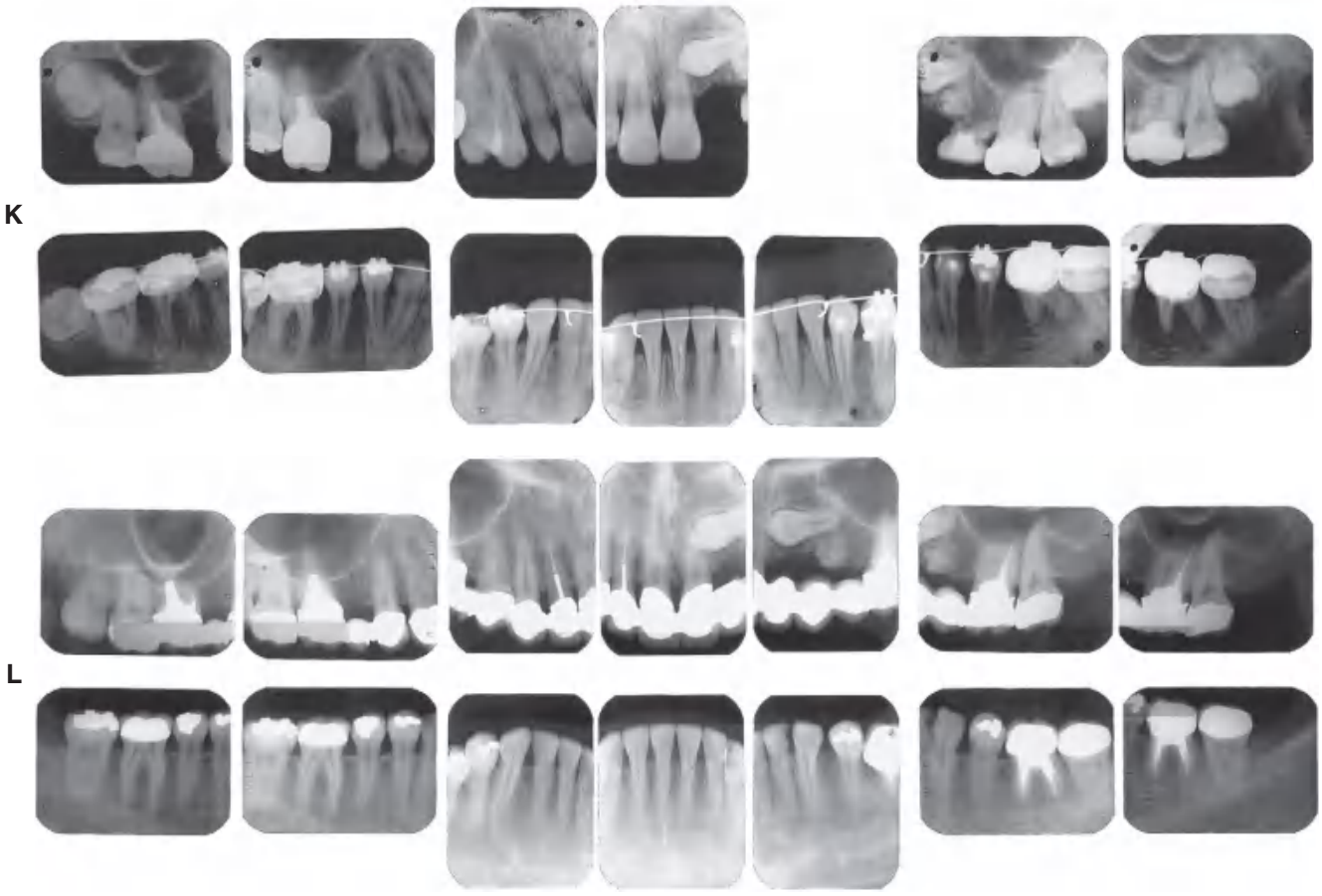


Fig. 32-43, cont'd

K, Preoperative radiographs. **L,** Fourteen-year postoperative radiographs. If the fixed prostheses have been designed carefully and the patient is cooperative and maintains excellent plaque control, fixed dental prostheses can withstand the test of time. Today, these prostheses continue to provide excellent esthetics and function after more than 16 years of service. Note that no intervention was done for the impacted canine. Initially, this patient presented with only posterior guidance on the left and right first molars. A gingival graft was performed on the left side before the fixed prosthodontic treatment. Fourteen years later, all teeth are stable without any clinically significant mobility, and the anterior guidance components exhibit no visible faceting. No significant change has occurred in bone levels, whereas apparent radiographic bone densities appear slightly increased. Meticulous attention to precise adjustment of the occlusion, especially the anterior guidance component, contributed to the long-term success of this treatment. On the 14-year postoperative radiographs, no signs of occlusal trauma are seen. Also, note that three endodontically treated molars have very large access cavities. Such teeth have a guarded prognosis and are prone to fracture, but no fractures have occurred. Again, this suggests the importance of precise and optimal load distribution at the time of initial treatment and during periodic follow-up appointments. This patient was recalled every 6 months.



Fig. 32-44

Treatment of a severely periodontally compromised dentition (Treatment XII). **A** to **C,** Preoperative photographs. **D** to **F,** Fourteen-year postoperative photographs. In the initial discussion of an extensive treatment plan with a patient with a severely compromised dentition, the many risks and possibilities of failure must be fully understood by all parties. This extremely complex rehabilitation continues to serve well today. A meticulous design and frequent recall appointments, combined with outstanding home care, enables this patient to enjoy improved function 14 years later. Throughout the follow-up, the patient was seen at 1-month and periodic 3-month recall appointments, depending on pocket charting and patient motivation. Today, tooth #4 has no attached gingiva and little bone support, but *no pocket formation.* Initially, it was expected that this tooth would be the first to be lost. In conjunction with loss of tooth #1, this would have necessitated a partial removable dental prosthesis or implant-supported fixed dental prosthesis. Occlusal rests, undercuts, and guide planes had been incorporated in the initial prosthesis to anticipate such failure. After more than 14 years, the prostheses continue to serve satisfactorily. The anterior guidance component is starting to show some wear. Throughout the recall, wherever posterior tooth contact was observed in excursive movements, they were eliminated as part of ongoing occlusal adjustment. Meticulous management of load distribution has contributed to the long-term success of this very complex rehabilitation.

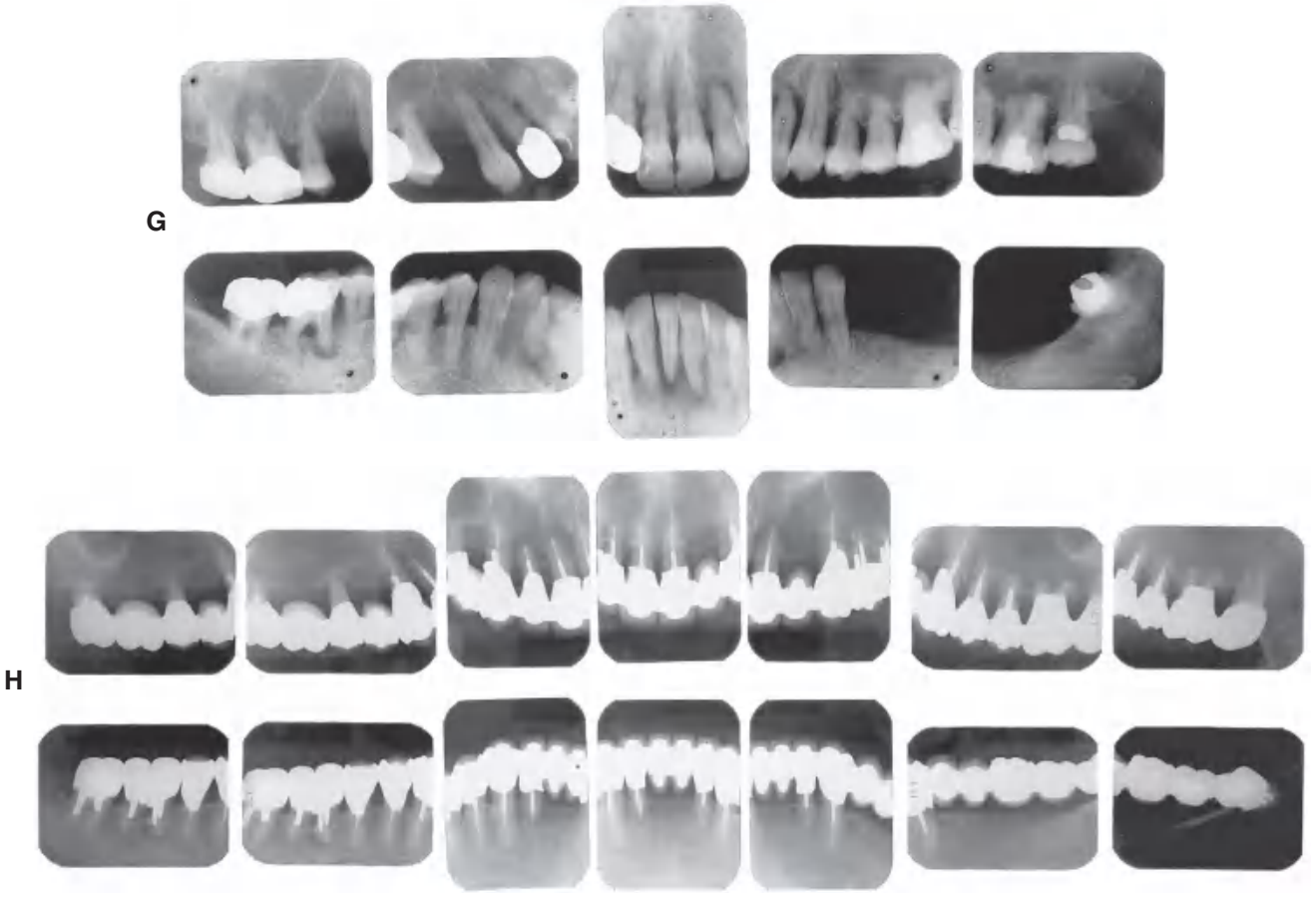


Fig. 32-44, cont'd

G, Preoperative radiographs. **H,** Fourteen-year postoperative radiographs. This patient was referred initially for complete maxillary and mandibular denture fabrication. Before prosthodontic treatment, the periodontal condition was treated. Treatment included a modified Widman flap, performed throughout both arches. A root resection was done for tooth #14, and tooth #30 was hemisected, which resulted in two premolar-like restorations. Use of the severely tilted tooth #17 as a single abutment to support a very long span posed a substantial risk to the long-term success of this treatment, and the tooth's future loss was anticipated in the design of the prostheses. Another risk was posed by the root structure of tooth #1, with a small, fused root. This tooth was lost after 14 years as a result of a periodontal defect that progressed along a vertical groove in the fused root.



Fig. 32-45

Long-term evaluation (Treatment XIII). **A** to **E,** Preoperative photographs. **F** to **J,** Eighteen-year posttreatment photographs. Three simple fixed dental prostheses combining conventional and metal-ceramic prostheses with postsoldered connectors continue to serve 18 years after initial placement. Complications over the years included the reshaping of some restorations to correct occlusal discrepancies and the endodontic treatment of tooth #19 through the prosthesis (the access cavity was restored with amalgam). This patient presented with congenitally missing teeth #4 and #12. The maxillary canine was left in the premolar position for use as an abutment with posterior disocclusion resulting from guidance on the canine-shaped pontic. This is not ideal from the perspective of force distribution; however, the canine root successfully withstood the loading over time. Risk factors initially discussed with the patient included uncertainty regarding the effect of the crown/root ratios on the long-term prognosis. At the time of prosthetic treatment, more than 25 years ago, osseous integration was not the reliable treatment modality that it is today. The young woman declined a removable prosthesis as an alternative to fixed dental prostheses. A pinledge retainer was used on the small lateral incisor. Over time, not only was this esthetically effective, but it contributed to long-term maintenance of its periodontal health. Similarly, a pinledge was used on the left mandibular canine, a far more conservative option than a metal-ceramic restoration. If instead metal-ceramic retainers had been used, by now this likely would have resulted in additional treatment needs and possibly the loss of the lateral incisor. Teeth #18, #19, and #3 were treated endodontically; cast posts and cores were used. Also, note that tooth #8 has served well over time. The conservative access cavity was restored, and the favorable position in the arch results in favorable loading. Recall appointments for this patient were scheduled at 6-month intervals throughout the evaluation period.

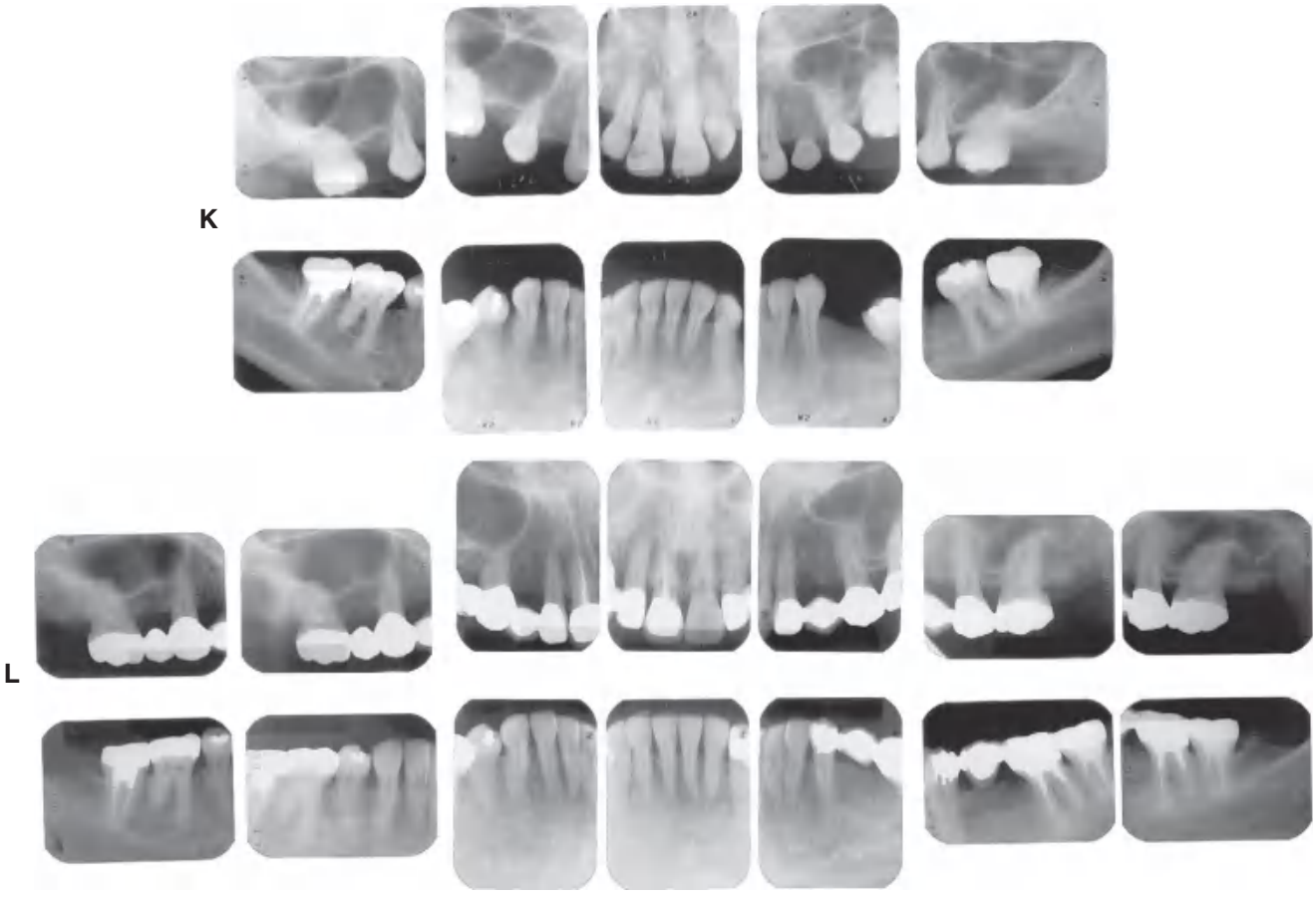


Fig. 32-45, cont'd

K, Preoperative radiographs. **L,** Eighteen-year postoperative radiographs.

STUDY QUESTIONS

1. What should be included in a typical posttreatment assessment once the previously rendered treatment has been completed? When and how often should the patient be reexamined? Provide examples of variables that influence this frequency.
2. What are typical complications for short-term post cementation? How can they be avoided? Once they have been identified, how can they be resolved?
3. How can advanced root caries be satisfactorily resolved?
4. How is a loose retainer confirmed? Once this has been confirmed, how is the FDP removed?
5. Give three examples of treatment planning that takes future failure into consideration.

SUMMARY

Well-organized and efficient postoperative care is the chief mechanism for ensuring optimal longevity and success in fixed prosthodontics. A restoration that is cemented, forgotten, and ignored is likely to fail, regardless of how skillfully it was designed and executed. Restored teeth require more assiduous plaque removal and maintenance than do healthy unrestored teeth, and, similarly, an FDP requires additional care and attention.

Common complications after completion of the active phase of treatment include caries, periodontal failure, endodontic failure, loose retainers, porcelain fracture, and root fracture.[50,51] If possible, the dentist should anticipate the long-term prognosis and treatment needs of the patient and attempt to design the treatment plan accordingly. On occasion, FDPs can be designed so that future re-treatment can be anticipated and simplified. However, it is impossible, even for the most experienced and talented clinicians, to anticipate every contingency and complication. The patient must understand the limitations of fixed prosthodontics before treatment begins.

GLOSSARY*

adhesive failure \ăd-hē′siv,-ziv fāl′yur\ (1998)**:** bond failure at an interface between two materials due to a tensile or shearing force—*see* COHESIVE FAILURE

car·ies *n singular:* a dental disease causing the destruction of enamel, dentin and/or cementum. The etiology is generally ascribed to acid-producing bacteria

occlusal adjustment \a-klōō′zal, -sal a-jŭst′mant\ **1:** any change in the occlusion intended to alter the occluding relation **2:** any alteration of the occluding surfaces of the teeth or restorations—see also OCCLUSAL RESHAPING

occlusal trauma \a-klōō′zal, -sal trou′ma, trô′-**:** trauma to the periodontium from functional or parafunctional forces causing damage to the attachment apparatus of the periodontium by exceeding its adaptive and reparative capacities. It may be self-limiting or progressive—see PRIMARY O.T., SECONDARY O.T.

occlusion analysis \a-klōō′shun a-năl′ĭ-sĭs\ *obs***:** a systematic examination of the masticatory system with special consideration to the effect of tooth occlusion on the teeth and their related structures (GPT-4)

o·ver·clo·sure \ō′var-klō′zhar\ *n***:** an occluding vertical dimension at a reduced interarch distance; an occluding vertical dimension that results in excessive interocclusal distance when the mandible is in the rest position; it results in a reduced interridge distance when the teeth are in contact

o·ver·den·ture \ō′var-dĕn′chur\ *n***:** any removable dental prosthesis that covers and rests on one or more remaining natural teeth, the roots of natural teeth, and/or dental implants; a dental prosthesis that covers and is partially supported by natural teeth, natural tooth roots, and/or dental implants—called also *overlay denture, overlay prosthesis, superimposed prosthesis*

root \rōōt, rŏŏt\ *n* (bef. 12c)**:** the portion of the tooth apical to the cementoenamel junction that is normally covered by cementum and is attached to the periodontal ligament and hence to the supporting bone

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REFERENCES

1. Tolboe H, et al: Influence of oral hygiene on the mucosal conditions beneath bridge pontics. Scand J Dent Res 95:475, 1987.
2. Tolboe H, et al: Influence of pontic material on alveolar mucosal conditions. Scand J Dent Res 96:442, 1988.
3. Ericson G, et al: Cross-sectional study of patients fitted with fixed partial dentures with special ref-

erence to the caries situation. Scand J Dent Res 98:8, 1990.
4. Akerboom HB, et al: Radiopacity of posterior composite resins, composite resin luting cements, and glass ionomer lining cements. J Prosthet Dent 70:351, 1993.
5. Matsumura H, et al: Radiopacity of dental cements. Am J Dent 6:43, 1993.
6. el-Mowafy OM, Benmergui C: Radiopacity of resin-based inlay luting cements. Oper Dent 19:11, 1994.
7. Gibson G: Identifying and treating xerostomia in restorative patients. J Esthet Dent 10:253, 1998.
8. Keene JJ Jr, et al: Antidepressant use in psychiatry and medicine: importance in dental practice. J Am Dent Assoc 134:71, 2003.
9. Walton JN, et al: A survey of crown and fixed partial denture failures: length of service and reasons for replacement. J Prosthet Dent 56:416, 1986.
10. Libby G, et al: Longevity of fixed partial dentures. J Prosthet Dent 78:127, 1997.
11. Sundh B, Odman P: A study of fixed prosthodontics performed at a university clinic 18 years after insertion. Int J Prosthodont 10:513, 1997.
12. Priest GF: Failure rates of restorations for single-tooth replacement. Int J Prosthodont 9:38, 1996.
13. Bauer JG, et al: The reliability of diagnosing root caries using oral examinations. J Dent Educ 52:622, 1988.
14. Silverstone LM: Remineralization phenomena. Caries Res 11(suppl 1):59, 1977.
15. Gordon SR: Older adults: demographics and need for quality care. J Prosthet Dent 61:737, 1989.
16. Hellyer PH, et al: Root caries in older people attending a general dental practice in East Sussex. Br Dent J 169:201, 1990.
17. Guivante-Nabet C, et al: Active and inactive caries lesions in a selected elderly institutionalised French population. Int Dent J 48:111, 1998.
18. Gustafsson BE, et al: The Vipeholm dental caries study: the effect of different levels of carbohydrate intake on caries activity in 436 individuals observed for 5 years. Acta Odontol Scand 11:232, 1954.
19. Fure S: Five-year incidence of caries, salivary and microbial conditions in 60-, 70- and 80-year-old Swedish individuals. Caries Res 32:166, 1998.
20. Winn DM, et al: Coronal and root caries in the dentition of adults in the United States, 1988-1991. J Dent Res 75(Spec. No.):642, 1996.
21. Reiker J, et al: A cross-sectional study into the prevalence of root caries in periodontal maintenance patients. J Clin Periodont 26:26, 1999.
22. Younger H, et al: Relationship among stimulated whole, glandular salivary flow rates, and root caries prevalence in an elderly population: a preliminary study. Spec Care Dentist 18:156, 1998.
23. Powell LV, et al: Factors associated with caries incidence in an elderly population. Community Dent Oral Epidemiol 26:170, 1998.
24. Sorensen JA: A rationale for comparison of plaque-retaining properties of crown systems. J Prosthet Dent 62:264, 1989.
25. Alexander AG: Periodontal aspects of conservative dentistry. Br Dent J 125:111, 1968.
26. Valderhaug J: Gingival reaction to fixed prostheses. J Dent Res 50:74, 1971.
27. Reichen-Graden S, Lang NP: Periodontal and pulpal conditions of abutment teeth. Status after four to eight years following the incorporation of fixed reconstructions. Schweiz Monatsschr Zahnmed 99:1381, 1989.
28. Wagman SS: The role of coronal contour in gingival health. J Prosthet Dent 37:280, 1977.
29. Mojon P, et al: Relationship between prosthodontic status, caries, and periodontal disease in a geriatric population. Int J Prosthodont 8:564, 1995.
30. Rantanen T: A control study of crowns and bridges on root canal filled teeth. Suom Hammaslaak Toim 66:275, 1970.
31. Abou-Rass M: The stressed pulp condition: an endodontic-restorative diagnostic concept. J Prosthet Dent 48:264, 1982.
32. Saunders WP, Saunders EM: Prevalence of periradicular periodontitis associated with crowned teeth in an adult Scottish subpopulation. Br Dent J 185:137, 1998.
33. Karlsson S: A clinical evaluation of fixed bridges, 10 years following insertion. J Oral Rehabil 13:423, 1986.
34. Eckerbom M, et al: Prevalence of apical periodontitis, crowned teeth and teeth with posts in a Swedish population. Endod Dent Traumatol 7:214, 1991.
35. Valderhaug J, et al: Assessment of the periapical and clinical status of crowned teeth over 25 years. J Dent 25:97, 1997.
36. Olin PS: Effect of prolonged ultrasonic instrumentation on the retention of cemented cast crowns. J Prosthet Dent 64:563, 1990.
37. Oliva RA: Clinical evaluation of a new crown and fixed partial denture remover. J Prosthet Dent 44:267, 1980.
38. Parreira FR, et al: Cast prosthesis removal using ultrasonics and a thermoplastic resin adhesive. J Endod 20:141, 1994.
39. Robbins JW: Intraoral repair of the fractured porcelain restoration. Oper Dent 23:203, 1998.

40. Chung KH, Hwang YC: Bonding strengths of porcelain repair systems with various surface treatments. J Prosthet Dent 78:267, 1997.
41. Kupiec KA, et al: Evaluation of porcelain surface treatments and agents for composite-to-porcelain repair. J Prosthet Dent 76:119, 1996.
42. Pameijer CH, et al: Repairing fractured porcelain: how surface preparation affects shear force resistance. J Am Dent Assoc 127:203, 1996.
43. Nowlin TP, et al: Evaluation of the bonding of three porcelain repair systems. J Prosthet Dent 46:516, 1981.
44. Gregory WA, et al: Composite resin repair of porcelain using different bonding materials. Oper Dent 13:114, 1988.
45. Barreto MT, Bottaro BF: A practical approach to porcelain repair. J Prosthet Dent 48:349, 1982.
46. Welsh SL, Schwab JT: Repair technique for porcelain-fused-to-metal restorations. J Prosthet Dent 38:61, 1977.
47. Miller TH, Thayer KE: Intraoral repair of fixed partial dentures. J Prosthet Dent 25:382, 1971.
48. Cardoso AC, Spinelli Filho P: Clinical and laboratory techniques for repair of fractured porcelain in fixed prostheses: a case report. Quintessence Int 25:835, 1994.
49. Westerman RD: A new paradigm for the construction and service of fixed prosthodontics. Dent Today 18:62, 1999.
50. Goodacre CJ, et al: Clinical complications in fixed prosthodontics. J Prosthet Dent 90:31, 2003.
51. Goodacre CJ, et al: Clinical complications with implants and implant prostheses. J Prosthet Dent 90:121, 2003.

Appendix A

DENTAL MATERIALS AND EQUIPMENT INDEX

*The authors thank all of the companies who provided images in this appendix

AIRBORNE PARTICLE ABRASION UNITS



(Paasche Airbrush Company)

RECOMMENDED USE

Metal preparation before porcelain application (Chapter 24)
Identification of unwanted metal contact (Chapters 22 and 30)
Preparation of casting before cementation (Chapter 31)

SELECTED SUPPLIERS

Hand-held clinical units
Paasche Airbrush Company
Danville Engineering, Inc.
Henry Schein, Inc.
Buffalo Dental Manufacturing Co., Inc.
Laboratory units
Bego
Comco, Inc.
Heraeus Kulzer, Inc.
Buffalo Dental Manufacturing Co., Inc.
Hydro-Cast Dental Products
Integral Systems, Inc.
Denerica Dental Corporation
Renfert USA
Vaniman Manufacturing Co.
Worldent Group

ARTICULATORS

Fully adjustable



(Waterpik Technologies)

RECOMMENDED USE

Complex prosthodontics

SELECTED PRODUCTS

Denar D5A (Waterpik Technologies)
Stuart Articulator (CE Stuart)

Semiadjustable



(Whip Mix Corporation)

RECOMMENDED USE

Most prosthodontic diagnosis and treatment

SELECTED PRODUCTS

Denar Mark II, Advantage (Waterpik Technologies)
Panadent (Panadent Corporation)
Hanau Wide-Vue Arcon 183-2 (Waterpik Technologies)
Model 2240, Model 2340 (Whip Mix Corporation)

ASH'S METAL: SEE SOFT METAL SHEET

ATTACHMENTS

Bar attachments



(Sterngold Dental, LLC)

RECOMMENDED USE

RDP and overdenture support and retention

SELECTED PRODUCTS

ABS Bar, CBS Bar, Dolder Bar, Hader Bar (Attachments International)
CM 342 (Sterngold Dental, LLC)

Extracoronal attachments



(Sterngold Dental, LLC)

RECOMMENDED USE

RDP retention and support (Chapter 21)

SELECTED PRODUCTS

ERA (Sterngold Dental, LLC)
Ceka (Alphadent NV)
Dalbo (Cendres & Métaux)
COMPAS (Comdent)
Dawson 2.7 (Comdent)

Intracoronal rests



RECOMMENDED USE

RDP support (Chapter 21)
FDP connectors (Chapter 28)

SELECTED PRODUCTS

PRP Mandrels (Ticonium Co.)
PD Attachments (Austenal, Inc.)
P/S Splint (Bell International)
Interlock, Omega-M, PDC, Swiss Taper (Attachments International)

Intracoronal slider attachments



(Sterngold Dental, LLC)

RECOMMENDED USE

RDP retention and support (Chapter 21)

SELECTED PRODUCTS

C&M McCollum (Cendres & Métaux)
Stern Latch (Sterngold Dental, LLC)

Stud attachments



(Sterngold Dental, LLC)

RECOMMENDED USE

Overdenture retention (Chapter 21)

SELECTED PRODUCTS

ERA Stud (Sterngold Dental, LLC)
Stern Root Anchor (Sterngold Dental, LLC)
Dalla Bona Spherical (Sterngold Dental, LLC)
ZAAG, Zest (Zest Anchors, Inc.)
Flexi-Post (Essential Dental Systems)

BURS, DIAMONDS, AND STONES

High-speed diamonds



(Premier Dental Products Company)

RECOMMENDED USE

Extracoronal tooth preparation (Chapters 8 to 11)

SELECTED PRODUCTS

Two Striper (Premier Dental Products Company)
Brasseler Diamonds (Brasseler USA)
BluWhite Diamonds (Kerr Corporation)

Tungsten-carbide burs



(Sullivan-Schein Dental)

RECOMMENDED USE

Intracoronal tooth preparation
Retention features (Chapters 8 to 11)
Finishing preparations

SELECTED PRODUCTS

Midwest American Burs (Midwest Dental Products Corporation)
Brasseler Burs (Brasseler USA)
Busch Burs (Pfingst & Co., Inc.)
Carbide Burs (Sullivan-Schein Dental)

Laboratory stones (for metal)



RECOMMENDED USE

Grinding castings (Chapter 29)

SELECTED SUPPLIERS

Dentsply Ceramco
Brasseler USA
Shofu Dental Corporation
Heraeus Kulzer, Inc.

Laboratory stones (for porcelain)

RECOMMENDED USE

Grinding porcelain (Chapters 24 and 25)

SELECTED PRODUCTS

Ceramiste Mounted Points (Shofu Dental Corporation)
Busch Silent, Horico Diamond (Pfingst & Co., Inc.)
Unitek Green Stones (3M Unitek Corp.)
Green Mounted Points (Heraeus Kulzer, Inc.)

CASTING ALLOYS

American Dental Association (ADA) type III gold casting alloys



RECOMMENDED USE

Extracoronal and intracoronal restorations (Chapter 22)

SELECTED PRODUCTS

Firmilay (Heraeus Kulzer, Inc.)
Degulor C (Dentsply Ceramco)
Ney-Oro B-2 (Dentsply Ceramco)
Williams Harmony Line Hard (Ivoclar Vivadent, Inc.)

ADA type IV gold casting alloys

RECOMMENDED USE

Extracoronal restorations (high stress)

SELECTED PRODUCTS

Jelenko No. 7 (Heraeus Kulzer, Inc.)
Primallor G (Dentsply Ceramco)
Ney-Oro G3 (Dentsply Ceramco)

Lower gold content casting alloys

RECOMMENDED USE

Extracoronal and intracoronal restorations

SELECTED PRODUCTS
Midas (Heraeus Kulzer, Inc.)
Midigold (Ivoclar Vivadent, Inc.)
Miracast (Dentsply Ceramco)
Rx Midacast (Pentron Clinical Technologies, LLC)

Metal-ceramic alloys (base metal)

RECOMMENDED USE
Substructure for metal-ceramic restorations

SELECTED PRODUCTS* (see Table 19-1)
Rexillium III (Pentron Clinical Technologies, LLC)
Neobond II (Neoloy Products, Inc.)

Metal-ceramic alloys (high noble metal)

RECOMMENDED USE
Substructure for metal-ceramic restorations (Chapter 19)

SELECTED PRODUCTS* (see Table 19-1)

CEMENTS/LUTING AGENTS

Glass ionomer



(3M ESPE)

RECOMMENDED USE
Permanent cementation (especially with esthetic considerations)

SELECTED PRODUCTS
Ketac-Cem, Ketac-Cem Aplicap (3M ESPE)
Fuji I (GC America, Inc.)
Vivaglass Cem (Ivoclar Vivadent, Inc.)

Interim



(Kerr Corporation)

*Choice may depend on porcelain used.

RECOMMENDED USE
Luting interim restorations (Chapter 15)

SELECTED PRODUCTS
TempBond (Kerr Corporation)
Zone (Cadco Dental Products, Inc.)

Resin (adhesive)



(Kuraray America, Inc.)

RECOMMENDED USE
Permanent cementation (Chapter 31)

SELECTED PRODUCTS
Panavia (Kuraray America, Inc.)
C&B Metabond (Parkell Products)

Resin (autopolymerizing)



(Caulk/Dentsply)

RECOMMENDED USE
Luting ceramic inlays and veneers (Chapter 25)

SELECTED PRODUCTS
Calibra, Comspan (Caulk/Dentsply)
C&B Luting Composite (Bisco, Inc.)
Cement-It! (Pentron Clinical Technologies, LLC)
RelyX ARC (3M ESPE)

Resin (photopolymerizing)

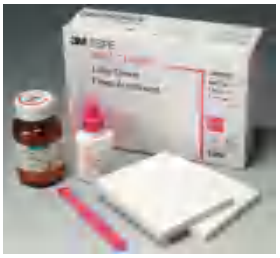


(Kerr Corporation)

RECOMMENDED USE
Luting ceramic inlays and veneers (Chapter 25)

SELECTED PRODUCTS
Nexus (Kerr Corporation)
Appeal, Variolink II (Ivoclar Vivadent, Inc.)
Duo-Link (Bisco, Inc.)
Lute-It! (Pentron Clinical Technologies, LLC)
RelyX Veneer (3M ESPE)
Ultra-Bond (Den-Mat Corporation)

Resin-modified glass ionomer



(3M ESPE)

RECOMMENDED USE
Permanent cementation (Chapter 31)

SELECTED PRODUCTS
RelyX (3M ESPE)
Fuji Plus (GC America, Inc.)
Principle (Caulk/Dentsply)
ProTec CEM (Ivoclar Vivadent, Inc.)

Zinc phosphate



(Keystone Industries)

RECOMMENDED USE
Permanent cementation (Chapter 31)
Bases (Chapter 6)

SELECTED PRODUCTS
Fleck's Extraordinary Cement (Keystone Industries)
Smith's Zinc (Waterpik Technologies)

Zinc polycarboxylate



(3M ESPE)

RECOMMENDED USE
Permanent cementation (Chapter 31; especially with pulpal considerations)

SELECTED PRODUCTS
Durelon, Durelon Aplicap (3M ESPE)
HY-Bond (Shofu Dental Corporation)
LIVCARBO (GC America, Inc.)
PCA (Mission Dental, Inc.)
Tylok Plus (Caulk/Dentsply)

CROWN AND FDP REMOVERS



(Dent Corp Research and Development)



(KaVo America)

RECOMMENDED USE
See Chapter 32

SELECTED PRODUCTS
CORONAflex crown remover (KaVo America)
Metalift Crown and Bridge Removal System (Classic Practice Resources)
Roydent Bridge and Crown Remover (Roydent Dental Products)
Richwell Crown and Bridge Remover (Almore International, Inc.)
Atwood Crown and Bridge Remover (Atwood Industries)
Crown and Bridge Removers (Parkell Products)
Easy Pneumatic C&B Remover II (Dent Corp Research and Development)

CYANOACRYLATE RESIN

RECOMMENDED USE
Impregnating stone dies (Chapters 17, 18, 19, and 24)
Cementing Pindex dowel pins (Chapter 17)

SELECTED PRODUCTS
Hot Stuff (Satellite City, Inc.) (hardware stores)
Permabond 910 (George Taub Products & Fusion Co.)
Krazy Glue (hardware stores)
DVA Rocket System (Dental Ventures of America, Inc.)

DENTURE TEETH

SELECTED PRODUCTS
Trubyte (Dentsply/York Division)
Justi (American Tooth Industries)
Ivoclar (Ivoclar Vivadent, Inc.)
Vitapan (Vident)

DIAMONDS: SEE BURS, DIAMONDS, AND STONES

DIE LUBRICANT



(Slaycris Products, Inc.)

RECOMMENDED USE
Lubricating dies before waxing (Chapter 17)

SELECTED PRODUCTS
Slikdie Lubricant (Slaycris Products, Inc.)
Gator Die Lube (Whip Mix Corporation)
Die Lube, Isolit (Dentsply Ceramco)

DIE MATERIALS (ALTERNATIVES TO GYPSUM)


(Keystone Industries)

RECOMMENDED USE
Dies for complete ceramic crowns (Chapter 25)

Electroplating materials

SELECTED SUPPLIERS
Baker Dental Corp.

Resins

SELECTED PRODUCTS
Epoxy-Die (Ivoclar Vivadent, Inc.)
Poly-Roqq (Dental Ventures of America, Inc.)
Epoxy Die (National Keystone)
AlphaDie Polyurethane (Schütz Dental GmbH)
Tri-Dynamic Bulk Die Material (Keystone Industries)

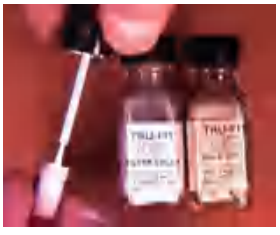
DIE SAWS



RECOMMENDED USE
Sectioning definitive casts (Chapter 17)

SELECTED PRODUCTS
Ney Die Saw (Dentsply Ceramco)
Pindex Hand Saw (Coltène/Whaledent, Inc.)

DIE SPACERS



RECOMMENDED USE
To increase space for luting agent (Chapter 17)

SELECTED PRODUCTS
Pactra Aero Gloss (hobby stores)
Die Spacer (Kerr Corporation)
Tru-Fit (George Taub Products & Fusion Co.)

DIE SYSTEMS

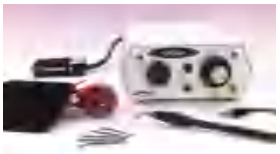


RECOMMENDED USE
Fabricating removable dies (Chapter 17)

SELECTED PRODUCTS
(See Table 17-2)
Pindex (Coltène/Whaledent, Inc.)
Di-Lok (Di-Equi)
DVA Model System (Dental Ventures of America, Inc.)
Zeiser model system (Girrbach Dental GmbH)
Dowel pins (Buffalo Dental Manufacturing Co., Inc.; Dentsply Ceramco)
V2 Quadrant (Monotrac Articulation)

ELECTROPLATING MATERIALS: see DIE MATERIALS

ELECTROSURGICAL EQUIPMENT



(Macan Engineering & Manufacturing Co.)

RECOMMENDED USE
Removal of hyperplastic tissue before impression making (Chapter 14)

SELECTED PRODUCTS
Macan MC-4A, MC-6, MC-6A (Macan Engineering & Manufacturing Co.)
Dento-Surg 90 FFP (Ellman International, Inc.)
PerFect TCS (Coltène/Whaledent, Inc.)
Sensimatic (Parkell, Inc.)

EPOXY RESIN DIE MATERIALS: see DIE MATERIALS

FACEBOWS



(Waterpik Technologies)

RECOMMENDED USE
Articulator mounting casts (Chapters 2 and 17)

SELECTED PRODUCTS
Denar Slidematic (Waterpik Technologies)
Quick Mount (Whip Mix Corporation)
Earpiece Facebow (Waterpik Technologies)
Hinge Axis Locator (Almore International, Inc.)

FIBER-REINFORCED COMPOSITES

RECOMMENDED USE
Alternative to metal ceramic restorations (Chapter 27)

SELECTED PRODUCTS
Ribbond/BelleGlass (Kerr Corporation)
Connect (GlasSpan, Inc.)
Fibrekor/Sculpture, Splint-It (Pentron Clinical Technologies, LLC)

GINGIVAL DISPLACEMENT

Astringent solutions



(Premier Dental Products)

RECOMMENDED USE
Gingival displacement before impression making (Chapter 14)

SELECTED PRODUCTS
Hemodent (Premier Dental Products Company)
Gingi-Aid (Belport Corp./Gingi-Pak)
Astringedent, ViscoStat (Ultradent Products, Inc.)
Visine Eye Drops (Pfizer, Inc.)
Afrin [oxymetazoline] Nose Spray (Schering-Plough Corporation)

Displacement cord



(Belport Corp./Gingi-Pak)

RECOMMENDED USE
Gingival displacement before impression making (Chapter 14)

SELECTED PRODUCTS
Gingi-Pak (Belport Corp./Gingi-Pak)
GingiBraid, Gingigel (Dux Dental)
Sil-Trax (Pascal Company, Inc.)
Ultrapak (Ultradent Products, Inc.)

Displacement putty and foam



(Kerr Corporation)

RECOMMENDED USE

Gingival displacement before impression making (Chapter 14)

SELECTED PRODUCTS

Expa-syl (Kerr Corporation)
Magic FoamCord (Coltène/Whaledent, Inc.)

GYPSUM PRODUCTS

ADA types IV and V die stones



(Whip Mix Corporation)

RECOMMENDED USE

Casts and dies (Chapters 2 and 17)

SELECTED PRODUCTS

Silky-Rock, Prima-Rock, Jade Stone, Super Die, ResinRock, Hard Rock (Whip Mix Corporation)
Vel-Mix Stone, Suprastone (Kerr Corporation)
Glastone, Glastone 2000 (Dentsply/Trubyte)
Die-Keen, Milestone, Die-Stone, Tru-Stone (Modern Materials; Heraeus Kulzer, Inc.)
Synthetic Die Stone (Microstar Corporation)

Impression plaster

RECOMMENDED USE

Soldering index (Chapter 28)
Occlusal registration (Chapter 17)

SELECTED PRODUCTS

Snow White Plaster #2 (Kerr Corporation)

Mounting stone



RECOMMENDED USE

Articulator mounting casts (Chapters 2 and 17)

SELECTED PRODUCTS

Mounting Stone (Whip Mix Corporation)
Castone Dental Stone (Dentsply/Trubyte)

IMPLANT MATERIALS



SELECTED SUPPLIERS

Nobel Biocare USA, Inc.
Zimmer Dental
Astra Tech, Inc.
3i, Implant Innovations, Inc.
Straumann Company (ITI)
Attachments International
Lifecore Biomedical, Inc.
Dentsply/Friadent/CeraMed

IMPRESSION MATERIALS

Addition silicone



(GC America, Inc.)

RECOMMENDED USE
Impressions of preparations (Chapter 14)

SELECTED PRODUCTS
Affinis, President (Coltène/Whaledent, Inc.)
Extrude, Take 1 (Kerr Corporation)
Reprosil, Aquasil (Caulk/Dentsply)
Exaflex, Examix (GC America, Inc.)
Imprint, Express (3M ESPE)

Irreversible hydrocolloid (alginate)



(Caulk/Dentsply)

RECOMMENDED USE
Impressions for diagnostic casts (Chapter 2)
Duplicating diagnostic waxing

SELECTED PRODUCTS
Jeltrate (Caulk/Dentsply)
Coe Alginate (GC America, Inc.)
Supergel (Harry J. Bosworth Co.)

Polyether


(3M ESPE)

RECOMMENDED USE
Impressions of preparations (Chapter 14)

SELECTED PRODUCTS
Impregum, Impregum Penta Soft, Permadyne (3M ESPE)
Polygel NF (Caulk/Dentsply)

Polysulfide polymer



(GC America, Inc.)

RECOMMENDED USE
Impressions of preparations (Chapter 14)

SELECTED PRODUCTS
Permlastic (Kerr Corporation)
COE-FLEX (GC America, Inc.)

Reversible hydrocolloid (agar)


(Dux Dental)

RECOMMENDED USE
Impressions of preparations (Chapter 14)

SELECTED PRODUCTS
Rubberloid, Acculoid, Agarloid, Qwik (Dux Dental)
Gingi-Pak (Belport Corp./Gingi-Pak)

Silicone putty



(Sullivan-Schein Dental)

RECOMMENDED USE
External mold for interim restorations (Chapter 15)
Preparation reduction guide (Chapters 8 to 11)

SELECTED PRODUCTS
CutterSil Putty PLUS (Heraeus Kulzer, Inc.)
Coltoflax (Coltène/Whaledent, Inc.)
Henry Schein Condensation Silicone Putty (Sullivan-Schein Dental)

Zinc oxide-eugenol occlusal registration (impression) pastes



(GC America, Inc.)

RECOMMENDED USE
Occlusal records (Chapters 2 and 17)
Soldering records (Chapter 28)
Remount procedure (Chapter 30)

SELECTED PRODUCTS
Superpaste, Plastopaste (Harry J. Bosworth Co.)
Opotow, Krex (Waterpik Technologies)
COE-FLO (GC America, Inc.)

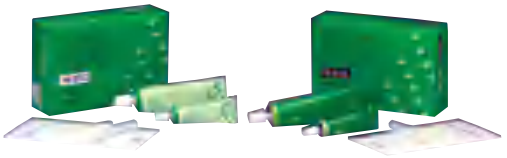
IMPRESSION SYRINGES


(Kerr Corporation)

RECOMMENDED USE
Making elastomeric impressions (Chapter 14)

SELECTED PRODUCTS
Coe Syringe, Plastic Syringe (GC America, Inc.)
Free-Flo Syringe (Kerr Corporation)
Impregum Syringe (3M ESPE)
Disposable Impression Syringe (Sullivan-Schein Dental)

INTERNAL FITTING AGENTS


(GC America, Inc.)

RECOMMENDED USE
Evaluating and refining internal fit of restoration (Chapter 30)

SELECTED PRODUCTS
Fit Checker, Fit Checker II (GC America, Inc.)
Disclosing Wax (Kerr Corporation)
PIP Pressure Indicator Paste (Mizzy, Inc.)

INVESTING EQUIPMENT

Casting rings, liners, and crucible formers

SELECTED SUPPLIERS
Whip Mix Corporation
Dentsply Ceramco
Kerr Corporation
Buffalo Dental Manufacturing Co., Inc.

INVESTMENT MATERIALS

Gypsum bonded



(Whip Mix Corporation)

RECOMMENDED USE
Conventional (low-heat) casting (Chapter 22)

SELECTED PRODUCTS
Beauty-Cast (Whip Mix Corporation)
Luster Cast (Kerr Corporation)

Investments for porcelain



RECOMMENDED USE

Ceramic inlays and veneers (Chapter 25)

SELECTED PRODUCTS (Note: some ceramic systems require manufacturer's specified material)

VHT, Polyvest, Formula 1 (Whip Mix Corporation)
Neo-Brillat (Vident)

Phosphate bonded



(Whip Mix Corporation)

RECOMMENDED USE

Casting metal-ceramic alloys (Chapter 19)
Preceramic application soldering (Chapter 28)

SELECTED PRODUCTS

Cera-Fina, Ceramigold, Hi-Temp, FastFire 15, PowerCast, Formula 1 (Whip Mix Corporation)
Complete, High-Span II, JelVest (Heraeus Kulzer, Inc.)
Deguvest F (Dentsply Ceramco)

Soldering investment

RECOMMENDED USE

Soldering (Chapter 28)

SELECTED PRODUCTS

Hi-Heat, Speed-E, Soldering Investment (Whip Mix Corporation)
Quick Set Soldering Investment (KerrLab Corporation)

MAGNIFICATION EQUIPMENT

Laboratory microscope



SELECTED SUPPLIERS

Nikon Instruments Inc., Instrument Group
Olympus America, Inc.
Austenal, Inc.
Carl Zeiss, Inc.

Loupes



(Vision USA)

SELECTED SUPPLIERS

Almore International, Inc.
Lactona Universal
Designs for Vision, Inc.
American Optical
Orascoptic Research, Inc.
General Scientific Corporation
Vision USA, A Dentrex Company

MARKING AGENTS



(Pascal Company, Inc.)

RECOMMENDED USE
Identifying unwanted contacts on the fitting surface of castings (Chapters 20 and 26)

SELECTED PRODUCTS
Occlude (Pascal Company, Inc.)
AccuFilm IV (Parkell Products)
Liqua-Mark (The Wilkinson Company, Inc.)

MODELING COMPOUND



(GC America, Inc.)

RECOMMENDED USE
Modifying impression trays (Chapter 2)
Supporting rubber dam clamps, matrix bands (Chapter 6)
Transfer fork registration (Chapter 2)

SELECTED PRODUCTS
Mizzy Impression Compound (Mizzy, Inc.)
Impression Compound (Kerr Corporation)
Adaptol (Heraeus Kulzer, Inc.)
ISO Functional (GC America, Inc.)

MOISTURE-CONTROL PRODUCTS

Adhesive foil



RECOMMENDED USE
Moisture control during cementation (Chapter 31)

SELECTED PRODUCTS
Burlew Dryfoil (Heraeus Kulzer, Inc.)

Saliva ejectors



RECOMMENDED USE
Moisture and tongue control (Chapters 8 to 11 and 14)

SELECTED PRODUCTS
Svedopta (E. C. Moore Co.)
Speejector (Pulpdent Corporation)
DentaPops (Primotec, Inc.)
Hygoformic (Tidi/Banta)

OCCLUSAL CONTACT INDICATORS

Articulating film



RECOMMENDED USE
Identifying the location of occlusal contacts (Chapters 4, 6, and 30)

SELECTED PRODUCTS
AccuFilm II (Parkell Products)
Articulating Silk-Mark Ribbon (J. R. Rand Corporation)
ArtTape, GHM Articulating film, Madame Butterfly Silk (Almore International, Inc.)
Articodent (Miltex, Inc.)
Articu-Film (Sullivan-Schein Dental)

Powdered wax



RECOMMENDED USE
As an alternative to zinc stearate for identifying wax contacts (Chapter 18)

SELECTED PRODUCTS
Powdered Dusting Wax (Almore International, Inc.)
Powdered Dusting Wax (DeLar Corporation)

Thin Mylar film



(Pulpdent Corporation)

RECOMMENDED USE
Identifying the presence of occlusal contact (Chapters 4, 6, and 30)

SELECTED PRODUCTS
Plastic Shim Stock (.0005 inch) (Artus Corporation)
Shimstock Occlusion Foil (Almore International, Inc.)
Arti-Fol Metallic Shim Stock (Pulpdent Corporation)

PICKLING SOLUTION

RECOMMENDED USE
Removing oxides from castings (Chapter 22)

SELECTED PRODUCTS
Pickle-It (American Dental Supply, Inc.)
Prevox (Ivoclar Vivadent, Inc.)

POLISHING MATERIALS

Acrylic resins (Chapters 4 and 14)

SELECTED PRODUCTS
Pumice (Whip Mix Corporation)
Finalustre (Buffalo Dental Manufacturing Co., Inc.)
Fabulustre (William Dixon Co.)

Castings (Chapter 29)



(George Taub Products & Fusion Co.)



(Dedeco International)

SELECTED PRODUCTS
Moore's Discs (E. C. Moore Co.)
White Flexies (Dedeco International, Inc.)
Tripoli, Rouge (Buffalo Dental Manufacturing Co., Inc.)
BBC (Heraeus Kulzer, Inc.)

Porcelain (Chapter 30)



(Heraeus Kulzer, Inc.)



(Axis Dental Corporation)

SELECTED PRODUCTS
Ceraglaze® Ultimate Porcelain Polishing Set (Axis Dental Corporation)
Two-Striper, Luminescence Plus (Premier Dental Products Company)
Porcelain Adjustment Kit (Shofu Dental Corporation)
Diamond Polishing Paste (Vident)
Insta-Glaze (George Taub Products & Fusion Co.)

PORCELAIN

Complete ceramic

RECOMMENDED USE
Crowns, inlays, and veneers with high esthetic need (Chapter 25)

SELECTED PRODUCTS
Empress, Empress 2 (Ivoclar Vivadent, Inc.)
In-Ceram, Vitadur Alpha, VM7 (Vident)
Optimal (Pentron Clinical Technologies, LLC)

Metal-ceramic



(Ivoclar Vivadent, Inc.)

RECOMMENDED USE
Esthetic crowns and FDPs (Chapter 24)

SELECTED PRODUCTS
IPS Classic (Ivoclar North America, Inc.)
Vita VMK-95, Omega 900, VM13 (Vident)

PORCELAIN INSTRUMENTS



(KerrLab Corporation)

SELECTED SUPPLIERS
Vident
KerrLab Corporation
Heraeus Kulzer, Inc.

PORCELAIN STAINS



(Ivoclar Vivadent, Inc.)

RECOMMENDED USE
Characterizing ceramic restorations (Chapter 30)

SELECTED PRODUCTS
IPS Classic Stains-P, IPS Shade V (Ivoclar Vivadent, Inc.)
Akzent Stains (Vident)
DTC Color System Kit (Heraeus Kulzer, Inc.)

POST REMOVERS



SELECTED PRODUCTS
Masserann Kit (Medidenta International, Inc.)
Post Puller (DentalEZ/StarDental)
Peerless Crown Remover (Peerless International, Inc.)
Gonon (Thomas Extracteur de Pivots)

POST SYSTEMS

Post preparation drills



(Miltex, Inc.)

RECOMMENDED USE
Restoration of endodontically treated teeth (Chapter 12)

SELECTED PRODUCTS
Gates-Glidden drills (Pulpdent Corporation)
Gates-Glidden drills (Miltex, Inc.)

Posts



(Coltène/Whaledent AG)

RECOMMENDED USE
Restoration of endodontically treated teeth (Chapter 12)

SELECTED PRODUCTS (see also Table 12-5)
EZ Cast Post (Merritt EZ Cast Post, Inc.)
Endowel (StarDental/Syntex Dental Products, Inc.)
ParaPost (Coltène/Whaledent AG)
Flexi-Post (Essential Dental Systems)
PGP Wire (Dentsply Ceramco)

PREFABRICATED CROWN FORMS

RECOMMENDED USE
Interim restorations (Chapter 15)

Metal (posterior teeth)



SELECTED PRODUCTS
Aluminum Crowns (3M ESPE)
Iso-Form Ion Crowns (3M ESPE)

Resin (anterior teeth)


(Harry J. Bosworth Co.)

SELECTED PRODUCTS
Ion Polycarbonate Crowns (3M ESPE)
B-Crowns (Harry J. Bosworth Co.)
Polycarbonate Crowns (Sullivan-Schein Dental)

RESINS

Autopolymerizing acrylic resin pattern material



RECOMMENDED USE
Direct patterns for posts and cores (Chapter 12)
Soldering index (Chapter 28)
Recording occlusal relationship (Chapter 17)

SELECTED PRODUCTS
Duralay (Reliance Dental Manufacturing Company)
Pattern Resin (GC America, Inc.)
Relate Monomer (Parkell Products)
Palavit G (Heraeus Kulzer, Inc.)

Autopolymerizing clear acrylic resin



(Caulk/Dentsply)

RECOMMENDED USE
Fabricating occlusal appliances (Chapter 4)

SELECTED PRODUCTS
Caulk Orthodontic Resin (Caulk/Dentsply)
COE Ortho-Resin II (GC America, Inc.)

Custom tray resin


(Harry J. Bosworth Co.)

RECOMMENDED USE
Impression trays (Chapter 14)
Anterior guide table (Chapter 2)
Remount procedure (Chapter 30)

SELECTED PRODUCTS
Harry J. Bosworth Fastray (Harry J. Bosworth Co.)
Formatray (Kerr Corporation)
Tray Resin (Caulk/Dentsply)
TMJ Resin (TMJ Instrument Co., Inc.)
Hygon Tray Resin (The Hygenic Corporation)
COE Tray Plastic (GC America, Inc.)

Heat-polymerized clear acrylic resin

RECOMMENDED USE
Fabricating occlusal appliances (Chapter 4)

SELECTED PRODUCTS
Perma-Cryl Clear (GC America, Inc.)
Lucitone Clear Resin (Caulk/Dentsply)

Interim resin


(Lang Dental Manufacturing Co., Inc.)

RECOMMENDED USE
Fabricating interim restorations (Chapter 15)

SELECTED PRODUCTS
Jet (Lang Dental Manufacturing Co., Inc.)
Temporary Bridge Resin (Caulk/Dentsply)
Alike (GC America, Inc.)

SNAP (Parkell Products)
Temporary Bridge Resin (Caulk/Dentsply)
Trim (Harry J. Bosworth Co.)
Temporary Bridge Resin (Caulk/Dentsply)
Protemp 3 Garant (3M ESPE)
Integrity (Caulk/Dentsply)
Temphase (Kerr Corporation)
Luxatemp (Zenith)

Light-cured pattern resin



RECOMMENDED USE
Direct patterns for cores (Chapter 12)
Soldering index (Chapter 28)
Recording occlusal relationship (Chapter 17)

SELECTED PRODUCTS
Palavit G LC (Heraeus Kulzer, Inc.)
Luminex (Dentatus USA, Ltd.)

Thermoplastic resin

RECOMMENDED USE
Anterior programming device fabrication (Chapter 2)
Exterior surface mold for interim restorations (Chapter 15)

SELECTED PRODUCTS
Matrix Button (Advantage Dental Products, Inc.)

RESIN STAINS



(Lang Dental Manufacturing Co., Inc.)

RECOMMENDED USE
Characterizing interim restorations (Chapter 15)

SELECTED PRODUCTS
Jet adjusters (Lang Dental Manufacturing Co., Inc.)
Minute Stains (George Taub Products & Fusion Co.)

SEATING STICKS



(Temrex Corporation)

RECOMMENDED USE
Seating cast restorations (Chapter 31)

SELECTED PRODUCTS
Aidaco Bite Sticks (Temrex Corporation)

SEPARATING FLUIDS: SEE ALSO DIE LUBRICANT

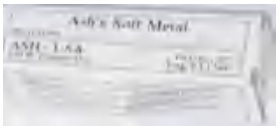


(Caulk/Dentsply)

RECOMMENDED USE
Fabricating interim restorations (Chapter 15)
Fabricating occlusal appliances (Chapter 4)

SELECTED PRODUCTS
Al-Cote (Caulk/Dentsply)
Modern Foil (Heraeus Kulzer, Inc.)
Foil Cote (Buffalo Dental Manufacturing Co., Inc.)

SOFT METAL SHEET (ASH'S METAL)



RECOMMENDED USE
Reinforcing centric record (Chapter 2)

SELECTED PRODUCTS
Relief Metal (William Dixon Co.)

SOFT TISSUE LASER

RECOMMENDED USE

Removal of hyperplastic tissue before impression making (Chapter 14)

SELECTED PRODUCTS

Waterlase MD (Biolase Technology, Inc.)

SOLDERING FLUX



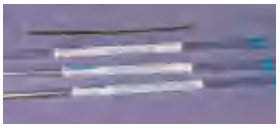
RECOMMENDED USE

Preventing oxidation during soldering (Chapter 28)

SELECTED PRODUCTS

DS 1 Soldering Flux (Degussa Corporation)
Soldering Flux (Dentsply Ceramco)
M20-129 Flux Paste (Vident)

SOLDERS



High-heat

RECOMMENDED USE

Preceramic soldering (Chapter 28)

SELECTED PRODUCTS

(Use material recommended by alloy manufacturer.)

Low-heat

RECOMMENDED USE

Soldered connectors for conventional gold restorations (Chapter 28)
Postceramic soldered connectors (Chapter 28)

SELECTED PRODUCTS

Slim strip 650 solder (Heraeus Kulzer, Inc.)
Ney Balanced Line Regular Solder (Dentsply Ceramco)
Dental solders (Baker Dental Corp.)

STONES: SEE BURS, DIAMONDS, AND STONES

SURFACTANTS



RECOMMENDED USE

Painting patterns before investing (Chapter 22)

SELECTED PRODUCTS

Smoothex Debubbling Solution (Whip Mix Corporation)
DeBubblizer (Kerr Corporation)
DeLar Surfactant (DeLar Corporation)

THERMOPLASTIC RESIN SHEETS



(Buffalo Dental Manufacturing Co., Inc.)

RECOMMENDED USE

External mold for interim restorations (Chapter 15)
Matrix for occlusal appliance (Chapter 4)
Tooth-preparation reduction guides (Chapters 8 to 11)

SELECTED PRODUCTS

Sta-Vac (Buffalo Dental Manufacturing Co., Inc.)
Temporary Splint (Dentiform, Inc.)
Thermo-Forming Sheets (Sullivan-Schein Dental)

THICKNESS GAUGES



(KerrLab Corporation)

RECOMMENDED USE

Measuring thickness of patterns and restorations

SELECTED PRODUCTS

Dial Caliper (Almore International, Inc.)
Crown gauge (Miltex Instrument Co., Inc.)
Iwanson Spring Caliper (Hu-Friedy Mfg. Co.)
Calipers (KerrLab Corporation)
Iwanson Caliper (Sullivan-Schein Dental)

ULTRASONIC CLEANERS AND SOLUTIONS



(L & R Manufacturing Co.)

RECOMMENDED USE

Cleaning restorations and interim restorations

SELECTED SUPPLIERS

Heraeus Kulzer, Inc.
L & R Manufacturing Co.
Hu-Friedy Mfg. Co.
Coltène/Whaledent, Inc.

VACUUM FORMERS



(Buffalo Dental Manufacturing Co., Inc.)

RECOMMENDED USE

External molds for interim restorations (Chapter 15)
Tooth preparation reduction guides (Chapters 8 to 11)

SELECTED SUPPLIERS

Buffalo Dental Manufacturing Co., Inc.
Ultradent Products, Inc.
Sullivan-Schein Dental

WAXES

Boxing wax



(Heraeus Kulzer, Inc.)

RECOMMENDED USE

Boxing impressions (Chapter 14)
Boxing soldering assembly (Chapter 28)

SELECTED PRODUCTS

Boxing Wax (Heraeus Kulzer, Inc.)
Pro-Craft Boxing Wax Strips (William Dixon Co.)
also Magnetic Boxing Strips:
Magnetic Vinyl Strips (Almore International, Inc.)
DeLar Magnetic Boxing Strip (DeLar Corporation)

Inlay casting wax



(Slaycris Products, Inc.)

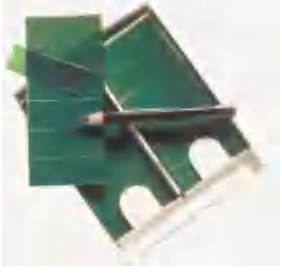
RECOMMENDED USE

Making wax patterns (Chapter 18)

SELECTED PRODUCTS

Inlay Casting Wax (Kerr Corporation)
Plastodent (Degussa Corporation)
Red Casting Wax (Heraeus Kulzer, Inc.)
Flex 200 (MDL Dental Products, Inc.)
Green #2 Hard Wax (Slaycris Products, Inc.)

Occlusal registration wax



(KerrLab Corporation)

RECOMMENDED USE
Centric recording for diagnostic casts (Chapter 2)

SELECTED PRODUCTS
Aluwax (Aluwax Dental Products Company)
Delar Wax (Almore International, Inc.)
Occlusal Indicator Wax (KerrLab Corporation)

Sprue wax

RECOMMENDED USE
Sprue former (Chapter 22)

SELECTED PRODUCTS
Sprue Wax (Heraeus Kulzer, Inc.)
Stalite Round Wire Wax (Buffalo Dental Manufacturing Co., Inc.)
Pro-Craft Sprue Rod Wax (William Dixon Co.)

WAXING INSTRUMENTS



(KerrLab Corporation)

SELECTED SUPPLIERS
American Dental Manufacturing
KerrLab Corporation
Hu-Friedy Mfg. Co.
Premier Dental Products Company
Sullivan-Schein Dental

Electric waxing instructments



(KerrLab Corporation)

Electra Waxer, Gemini Waxer (Almore International, Inc.)
Ultra-Waxer, MasterTouch, (KerrLab Corporation)

Appendix B

MANUFACTURERS' INDEX

Abrasive Technology, Inc.
8400 Green Meadows Drive
P.O. Box 545
Lewis Center, Ohio 43035
(800) 964-8324
Fax: (740) 548-7617
www.abrasive-tech.com

Advantage Dental Products, Inc.
P.O. Box 415
Lake Orion, Michigan 48361
(800) 388-6319
Fax: (248) 391-1727
www.advantagedentalinc.com

Almore International, Inc.
P.O. Box 25214
Portland, Oregon 97298
(800) 547-1511
Fax: (503) 643-9748
www.almore.com

Alphadent NV
Noorderlaan 79
2030 Antwerpen
Belgium
+32 3 542 25 27
Fax: +32 3 542 24 30
Email: export@alphadent.be

Aluwax Dental Products Company
6841 Lake Michigan Drive
P.O. Box 87
Allendale, Michigan 49401
(616) 895-4385
Fax: (616) 895-5060
www.aluwaxdental.com

AmeraDent, Inc., of Nevada
2533 North Carson Street
Carson City, Nevada 89706
(800) 959-8517
(916) 858-1250

American Dental Mfg.
(*see* GC America, Inc.)

American Dental Supply, Inc.
2600 William Penn Highway
Easton, Pennsylvania 18045-5277
(800) 558-5925
Fax: (610) 252-2822
www.americandentalinc.com

American Optical
P.O. Box 8020
Southbridge, Massachusetts 01550
(800) 358-8258
Fax: (508) 764-5010
www.aolens.com

American Tooth Industries
1200 Stellar Drive
Oxnard, California 93033
(800) 235-4639
Fax: (805) 483-8482
www.americantooth.com

APM-Sterngold
(*see* Sterngold Dental, LLC)

Artus Corporation
P.O. Box 511
201 South Dean Street
Englewood, New Jersey 07631
(201) 568-1000
Fax: (201) 568-8865
www.artuscorp.com

Aseptico International
P.O. Box 1548
Woodinville, Washington 98072
(800) 426-5913
Fax: (360) 668-8722
www.aseptico.com

Astra Tech, Inc.
890 Winter Street
Waltham, Massachusetts 02451
(800) 531-3481
Fax: (781) 890-6808
www.astratech.com

Attachments International
600 S. Amphlett Blvd
San Mateo, California 94402
(800) 999-3003
Fax: (650) 340-8423
www.attachments.com

Atwood Industries
1708 Rubenstein Drive
Cardiff-by-the-Sea, California 92007
(800) 451-6733
Fax: (760) 944-0112
www.atwoodindustries.net

Aurium Research U.S.A.
5855 Oberlin Drive
San Diego, California 92121
(800) 645-6110
Fax: (516) 763-6710
www.aurium-alloys.com

Austenal, Inc.
(*see* Dentsply Austenal)

Axis Dental Corporation
3008 West Story Road
Irving, Texas 75038
(888) 654-2947
Fax: (972) 257-3647
www.axisdental.net

Baker Dental Corp.
P.O. Box 339
Lake Zurich, Illinois 60047
(800) 631-5599
Fax: (847) 726-3803
www.bakerdental.com

Bausch Articulating Papers, Inc.
One Chestnut Street
Nashua, New Hampshire 03060
(888) 622-8724
Fax: (603) 883-0606
www.bauschdental.com

Bayer, Inc.
(*see* Heraeus Kulzer, Inc.)

Bego
Bremer Goldschlagerei Wilh. Herbst GmbH & Co. KG

Technologiepark Universitat
Wilhelm-Herbst-Str. 1
D-28359 Bremen
Germany
49-(0)421 / 20 28-0
Fax: 49-(0)421 / 20 28-100
www.bego.com

BELL HANDENGINE, INC.
552 Greens Creek Rd.
Grants Pass, Oregon 97527
(800) 523-6640
Fax: (541) 472-0493
www.bellhandengineinc.net

BELL DENTAL PRODUCTS
3003 Arapahoe Street, Suite 101B
Denver, Colorado 80205
(303) 292-2137
Fax: (303) 292-4411
www.belldental.com

BELLE DE ST. CLAIRE
A division of SDS Kerr
1717 West Collins Avenue
Orange, California 92867
(800) 322-6666
Fax: (800) 537-7345
www.kerrlab.com

BELPORT CORP./GINGI-PAK
P.O. Box 240
4825 Calle Alto
Camarillo, California 93011-0240
(800) 437-1514
Fax: (805) 484-5076
www.gingi-pak.com

BENCO DENTAL
11 Bear Creek Boulevard
Wilkes-Barre, Pennsylvania 18702
(800) 462-3626
Fax: (888) 329-2362
www.benco.com

BIOLASE TECHNOLOGY, INC.
981 Calle Amanecer
San Clemente, California 92673
(888) 424-6527
Fax: (949) 361-0204
www.biolase.com

BISCO, INC.
1100 W. Irving Park Road
Schaumburg, Illinois 60193
(800) 247-3368
Fax: (800) 959-9550
www.bisco.com

HARRY J. BOSWORTH CO.
7227 N. Hamlin Avenue
Skokie, Illinois 60076
(800) 323-4352
Fax: (847) 679-2080
www.bosworth.com

BRASSELER USA
One Brasseler Boulevard
Savannah, Georgia 31419
(800) 841-4522
Fax: (888) 610-1937
www.brasselerusa.com

BUFFALO DENTAL MANUFACTURING CO., INC.
129 Lafayette Drive
Syosset, New York 11791
(800) 828-0203
Fax: (516) 496-7751
www.buffalodental.com

JOHN O. BUTLER COMPANY
4635 West Foster Avenue
Chicago, Illinois 60630
(800) 528-8537
Fax: (800) 553-2014
www.jbutler.com

CADCO DENTAL PRODUCTS, INC.
(*see* DUX DENTAL)

CALCITEK
(*see* SULZER CALCITEK, INC.)

CAPTEK PRECIOUS CHEMICALS
250 Altamonte Commerce Blvd.
Altamonte Springs, Florida 32714
(800) 921-2227
Fax: (407) 889-8893
www.captek.com

CARL ZEISS, INC., NORTH AMERICA
One Zeiss Drive
Thornwood, New York 10594
(800) 442-4020
Fax: (914) 682-8296
www.zeiss.com

CAULK/DENTSPLY
38 West Clarke Avenue
Milford, Delaware 19963
(800) 532-2855
Fax: (800) 788-4110
www.caulk.com

CERAMCO, INC.
Six Terri Lane
Burlington, New Jersey 08016
(800) 487-0100
Fax: (609) 386-8282
www.ceramco.com

CERTOL INTERNATIONAL, LLC
7399 S. Tucson Way
Englewood, Colorado 80112
(800) 843-3343
Fax: (303) 799-9408
www.certol.com

CHAMELEON DENTAL PRODUCTS
200 N 6th Street
Kansas City, Kansas 66101
(800) 366-0001
Fax: (913) 621-7012
www.miragecdp.com

R. CHIGE, INC.
9004 Villa Portfino Circle
Boca Raton, Florida 33496
(800) 645-2628
Fax: (561) 338-5668

CLASSIC PRACTICE RESOURCES
a Division of Westerman Enterprises, Inc.
7855 Jefferson Highway
Baton Rouge, Louisiana 70809
(800) 928-9289
Fax: (225) 923-2499
www.classicpractice.com

CLIVE CRAIG
(*see* DUX DENTAL)

COE LABORATORIES, INC.
(*see* GC AMERICA, INC.)

COLGATE ORAL PHARMACEUTICALS, INC.
1 Colgate Way
Canton, Massachusetts 02021
(800) 527-0222
Fax: (781) 821-2187
www.colgate.com

COLTÈNE/WHALEDENT, INC.
235 Ascot Parkway
Cuyahoga Falls, Ohio 44223
(800) 221-3046
Fax: (201) 529-2103
www.coltenewhaledent.com

COLTÈNE/WHALEDENT AG
Feldwiesenstrasse 20
CH9450 Altstätten
Switzerland
(071) 757-5300
Fax: (071) 757-5310

COLUMBIA DENTOFORM CORPORATION
34-24 Hunters Point Avenue
Long Island City, New York 11101
(800) 688-0662
Fax: (718) 482-1585
www.columbiadentoform.com

COLUMBUS DENTAL
(*see* HERAEUS KULZER, INC.)

COMCO, INC.
2151 N. Lincoln Street
Burbank, California 91504-3344
(800) 796-6626
Fax: (818) 955-8365
www.comcoinc.com

COMDENT, INC.
(877) 524-2440
Fax: (727) 535-8376
Email: web-inquiry@comdentinc.com
www.comdentinc.com

COPALITE/COOLEY & COOLEY, LTD.
8550 Westland West Blvd.
Houston, Texas 77041
(800) 215-4487
Fax: (800) 215-4489
www.copalite.com

CORE-VENT CORPORATION
(*see* ZIMMER DENTAL)

COTTRELL, LTD.
(*see* CERTOL INTERNATIONAL, LLC)

CRESCENT DENTAL MFG. CO.
9444 Deerwood Lane North
Maple Grove, Minnesota 55369
(800) 989-8085
Fax: (763) 315-4924
www.crescentproducts.com

CTH
393 Sunrise Highway, Suite 1
West Babylon, New York 11704
(800) 458-6152
Fax: (631) 661-8792

DALBO/CENDRES & MÉTAUX
Rue de Boujean 122
Biel-Bienne, CH-2501
France
41 32 344 2211
Fax: 41 32 344 2212

DANVILLE ENGINEERING, INC.
2021 Omega Road
San Ramon, California 94583
(800) 827-7940
Fax: (925) 838-0944
www.daneng.com

DANVILLE MATERIALS
3420 Fostoria Way, Suite A-200
San Ramon, California 94583
(800) 822-9294
Fax: (925) 973-0764
www.danvillematerials.com

DEDECO INTERNATIONAL, INC.
Route 97
Long Eddy, New York 12760
(888) 433-3326
Fax: (845) 887-5281
www.dedeco.com

DEGUSSA CORPORATION
379 Interpace Parkway
P.O. Box 677
Parsippany, New Jersey
07054-0677
(973) 541-8000
Fax: (973) 541-8501
www.degussa.com

DELAR CORPORATION
P.O. Box 226
Lake Oswego, Oregon 97034
(800) 669-7499
Fax: (503) 635-2978
www.delar.com

DENERICA DENTAL CORPORATION
(*see* RENFERT USA, INC.)

DEN-MAT CORPORATION
2727 Skyway Drive
Santa Maria, California 93455
(800) 445-0345
Fax: (805) 922-6933
www.denmat.com

DENOVO DENTAL, INC.
5130 Commerce Dr.
Baldwin Park, California 91706
(800) 854-7949
Fax: (800) 847-8599
www.denovodental.com

DENTAL ANCHOR SYSTEMS, INC.
179-9 Route 46 West, #112
Rockaway, New Jersey 07866
(800) 397-4433
Fax: (973) 328-0288
www.dentalanchor.com

DENTALEZ/STARDENTAL
1816 Colonial Village Lane
Lancaster, Pennsylvania 17601
(800) 275-3320
Fax: (717) 291-5699
www.dentalez.com

DENTAL POWER
(*see* WESTERN DENTAL SPECIALTIES/DENTAL POWER)

DENTAL VENTURES OF AMERICA, INC.
217 Lewis Court
Corona, California 92882
(800) 228-6696
Fax: (951) 270-0636
www.dentalventures.com

DENTATUS USA, LTD.
192 Lexington Avenue
New York, New York 10016
(800) 323-3136
Fax: (212) 532-9026
www.dentatus.com

DENT CORP RESEARCH & DEVELOPMENT
7-11 South Broadway, Suite LL-3
White Plains, New York 10601
(800) 454-9244
Fax: (914) 948-1711
www.dentcorp.com

DENTIFAX/DI-EQUI
693 Seneca Street
Buffalo, New York 14210
(800) 643-1603
Fax: (716) 852-3831
www.dentifax.com

DENTIFORM, INC.
210 Division Street
Kingston, Pennsylvania 18704
(800) 441-5421
Fax: (800) 895-9094
www.dentiform.com

DENTSPLY AUSTENAL
570 West College Avenue
York, Pennsylvania 17404
(800) 621-0381
Fax: (717) 849-4712
www.austenal.dentsply.com

DENTSPLY INTERNATIONAL
221 W. Philadelphia Street
P.O. Box 872
York, Pennsylvania 17405
(800) 877-0020
www.dentsply.com

DENTSPLY MAILLEFER
5100 E. Skelly Drive, Suite 300
Tulsa, Oklahoma 74135
(800) 924-7393
Fax: (800) 924-7389
www.maillefer.com

DENTSPLY TULSA DENTAL
5100 E. Skelly Drive, Suite 300
Tulsa, Oklahoma 74135
(800) 662-1202
Fax: (800) 597-2779
www.tulsadental.com

DESIGNS FOR VISION, INC.
760 Koehler Avenue
Ronkonkoma, New York 11779
(800) 727-6407
Fax: (631) 585-3404
www.designsforvision.com

DI-EQUI
(*see* DENTIFAX/DI-EQUI)

DILLON COMPANY, INC.
Leach & Dillon Products
161 Comstock Pkwy
Cranston, RI 02921
(800) 535-2633
Fax: (401) 464-5862
www.leachdillon.com

LESTER A. DINE, INC.
PGA Commerce Park
351 Hiatt Drive
Palm Beach Gardens, Florida 33418
(800) 624-9103
Fax: (561) 624-9103
www.dinecorp.com

WILLIAM DIXON CO.
750 Washington Avenue
Carlstadt, New Jersey 07072
(800) 847-4188
Fax: (201) 939-5067
www.grobetusa.com

DMG-HAMBURG
(*see* ZENITH)

DUX DENTAL
600 East Hueneme Road
Oxnard, California 93033
(800) 833-8267
Fax: (805) 488-2266
www.duxdental.com

ELLMAN INTERNATIONAL, INC.
3333 Royal Avenue
Oceanside, New York 11572
(800) 835-5355
Fax: (516) 569-0054
www.ellman.com

ESSENTIAL DENTAL SYSTEMS
89 Leuning Street
South Hackensack, New Jersey 07606
(800) 223-5394
Fax: (201) 487-5120
www.edsdental.com

FILHOL DENTAL USA
1219B Greenwood Road
Baltimore, Maryland 21208
(800) 910-2050
Fax: (410) 484-6354
www.filhol.com

FLORIDA PROBE CORPORATION
3700 NW 91st Street
Suite C-100
Gainesville, Florida 32606
(352) 372-1142
Fax: (352) 372-0257
www.floridaprobe.com

GC AMERICA, INC.
3737 West 127th Street,
Alsip, Illinois 60803
(800) 323-7063
Fax: (800) 423-2963
www.gcamerica.com

GEL-KAM
(*see* COLGATE ORAL PHARMACEUTICALS)

GENERAL SCIENTIFIC (SURGITEL)
77 Enterprise Drive
Ann Arbor, Michigan 48103
(800) 959-0153
Fax: (734) 662-0520
www.surgitel.com

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D-15177 Pforzheim
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Fax: +49 (7231) 957-169
Email: info@girrbach.de

GLASSPAN, INC.
101 J. R. Thomas Drive
Exton, Pennsylvania 19341
(800) 280-7726
Fax: (610) 363-6391
www.glasspan.com

GRESCO PRODUCTS, INC.
P.O. Box 865
Stafford, Texas 77497
(800) 527-3250
Fax: (281) 499-6515
www.grescoproducts.com

HAGER WORLDWIDE
13322 Byrd Drive
Odessa, Florida 33556
(800) 328-2335
Fax: (800) 573-9392
www.hagerworldwide.com

HANDLER MFG. COMPANY, INC.
P.O. Box 520
Westfield, New Jersey 07091-0520
(800) 274-2635
Fax: (908) 233-7340
www.handlermfg.com

HERAEUS KULZER, INC.
4315 S. Lafayette Blvd.
South Bend, Indiana 46614
(800) 343-5336
Fax: (574) 299-6673
www.heraeus-kulzer-us.com

HU-FRIEDY MFR. CO., INC.
3232 N. Rockwell Street
Chicago, Illinois 60618
(800) 729-3743
Fax:(773) 975-1683
www.hufriedy.com

HYDRO-CAST DENTAL PRODUCTS
A Division of Kay-See Dental
Manufacturing Company
124 East Missouri Avenue
Kansas City, Missouri 64106
(800) 842-8844
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THE GLOSSARY OF PROSTHODONTIC TERMS*

A

Abbe flap \Ăb′ē flăp\ [Robert Abbe, New York, N.Y. surgeon, 1851-1928]**:** *eponym* for a lip switch operation. A triangular, full thickness flap from the lower lip used to fill in a deficit in the upper lip. Specifically applied to the midportion of the upper or lower lip–called also *lip switch operation*

Abbe, R. A new plastic operation for the relief of deformity due to double harelip. Med Rec 1898;53:477.

ab·duct \ăb dŭkt′\ *vt* (1834)**:** to draw away from the median plane–*comp* ADDUCT

ab·er·rant \ă-bĕr′ant\ *adj* (ca. 1798)**: 1:** a deviation from the normal or usual course, form, or location **2:** straying from the normal way

ab·frac·tion \ăb frăk′shun\ *n* (1991)**:** the pathologic loss of hard tooth substance caused by biomechanical loading forces. Such loss is thought to be due to flexure and chemical fatigue degradation of enamel and/or dentin at some location distant from the actual point of loading–*comp* ABLATION, ABRASION, ATTRITION, and EROSION

ab·la·tion \ă-blā′shun\ *n* (15c)**: 1:** separation or detachment; extirpation; eradication **2:** removal of a part, especially by cutting–see ABFRACTION, EROSION

abrade \uh-brād′*vt* (1677)**:** to rub away the external covering or layer of a part–*comp* ATTRITION, EROSION

abra·sion \ă-brā ′shun\ *n* (1656)**: 1:** the wearing away of a substance or structure (such as the skin or the teeth) through some unusual or abnormal mechanical process **2:** an abnormal wearing away of the tooth substance by causes other than mastication–*comp* ATTRITION, EROSION

[1]abra·sive \uh-brā ′ siv, -ziv\ *n* (1853)**:** a substance used for abrading, smoothing, or polishing

[2]abra·sive \uh-brā ′ siv, -ziv\ *adj* (1875)**: 1:** tending to abrade **2:** causing irritation–**abra·sive·ly** *adv*, **abra·sive·ness** *n*

ab·ra·si·vity \uh-brā′siv-ĭ-tē, -ziv-ĭ-tē\ *v* (1998)**:** the property of one material to wear away another material by means of frictional contact

absorbed dose \ab-sôrbd′,-zôrbd′ dōs**:** the amount of energy from ionizing radiation absorbed per unit mass of matter, expressed in Gray units

ab·sorp·tance \ab-sôrp′tans, -zôrp′tans\ *n* (ca. 1931)**:** the ratio of the radiant energy absorbed by a body to that incident upon it

ab·sorp·tion \ab-sôrp′shun, -zôrp′-\ *n* (1741)**: 1:** the uptake of substances into or through tissues, e.g., mucosa, skin, and intestine **2:** in radiology, the uptake of energy by matter with which the radiation interacts–see A. of RADIATION–*comp* ADSORPTION

absorption of radiation \ab-sôrp′shun ŭv rā′dē-ā′shun**:** collision-like interactions between the individual particulate or quantum components of a beam of radiation and the subatomic parts of matter that occur at random during irradiation. Each interaction may result in partial or complete transfer of energy

abut·ment \a-bŭt′ment\ *n* (1634)**: 1:** that part of a structure that directly receives thrust or pressure; an anchorage **2:** a tooth, a portion of a tooth, or that portion of a dental implant that serves to support and/or retain a prosthesis–*usage* see ANGULATED A., HEALING A., DENTAL IMPLANT A., INTERMEDIATE A., ONE PIECE A., PREPARATION PIECE A., STANDARD A., TWO PIECE A.

abutment analog *n* (2005)**:** a replica of the superior portion of a dental implant. Usually used to provide an exact form of the dental implant abutment within the dental laboratory during fabrication of a prosthesis supported in part or whole by the dental implant

abutment clamp \a-bŭt′ment klămp\ (1998)**:** any device used for positioning a dental implant abutment upon the dental implant body

abutment driver *n* (2005)**:** any hand instrument usually specifically made to assist in insertion and securing of a dental implant abutment to the superior portion of a dental implant

abutment healing cap *n* (2005)**:** any temporary cover used to provide a seal over the superior portion of a dental implant; most such covers are metallic and are intended for interim usage following exposure of the dental implants superior surface

abutment post *n* (2005)**:** that component of a dental implant abutment which extends into the internal structure of a dental implant and is used to provide retention and/or stability to the dental implant abutment

abutment screw *n* (1998)**:** that component which secures the dental implant abutment to the dental implant body. See also ATTACHMENT SCREW

ac·cel·er·ant \ăk-săl′a-rănt′\ *n* (1916)**:** a substance used to accelerate a process (as in enhancing the speed of a chemical reaction)

ac·cel·er·a·tor \ăk-sĕl′a-rā′ter\ *n* (1611)**: 1:** a substance that speeds a chemical

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reaction **2:** in physiology, a nerve, muscle, or substance that quickens movement or response

ac·cre·tion \a-krē′shun\ *n* (1615)**: 1:** the process of enlargement or growth by a gradual build-up **2:** in periodontics, the accumulation on teeth or dental implants of foreign material such as plaque, calculus, and materia alba

acentric relation: see ECCENTRIC RELATION

ach·ro·mat·ic \ăk′ra-măt′ĭk\ *adj* (1766)**: 1:** lacking in hue and saturation, therefore falling into a series of colors that varies only in lightness or brightness **2:** possessing no hue; being or involving black, gray or white

achromatopsia \ā-krō′ma-tŏp′zhē-a\ *n*: **1:** monochromatism **2:** a type of monochromatism in which all colors are perceived as achromatic, called also *achromatism*, *total color perception deficiency*

acid etched bonded splint: see RESIN-BONDED SPLINT

acid etched bridge: see RESIN-BONDED PROSTHESIS

acid etched fixed partial denture: see RESIN-BONDED PROSTHESIS

ac·quire \a-kwīr′\ *vt* **ac·quired**; **ac·quir·ing** (15c) **1:** to obtain as one's own; to come to have as a new or additional trait, characteristic or capability **2:** attained with time

acquired centric: see ECCENTRIC RELATION, MAXIMAL INTERCUSPAL POSITION

acquired centric occlusal position: see ECCENTRIC RELATION, MAXIMAL INTERCUSPAL POSITION

acquired centric position: see ECCENTRIC RELATION, MAXIMAL INTERCUSPAL POSITION

acquired centric relation: see ECCENTRIC RELATION, MAXIMAL INTERCUSPAL POSITION

acquired eccentric relation \a-kwīrd′ ĭk-sĕn′trĭk rĭ-lā′shun**:** any eccentric relationship position of the mandible relative to the maxilla, whether conditioned or learned by habit, which will bring the teeth into contact

acquired occlusal position \a-kwīrd′ a-klōō′zal pa-zish′an**:** the relationship of teeth in maximum intercuspation regardless of jaw position—see MAXIMAL INTERCUSPAL POSITION

acquired occlusion: see MAXIMAL INTERCUSPAL POSITION

acrylic resin \a-krĭl′ĭk rĕz′ĭn**: 1:** pertaining to polymers of acrylic acid, methacrylic acid, or acrylonitrile; for example, acrylic fibers or acrylic resins **2:** any of a group of thermoplastic resins made by polymerizing esters of acrylic or methylmethacrylate acids

acrylic resin base \a-krĭl′ĭk rĕz′ĭn bās**:** a denture base made of acrylic resin

acrylic resin veneer: usually referring to fixed dental prosthesis, the veneering or lamination of the facial and/or buccal surfaces of a crown or fixed dental prosthesis using acrylic resin. The intention of such veneering is to provide a natural tooth color to the viewable portions of the restoration

activated resin *obs*: see AUTOPOLYMERIZING RESIN

ac·ti·va·tor \ăk′tĭ-vā′ tôr\ *n*: a removable orthodontic prosthesis intended to stimulate perioral muscles

ac·tiv·a·tor \ăk′tĭ-vā′ tôr\ *n.* (1998)**: 1:** any chemical agent which triggers an initiator chemical to begin a chemical reaction. **2:** a substance used in small proportions to increase the effectiveness of an accelerator chemical

acute closed lock \a-kyōōt′ klōzd lŏk**:** a form of temporomandibular joint dysfunction characterized by limitation in jaw movement caused by anterior displacement of the intra-articular disc and associate with pain, limitation of jaw opening to 25 to 30 mm (as measured in the incisor area) and, with jaw opening, a deflection of the mandible toward the affected joint

acute pain: pain having a brief and relatively severe course

adaptation \ăd′ăp-tā′shun\ *n* (1610)**: 1:** the act or process of adapting; the state of being adapted **2:** the act of purposefully adapting two surfaces to provide intimate contact **3:** the progressive adjustive changes in sensitivity that regularly accompany continuous sensory stimulation or lack of stimulation **4:** in dentistry, (**a**) the degree of fit between a prosthesis and supporting structures, (**b**) the degree of proximity of a restorative material to a tooth preparation, (**c**) the adjustment of orthodontic bands to teeth

adaptation syndrome \ăd′ăp-tā′shun sĭn′drōm′**:** a syndrome characterized by alterations in response as an accommodation to the environment

adaptive occlusion: see MAXIMAL INTERCUSPAL POSITION

additive color mixture \ăd′ ĭ-tĭv kŭl′ur mĭks′chur**:** the perceived color that results when the same area of the retina of the eye is illuminated by lights of different spectral distribution such as by two colored lights—*comp* SUBTRACTIVE COLOR SYSTEM

ad·duct \a-dŭkt′,-ă-\ *vt* (1836)**:** to draw toward the median plane or toward the axial line—*comp* ABDUCT

ad·her·ence \ăd-hîr′ens, -enz\ *n* (1531)**:** the act, quality, or action of adhering; persistent attachment

ad·he·sion \ăd-hē′zhun\ *n* (1624)**: 1:** the property of remaining in close proximity, as that resulting from the physical attraction of molecules to a substance or molecular attraction existing between the surfaces of bodies in contact **2:** the stable joining of parts to each other, which may occur abnormally **3:** a fibrous band or structure by which parts abnormally adhere—*comp* CAPSULAR FIBROSIS, FIBROUS A., INTRACAPSULAR A., MYOFIBROTIC CAPSULAR CONTRACTURE

[1]ad·he·sive \ăd-hē′siv, -ziv\ *adj* (1670)**:** sticky or tenacious

[2]ad·he·sive \ăd-hē′siv, -ziv\ *n* (1912)**: 1:** any substance that creates close adherence to or on adjoining surfaces **2:** a luting agent—see DENTURE A., MAXILLOFACIAL PROSTHETIC A.

adhesive capsulitis \ăd-hē′siv,-ziv kăp′sul-ī′tis**:** within the temporomandibular joint, any situation in which the disk is in normal position, joint space volume is decreased, and motion is restricted

adhesive failure \ăd-hē′siv,-ziv fāl′yur\ (1998)**:** bond failure at an interface between two materials due to a tensile or shearing force—*see* COHESIVE FAILURE

adhesive resin: any resin material with incorporated adhesive chemicals such as organophosphates, HEMA (hydroxyethyl methacrylate), or 4-META (4 methacrylethyl trimellitic anhydride); in dentistry, it describes the luting agents used with resin bonded prostheses

adiadochokinesia \ăd′ē-ă dō chō kĭ nē′zha\ *n*: inability to perform rapid alternating movements such as opening and closing the jaws or lips, raising and lowering the eyebrows, or tapping the finger

adipose atrophy \ăd′ĭ-pōs′ ăt′ra-fē**:** reduction of fatty tissue

adjustable anterior guidance \a-jŭst′a′bul ăn-tîr′ē-or gīd′ns**:** an

anterior guide on an articulator whose surface may be altered to provide desired guidance of the articulator's movement mechanism; the guide may be programmed (calibrated) to accept eccentric interocclusal records

adjustable articulator \a-jŭst′a′bul ärtĭk′ya-lā′tor\: an articulator that allows some limited adjustment in the sagittal and horizontal planes to replicate recorded mandibular movements—see ARTICULATOR

adjustable axis facebow: see FACE-BOW

adjustable occlusal pivot \a-just′a′bul a klōō′sal pĭv′ot\ *obs*: an occlusal pivot that may be adjusted vertically by means of a screw or other device (GPT4)

ad·just·ment \a-jŭst′mant\ *n* (1644): **1:** the act or process of modifying physical parts **2:** in dentistry, a modification made on a dental prosthesis or natural tooth to enhance fit, function, or acceptance by the patient—see OCCLUSAL A.

ad·sorp·tion \ăd-sôrp′shun, -zôrp′-\ *n* (1882): the adhesion, in an extremely thin layer, of molecules to the surfaces of liquids or solids with which they are in contact—*comp* ABSORPTION—**ad·sorp·tive** *adj*

adult speech aid prosthesis \a-dŭlt′ sp′ēch ād prŏs-thē′sĭs\: a definitive maxillofacial prosthesis which can improve speech in adult cleft palate patients either by obturating (sealing off) a palatal cleft or fistula, or occasionally by assisting an incompetent soft palate. Both mechanisms are necessary to achieve velopharyngeal competency. *Editor's note: Generally this prosthesis is fabricated when no further growth is anticipated and the objective is to achieve long term use, hence, more precise materials and techniques are utilized. Occasionally such procedures are accomplished in conjunction with precision attachments in fixed dental prostheses undertaken on some or all maxillary teeth, to achieve improved esthetics—syn* PROSTHETIC SPEECH APPLIANCE, SPEECH AID, SPEECH BULB

af·ter·im·age \ăf′ter ĭm′ĭj\ *n* (1874): in visual acuity, a prolongation or renewal of a visual sensory experience, ascribable to residual excitation after external stimuli have ceased to operate

afterloading technique \ăf′ter-lōd′ing tĕk-n′ēk′\: in therapeutic radiology, the use of applicators for brachytherapy so designed that they may be quickly loaded with radioactive sources after placement within the patient

agar \ā′gar′, ä′gar′\ *n* (1889): a complex sulfated polymer of galactose units, extracted from *Gelidium cartilagineum, Gracilaria confervoides*, and related red algae. It is a mucilaginous substance that melts at approximately 100° C and solidifies into a gel at approximately 40° C. It is not digested by most bacteria and is used as a gelation agent in dental impression materials and a solid culture media for microorganisms.

age atrophy \āj ăt′ra-fē\: a wasting away; the normal diminution of all tissues due to advanced age

agen·e·sis \ā-jĕn′ĭ-sĭs\ *n* (ca. 1879): absence, failure of formation, or imperfect development of any body part—see CONDYLAR AGENESIS

ag·na·thia \ăg-nā′thē-a\ *n*: a developmental anomaly characterized by absence of the mandible

ag·no·sia \ăg-nō′zha\ *n* (ca. 1900): diminution or loss of the ability to recognize the import of sensory stimuli; the varieties correspond with the senses and are distinguished as auditory, gustatory, olfactory, tactile, and visual

ag·o·nist \ăg′a-nĭst\ *n* (ca. 1626): **1:** in physiology, a muscle that is controlled by the action of an antagonist with which it is paired **2:** in anatomy, a prime mover **3:** in pharmacology, a drug that has an affinity for and stimulates physiologic activity in cell receptors normally stimulated by naturally occurring substances

air abrasion: see AIRBORNE PARTICLE ABRASION

air-bone gap \âr′bōn′ găp\: in audiology, the difference in patient acuity to sound transmitted though air and through bone that reflects hearing loss due to middle ear dysfunction or pathology

airborne-particle abrasion \âr′bôrn′ pär′tĭ-kal a-brā′zhun\: the process of altering the surface of a material through the use of abrasive particles propelled by compressed air or other gases

air chamber: see RELIEF AREA

air conduction \âr kon-dŭk′shun\: the normal process of conducting sound waves through the ear canal to the tympanic membrane

air dose \âr dōs\: in therapeutic radiology, the amount of energy absorbed per unit mass of tissue at a given site, in air

Akers clasp \Ā′kerz klăsp\ [Polk E. Akers, Chicago, Ill, dentist]: *eponym* for a one piece cast partial denture with cast clasps. He is said to have improved and standardized the one piece casting method for fabricating gold alloy removable partial dental prostheses in the early 1920s—see SUPRABULGE CLASP

Akers PE Partial dentures. J Amer Dent Assoc 1928;15:717-22.

ala \ā′la\ *n, pl* **alae** \ā′lē\ (1738): a wing or a wing-like anatomic part or process—**alar** *adj*

ala nasi \ā′la nās′ē\ *n*: in anatomy, the cartilaginous processes forming the wing-like flare of each nares

ala-tragus line \a′lah trā′gŭs līn\: a line running from the inferior border of the ala of the nose to some defined point on the tragus of the ear, usually considered to be the tip of the tragus. It is frequently used, with a third point on the opposing tragus, for the purpose of establishing the ala tragus plane. Ideally the ala-tragus plane is considered to be parallel to the occlusal plane. The occlusal plane is at an angle of approximately 10 degrees relative to the Frankfort horizontal plane, when viewed in the mid-sagittal plane—see CAMPER'S LINE

al·gi·nate *n* (ca. 1909): see IRREVERSIBLE HYDROCOLLOID

all-ceramic restoration: see CERAMIC RESTORATION

al·lo·dynia \ăl ō deen′ya\ *n*: pain resulting from a non-noxious stimulus to normal skin or mucosa

al·lo·ge·ne·ic \al ă jĕn′ĭk\ *adj* (1963): in transplantation biology, denoting individuals (or tissues) that are of the same species however antigenically distinct—called also *homologous*

allogeneic graft: see HOMOGRAFT

al·lo·graft \ăl′a-grăft′\ *n* (1964): a graft of tissue between genetically dissimilar members of the same species—called also *allogeneic graft* and *homograft*

al·lo·plast \ăl′a plăst′\ *n*: **1:** an inert foreign body used for implantation within tissue **2:** a material originating from a nonliving source that surgically replaces missing tissue or augments that which remains

alloplastic graft \ăl′a-plăs′tĭk grăft\: a graft consisting of an inert material

alloplastic material \ăl′a-plăs′tĭk ma-tîr′ē-al\: any non-biologic material suitable for implantation as an alloplast

al·loy \ăl′oi′, a-loi′\ *n* (14c): a mixture of two or more metals or metalloids that

are mutually soluble in the molten state; distinguished as binary, ternary, quaternary, etc., depending on the number of metals within the mixture. Alloying elements are added to alter the hardness, strength, and toughness of a metallic element, thus obtaining properties not found in a pure metal. Alloys may also be classified on the basis of their behavior when solidified—*usage*: see BASE METAL, NOBLE METAL

alloying element \a-loi′ĭng ĕl′a-ment\ (1998): metallic or non-metallic elements added to or retained by a pure metal for the purpose of giving that metal special properties

all-polymer prosthesis: a fixed dental prosthesis fabricated from non-metallic or ceramic components typically composed of an internal glass fiber-reinforced composite framework covered by a particulate composite resin

alpha particle \ăl′fa păr′tĭ-kal\ *n* (1903): a positively charged nuclear particle identical with the nucleus of a helium atom that consists of two protons and two neutrons and is ejected at high speed in certain radioactive transformations

altered cast \ôl′terd kăst\: a final cast that is revised in part before processing a denture base—called also *corrected cast*, *modified cast*

altered cast partial denture impression \ôl′terd kăst pär′shal dĕn′cher ĭm-prĕsh′an\: a negative likeness of a portion or portions of the edentulous denture bearing area(s) made independent of and after the initial impression of the natural teeth. This technique employs an impression tray(s) attached to the removable dental prosthesis framework or its likeness

aluminum oxide \a-lōō′mi-num ŏk′sīd′\: **1:** a metallic oxide constituent of dental porcelain that increases hardness and viscosity **2:** a high strength ceramic crystal dispersed throughout a glassy phase to increase its strength as in aluminous dental porcelain used to fabricate aluminous porcelain crowns **3:** a finely ground ceramic particle (frequently 50 um) often used in conjunction with air-borne particle abrasion of metal castings before the application of porcelain as with metal ceramic restorations

aluminous porcelain \a-lōō′mi-nus pôr′si-lin, pōr′-\: a ceramic material composed of a glass matrix phase with 35% or more of aluminum oxide, by volume

al·ve·o·lar \ăl-vē′a-ler\ *adj* (1799): that part of the jaws where the teeth arise

alveolar augmentation \ăl-vē′a-ler ôg′mĕn-tā′shun\: any surgical procedure employed to alter the contour of the residual alveolar ridge

alveolar bone \ăl-vē′a-ler bōn\: the bony portion of the mandible or maxillae in which the roots of the teeth are held by fibers of the periodontal ligament—called also *dental alveolus*

alveolar crest: see RESIDUAL RIDGE CREST

alveolar mucosa \ăl-vē′a-ler myōō-kō′sa\: the fixed mucosal covering of the alveolar process, loosely attached to the bone

alveolar process \ăl-vē′a-ler pro-sĕs′\: the cancellous and compact bony structure that surrounds and supports the teeth

alveolar reconstruction \ăl-vē′a-ler rē′kon-strŭk′shun\: any surgical procedure employed to recreate a severely resorbed residual alveolar ridge

alveolar resorption: see RESIDUAL RIDGE RESORPTION

alveolar ridge: see RESIDUAL RIDGE

al·ve·o·lec·tomy *n*: see OSTEOTOMY

al·ve·o·lo·plasty *n*: see OSTEOTOMY

al·ve·o·lus *n, pl* **al·ve·o·li** \ăl-vē′a-lus, ăl-vē′a-lē\ (ca. 1706): one of the cavities or sockets within the alveolar process of the maxillae or mandible in which the attachment complex held the root of a tooth after the tooth's removal

amal·gam *n*: **1:** an alloy of mercury **2:** dental amalgam is an alloy of mercury, silver, copper, and tin, which may also contain palladium, zinc, and other elements to improve handling characteristics and clinical performance

am·bient \AM-bee-unt\ *adj*: existing or present on all sides; encompassing

a·mor·phous \a-mōr′fus\: without crystalline structure; having random arrangement of atoms in space

an·al·ge·sia \ăn′al-jē zē-a,-zha\ *n* (ca. 1706): absence of sensibility to pain, designating particularly the relief of pain without loss of consciousness

[1]an·al·ge·sic \ăn′al-jē′ zĭk, -sĭk\ *adj*: relieving pain

[2]an·al·ge·sic \ăn′al-jē′zĭk, -sĭk\ *n*: an agent that alleviates pain without causing loss of consciousness—see A. BLOCKING AGENT, A. DIAGNOSTIC BLOCK

analgesic blocking agent \ăn′al-jē′zĭk blŏk′ing ā′jent\: any analgesic that blocks or prohibits sensory perception

analgesic diagnostic block \ăn′al-jē′zĭk dī′ag-nŏs′tĭk blŏk\: the selective use of a local anesthetic injection or application of a topical anesthetic to identify a pain source

an·a·log \ăn′a-lôg, -lŏg\ *n* (1826): **1:** in dentistry, something that is analogous in part or whole to something else; i.e., a replica of a portion of an implant abutment made of brass, aluminum, steel, or plastic **2:** an organ similar in function to an organ of another animal or plant but with different structure and origin—spelled also *analogue*

an·am·ne·sis \ăn′ăm-nē′sĭs\ *n, pl* **-ne·ses** (ca. 1593): **1:** a recalling to mind; a reminiscence **2:** the past history of disease or injury based on the patient's memory or recall at the time of interview and examination **3:** a preliminary past medical history of a medical or psychiatric patient

anatomic crown \ăn′a-tŏm′ĭk kroun\: the portion of a natural tooth that extends coronal from the cementoenamel junction—called also *anatomical crown*

anatomic landmark \ăn′a-tŏm′ĭk lănd′mărk\: a recognizable anatomic structure used as a point of reference

anatomic occlusion \ăn′a-tŏm′ĭk a-klōō′zhun\: an occlusal arrangement for dental prostheses wherein the posterior artificial teeth have masticatory surfaces that closely resemble those of the natural healthy dentition and articulate with similar natural or artificial surfaces—called also *anatomical occlusion*

anatomic teeth \ăn′a-tŏm′ĭk tēth\: **1:** artificial teeth that duplicate the anatomic forms of natural teeth **2:** teeth that have prominent cusps on the masticating surfaces and that are designed to articulate with the teeth of the opposing natural or prosthetic dentition **3:** anatomic teeth with cuspal inclinations greater than 0 degrees that tend to replica natural tooth anatomy—*usage* cusp teeth (30 to 45 degrees) are considered anatomic teeth. Modified occlusal forms are those with a 20-degree cusp incline or less—called also *anatomical teeth*

Boucher CO. J PROSTHET DENT 1953; 3:633-56.

anatomy \a-năt′a-mē\ *n, pl* **-mies** (14c): **1:** a branch of morphology that involves

the structures of organs **2:** the structural makeup esp. of an organ or any of its parts **3:** separating or dividing into parts for examination—**an·a·tom·ic** \ăn′a-tŏm′ĭk\or **an·a·tom·i·cal** \ăn′a-tŏm′ĭ-kal\ *adj*

ANB angle \A N B ăng′gl**:** in cephalometric analysis, the angle formed between the nasion point A line and the nasion point B line

anchorage area \ăng′ker-ĭj âr′ē-a**:** that area which, by its situation, configuration and/or preparation, is suitable for the retention of a prosthesis

anchorage component: *see* ENDOSTEAL DENTAL IMPLANT BODY

anchorage element: *see* ENDOSTEAL DENTAL IMPLANT ABUTMENT ELEMENT(S)

ancillary prostheses: one of the three main categories of dental prostheses made by those in the field of prosthodontics; any prosthesis not able to be described as either a dental prosthesis or a maxillofacial prosthesis. Examples may include guides, stents, splints, conformers, carriers and the like. Most such prostheses are intended for short term or special usage

Anderson splint [Roger Anderson, American orthopedic surgeon, 1891-1971]**:** eponym for a skeletal traction splint with pins inserted into proximal and distal ends of a fractured bone. Reduction is obtained by an external plate attached to the pins—*called also* BYPHASIC SPLINT

Anderson R. Ambulatory method of treating fractures of the shaft of the femur. Surg Gynecol Obstet 1936;62: 865.

Andrews bridge \Ăn′drōōs brĭj**:** the combination of a fixed dental prosthesis incorporating a bar with a removable dental prosthesis that replaces teeth within the bar area, usually used for edentulous anterior spaces. The vertical walls of the bar may provide retention for the removable component. First attributed to James Andrews, DDS, Amite, LA

Everhart, RJ and Cavazos, E. Jr. Evaluation of a fixed removable partial denture: Andrews Bridge System. J Prosthet Dent 1983;50(2):180-184

an·es·the·sia \ăn′ĭs-thē′zha\ *n* (ca. 1721)**:** loss of feeling or sensation; also spelled *anaesthesia*

anesthesia dolorosa \ăn′ĭs-thē′zha dō′la-rō′sa**:** pain within an area or region that is anesthetic or anesthetized

[1]an·es·thet·ic \ăn′ĭs-thĕt′ĭk\ *adj* (1846)**: 1:** capable of producing anesthesia **2:** lacking awareness or sensitivity

[2]an·es·thet·ic \ăn′ĭs-thĕt′ĭk\ *n* (1848)**: 1:** a substance that produces anesthesia **2:** something that brings relief

angle of gingival convergence \ăng′gl ŭv jĭn′ji-val, -jĭn-jī′- kun-vûr′jens**: 1:** according to Schneider, the angle of gingival convergence is located apical to the height of contour on the abutment tooth. It can be identified by viewing the angle formed by the tooth surface gingival to the survey line and the analyzing rod or undercut gauge in a surveyor as it contacts the height of contour **2:** the angle formed by any surface of the tooth below the survey line of the height of contour, with the selected path of insertion of a prosthesis **3:** the angle formed by the tooth surface below the height of contour with the vertical plane, when the occlusal surface of the tooth is oriented parallel to the horizontal plane

Schneider RL. J Prosthet Dent 1987; 58:194-6.

angle of incidence \ăng′gl ŭv ĭn′sĭ-dens**:** the angle formed between the axis of a light beam and a perpendicular to the object's surface

angle of reflection \ăng′gl ŭv rĭ-flĕk′shun**:** the angle formed between the axis of a reflected light beam and a perpendicular to the object's surface

Angle's classification of occlusion \Ăng′gulz klăs′a-fĭ-kā′shun ŭv a-klōō′shun\ [Edward Harley Angle, American orthodontist, 1855-1930]**:** *eponym* for a classification system of occlusion based on the interdigitation of the first molar teeth originally described by Angle as four major groups depending on the anteroposterior jaw relationship. Class IV is no longer in use. Class I (normal occlusion or *neutrooclusion*): the dental relationship in which there is normal anteroposterior relationship of the jaws, as indicated by correct interdigitation of maxillary and mandibular molars, but with crowding and rotation of teeth elsewhere, i.e., a dental dysplasia or arch length deficiency. Class II *(distoclusion):* the dental relationship in which the mandibular dental arch is posterior to the maxillary dental arch in one or both lateral segments; the mandibular first molar is distal to the maxillary first molar. Class II can be further subdivided into two divisions. Division 1: bilateral distal retrusion with a narrow maxillary arch and protruding maxillary incisors. Subdivisions include right or left (unilaterally distal with other characteristics being the same). Division 2: bilateral distal with a normal or square-shaped maxillary arch, retruded maxillary central incisors, labially malposed maxillary lateral incisors, and an excessive vertical overlap. Subdivisions include right or left (unilaterally distal with other characteristics the same). Class III *(mesiooccclusion):* the dental relationship in which the mandibular arch is anterior to the maxillary arch in one or both lateral segments; the mandibular first molar is mesial to the maxillary first molar. The mandibular incisors are usually in anterior cross bite. Subdivisions include right or left (unilaterally mesial with other characteristics the same). Class IV: the dental relationship in which the occlusal relations of the dental arches present the peculiar condition of being in distal occlusion in one lateral half and in mesial occlusion in the other (no longer used).

Angle EM. Classification of malocclusion. Dental Cosmos 1899, 41:248-64, 350-7.

angular cheilitis \ăng′gya-ler kī-lī′tĭs**:** inflammation of the angles of the mouth causing redness and the production of fissures—called also *perleche*

angulated abutment \ăng′gya-lāt′ĭd a-bŭt′ment\ (1998)**:** any endosteal dental implant abutment which alters the long axis angulation between the dental implant and the angulated dental implant abutment—***syn*** ANGLED ABUTMENT

an·ky·lo·glos·sia \ang′kĭ-lo-glos′e-ah, -glo-sha\ *n***:** the binding of the tip of the tongue to the floor of the mouth or the alveolar ridge due to abnormal attachment of the lingual frenum. This often restricts movement of the tongue, often due to the position of the lingual frenulum, resulting in speech impediments; may be complete or partial—called also *adherent tongue, lingua frenata,* and *tongue-tie*

ankylosis \ăng′ki-lō′sĭs\ *n, pl* **-lo·ses** (1713)**:** immobility and consolidation of a joint or tooth due to injury, disease, or a surgical procedure—see BONY A., EXTRACAPSULAR A., FIBROUS A., INTRACAPSULAR A.; spelled also *anchylosis*

an·neal \a-nēl′\ *vt* (1580)**: 1:** to heat a material, such as metal or glass, followed by controlled cooling to remove internal stresses and create a desired degree of toughness, temper, or softness to a material **2:** to heat a material, such as gold foil, to volatilize and drive off impurities from its surface, thus increasing its cohesive properties. This process is termed *degassing* **3:** to homogenize an amalgam alloy by heating in an oven

an·nu·lar \ăn′ya-ler\ *n* (1571)**:** a term used to describe a ring like anatomic structure

an·o·don·tia \ăn′ō-dŏn′shē-a\ *n***:** a rare dental condition characterized by congenital absence of all teeth (both deciduous and permanent)—*comp* HYPODONTIA, OLIGODONTIA

an·o·don·tism *n***:** see ANODONTIA

anomalous trichromatic vision \a-nŏm′a-lus trī′krō-măt′ĭk vĭzh′un**:** a form of defective color vision in which three stimuli are required for color matching, but the proportions in which they are matched differ significantly from those required by the normal trichromat. There are three forms of anomalous trichromatic vision: *protanomalous, deuteranomalous,* and *tritanomalous*

a·nom·a·ly \a-nŏm′a-lē\ *n, pl* **a·nom·a·lies** \a-nŏm′a-l′ēz\ (1664)**: 1:** something different, abnormal, peculiar, or not easily classified **2:** an aberration or deviation from normal anatomic growth, development, or function **3:** marked deviation from the normal standard, especially as a result of congenital defects

ANS: A*cronym* for ***Anterior Nasal Spine.*** The outline of the anterior nasal spine as seen on the lateral cephalometric radiograph. It is used as a cephalometric landmark

an·tag·on·ist \ăn-tăg′a-nĭst\ *n* (1599)**: 1:** a tooth in one jaw that articulates with a tooth in the other jaw—called also *dental antagonist* **2:** a substance that tends to nullify the actions of another, as a drug that binds to cell receptors without eliciting a biologic response **3:** a muscle whose action is the direct opposite of another muscle

Ante's Law [Irwin H: Ante, Toronto, Ontario Canada, dentist]**:** *eponym,* in fixed dental prosthodontics, for the observation that the combined pericemental area of all abutment teeth supporting a fixed dental prosthesis should be equal to or greater in pericemental area than the tooth or teeth to be replaced; as formulated for removable dental prosthodontics, the combined pericemental area of the abutment teeth plus the mucosa area of the denture base should be equal to or greater than the pericemental area of the missing teeth

Ante IH. The fundamental principles, design and construction of crown and bridge prosthesis. Dent Item Int 1928;50:215-32.

an·te·ri·or \ăn-tîr′ē-or\ *adj* (1541)**: 1:** in front of or the front part; situated in front of **2:** the forward or ventral position **3:** a term used to denote the incisor or canine teeth or the forward region of the mouth

anterior disk displacement: see DISK DISPLACEMENT

anterior guidance \ăn-tîr′ē-or gīd′ns**: 1:** the influence of the contacting surfaces of anterior teeth on tooth limiting mandibular movements **2:** the influence of the contacting surfaces of the guide pin and anterior guide table on articulator movements—*usage* see ANTERIOR GUIDE TABLE 3: the fabrication of a relationship of the anterior teeth preventing posterior tooth contact in all eccentric mandibular movements—see ANTERIOR PROTECTED ARTICULATION, GROUP FUNCTION, MUTUALLY PROTECTED ARTICULATION

anterior guide: see ANTERIOR GUIDE TABLE

anterior guide pin \ăn-tîr′ē-or gīd pĭn**:** that component of an articulator, generally a rigid rod attached to one member, contacting the anterior guide table on the opposing member. It is used for the purpose of maintaining the established vertical separation. The anterior guide pin and table, together with the condylar elements, direct the movements of the articulators' separate members

anterior guide table \ăn-tîr′ē-or gīd tā′bl**:** that component of an articulator on which the anterior guide pin rests to maintain the occlusal vertical dimension and influence articulator movements. The guide table influences the degree of separation of the casts in all relationships—see also ANTERIOR PROGRAMMING DEVICE

anterior nasal spine \ăn-tîr′ē-or nā′zal spīn**:** a sharp median bony process, adjacent to the inferior margin of the anterior aperture of the nose, formed by the forward prolongation of the two maxillae

anterior open bite *(obs)***:** see ANTERIOR OPEN OCCLUSAL RELATIONSHIP

anterior open occlusal relationship \ăn-tîr′ē-or ō′pen a-klōō′zal rĭ-lā′shen-shĭp′**:** the lack of anterior tooth contact in any occluding position of the posterior teeth

anterior programming device \ăn-tîr′ē-or prō′grăm′ĭng dĭ-vīs′**:** an individually fabricated anterior guide table that allows mandibular motion without the influence of tooth contacts and facilitates the recording of maxillomandibular relationships; also used for deprogramming—see also *deprogrammer*

anterior protected articulation \ăn-tîr′ē-or prō-tĕk′tĭd är-tĭk′ya-lā′shun**:** a form of mutually protected articulation in which the vertical and horizontal overlap of the anterior teeth disengages the posterior teeth in all mandibular excursive movements—see CANINE PROTECTED ARTICULATION

anterior reference point \ăn-tîr′ē-or rĕf′er-ens, rĕf′rens point**:** any point located on the midface that, together with two posterior reference points, establishes a reference plane

anterior teeth \ăn-tîr′ē-or tēth**:** the maxillary and mandibular incisors and canines

anterior tooth arrangement \ăn-tîr′ē-or tōōth a-rānj′ment**:** the positioning of the anterior teeth for esthetics and phonetics

anterior tooth form \ăn-tîr′ē-or tōōth form**:** the outline form as viewed in any selected plane or/and other contours of an anterior tooth

anteroposterior curve \ăn-ter-o-pŏ-stîr′ē-or kûrv**:** the anatomic curve established by the occlusal alignment of the teeth, as projected onto the median plane, beginning with the cusp tip of the mandibular canine and following the buccal cusp tips of the premolar and molar teeth, continuing through the anterior border of the mandibular ramus, ending with the anterior most portion of the mandibular condyle. First described by Ferdinand Graf Spee, German anatomist, in 1890—see CURVE OF SPEE

antiflux \ăn′tē-flŭks′\ *n***:** materials that prevent or confines solder attachment or flow

an·ti·me·tab·o·lite \ăn′tē-ma-tăb′a-līt\ *n* (1945): a substance that competes with, replaces, or antagonizes a particular metabolite

anti-Monson curve: see REVERSE CURVE

an·ti·neo·plas·tic \ăn′tē-nē′a-plăs′tĭk\ *adj* (1969): **1:** inhibiting or preventing the development of neoplasms; inhibiting the maturation and proliferation of malignant cells **2:** an agent having such properties

antineoplastic drug \ăn′tē-nē′a-plăs′tĭk drŭg\: an agent used in treatment or palliation of the symptoms of cancer

anti-rotation \ăn′tē-rō-tā′shun\ (1998): a structural feature of some endosteal dental implant components that prevents relative rotation of fastened parts. This feature may exist between a dental implant body and the dental implant abutment, and/or the dental implant abutment and dental implant abutment element(s)

an·ti·tra·gus \ăn′tĭ-trā′gŭs\ *n, pl* **an·ti·tra·gi** \ăn′tē-trā′jē\: a projection of the cartilage of the auricle in front of the cauda helicis, just above the lobule and posterior to the tragus, from which it is separated by the inter tragal notch

ap·at·ite \ăp′a-tīt′\ *n* (1803): calcium phosphate of the composition $Ca_5(PO_4)_3OH$; one of the mineral constituents of teeth and bones (with Ca CO_3)

apertognathia: a condition in which the anterior or posterior teeth are not in contact. See OPEN BITE; OPEN OCCLUSAL RELATIONSHIP

ap·er·ture \ăp′er-chur\ *n* (15c): an opening or open space; a hole

apex \ā′pĕks′\ *n, pl* **apex·es** or **api·ces** \ā′pĭ-sēz′, ăp′ĭ-\ (1601): **1:** the uppermost point; the vertex **2:** in dentistry, the anatomic end of a tooth root

apha·gia \a fā′jē-a, -ja\ *n*: inability to swallow; abstention from eating

apha·sia \a-fā′zha\ *n* (1867): defect or loss of the power of expression by writing, speech or signs, or of comprehending written or spoken language due to disease of or injury to the brain

apho·nia \ā-fō′nē-a\ *n.* (1778): loss or absence of voice as a result of the failure of the vocal cords to vibrate properly

api·cal \ăp′ĭ-kal, -ā′pĭ-\ *adj* (1828): of, relating to or pertaining to the top or apex—**api·cal·ly** *adv*

a·plastic \ā-plăs′tĭk\ *adj*: devoid of form; without development

apho·nia *n* (1778): loss or absence of voice as a result of the failure of the vocal cords to vibrate properly

apla·sia \a-plā′zha, -zhē-\ *n*: defective development or congenital absence of an organ or tissue

ap·pli·ance *n, slang, obs* (1561): see DEVICE, RESTORATION, PROSTHESIS

ap·posi·tion \ăp′a-zĭsh′un\ *n* (15c): the condition of being placed or fitted together; in juxtaposition or coadaptation

ap·prox·i·ma·tion \a-prŏk′si-mā′shun\ *n* (15c): **1:** the process of drawing together **2:** the quality of being close or near—**ap·prox·i·ma·tive** \a-prŏk′sĭ-mā′tĭv\ *adj*

aprax·ia \ā-prăk′sē-a\ *n* (1888): the loss of ability to carry out familiar, purposeful movements in the absence of paralysis or other sensory or motor impairment, especially the inability to make proper use of an object

apron *n, obs*: *see* LINGUAL PLATE

arc of closure \ărk ŭv klō′zhur\: the circular or elliptic arc created by closure of the mandible, most often viewed in the mid-sagittal plane, using a reference point on the mandible (frequently either mandibular central incisors' mesial incisal edge)

arc therapy \ărk thĕr′a-pē\: in therapeutic radiology, external beam radiation in which the source of radiation is moved about the patient on an arc during treatment. Multiple arcs may be used. In some cases the beam is stationary and the patient is rotated in a vertical plane

arch bars \ărch bärz\: a rigid bar or/and wire used for intermaxillary fixation in treatment of fractures of the maxillae and mandible and/or stabilization of injured teeth, generally attached to the remaining natural dentition and/or occlusal splints

arch form \ărch form\: the geometric shape of the dental arch when viewed in the horizontal plane (square, tapering, ovoid, etc.)

arch length discrepancy \ărch lĕngkth dĭ-skrĕp′ens-sē\: the abnormal relationship between the size of the mandible and/or maxilla and their component teeth, especially as viewed and analyzed in the occlusal plane

arch·wire \ărch-wīr\ *n*: an orthodontic wire placed intraorally for the application of force

ar·con \ar′kon\ *n*: a contraction of the words "ARTICULATOR" and "CONDYLE," used to describe an articulator containing the condylar path elements within its upper member and the condylar elements within the lower member

arcon articulator \ar'kon är-tĭk′ya-lā′tor\: an articulator that applies the arcon design; this instrument maintains anatomic guidelines by the use of condylar analogs in the mandibular element and fossae assemblies within the maxillary element

arrow point tracer \ăr′ō point trā′ser\: **1:** a mechanical device used to trace a pattern of mandibular movement in a selected plane—usually parallel to the occlusal plane **2:** a mechanical device with a marking point attached to one jaw and a graph plate or tracing plane attached to the other jaw. It is used to record the direction and range of movements of the mandible—see GOTHIC ARCH TRACER

arrow point tracing: see STYLUS TRACING

ar·thral·gia \ăr-thrăl′ja, -jē-a\ *n* (ca. 1848): pain in a joint or joints

ar·thri·tis \ăr-thrī′tis\ *n* (14c): inflammation of a joint or joints

arthrodial joint \är-thrō′dē al joint\: a joint that allows gliding motion of the surfaces

arthrodial movement \är-thrō′dē al mōōv′ment\: gliding joint movement

ar·throg·ra·phy \är-thrŏp′a-thē\ *n*: **1:** roentgenography of a joint after injection of an opaque contrast material **2:** in dentistry, a diagnostic technique that entails filling the lower, upper, or both joint spaces of the temporomandibular joint with a contrast agent to enable radiographic evaluation of the joint and surrounding structures; used to diagnose or confirm disk displacements and perforations

ar·throp·a·thy *n* (ca. 1860): a disease of a joint

ar·thro·plas·ty \är-thrō′plăs-tē\ *n*: the surgical formation or reformation of a joint

ar·thro·sis \är-thrō′sĭs\ *n* (1634): **1:** a joint or articulation **2:** a disease of a joint

ar·tic·u·lar \är tĭk′ya-ler\ *adj* (15c): of or relating to a joint

articular capsule \är tĭk′ya-ler kăp′sel\: the fibrous ligament that encloses a joint and limits its motion. It is lined with the synovial membrane

articular cartilage \är tĭk′ya-ler kär′tl-ĭj\: a thin layer of hyaline cartilage located

on the joint surfaces of some bones not found on the articular surfaces of the temporomandibular joints which is covered with an avascular fibrous tissue

articular disc: a ring of fibrocartilage that separates the articular surfaces of a joint

articular temporomandibular joint disk: see DISK

[1]ar·tic·u·late \är-tĭk′ya-lāt′\ *vb* (1691)**: 1:** to join together as a joint **2:** the relating of contacting surfaces of the teeth or their artificial replicas in the maxillae to those in the mandible

[2]ar·tic·u·late \är-tĭk′ya-lāt′, -lĭt\ *adj* (1586)**:** in speech, to enunciate clearly or be clearly spoken

articulating paper \är-tĭk′ya-lāt′ing pā′per**:** ink-coated paper strips used to locate and mark occlusal contacts

ar·tic·u·la·tion \är-tĭk′ya-lā′shun\ *n* (15c)**: 1:** the place of union or junction between two or more bones of the skeleton—see CRANIOMANDIBULAR A., TEMPOROMANDIBULAR A. **2:** in speech, the enunciation of words and sentences—see SPEECH A. **3:** in dentistry, the static and dynamic contact relationship between the occlusal surfaces of the teeth during function—see ANTERIOR PROTECTED A., BALANCED A., DENTAL A., FUNCTIONAL A., MONOPLANE A., MUTUALLY PROTECTED A.

ar·tic·u·la·tor \är-tĭk′ya-lā′tor\ *n***:** a mechanical instrument that represents the temporomandibular joints and jaws, to which maxillary and mandibular casts may be attached to simulate some or all mandibular movements—*usage:* articulators are divisible into four classes. Class I articulator: a simple holding instrument capable of accepting a single static registration; vertical motion is possible—see NONADJUSTABLE A. Class II articulator: an instrument that permits horizontal as well as vertical motion but does not orient the motion to the temporomandibular joints. Class III articulator: an instrument that simulates condylar pathways by using averages or mechanical equivalents for all or part of the motion; these instruments allow for orientation of the casts relative to the joints and may be arcon or nonarcon instruments—see SEMI-ADJUSTABLE A. Class IV articulator: an instrument that will accept three dimensional dynamic registrations; these instruments allow for orientation of the casts to the temporomandibular joints and simulation of mandibular movements—see FULLY ADJUSTABLE A., FULLY ADJUSTABLE GNATHOLOGIC A.

ar·ti·fact \är′ti-făkt′\ *n* (1821)**: 1:** any characteristic product of human activity, i.e., any hand-made object that could represent a particular culture or stage in its technologic development **2:** a product of an artificial character due to extraneous agency—used in medicine to signify details or conditions that are misleading or unnatural due to imperfect materials or techniques

artificial crown \är′ti-fish′al kroun**:** a metal, plastic, or ceramic restoration that covers three or more axial surfaces and the occlusal surface or incisal edge of a tooth

artificial denture: see COMPLETE DENTURE

artificial stone: see DENTAL STONE

asep·sis \a-sĕp′sĭs, ā-\ *n* (1892)**: 1:** free from infection **2:** the prevention of contact with microorganisms

asep·tic \a-sĕp′tĭk, ā-\ *adj* (ca 1859)**:** free of infection or septic material; sterile; free from pathogenic microorganisms—**asep·ti·cal·ly** \a-sep′ti ka′ le\ *adv*

asym·met·ri·cal \ā′sĭ-mĕt′rĭ-kal\ *adj* (1690)**:** characterized by or pertaining to asymmetry

asym·me·try \ā-sĭm′ĭ-trē\ *n* (1690)**:** absence or lack of symmetry or balance; dissimilarity in corresponding parts or organs on opposite sides of the body

asymmetry of movement \ā-sĭm′ĭ-trē ŭv mōōv′mant**:** the condition observed when mandibular movement has a lateral component on opening and closing, especially when viewed in the frontal plane

asymmetry of the mandible \ā-sĭm′ĭ-trē ŭv the măn′di-bul**:** the condition that exists when the right and left sides of the mandible are not mirror images of one another

atrophic fracture \ă trŏf′ĭk frăk′cher**:** spontaneous fracture due to atrophy

at·ro·phy \ăt′ra-fē\ *n, pl* **-phies** \-fēz\ (1601)**: 1:** a wasting away **2:** a diminution in size of a cell, tissue, organ or part—**atro·phic** *adj*—**atro·phy** \ăt′rē-fē\ *vb*—see ADIPOSE A., AGE A., BONE A., DISUSE A., MUSCULAR A., POSTMENOPAUSAL A., SENILE A.

attached gingival \a-tăchd′ jĭn′ja-va, jĭn′jī-**:** the portion of the gingiva that is firm, dense, stippled, and tightly bound to the underlying periosteum, bone, and tooth

attachment \a-tăch′ment\ *n* (15c)**: 1:** a mechanical device for the fixation, retention, and stabilization of a prosthesis **2:** a retainer consisting of a metal receptacle and a closely fitting part; the former (the female *{matrix}* component) is usually contained within the normal or expanded contours of the crown of the abutment tooth and the latter (the male *{patrix}* component), is attached to a pontic or the denture framework—see FRICTIONAL A., INTERNAL A., KEY and KEYWAY A., PARALLEL A., PRECISION A., RESILIENT A., SLOTTED A.

attachment apparatus \a-tăch′ment ăp′a-rā′tus, -răt′us**:** in periodontics, a general term used to designate the cementum, periodontal ligament and alveolar bone

attachment screw (1998)**:** any component used to secure a fixed dental prosthesis to the dental implant abutment(s). See also ABUTMENT SCREW

attenuation of radiation \a-tĕn′yōō-ā′shun ŭv rā′dē-ā′shun**:** the reduction in intensity of radiation as a result of scattering and absorption of radiation. Attenuation of electron beams always lowers the average beam energy

attrition \a-trĭsh′un\ *n* (14c)**: 1:** the act of wearing or grinding down by friction **2:** the mechanical wear resulting from mastication or parafunction, limited to contacting surfaces of the teeth—*comp* ABRASION, EROSION

atypical facial pain \ā-tĭp′ĭ-kul fā′shul pān**:** a painful syndrome characterized by dull aching or throbbing, rather than paroxysms of pain, such as seen in trigeminal, glossopharyngeal, or postherpetic neuralgia, occurring in areas supplied by various nerve groups, including the fifth and ninth cranial nerves and the second and third cervical nerves. The distribution of atypical facial pain does not follow the established pathways of innervation of the major sensory nerves, however (i.e., trigeminal neuralgia). Attacks last from a few days to several months and often occur after dental care or sinus manipulation, but examination of the teeth, nose, sinuses, ears, and temporomandibular joints seldom reveals any abnormalities. A psychogenic or vascular etiology has been suggested. This is

believed by some to not be a specific disease entity but rather a symptom, the etiology of which has not been determined—called also *atypical facial neuralgia* and *facial causalgia*

au·dio·gram \ô′dē-ō-grăm\ *n* (1927): a record of the thresholds of hearing of an individual over various sound frequencies

au·di·ol·o·gy \ô′dē-ŏl-a-jē\ *n* (1946): the study of the entire field of hearing, including the anatomy and function of the ear, impairment of hearing, and the education or reeducation of the person with hearing loss

au·di·om·e·ter \ô′dē-ŏm′ĭ-ter\ *n* (1879): an instrument used to assess hearing at various intensity levels and frequencies

au·di·tion \ô-dĭsh′un\ *n* (1599): the power or sense of hearing

auditory discrimination \ô′dĭ-tôr′ē, -tōr′ē- dĭ-skrĭm′a-nā′shun\: ability to discriminate between sounds of different frequency, intensity, and pressure pattern components; ability to distinguish one speech sound from another

aug·ment \ôg-mĕnt′\ *vb* (15c): to make greater, more numerous, larger, or more intense

aug·men·ta·tion \ôg′mĕn-tā′shun\ *n* (14c): to increase in size beyond the existing size. In alveolar ridge augmentation, bone grafts or alloplastic materials are used to increase the size of an atrophic alveolar ridge

auricular defect \ô-rĭk′ya-lar dē′fĕkt′, dĭ-fĕkt′\: absence or partial absence of the external ear

auricular prosthesis \ô-rĭk′ya-ler prŏs-thē′sĭs\: a removable maxillofacial prosthesis that artificially restores part or the entire natural ear—called also *artificial ear, ear prosthesis*

auriculotemporal syndrome \ô-rĭ-kū-lō-tĕm′pral sĭn′drōm\: sweating and flushing in the preauricular and temporal areas when certain foods are eaten

aus·cul·ta·tion \ô′skal-tā′shun\ *n* (ca. 1828): the process of determining the condition of various parts of the body by listening to the sounds they emit

au·tog·e·nous \ô-tŏj′a-nus\ *adj* (1846): originating or derived from sources within the same individual; self-produced; self-generated; autologous

autogenous graft \ô-tŏj′a-nus grăft\ : a graft taken from the patients own body—called also *autograft*

auto·glaze *v*: the production of a glazed surface by raising the temperature of a ceramic to create surface flow—*comp* OVERGLAZE

au·to·graft \ô′ta-grăft\ *n* (ca.1913): a graft of tissue derived from another site in or on the body of the organism receiving it—called also *autochthonous graft, autologous graft,* and *autoplast*

au·tol·o·gous \ô-tŏl′ō-gŭs\ (ca. 1921): **1:** related to self; designating products or components of the same individual organism **2:** autogenous

autonomic nervous system \ô′ta-nŏm′ĭk nûr′vus sĭs′tam\: the part of the nervous system that enervates the cardiovascular, digestive, reproductive, and respiratory organs. It operates outside of consciousness and controls basic life-sustaining functions such as heart rate, digestion, and breathing. It includes the sympathetic nervous system and the parasympathetic nervous system

au·to·poly·mer \ô′tō-pŏl′a-mer\ *n*: a material that polymerizes by chemical reaction without external heat as a result of the addition of an activator and a catalyst—**au·to·poly·mer·i·za·tion** \ô′tō-pŏl′a-mĕr-zā′shun\ *vb*

auto polymerizing resin \ô′tō-pŏl-a-mĕr-ī′zing rĕz′ĭn\: a resin whose polymerization is initiated by a chemical activator

average axis facebow \ăv′er-ĭj, ăv′rĭj ăk′sĭs fās bō\: a device used to relate the maxillary cast to the condylar elements of an articulator using average anatomic landmarks to estimate the position of the transverse horizontal axis on the face.

average value articulator \ăv′rĭj văl′yōō ăr-tĭk′ya-lā′ter\: an articulator that is fabricated to permit motion based on mean mandibular movements—called also *Class III articulator*

avul·sion \a-vŭl′shun\ *n* (1622): a forcible separation or detachment, as in a tearing away of a body part surgically or accidentally

avulsion fracture \a-vŭl′shun frăk′cher\: a tearing away or traumatic separation of a part of a bone

axial contour: the shape of a body that is in its long axis

axial inclination \ăk′sē-al ĭn′kla nā′shun\: **1:** the relationship of the long axis of a body to a designated plane **2:** in dentistry, the alignment of the long axis of a tooth to a selected plane, often the horizontal plane

axial loading \ăk′sē-al lō′dĭng\: the force directed down the long axis of a body

Editorial note—Usually used to describe the force of occlusal contact upon a natural tooth, dental implant or other object, axial loading is best described as the force down the long axis of the tooth or whatever body is being described. Loading "the axis" is an error in syntax

axial reduction: the amount of tooth removal (alteration, preparation) along its long axis—*comp* INCISAL REDUCTION, OCCLUSAL REDUCTION

axial surface: the exterior of a body that is oriented in its long axis

axial wall: 1: the side of a body that is in its long axis 2: in dentistry, the surface of a tooth preparation that is in its long axis

ax·is \ăk′sĭs\ *n, pl* **ax·es** \ăk′sēz\ (14c): a line around which a body may rotate or about which a structure would turn if it could revolve—see CONDYLAR A., SAGITTAL A., TRANSVERSE HORIZONTAL A., VERTICAL A.

axis of preparation \ăk′sĭs ŭv prĕp′a-rā′shun\: the planned line or path of placement and removal for a dental restoration

axis orbital plane \ăk′sĭs ôr′bĭ tăl plān\: the horizontal plane established by the transverse horizontal axis of the mandible with a point on the inferior border of the right or left bony orbit (orbitale). This plane can be used as a horizontal reference point

ax·le \ăk′sul\ *n* (14c): a rigid shaft or rod that directs rotary motion

B

back pressure porosity \băk prĕsh′er pa-rŏs′ĭ-tē\: porosity produced in dental castings thought to be due to the inability of gases in the mold to escape during the casting procedure

back·ing \băk′ĭng\ *n* (1793): a metal support that attaches a veneer to a prosthesis

back·scat·ter or **back·scat·ter·ing** *n* (1940): see SCATTERED RADIATION

balanced articulation \băl ansd är-tĭk′ya-lā′shun\: the bilateral, simultaneous, anterior, and posterior occlusal contact of teeth in centric and eccentric positions—see CROSS ARCH B.A., CROSS TOOTH B.A.

balanced bite: see BALANCED ARTICULATION

balanced occlusal contact: see NONWORKING SIDE OCCLUSAL CONTACTS

balanced occlusion: see BALANCED ARTICULATION

balancing condyle: see NONWORKING SIDE CONDYLE

balancing contact: see BALANCING OCCLUSAL CONTACT

balancing interference \băl′ans ĭng ĭn′ter-fear′ans\: undesirable contact(s) of opposing occlusal surfaces on the nonworking side

balancing occlusal contact: see NONWORKING SIDE OCCLUSAL CONTACTS

balancing occlusal surfaces \băl′ans ĭng a klōō′zal sûr′fas es\ *obs*: the occluding surfaces of dentures on the balancing side (antero posteriorly or laterally) that are developed for the purpose of stabilizing dentures (GPT-4)

balancing side *obs*: see NONWORKING SIDE

bar \bär\ *n* (12c): a straight or curvolinear piece of metal or wood that is longer than it is wide. It may have several uses including a lever, barrier, fastener, handle, or support. In prosthodontics, it serves to connect two or more parts of a removable dental prosthesis or fixed dental prosthesis—*usage* see B. CONNECTOR

bar clasp \bär klăsp\: a clasp retainer whose body extends from a major connector or denture base, passing adjacent to the soft tissues and approaching the tooth from a gingivo-occlusal direction

bar clasp arm: see BAR CLASP

bar connector \bär ka-nĕk′tor\: a metal component of greater length than width that serves to connect the parts of a removable partial denture—usage see LABIAL B.C., LINGUAL B.C., PALATAL B.C.

bar retainer \bär rĭ-tā′ner\ *obs*: a metal bar usually resting on lingual surfaces of teeth to aid in their stabilization and to act as indirect retainers (GPT-4)—see BAR CONNECTOR

basal \bā′sal, -zal\ *adj* (1828): pertaining to or situated near the base

basal bone \bā′sak bōn\: the osseous tissue of the mandible and maxillae exclusive of the alveolar process

basal seat: see DENTURE FOUNDATION AREA

basal surface: see DENTURE BASE

[1]base \bās\ *vt* (1587): the act of placing a lining material under a dental restoration

[2]base \bās\ *n* (14c): any substance placed under a restoration that blocks out undercuts in the preparation, acts as a thermal or chemical barrier to the pulp, and/or controls the thickness of the overlying restoration—called also *base material*—*usage:* adjectives such as insulating b., therapeutic b. may also be used

[3]base \bās\ *n* (19c): the portion of a denture that supports the artificial dentition and replaces the alveolar structures and gingival tissues—see DENTURE B.

base material \bās mă-tîr′ē-al\ *obs*: any substance of which a denture base may be made, such as acrylic resin, vulcanite, polystyrene, or metal (GPT-4)

base metal \bās mĕt′l\: any metallic element that does not resist tarnish and corrosion—see NOBLE METAL

base metal alloy \bās mĕt′l ăl′oi′\: an alloy composed of metals that are not noble

baseplate \bās′plāt\ *n*: a rigid, relatively thin layer of wax, shellac, or thermoplastic (heat, chemical, photo activated) polymer adapted over edentulous surfaces of a definitive cast to form a base which, together with an attached occlusion rim made of wax or similar material, serves as the record base—see RECORD BASE

baseplate wax \bās′plāt wăks\: a hard wax used for making occlusion rims, waxing dentures, and other dental procedures

basket endosteal dental implant \băs′kĭt ĕn′da-stēl′ dĕn′tl ĭm-plănt\: a perforated, cylindric, endosteal dental implant, the implant body of which is designed in the form of single, double, and/or triple contiguous cylinder(s)

bead-brush technique: a method of applying an auto polymerizing resin mix to a surface whereby a brush tip is first dipped in liquid monomer and then polymer powder forming a small bead that is incrementally applied to form the desired shape

beading \bē′dĭng\: creating an irregular surface by means of stipples, dots, speckles, or the like

beam \bēm\ *n, obs*: a term once used instead of bar with specific reference to the bar connector—usage included cantilever beam, continuous beam, simple beam (GPT-4)

bees' wax \bēz wăks′\ *n* (1676): a low-melting wax obtained from honeycomb and used as an ingredient of many dental impression waxes

Beilby layer [Sir George Thomas Beilby, British chemist, 1850-1924]: *eponym* for the molecular disorganized surface layer of a highly polished metal. A relatively scratch-free microcrystalline surface produced by a series of abrasives of decreasing coarseness.

Beilby GT. Aggregation and flow of solids, 1921.

bench set \bĕnch sĕt\: a stage of resin processing that allows a chemical reaction to occur under the conditions present in the ambient environment; also used to describe the continuing polymerization of impression materials beyond the manufacture's stated set time

Bennett angle \Bĕn′ĕt ăng′gal\ *obs*: the angle formed between the sagittal plane and the average path of the advancing condyle as viewed in the horizontal plane during lateral mandibular movements (GPT-4)

Bennett's movement [Sir Norman Godfrey Bennett, British dental surgeon, 1870-1947]: see LATEROTRUSION

Bennett NG. A contribution to the study of the movements of the mandible. Proc Roy Soc Med (Lond) 1908;1:79-98 (Odont Section)

Bennett's side shift [Sir Norman Godfrey Bennett, British dental surgeon, 1870-1947]: see MANDIBULAR LATERAL TRANSLATION

Bennett NG A contribution to the study of the movements of the mandible. Proc Roy Soc Med (Lond) 1908;1:79-98 (Odont Section)

[1]bevel \bĕv′al\ *n* (1611): a slanting edge

[2]bevel \bĕv′al\ *vt*: the process of slanting the finish line and curve of a tooth preparation

Bezold-Brucke effect [Helmholtz, 1867]: the apparent change in hue that accompanies a change in luminance

B.I.D.: *acronym* for L. *Bis In Di'e,* twice a day

bifid condyle \bī′fĭd kŏn′dīl′, -dl′\: a condylar anomaly where an exaggerated central depression exists

bi·fur·ca·tion \bī′fur-kā′shu\ *n* (1615): **1:** division into two branches 2: the site where a single structure divides into two parts, as in two roots of a tooth

bilaminar zone: see RETRODISCAL TISSUE

bi·lat·er·al \bī-lăt′er-al\ *adj* (1775): having or pertaining to two sides

bilateral balanced articulation: also termed *balanced articulation,* the

bilateral, simultaneous anterior and posterior occlusal contact of teeth in centric and excentric positions

bilateral distal extension removable partial denture \bī-lăt′er-al dĭs′tal ĭk-stĕn′shun rĭ-mōō′va-bal păr′shal dĕn′chur\: a removable dental prosthesis replacing the distal most tooth or teeth on each side of one arch of the mouth—see KENNEDY CLASSIFICATION OF REMOVABLE PARTIAL DENTURES

bimanual manipulation technique: a method for placement of the mandible using both thumbs on the chin and the fingers on the inferior border of the mandible to guide the jaw into centric relation. First described by Peter Dawson, DDS, St. Petersburg, FL

Dawson PE Temporomandibular joint pain-dysfunction problems can be solved. J Prosthet Dent 1973;29: 100-12

bimaxillary protrusion \bī-măk′sa-lĕr′ē prō-trōō′zhen\: a simultaneous dental or skeletal protrusion of both the maxillary and mandibular jaws and/or teeth

bi·meter \bī-mē′ter\ *n* (20c): a gnathodynamometer equipped with a central bearing plate of adjustable height—see GNATHODYNAMOMETER

bio·ac·cept·ability \bī′ō-ăk-sĕp′ta-bĭl′ĭ-tē′\ (1998): the quality of compatibility in a living environment in spite of adverse or unwanted side effects

bio·com·pat·i·ble \bī′ō-kom-păt′a-bal\ *adj*: capable of existing in harmony with the surrounding biologic environment

bio·feed·back \bī′ō-fēd′băk′\ *n* (1971): **1:** the process of furnishing an individual information, usually in an auditory or visual mode, on the state of one or more physiologic variables such as blood pressure, skin temperature muscle tonus or heart rate; this procedure often enables an individual to gain some voluntary control over the variable being sampled **2:** the instrumental process or technique of learning voluntary control over automatically regulated body functions

bio functional orthopedics: see FUNCTIONAL JAW ORTHOPEDICS

bio·in·te·gra·tion \bī′ō-in′tĭ-grā′shun\ *n* (1998): the benign acceptance of a foreign substance by living tissue—*see* OSSEOUS INTEGRATION

biologic width \bī′a-lŏj′ĭ-kal\ (1998): the combined width of connective tissue and junctional epithelial attachment formed adjacent to a tooth and superior to the crestal bone

Gargiulo, AW et al J Periodontology 1961; 32:261-267

Cohen, DW. Lecture at Walter Reed Army Medical Center, June 3, 1962

bio·ma·te·ri·al \bī′ō-ma-tîr′ē-al\ *n* (1966): any substance other than a drug that can be used for any period of time as part of a system that treats, augments, or replaces any tissue, organ, or function of the body

bio·me·chan·ics \bī′ō-mĭ-kăn′iks\ *n, pl but sing* or *pl in constr* (1933): **1:** the application of mechanical laws to living structures, specifically the locomotor systems of the body **2:** the study of biology from the functional viewpoint **3:** an application of the principles of engineering design as implemented in living organisms—see also DENTAL B

bi·om·e·try \bī-ŏm′ĭ-trē\ *n* (1831): the science of the application of statistical methods to biologic facts, as the mathematical analysis of biologic data

bi·op·sy *n, pl* **-sies** \bī′ŏp′sē, -sēz\ (1895): the removal of tissue for histologic examination and diagnosis

bio·sta·tis·tics \bī′ō-sta-tĭs′tĭks\ *n, pl but sing in constr* (1950): the science of the application of statistical methods to biologic facts, as the mathematical analysis of biologic data—see BIOMETRY

biphasic pin fixation \bī′ō-fāz′ĭk pĭn fĭk-sā′shun\: the use of external pin fixation in the treatment of bone fractures

Bis-GMA: *acronym* for BISPHENOL-A GLYCIDYL DIMETHACRYLATE

Bisphenol-A glycidyl dimethacrylate: a high molecular weight resin constituent of most dental composite resins

biscuit bite *slang*: see MAXILLOMANDIBULAR RELATIONSHIP RECORD

bisque bake \bĭsk bāk\: a series of stages of maturation in the firing of ceramic materials relating to the degree of pyro chemical reaction and sintering shrinkage occurring before vitrification (glazing)—called also *biscuit bake*

bite \bīt\ *vb, obs*: the act of incising or crushing between the teeth—see OCCLUSION RECORD

bite analysis: see OCCLUSAL ANALYSIS

bite block: see OCCLUSION RIM, RECORD RIM

bite closing: see DECREASED OCCLUSAL VERTICAL DIMENSION

bite guard: see OCCLUSAL DEVICE

bite opening: see OCCLUSAL VERTICAL DIMENSION

bite plane: see OCCLUSAL PLANE

bite plate: see OCCLUSION RIM, RECORD RIM

bite raising: see OCCLUSAL VERTICAL DIMENSION

bite rim: see OCCLUSION RIM, RECORD RIM

biting force: see OCCLUSAL FORCE

biting pressure: see OCCLUSAL FORCE

biting strength: see OCCLUSAL FORCE

black triangle: see INTERDENTAL GINGIVAL VOID

blade endosteal dental implant \blād ĕn-dŏs-tē′al dĕn′tl ĭm-plănt\: a faciolingual narrowed, wedge-shaped dental implant body with openings or vents through which tissue may grow

blade implant: see BLADE ENDOSTEAL DENTAL IMPLANT

block out \blŏk out\ *adj*: 1: elimination of undesirable undercuts on a cast, 2: the process of applying wax or another similar temporary substance to undercut portions of a cast so as to leave only those undercuts essential to the planned construction of a prosthesis. A blocked out cast may also include other surface modifications needed relative to the construction of the prosthesis

bo·lus \bō′lus\ *n* (1562): a rounded mass, as a large pill or soft mass of chewed food

blowout fracture \blō′out frăk′chur\: *coll* expression for a fracture of the orbital floor caused by a sudden increase in intraorbital pressure due to traumatic force

board-certified prosthodontist \bôrd-sûr′ta-fīd prŏs′tha-dŏn′tĭst\: in the United States, as defined by the American Board of Prosthodontics, a prosthodontist who has passed the certifying examination administered by the American Board of Prosthodontics

board-eligible prosthodontist \bôrd-ĕl′ĭ-ja-bal prŏs′tha-dŏn′tĭst\: in the United States, as defined by the American Board of Prosthodontics, a prosthodontist whose application for examination for certification is current and has been accepted for examination by the American Board of Prosthodontics

body porcelain: a porcelain blend used for the bulk of a ceramic restoration—*comp* INCISAL PORCELAIN, GINGIVAL PORCELAIN

boil out: see WAX ELIMINATION

Boley gauge: a caliper-type sliding gauge used for measuring thickness and linear dimension

bond \bŏnd\ *n* (12c): **1:** the linkage between two atoms or radicals of a chemical compound **2:** the force that holds two or more units of matter together—see SECONDARY BONDS, VANDERWALL'S BOND

bond strength \bŏnd strĕngkth, strĕngth\: the force required to break a bonded assembly with failure occurring in or near the adhesive/adherens interface

bonded bridge: see RESIN-BONDED PROSTHESIS

bond·ing \bŏn′dĭng\ *n* (1976): **1:** joining together securely with an adhesive substance such as cement or glue **2:** the procedure of using an adhesive, cementing material or fusible ingredient to combine, unite, or strengthen **3:** an adhesive technique in dentistry involving conditioning of enamel and/or dentin so as to create tags in the tooth structure for mechanical retention of restorative material

bonding agent \bŏn′dĭng ā′jent\: a material used to promote adhesion or cohesion between two different substances, or between a material and natural tooth structures

bone \bōn\ *n* (bef. 12c): the hard portion of the connective tissue which constitutes the majority of the skeleton; it consists of an inorganic or mineral component and an organic component (the matrix and cells); the matrix is composed of collagenous fibers and is impregnated with minerals, chiefly calcium phosphate (approx. 85%) and calcium carbonate (approx. 10%), thus imparting the quality of rigidity—called also *osseous tissue*—see ALVEOLAR B. BASAL B. CANCELLOUS B. COMPACT B., CORTICAL B.

bone atrophy \bōn ă-trō′fē\: bone resorption noted internally by a decrease in density and externally by a reduction in form

bone augmentation: see AUGMENTATION

bone conduction \bōn kun-dŭk′shun\: the conduction of sound to the inner ear through the bones of the skull—called also *cranial conduction, osteotympanic conduction* and *tissue conduction*

bone curettage \bōn kyōōr′ĭ-tăzh\: the surgical shaving or smoothing of the bones external surface

bone expansion \bōn ik-spăn′shun\: manipulation of a bony ridge by placement of an osteotome to split the cortical ridge and hence enhance bone width

bone factor \bōn făk′tor\: relative response of alveolar bone to stimulation or irritation; the ratio of osteogenesis to osteolysis

bone marrow \bōn măr′ō\: the soft vascular tissue that fills bone cavities and cancellous bone spaces which consists primarily of fat cells, hematopoietic cells, and osteogenetic reticular cells

Bonwill triangle \Bŏn′wĭl trī′ăng′gl\ [William Gibson Arlington Bonwill, American dentist, 1833-1899]: *eponym* for a 4 inch equilateral triangle bounded by lines connecting the contact points of the mandibular central incisor's incisal edge (or the mid-line of the mandibular residual ridge) to each condyle (usually its mid point) and from one condyle to the other, first described by Bonwill in 1858 while introducing his Anatomical Articulator

Bonwill WGA. Scientific articulation of the human teeth as founded on geometrical, mathematical and mechanical laws. Dental Items Int 1899;21:617-56, 873-80.

bony ankylosis \bō′nē ăng′ka-lō′sĭs\: the bony union of the components of a joint resulting in complete immobility

bor·der \bôr′der\ *n* (14c): the circumferential margin, edge or surface; a bounding line, edge, or surface—see DENTURE BORDER

border molding \bôr′der mōl′ding\: **1:** the shaping of the border areas of an impression material by functional or manual manipulation of the soft tissue adjacent to the borders to duplicate the contour and size of the vestibule **2:** determining the extension of a prosthesis by using tissue function or manual manipulation of the tissues to shape the border areas of an impression material

border movement \bôr′der mōōv′ment\: mandibular movement at the limits dictated by anatomic structures, as viewed in a given plane

border position: see POSTERIOR B. P.

border seal \bôr′der sēl\: the contact of the denture border with the underlying or adjacent tissues to prevent the passage of air or other substances

border tissue movements' \bôr′der tish′ōō\: the action of the muscles and other tissues adjacent to the borders of a denture

boxing an impression \bŏk′sing ăn ĭm-prĕsh′an\: the enclosure (box) of an impression to produce the desired size and form of the base of the cast and to preserve desired details

boxing wax \bŏk′sing wăks\: wax used for boxing an impression

brac·ing \brā′sĭng\ *adj*: the resistance to horizontal components of masticatory force

brack·et \brăk′ĭt\ *n*: an orthodontic device attached to an individual tooth to hold arch wires

brazing investment \brā′zing ĭn-vĕst′ment\: an investment having a binding system consisting of acidic phosphate such as monoammonium phosphate and a basic oxide such as magnesium oxide

brazing material \brā′zing ma-tîr′ē-al\: an alloy suitable for use as a filler material in operations with which dental alloy(s) is/are joined to form a dental restoration

braze \brāz\ *vt* (1677): to join with a nonferrous alloy that melts at a lower temperature than that of the metals being joined

breakdown potential \brāk′doun′ pa-tĕn′shul\: the last noble potentia where pitting and/or crevice corrosion will initiate and propagate

bridge *n, slang*: see FIXED DENTAL PROSTHESIS

bridge work *slang*: see FIXED DENTAL PROSTHESIS

brittle \brĭt′l\: **1:** easily broken or shattered; fragile or crisp, **2:** prone to fracture or failure; the fracture that occurs when the proportional limit of a material is exceeded

brux·ism \brŭk-sĭz′em\ *n* (ca. 1940): **1:** the parafunctional grinding of teeth **2:** an oral habit consisting of involuntary rhythmic or spasmodic nonfunctional gnashing, grinding, or clenching of teeth, in other than chewing movements of the mandible, which may lead to occlusal trauma—called also *tooth grinding, occlusal neurosis*

brux·o·ma·nia \brŭks-ō-mā′nē-a, -mān′ya\ *vb, obs*: the grinding of teeth occurring as a neurotic habit during the waking state (GPT-4)

buc·cal \bŭk′al\ *adj* (ca. 1771): pertaining to or adjacent to the cheek

buccal flange \bŭk′al flănj\: the portion of the flange of a denture that occupies the buccal vestibule of the mouth

buccal vestibule \bŭk′al vĕs′ti-byōōl\: the portion of the oral cavity that is bounded on one side by the teeth, gingiva, and alveolar ridge (in the edentulous mouth, the residual ridge) and on the lateral side by the cheek posterior to the buccal frenula

buccolingual relationship \bŭk′o-lĭng′gwal rĭ-lā′shun-shĭp\: any position of reference relative to the tongue and cheeks

buc·co·ver·sion \bŭk′kō-vûr′shun\ *n*: a deviation toward the cheek

bulb \bŭlb\ *n, slang, chiefly dialectic*: see OBTURATOR, SPEECH AID PROSTHESIS

BULL: *acronym* for *Buccal* of the *Upper*, *Lingual* of the *Lower* (cusps); applies to Clyde H. Schuyler's rules for occlusal adjustment of a normally related dentition in which those cusps contacting in maximum intercuspation (mandibular buccal and maxillary lingual) are favored by adjustment of those cusps that are not in occlusal contact in maximum intercuspation (maxillary buccal and mandibular lingual)–called also the BULL RULE

bur \bûr\ *n* (14c): a steel or tungsten carbide rotary cutting instrument

bur head \bûr hĕd\ *n* (2005): the cutting portion of a dental bur

bur head length \bûr hĕd lĕngkth, lĕngth\ (2005): the axial dimension of the bur head

bur head shape \bûr hĕd shāp\ (2005): the geometrical outline form of the cutting surface edges, usually described successively by proximity from the shank to the tip end

bur shank \bûr shăngk\ *n* (2005): that component of a dental bur which fits into the hand piece; the shaft section of the dental bur that may be friction gripping or latch-type in form

bur·nish \bûr′nĭsh\ *vt* (14c): to make shiny or lustrous by rubbing; also to facilitate marginal adaptation of restorations by rubbing the margin with an instrument

bur·nish·ibil·i·ty \bûr′nĭsh-a-bĭl′ĭ-tē\ *n*: the ease with which a material can be burnished

burn out \burn out\ *adj*: see WAX ELIMINATION

butt \bŭt\ *v* (14c): to bring any two flat-ended surfaces into contact without overlapping, as in a butt joint

butt margin: see SHOULDER FINISH LINE

button implant *obs*: see MUCOSAL IMPLANT

C

Ca: *acronym* for *CArcinoma* or *CAncer*

CAD-CAM: *acronym* for *Computer Aided Design-Computer Aided Manufacturer* (or *Computer Assisted Machining*)

calcium hydroxide \kăl′sē-um hī-drŏk′sīd\: an odorless white powder that is very slightly soluble in water and insoluble in alcohol. Aqueous and non-aqueous suspensions of calcium hydroxide are often employed as cavity liners to protect the dental pulp from the irritant action of restorative materials; also used in pulp capping, pulpotomy and apexification procedures

calcium sulfate \kăl′sē-um sŭl′fāt′\: a product obtained by calcination of gypsum under steam pressure. The *alpha* form is composed of regularly shaped grains, with low porosity, and requiring little water for a satisfactory mix. Forms include *alpha, alpha-modified* and *beta*.

calcium sulfate plaster \kă′sē-um sŭl′fāt′ plăs′ter\: compounds occurring in anhydrous form as anhydrite and in the natural form as gypsum or gypsum dehydrate. The term "plaster" also applies to a mixture consisting of water and calcium sulfate hemihydrate ($CaSo_4 . ½ H_2O$)

cal·cu·lus *n*: in dentistry, a chalky or dark deposit attached to tooth structure, essentially made of mineralized microbial plaque. Found on tooth structure in a supragingival and/or a subgingival location

cameo surface \kăm′ē-ō sûr′fas\ *obs*: the viewable portion of a removable denture prosthesis; the portion of the surface of a denture that extends in an occlusal direction from the border of the denture and includes the facial, lingual, and palatal surface. It is the part of the denture base that is usually polished, and includes the buccal and lingual surfaces of the teeth (GPT-7)–see POLISHED DENTURE SURFACE

Camper's line: see ALA-TRAGUS LINE

Camper's plane \kăm′perz plān\: **1**: a plane established by the inferior border of the ala of the nose (or the average between the two) and the superior border of the tragus of each ear **2**: a plane passing from the acanthion to the center of each bony external auditory meatus; called also *acanthion-external auditory meatus plane*–see also ALA-TRAGUS LINE

cam·phoro·quin·one *n*: a visible-light-sensitive chemical responsible for initiating free-radical polymerization

can·cel·lous bone \kăn-sĕl′us, kăn′se-lus bōn\ (1836): the reticular, spongy or lattice-like portion of the bone; the spongy bone tissue located in the medulla of the bone; this bone is composed of a variable trabecular network containing interstitial tissue that may be hematopoietic

can·dle \kăn′dl\ *n* (12c): a unit of luminous intensity, equal to 1/60 of the luminous intensity of a square centimeter of a black body heated to the temperature of the solidification of platinum (1773° C)

candle power \kăn′dl pou′er\: luminous intensity expressed in candles

canine eminence \kā′nīn′ ĕm′i-nans\: the labial prominence on the maxillary alveolar process corresponding to the position of the root of the canine tooth

canine guidance: see CANINE PROTECTED ARTICULATION

canine protected articulation \kā′nīn prə-tĕk′tid är-tĭk′ya-lā′shun\: a form of mutually protected articulation in which the vertical and horizontal overlap of the canine teeth disengage the posterior teeth in the excursive movements of the mandible–*comp* ANTERIOR PROTECTED ARTICULATION

canine protection: see CANINE PROTECTED ARTICULATION

can·ti·lever \kăn′tl-ē′ver\ *n* (1667): a projecting beam or member supported on one end

cantilever bridge: *slang*, see CANTILEVER FIXED DENTAL PROSTHESIS

cantilever fixed dental prosthesis \kăn′tl-ē′ver fĭkst dĕn′tl prŏs-thē′sis \: a fixed dental prosthesis in which the pontic is cantilevered, i.e., is retained and supported only on one end by one or more abutments

cap splint \kăp splĭnt\: a plastic or metallic device used in the treatment of maxillary or mandibular fractures and designed to cover the clinical crowns of the teeth and usually luted to them

capillary attraction \kăp′a-lĕr′ē ə-trăk′shun\: that quality or state which, because of surface tension, causes elevation or depression of the surface of a liquid that is in contact with the solid walls of a vessel

cap·su·lar \kăp′su-ler\ *adj* (ca. 1730): pertaining to a capsule

capsular contracture: see CAPSULAR FIBROSIS

capsular fibrosis \kăp′su-ler fī-brō′sĭs\: fibrotic contracture of the capsular ligament of the temporomandibular joint

capsular ligament \kăp′su-ler lĭg′a-ment\: as it relates to the temporomandibular joint, a fibrous structure that separately encapsulates the superior and inferior synovial cavities of the temporomandibular articulation

cap·sule \kăp′sal,-sōōl\ *n* (1693): a fibrous sac or ligament that encloses a joint and limits its motion. It is lined with synovial membrane

capsulitis \kăp′sa-lī′tĭs\ *n*: the inflammation of a capsule, as that of the joint, lens, liver, or labyrinth

car·at \kăr′at\ *n* (15c): a standard of gold fineness. The percentage of gold in an alloy, stated in parts per 24. Pure gold is designated 24 carat

carbide bur: a rotary cutting instrument made from tungsten carbide

carbon fiber: filaments made by high temperature carbonizing of acrylic fiber. Used in the production of high strength composites

Cartesian coordinates: [René Descartes, French philosopher and mathematician, 1596-1650]: *eponym,* one of two coordinates relative to intersecting axes that locate a point on a plane or one of three coordinates that locate a point in space

car·ies *n singular*: a dental disease causing the destruction of enamel, dentin and/or cementum. The etiology is generally ascribed to acid-producing bacteria

car·ti·lage \kär′tl-ĭj\ *n* (15c): a derivative of connective tissue arising from the mesenchyme. Typical hyaline cartilage is a flexible, rather elastic material with a semitransparent glasslike appearance. Its ground substance is a complex protein through which there is distributed a large network of connective tissue fibers

case \kās\ *n, substand, chiefly dialect* (13c): **1:** the dental patient **2:** a particular instance of a disease, as a case of diphtheria; sometimes used incorrectly to designate the patient with the disease process

case series *substand*: a collection of common diagnostic findings or/treatment modalities within a group of patients, best termed a *patient series*

case study *substand*: presentation of the diagnostic findings and treatment for a patient, usually termed a *patient study*

case history *substand*: the collected data about an individual, family, environmental factors (including medical/dental history) and any other information that may be useful in analyzing and diagnosing conditions or for instructional purposes; best termed the *patient history*

[1]cast \kăst\ *vb* (13c): to produce a shape by thrusting a molten liquid or plastic material into a mold possessing the desired shape

[2]cast \kăst\ *n* (14c): a life-size likeness of some desired form. It is formed within or is a material poured into a matrix or impression of the desired form—see DENTAL C., DIAGNOSTIC C., FINAL C., PRELIMINARY C., REFRACTORY C., REMOUNT C.

cast clasp: a removable dental prosthesis clasp fabricated by the lost-wax casting process

cast connector: a cast metal union between the retainer(s) and pontic(s) in a fixed dental prosthesis

cast metal core: the foundation restoration made for a fixed dental prosthesis formed indirectly by lost-wax casting

cast post-and-core: a one-piece foundation restoration for an endodontically treated tooth that comprises a post within the root canal and a core replacing missing coronal structure to form the tooth preparation

cast relator \kăst rĭ-lā′tor\: a mechanical device that orients opposing casts to each other without reference to anatomic landmarks—see ARTICULATOR

castable \kăst′a-bl\ *n* (1998): any refractory material that has a bonding agent added and can be mixed with water or other liquid agents and poured in a mold to set

castable ceramic \kăst′a-bl se-răm′ik\: for dental applications, a glass-ceramic material that combines the properties of a restorative material for function with the capability to be cast using the lost wax process

[1]cast·ing \kăs′tĭng\ *n* (14c): something that has been cast in a mold; an object formed by the solidification of a fluid that has been poured or injected into a mold

[2]cast·ing \kăs′tĭng\ *vt*: the act of forming an object in a mold—see VACUUM C.

casting flask \kăs′tĭng flăsk\: see CASTING RING

casting ring \kăs′tĭng rĭng\: a metal tube in which a refractory mold is made for casting dental restorations

casting wax \kăs′tĭng wăks\: a composition containing various waxes with desired properties for making wax patterns to be formed into metal castings

cat·a·lyst \kăt′l-ĭst\ *n* (1902): a substance that accelerates a chemical reaction without affecting the properties of the materials involved

cath·ode \kăth′ōd\ *n* (1834): the negative pole in electrolysis

CAT: *acronym* for *Computerized Axial Tomography*

cau·tery \kô′te-rē\ *n, pl* **-ter·ies** \-ter-rēz\ (15c): the application of a caustic substance, hot instrument, electric current, or other agent used to burn, scar, or destroy tissue

cavity varnish \kăv′ĭ-tē\: a combination of copal resin or other synthetic resins dissolved in an organic solvent such as chloroform or ether

CD: *acronym* for *Complete Denture*

CDA: *acronym* for *Certified Dental Assistant*

CDL: *acronym* for *Certified Dental Laboratory*

CDT: *acronym* for *Certified Dental Technician*

cel·lu·li·tis \sĕl′ya-lī′tĭs\ *n* (1861): diffuse and especially subcutaneous inflammation of connective tissue

[1]ce·ment \sĭ-mĕnt\ *n* (14c): **1:** a binding element or agent used as a substance to make objects adhere to each other, or something serving to firmly unite **2:** a material that, on hardening, will fill a space or bind adjacent objects- syn *luting agent*

[2]ce·ment \sĭ-mĕnt\ *vt* (15c): to unite or make firm by or as if by cement; to lute

ce·men·ta·tion \sē′mĕn-tā′shun\: **1:** the process of attaching parts by means of cement **2:** attaching a restoration to natural teeth by means of a cement (GPT-4)

cemented pin \sĭ-mĕn′tĭd\: a metal rod luted into a hole drilled in dentin to enhance retention

cemento-dentinal junction \sē′mĕn-tō dĕn′tĭ-năl jŭngk′shun\: the area of union of the dentin and cementum

cemento-enamel junction \sē′mĕn-tō ĭ-năm′al jŭngk′shun\: that area where the enamel and cementum meet at the cervical region of a tooth

ce·me·ntoid \sĭ-mĕn′toid′\ *n*: the uncalcified surface layer of cementum including incorporated connective tissue fibers

ce·men·tum \sĭ-mĕn′tum\ *n* (1842): the thin calcified tissue of ectomesenchymal origin that covers the root of a tooth

cementum fracture \sĭ-mĕn′tum frăk′chur\: the tearing of fragments of the cementum from the tooth root

center of the ridge \sĕn′ter ŭv thē rĭj\: the faciolingual or buccolingual midline of the residual ridge

center of rotation: see ROTATION CENTER

central bearing \sĕn′tral bâr′ĭng\ *obs*: the application of forces between the maxilla and mandible (by means of a central bearing tracing device) at a single point that is located as near as possible to the center of the supporting areas of the maxillary and mandibular jaws. It is used for the purpose of distributing closing forces evenly throughout the areas of the supporting structures during the registration and recording of maxillomandibular relations and during the correction of occlusal errors (GPT-4)

central bearing point \sĕn′tral bâr′ing point\ *obs*: the contact point of a central bearing device (GPT-4)

central bearing tracing \sĕn′tral bâr′ing trās′ing\: the pattern obtained on the horizontal plate used with a central bearing tracing device

central bearing tracing device \sĕn′tral bâr′ing trās′ing dĭ-vīs\: a device that provides a central point of bearing or support between the maxillary and mandibular dental arches. It consists of a contacting point that is attached to one dental arch and a plate attached to the opposing dental arch. The plate provides the surface on which the bearing point rests or moves and on which the tracing of the mandibular movement is recorded. It may be used to distrib ute occlusal forces evenly during the recording of maxillomandibular relationships and/or for the correction of disharmonious occlusal contacts. First attributed to Alfred Gysi, Swiss prosthodontist, in 1910

cen·tric \sĕn′trĭk\ *adj* (1590): **1:** located in or at a center; central **2:** concentrated about or directed toward a center

centric check bite: see CENTRIC RELATION RECORD

centric interocclusal record: see CENTRIC RELATION RECORD

centric jaw record: see CENTRIC RELATION RECORD

centric jaw relation: see CENTRIC RELATION

centric occlusion \sĕn′trĭk a-klōō′zhen\: the occlusion of opposing teeth when the mandible is in centric relation. This may or may not coincide with the maximal intercuspal position—*comp* MAXIMAL INTERCUSPAL POSITION

centric position \sĕn′trĭk pa-zish′en\ *obs*: the position of the mandible when the jaws are in centric relation (GPT-1)

centric range: see INTERCUSPAL CONTACT AREA

centric record: see CENTRIC RELATION RECORD

centric relation \sĕn′trĭk rĭ-lā′shun\: **1:** the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterior-superior position against the shapes of the articular eminencies. This position is independent of tooth contact. This position is clinically discernible when the mandible is directed superior and anteriorly. It is restricted to a purely rotary movement about the transverse horizontal axis (GPT-5) **2:** the most retruded physiologic relation of the mandible to the maxillae to and from which the individual can make lateral movements. It is a condition that can exist at various degrees of jaw separation. It occurs around the terminal hinge axis (GPT-3) **3:** the most retruded relation of the mandible to the maxillae when the condyles are in the most posterior unstrained position in the glenoid fossae from which lateral movement can be made at any given degree of jaw separation (GPT-1) **4:** The most posterior relation of the lower to the upper jaw from which lateral movements can be made at a given vertical dimension (Boucher) **5:** a maxilla to mandible relationship in which the condyles and disks are thought to be in the midmost, uppermost position. The position has been difficult to define anatomically but is determined clinically by assessing when the jaw can hinge on a fixed terminal axis (up to 25 mm). It is a clinically determined relationship of the mandible to the maxilla when the condyle disk assemblies are positioned in their most superior position in the mandibular fossae and against the distal slope of the articular eminence (Ash) **6:** the relation of the mandible to the maxillae when the condyles are in the uppermost and rearmost position in the glenoid fossae. This position may not be able to be recorded in the presence of dysfunction of the masticatory system **7:** a clinically determined position of the mandible placing both condyles into their anterior uppermost position. This can be determined in patients without pain or derangement in the TMJ (Ramsfjord)

Boucher CO. Occlusion in prosthodontics. J PROSTHET DENT 1953; 3:633-56. Ash MM. Personal communication, July 1993.

Lang BR, Kelsey CC. International prosthodontic workshop on complete denture occlusion. Ann Arbor: The University of Michigan School of Dentistry, 1973.

Ramsfjord SP. Personal communication, July 1993.

centric relation interocclusal record: see CENTRIC RELATION RECORD

centric relation occlusion: see CENTRIC OCCLUSION

centric relation position: see CENTRIC RELATION

centric relation record \sĕn′trĭk rĭ-lā′shun rĭ-kōrd\: a registration of the relationship of the maxilla to the mandible when the mandible is in centric relation. The registration may be obtained either intraorally or extraorally

centric slide \sĕn′trĭk slīd\ *obs*: the movement of the mandible while in centric relation, from the initial occlusal contact into maximum intercuspation (GPT-4)

centric stop \sĕn′trĭk stŏp\: opposing cuspal/fossae contacts that maintain the occlusal vertical dimension between the opposing arches

ceph·a·lo·gram *n*: see CEPHALOMETRIC RADIOGRAPH

ceph·a·lo·m·e·ter \sĕf′a-lom′a-ter\ *n*: an instrument for measuring the head or skull; an orienting device for positioning the head for radiographic examination and measurement

cephalometric radiograph \sĕf′a-lo-mĕt′rĭk rā′dē-ō-grăf′\: a standardized radiograph of the skull

cephalometric tracing \sĕf′a-lo-mĕt′rĭk trā′sing\: a line drawing of structural outlines of craniofacial landmarks and facial bones, made directly from a cephalometric radiograph

cephalometry \sĕf′a-lăm′a trē′\ *n*, **cephalometric** \sĕf′a-lo-mĕt′rĭk\ *adj*: **1:** the science of measurement of the dimensions of the head **2:** in dentistry, certain combinations of angular and linear measurements developed from tracing frontal and lateral radiographic head films used to assess craniofacial growth and development on a longitudinal basis and to determine the nature of orthodontic treatment response

ceph·a·lo·stat \sĕf′a-lo-stăt\ *n*: an instrument used to position the head to produce spatially oriented, reproducible, radiographs or photographs

ce·ram \sa-răm\ *n*: a heat treatment process that converts a specially formulated glass into a fine grained glass-ceramic material

[1]**ce·ram·ic** \sa-răm′ik\ *adj* (1850): of or relating to the manufacture of any product made essentially from a nonmetallic mineral (as clay) by firing at a high temperature

[2]**ce·ram·ic** \sa-răm′ik\ *n* (1859): the product of ceramic manufacture

ceramic crown \sa-răm′ik kroun\: a ceramic fixed dental prosthesis that restores a clinical crown without a supporting metal framework

ceramic inlay: a ceramic intracoronal restoration

ceramic flux \sa-răm′ĭk flŭks\: a glass modifier; metallic ions such as calcium, potassium or sodium, usually as carbonates, which interrupt the oxygen/silica bond, thus enhancing fluidity

ce·ram·ics \sa-răm′iks\ *n*: **1:** compounds of one or more metals with a nonmetallic element, usually oxygen. They are formed of chemical and biochemical stable substances that are strong, hard, brittle, and inert nonconductors of thermal and electrical energy **2:** the art of making porcelain dental restorations

ce·ram·ist \sa-răm′ist\ or **cer·am·i·cist** \sa-răm′ĭ-sist′\ *n* (1855): one who engages in ceramics

ceramometal restoration: see METAL CERAMIC RESTORATION

cermet \sûr′mĕt\ (1998): fused glass powder with silver particles formed through high temperature sintering of a mixture of the two minerals

Certified Dental Laboratory: in the United States, a dental laboratory that has met established specific standards for personnel skills, laboratory facilities and infection control and is certified by The National Board for Certification of Dental Laboratories **Certified Dental Technician:** in the United States, a dental technician who has met established specific standards and is certified by The National Board for Certification of Dental Laboratories

cervical \sûr′vĭ-kel\ *adj* (1681): **1:** in anatomy, pertaining to the cervix or neck **2:** in dentistry, pertaining to the region at or near the cementoenamel junction

cer·vix \sûr′viks\ *n, pl* **cer·vi·ces** \sûr′vĭ-sis\ (15c): **1:** the neck **2:** a constricted portion of a part or organ

[1]**cham·fer** \chăm′fer\ *n*: **1:** a finish line design for tooth preparation in which the gingival aspect meets the external axial surface at an obtuse angle **2:** a small groove or furrow **3:** the surface found by cutting away the angle of intersection of two faces of a piece of material (i.e., stone, metal, wood): a beveled edge

[2]**cham·fer** \chăm′fer\ *vt* **cham·fer·ed**; **cham·fer·ing**; **cham·fers**: **1:** to cut a furrow in **2:** to make a chamfer on; to cut or reduce to a chamfer; bevel **3:** generally thought of as producing a curve from the axial wall to the cavosurface

chamfer angle \chăm′fer ăng′gel\ *n*: the angle between a chamfered surface and one of the original surfaces from which the chamfer is cut

characterization: to alter by application of unique markings, indentations, coloration and similar custom means of delineation on a tooth or dental prosthesis thus enhancing natural appearance

char·ac·ter·ize \kăr′ak-ta-rīz\: to distinguish, individualize, mark, qualify, singularize, or differentiate something

characterized denture base \kăr′ak-ter′īzd dĕn′chur bās\: a denture base with coloring that simulates the color and shading of natural oral tissues

check bite *slang*: see INTEROCCLUSAL RECORD

che·ili·tis \kī-lī′tĭs\: inflammation of the lip

cheiloplasty: plastic surgery of the lip

cheilorrhaphy: surgical correction of the cleft lip deformity

che·ilo·sis \kī-lō′sĭs\: a fissured condition of the lips and angles of the mouth; often associated with riboflavin deficiency

chew-in record: see STEREOGRAPHIC RECORD

chewing cycle: see MASTICATORY CYCLE

chewing force: see MASTICATORY FORCE

Christensen's phenomenon \Krĭs′chen-senz fĭ-nŏm′a-nŏn′, -nen\ [Carl Christensen, Danish dentist and educator]: *eponym* for the space that occurs between opposing occlusal surfaces during mandibular protrusion

Christensen C. The problem of the bite. D Cosmos 1905;47:1184-95.

chroma \krō′ma\ *n* (1889): **1.** the purity of a color, or its departure from white or gray **2.** the intensity of a distinctive hue; saturation of a hue **3.** chrome describes the strength or saturation of the hue (color)—see also SATURATION

Munsell AH. A color notation. Baltimore: Munsell Color Co. Inc. 1975:14-7.

chromatic stimulus \krō-măt′ik stĭm′ya-lus\: a stimulus that under prevailing conditions of adaptation gives rise to a perceived chromatic color

chromaticity coordinates \krō′ma-tĭs′ĭ-tē kō-ôr′dĭ-nĭtz\: the two dimensions of any color order system that exclude the lightness dimension and describe the chromaticity. Unless otherwise specified, the term refers to the CIE coordinates x, y, and z for Illuminant C and 2 degrees (1931) Standard Observer—called also *color coordinates*

chromaticity diagram \krō′ma-tĭs′ĭ-tē dī′a-grăm\: a plane diagram in which each point represents a different combination of dominant wavelength and purity and which is usually constructed in some form of a triangle with colorimetric primaries represented at the corners. The CIE standard chromaticity diagram is essentially a right angle triangle representing hypothetical primaries and the complete chromaticity gamut of the CIE standard observer

chro·mat·ic·ness \krō′măt′ĭk-nĕs\ *n*: the intensity of hue as expressed in the Natural Color System

chro·ma·top·sia \krō′ma-tŏp′zha\ *n*: an abnormal state of vision in which colorless objects appear colored; a visual defect in which colored objects appear unnaturally colored and colorless objects appear color tinged

chron·ic \krŏn′ik\ *adj* (1601): marked by long duration or frequent recurrence; not acute; always present—**chron·ical·ly** *adj*—**chro·nic·i·ty** *n*

chronic closed lock \krŏn′ik klōzd lŏk\: with respect to the temporomandibular joint, a restriction in motion of the joint caused by an anteriorly displaced intraarticular disk and usually characterized by pain, especially during function

chronic pain \krŏn′ik pān\: pain marked by long duration or frequent recurrence

CIE: *acronym* for *Commission Internationale d'Eclairage*

CIE LAB system \C I E Lăb sĭs′tem\: CIE LAB relates the tristimulus values to a color space. This scale accounts for the illuminant and the observer. By establishing a uniform color scale, color measurements can be compared and movements in color space defined

CIE standard illuminant \C I E stăn′dard ĭ-lōō′ma-nent\: the illuminants A, B. C, D_{65} and other illuminants, defined by the CIE in terms of relative spectral power distributions; A = Planckion radiation (a theoretical body that absorbs all incident optical radiant energy) a temperature of about 2856° K; B = Direct solar radiation 48,000° K; C = Average daylight; D_{65} = Daylight including the ultraviolet region: 6500° K

cin·e·flu·o·ros·co·py \sĭn ē′flō răh skă′ko pē\ *n*: dynamic fluoroscopic images recorded on motion picture film **cin·e·ra·di·og·ra·phy** \sĭn′a-rā′dē-ō-gră′fē\ *n*: the making of a motion picture record of successive images appearing on a fluoroscopic screen

cin·gu·lum \sĭng′gya-lum\ *n, pl* **-la** (1845): **1:** an anatomical band or encircling ridge—**cin·gu·late** \sĭng′gya-lāt\ *adj* **2:** the lingual lobe of many anterior teeth; a convex protuberance at the lingual cervical one third of the anatomic crown

cingulum rest \sĭng′gya-lum rĕst\: a portion of a removable dental prosthesis that contacts the prepared or natural cingulum of the tooth, termed the *cingulum rest seat*

circumferential clasp \ser-kŭm-fa-rĕn′shal klăsp\: a retainer that encircles a tooth by more than 180 degrees, including opposite angles, and which generally contacts the tooth throughout the extent of the clasp, with at least one terminal located in an undercut area

circumferential clasp arm: see CIRCUMFERENTIAL CLASP

clamping force: the compressive force which a fastener exerts on a bolted joint. The stability of a bolted joint depends upon the maintenance of the clamping force

clasp \klăsp\ *n* (14c): the component of the clasp assembly that engages a portion of the tooth surface and either enters an undercut for retention or remains entirely above the height of contour to act as a reciprocating element. Generally it is used to stabilize and retain a removable dental prosthesis—see BAR C, CIRCUMFERENTIAL C., COMBINATION C., CONTINUOUS C.

clasp arm: see CLASP

clasp assembly \klăsp a-sĕm′blē\: the part of a removable dental prosthesis that acts as a direct retainer and/or stabilizer for a prosthesis by partially encompassing or contacting an abutment tooth—*usage:* components of the clasp assembly include the *clasp,* the *reciprocal clasp,* the *cingulum, incisal* or *occlusal rest,* and the *minor connector*

clasp bridge *slang*: see UNILATERAL REMOVABLE DENTAL PROSTHESIS

clasp guideline: see SURVEY LINE

classification system: see PROSTHODONTIC DIAGNOSTIC INDEX

clear·ance \klîr′ens\ *n* (1563) *obs*: a condition in which bodies may pass each other without hindrance. Also, the distance between bodies (GPT-4)

[1]cleft \klĕft\ *n*: **1:** a space or opening made through splitting **2:** a hollow between ridges or protuberances

[2]cleft \klĕft\ *adj*: partially split or divided

cleft palate \klĕft păl′ĭt\ *n* (1841): **1:** a congenital fissure or elongated opening in the soft and/or hard palate **2:** an opening in the hard and/or soft palate due to improper union of the maxillary process and the median nasal process during the second month of intrauterine development—***syn*** PALATAL CLEFT—see COMPLETE C.P., OCCULT C.P.

cleft palate prosthesis: see SPEECH AID PROSTHESIS

cleft palate speech aid prosthesis: see SPEECH AID PROSTHESIS

clench·ing \klĕn′chĭng\ *vt* (13c): the pressing and clamping of the jaws and teeth together frequently associated with acute nervous tension or physical effort

click \klĭk\ *n* (1611): a brief sharp sound; with reference to the temporomandibular joint, any bright or sharp sound emanating from the joint—see CLICKING, EARLY CLOSING C., EARLY OPENING C., LATE CLOSING C., LATE OPENING C., MID OPENING C. RECIPROCAL C.

click·ing \klĭ′kĭng\ *n* (611): a series of clicks, such as the snapping, cracking, or noise evident on excursions of the mandible; a distinct snapping sound or sensation, usually audible (or by stethoscope) or on palpation, which emanates from the temporomandibular joint(s) during jaw movement. It may or may not be associated with internal derangements of the temporomandibular joint

clin·i·cal \klĭn′ĭ-kel\ *adj* (ca. 1755): **1:** of or related to or conducted in or as if within a clinic **2:** analytical or detached—**clin·i·cal·ly** *adv*

clinical crown \klĭn′ĭ-kel kroun\: the portion of a tooth that extends from the occlusal table or incisal edge to the free gingival margin

clinical remount: see REMOUNT PROCEDURE

clin·om·e·ter *n* (1811): a device for measuring angles of elevation, inclination or declination—**cli·no·met·ric** *adj*—**cli·nom·etry** *n*

clip \klĭp\ *n* (15c) *slang*: **1:** any of numerous devices used to grip, clasp, or hook **2:** a device used to retain a removable dental prosthesis intraorally to a fixed abutment; i.e., a bar, crown, or other retainer

closed bite *slang*: see DECREASED OCCLUSAL VERTICAL DIMENSION

closed lock \klōzd lŏk\: an internal derangement of the temporomandibular joint in which the disk is dislocated anteriorly and usually medial to the condyle; displacement or dislocation of the disk without spontaneous reduction on mouth opening—see ACUTE CLOSED LOCK, CHRONIC CLOSED LOCK, DISK DISPLACEMENT WITHOUT REDUCTION

closed reduction of a fracture \klōzd rĭ-dŭk′shun ŭv ā frăk′chur\: reduction (repositioning) and fixation of fractured bones without making a surgical opening to the fracture site

closest speaking space \klō′sĕst spē′king spās\: the space between the anterior teeth that, according to Dr. Earl Pound, should not be more or less than 1 to 2 mm of clearance between the incisal edges of the teeth when the patient is unconsciously repeating the letter "S." Dr. Meyer M. Silverman termed this *speaking centric,* which was defined as the closest relationship of the occlusal surfaces and incisal edges of the mandibular teeth to the maxillary teeth

during function and rapid speech. This was later called *closest speaking level* by Dr. Silverman and finally the *closest speaking space*

Silverman MM. Speaking centric. Dent Digest 1950;55:106-11.

Silverman MM. Accurate measurement of vertical dimension by phonetics and speaking centric space. Dent Digest 1951;57:261-5.

Silverman MM. The speaking method in measuring vertical dimension. J PROSTET DENT 1953;3:193-9.

Pound E. Esthetics and phonetics in full denture construction. J Calif Dent Assoc 1950;20:179-85.

Pound E. The mandibular movements of speech and their seven related values. J PROSTHET DENT 1966;16: 835-43.

Pound E. The vertical dimension of speech, the pilot of occlusion. J Calif Dent Assoc 1975;6:42-7.

Pound E. Let /s/ be your guide. J PROSTHET DENT 1977;38:482-9.

clutch \klŭch\ *coll n*: a device placed in both the maxillary and mandibular arches for the purpose of supporting components used to record mandibular movement

co·ada·pt·ed \kō-a-dăp′tĭd\ *adj* (1836): **1:** mutually adapted, especially by natural selection **2:** in medicine, the proper realignment of displaced parts—**co·ad·ap·ta·tion** *n*

Coble balancer \Kō′bel băl′an-ser\ [Lucian G. Coble, North Carolina, U.S. dentist]: **1:** an intraoral balancing device used to determine centric relation and the centric relation record **2:** used to equilibrate complete removable dental prostheses intraorally—see CENTRAL BEARING TRACING DEVICE

Coble LG. Correct centric position must be established for good denture fit and function. Dent Survey 1951;27:1391-3.

Coble LG. A complete denture technique for selecting and setting up teeth. J PROSTHET DENT 1960;10:455-8.

co·he·sion \kō-hē′zhun\ *n* (1660): **1:** the act or state of sticking together tightly **2:** the force whereby molecules of matter adhere to one another; the attraction of aggregation **3:** molecular attraction by which the particles of a body are united throughout their mass

cohesive failure \kō-hē′sĭv fāl′yur\: bond failure within a dental material due to a tensile or shearing force—see ADHESIVE FAILURE

cold curing resin: see AUTOPOLYMERIZING RESIN

collarless metal ceramic restoration \kŏl′er-lĕs mĕ′l sa-răm′ĭk rĕs′ta-rā′shun\: a metal ceramic restoration whose cervical metal portion has been eliminated. Porcelain is placed directly in contact with the prepared finish line

collateral ligaments \ka-lăt′er-al\: two or more ligaments paired to a single joint for the specific purpose of restricting extension and flexion within one plane only

colloid \kŏl′oid\: a material in which is suspended a constituent in a finely divided state that is invisible to the eye but capable of scattering light

colloidal silica: submicroscopic fumed silica frequently used as a suspension in liquid; contained in the liquid mixed with many phosphate-bonded casting investments to improve casting smoothness and control expansion

col·or \kŭl′or\ *n* (13c): **1:** a phenomenon of light or visual perception that enables one to differentiate otherwise identical objects **2:** the quality of an object or substance with respect to light reflected or transmitted by it. Color is usually determined visually by measurement of hue, saturation, and luminous reflectance of the reflected light **3:** a visual response to light consisting of the three dimensions of hue, value, and saturation—see PERCEIVED C., PSYCHOPHYSICAL C.

color blindness \kŭl′or blīnd′nĭs\: abnormal color vision or the inability to discriminate certain colors, most commonly along the red-green axis

color constancy \kŭl′or kŏn′stan-sē\: relative independence of perceived color to changes in color of the light source

color deficiency \kŭl′or dĭ-fĭsh′en-sē\: a general term for all forms of color vision that yield chromaticity discrimination below normal limits, such as monochromatism, dichromatism, and anomalous trichromatism

color difference \kŭl′or dĭf′er-ens\: magnitude and character of the difference between two colors under specified conditions; referred to as delta E

color difference equations \kŭl′or dĭf′er-ens ĭ-kwā′zhanz, -shanz\: equations that transform CIE (Commission Internationals d'Eclairage) coordinates into a more uniform matrix such that a specified distance between two colors is more nearly proportional to the magnitude of an observed difference between them regardless of their hue

color notation \kŭl′or nō-tā′shun\: the use of symbols in some orderly fashion by which the attributes of color may be defined or may be set down in written formula

color rendering index \kŭl′or rĕn′der-ing ĭn′dĕks\: a number from 1 to 100 given to a light source to indicate its relative equivalence to pure white light which has a color rendering index (CRI) of 100. The closer the number is to 100, the more it resembles pure white light

color scale \kŭl′or skāl\: an orderly arrangement of colors showing graduated change in some attribute or attributes of color as a value scale

color solid \kŭl′or sŏl′ĭd\: a symbolic figure in three dimensions that represents the relations of all possible colors with respect to their primary attributes of hue, lightness, and saturation. Usually, value (lightness) appears as the vertical axis of the figure with hue and saturation represented in polar coordinates about the lightness axis, saturation being radial. The boundaries of the solid are actually irregular, but it is sometimes represented as a cylinder, a sphere, or a cube

color standard \kŭl′or stăn′dard\: a color whose psychophysical dimensions have been accurately measured and specified

color stimulus \kŭl′or stĭm′yu-lus\: visible radiation entering the eye and producing a sensation of color, either chromatic or achromatic

color temperature \kŭl′or tĕm′per-a-chōōr′, tĕm′pra-\: the temperature in degrees Kelvin (Celsius plus 273°) of a totally absorbing or black body (object) that produces colors as the temperature changes. The range is from a dull red to yellow to white to blue. This term is sometimes used incorrectly to describe the color of "white" light sources. The correct term to describe the color of light sources is correlated color temperature

col·or·im·e·ter \kŭl′a-rĭm′ĭ-ter\ *n* (ca. 1863): a device that analyzes color by measuring it in terms of a standard color, scale of colors, or certain primary colors; an instrument used to measure light reflected or transmitted by a specimen

col·or·ing \kŭl′or-ĭng\ *n* (14c): **1:** the act of applying colors **2:** something that

produces color or color effects **3:** the effect produced by applying or combining colors—see EXTRINSIC C., INTRINSIC C.

combination clasp \kŏm′bi-nā′shun klăsp**:** a circumferential retainer for a removable dental prosthesis that has a cast reciprocal arm and a wrought wire retentive clasp

combination syndrome \kŏm′bi-nā′shun sĭn′drōm**:** the characteristic features that occur when an edentulous maxilla is opposed by natural mandibular anterior teeth, including loss of bone from the anterior portion of the maxillary ridge, overgrowth of the tuberosities, papillary hyperplasia of the hard palate's mucosa, extrusion of the lower anterior teeth, and loss of alveolar bone and ridge height beneath the mandibular removable dental prosthesis bases—also called *anterior hyperfunction syndrome*

Kelly, E. Changes caused by a mandibular removable partial denture opposing a maxillary complete denture. J Prosthet Dent 1972;27:140-150.

comminuted fracture \kŏm′a-nōō′tĭd frăk′chur**:** a fracture in which the bone is broken in several places in the same region; a fracture in which the bone is crushed and splintered

com·mi·nu·te \kŏm′a-nōōt\ *vt* **-nut·ed**; **-nut·ing** (1626) *obs***:** the reduction of food into small parts (GPT-4)—**com·mi·nu·tion** \kŏm′a-nōō′shun\ *n*

com·mis·sure \kŏm′a-shōōr\ *n* (15c)**:** a point of union or junction especially between two anatomic parts i.e., corner of the mouth—**com·mis·sur·al** \kŏm′ĭz-ŭr′l\ *adj*

commissure splint \kŏm′a-shōōr splĭnt**: 1.** a ancillary prosthesis placed between the lips that assist in achieving increased opening between the lips **2.** a device placed between the lips which assists in achieving increased opening between the lips. Use of such devices enhances opening where surgical, chemical or electrical alterations of the lips has resulted in severe restriction or contractures—called also *lip splint*

compact bone \kŏm′pakt′ bōn**:** any osseous substance that is dense or hard

compaction composite resin \kon-dĕns-ă′bel kom-pŏz′ĭt rĕz′ĭn**:** a highly filled composite resin in which the filler particles have been altered so that the material is compacted in a layered, compression technique

compensating curve \kŏm′pen-sāt′ĭng kûrv**: 1:** the anteroposterior curving (in the median plane) and the mediolateral curving (in the frontal plane) within the alignment of the occluding surfaces and incisal edges of artificial teeth that is used to develop balanced occlusion **2:** the arc introduced in the construction of complete removable dental prostheses to compensate for the opening influences produced by the condylar and incisal guidance's during lateral and protrusive mandibular excursive movements—called also *compensating curvature, compensating curve*

complementary colors \kom′pla-mĕn′ta-rē, -trē kŭl′orz**: 1.** two colors that, when mixed together in proper proportions, result in a neutral color. Colored lights that are complementary when mixed in an additive manner form white light and follow the laws of additive color mixture. Colorants that are complementary when mixed together form black or gray and follow the laws of subtractive colorant mixture **2.** colors located in directly opposite positions on the color wheel. Colorants that are complementary when mixed together form black or gray and follow the laws of subtractive color

complete arch subperiosteal implant \kŏm-plēt′ ärch sŭb-pĕr′ē-ŏs-tēl ĭm-plănt**:** a device placed under the periosteum on the residual ridge to provide abutments for supporting a removable or fixed dental prosthesis in a fully edentulous arch—usage of such implants should be described by means of their relationship to their bases of support, the alveolar bone. As such, at placement, the implant is described as an *eposteal dental implant*—see EPOSTEAL DENTAL IMPLANT

complete cleft palate \kŏm-plēt′ klĕft păl′ĭt **:** an opening extending through the anterior alveolar ridge, and primary and secondary palates—see PALATAL CLEFT

complete crown \kŏm-plēt kroun**:** a restoration that covers all the coronal tooth surfaces (mesial, distal, facial, lingual, and occlusal)

complete denture \kŏm-plēt dĕn′chur**:** a removable dental prosthesis that replaces the entire dentition and associated structures of the maxillae or mandible; called a *complete removable dental prosthesis*

complete denture prosthetics \kŏm-plēt dĕn′chur prŏs-thĕt′iks**:** *obs***: 1:** the replacement of the natural teeth in the arch and their associated parts by artificial substitutes **2:** the art and science of the restoration of an edentulous mouth (GPT-4)—see COMPLETE DENTURE PROSTHODONTICS

complete denture prosthodontics \kŏm-plēt dĕn′chur prŏs′tho-dŏn′tĭks**:** that body of knowledge and skills pertaining to the restoration of the edentulous arch with a removable dental prosthesis

complete facial moulage \kŏm-plēt fā′shal mōō-läzh**:** an impression procedure used to record the soft tissue contours of the whole face

complicated fracture \kŏm′plĭ-kā′tĭd frăk′chur**:** a fracture with significant injury to adjacent soft tissues (i.e., neurovascular injury) components of mastication: those factors of food manipulation and comminution that follow ingestion and precede deglutition

com·po·mer \kŏm′pō-mĕr\ *n* (1998)**:** a poly-acid modified composite resin, composed of glass filler, acid-modified dimethacrylate resin, and a *photo initiator*

components of occlusion \kŏm-pō′nentz uv a-klōō′zhun**:** the various elements that are involved in occlusion, such as the temporomandibular joints, the associated musculature, the teeth, their contacting surfaces and investing tissues, and/or the dental supporting structures—see also DETERMINANTS OF MANDIBULAR MOVEMENT

composite resin: a highly cross-linked polymeric material reinforced by a dispersion of amorphous silica, glass, crystalline, or organic resin filler particles and/or short fibers bonded to the matrix by a coupling agent

com·pound *n, slang* (19c)**:** see MODELING PLASTIC IMPRESSION COMPOUND

compound joint \kŏm-pound′ joint**:** a joint involving three or more bones

compression molding \kom-prĕsh′on mōl′ding**:** the act of pressing or squeezing together to form a shape within a mold; the adaptation, under pressure, of a plastic material into a mold

compression of tissue: see TISSUE DISPLACEMENT

compressive stress \kŏm-prĕs′ĭv strĕs**:** the internal induced force that opposes

the shortening of a material in a direction parallel to the direction of the stresses; any induced force per unit area that resists deformation caused by a load that tends to compress or shorten a body

computerized tomography \kom-pyōō′ta-rīzd tō-mŏg′ra-fē\: (CT) the technique by which multidirectional x-ray transmission data through a body is mathematically reconstructed by a computer to form an electrical cross-sectional representation of a patient's anatomy. CT is used as an acronym to designate any technical field associated with these techniques

con·cres·cen·ce \kon-krĕs′ens\ *n*: the union of roots of approximating teeth via deposition of cementum

con·cre·tion \kon-krē′shun\ *n*: any inorganic mass in a natural cavity or organ

compaction composite resin \kon-dĕns-ā′bel kom-pŏz′ĭt rĕz′ĭn\: a highly filled composite resin in which the filler particles have been altered so that the material is compacted in a layered, compression technique

con·den·sa·tion *n*: 1: the compaction of dental amalgam using force to remove excess mercury and ensure continuity of the matrix phase 2: the process of increasing the density of dental porcelains during processing by removing excess water with vibration and blotting

condensation reaction \kŏn′dĕn-sā′shun rē-ăk′shun\: any chemical reaction between two molecules to form a larger molecule, with the elimination of a smaller molecule

conditional color match \kon-dĭsh′a-nal kŭl′or măch\: a pair of colors that appear to match only under limited conditions, such as a particular light source and a particular observer; a metameric match

condylar agenesis \kŏn′da-lar ā-jĕn′ĭ-sĭs\: a developmental abnormality characterized by the absence of the condyle

condylar articulator \kŏn′da-lar är-tĭk′ya-la-tôr\: an articulator whose condylar path components are part of the lower member and whose condylar replica components are part of the upper member—called also *nonarcon articulator*

condylar axis \kŏn′da-lar ăk′sĭs\: a hypothetical line through the mandibular condyles around which the mandible may rotate

condylar dislocation \kŏn′da-lar dĭs′lō-kā′shun\: a non self-reducing displacement of the mandibular condyle usually forward of the articular eminence

condylar displacement: positioning of the condyle out of its normal location in the glenoid fossa

[1]condylar guidance \kŏn′da-lar gīd′ns\ *vt*: mandibular guidance generated by the condyle and articular disc traversing the contour of the glenoid fossae

[2]condylar guidance \kŏn′da-lar gīd′ns\ *n*: the mechanical form located in the upper posterior region of an articulator that controls movement of its mobile member

condylar guide assembly \kŏn′da-lar gīd a-sĕm′blē\: the components of an articulator that guide movement of the condylar analogues

condylar guide inclination \kŏn′da-lar gīd ĭn′kla-nā′shun\: the angle formed by the inclination of a condylar guide control surface of an articulator and a specified reference plane—see LATERAL CONDYLAR INCLINATION

condylar hinge position \kŏn′da-lar hĭnj pa-zĭsh′an\ *obs*: the position of the condyles of the mandible in the glenoid fossae at which hinge axis movement is possible (GPT-4)

condylar inclination \kŏn′da-lar ĭn′kla-nā′shun\: the direction of the lateral condyle path (GPT-4)

condylar path \kŏn′da-lar păth\: that path traveled by the mandibular condyle in the temporomandibular joint during various mandibular movements

condylar path element \kŏn′da-lar păth ĕl′a-ment\: the member of a dental articulator that controls the direction of condylar movement

condylar path tracing \kŏn′da-lar păth trā′sĭng\: a graphic registration of the movement of the condyle—see MANDIBULAR TRACING

condylar slant: see CONDYLAR PATH, LATERAL CONDYLAR PATH

condylar subluxation \kŏn′da-lar sŭb′lŭk-sā′shun\: a self-reducing incomplete or partial dislocation of the condyle

con·dy·lar·throsis \kŏn′da-lar-thrō′sĭs\ *n*: an ellipsoidal articulation; a modification of the ball/socket type of synovial joint in which the articular surfaces are elŏlipsoid rather than spheroid. Owing to the arrangement of the muscles and ligaments around the joint, all movements are permitted except rotation about a vertical axis—called also *articulation ellipsoidea, condylar articulation, condylar joint, condyloid joint,* or *ellipsoidal joint*

con·dyle \kŏn′dīl, -dl\ *n* (1634): an articular prominence of a bone, i.e., in the mandible, an ellipsoidal projection of bone that articulates with the glenoid fossa—**con·dy·lar** *adj*—see CONDYLAR PATH, LATERAL CONDYLAR PATH, MANDIBULAR CONDYLE, NECK OF THE CONDYLE

condyle chord: see CONDYLAR AXIS

condyle head: see CONDYLE

condyle path: see CONDYLAR PATH

condylectomy: surgical removal of the condyle

condylotomy: surgical cut through the neck of the condyloid process. Also refers to surgical removal of a portion of the articulating surface of the mandibular condyle (called a *condylar shave*)

cone \kōn\ *n* (1562): one of the receptors of color vision found in the retinal layer of the eye and concentrated in the macula lutea

con·gen·i·tal \kon-jĕn′ĭ-tl\ *adj* (1796): existing at, and usually before, birth; referring to conditions that are present at birth, irrespective of their causation

connecting bar: see MAJOR CONNECTOR

connective tissue \ka-nĕk′tĭv tĭsh′ōō\: a tissue of mesodermal origin rich in interlacing processes that supports or binds together other tissues

[1]con·nec·tor \ka-nĕk′tor\ *n* (15c): in removable dental prosthodontics, the portion of a removable dental prosthesis that unites its components—*usage:* see BAR C., CONTINUOUS BAR C., MAJOR C., MINOR C.

[2]con·nec·tor \ka-nĕk′tor\ *n*: in fixed dental prosthodontics, the portion of a fixed dental prosthesis that unites the retainer(s) and pontic(s)—*usage:* see INTERNAL C., NONRIGID C., RIGID C., SUBOCCLUSAL C.

connector bar: see BAR CONNECTOR

con·sul·ta·tion \kŏn-sŭl′tā′shun\ *n* (15c): a deliberation between those who render health care regarding a patient's diagnosis and/or their treatment

[1]con·tact \kŏn′tăkt\ *n* (1626): the union or junction of surfaces; the apparent touching or tangency of bodies—*usage:* see PROXIMAL CONTACT

[2]con·tact \kŏn′tăkt\ *vi* (1834): to make contact; to bring into contact; to enter or be in contact with—*usage:* see BAL-

ANCING OCCLUSAL C., DEFLECTIVE OCCLUSAL C., INITIAL OCCLUSAL C., OCCLUSAL C.

contact surface \kŏn′tăkt sûr′fas**:** the region on the proximal surface of a tooth that touches an adjacent tooth

continuous bar connector \kon-tĭn′yōō-us bär ka-nĕk′tor**:** a metal bar usually resting on the lingual surfaces of mandibular anterior teeth to aid in their stabilization and act as an indirect retainer in extension base partial removable dental prostheses

continuous bar indirect retainer: see CONTINUOUS BAR CONNECTOR

continuous bar retainer: see CONTINUOUS BAR CONNECTOR, INDIRECT RETAINER

continuous beam \kon-tĭn′yōō-us bēm\ *obs***:** a beam that continues over several supports, with those supports not at the beam end bearing equally free supports (GPT-4)

continuous clasp \kon-tĭn′yōō-us klăsp**: 1:** in removable dental prosthodontics, a circumferential retainer (clasp) whose body emanates from an occlusal rest and extends across the buccal or lingual surface of more than one tooth (hence, continuing on) before engaging an undercut on the proximal wall farthest from the occlusal rest **2:** any one of several early 20th century designs for clasping natural teeth to retain a partial removable dental prosthesis; terms for such clasps included *wrought continuous interdental clasp, wrought continuous interdental support.*

Kennedy E. Partial denture construction. Brooklyn: Dental Items of Interest Publishing, 1928:377-90.

continuous gum denture \kon-tĭn′yōō-us gŭm dĕn′chur\ *obs***: 1:** an artificial denture consisting of porcelain teeth and tinted porcelain denture base material fused to a platinum base (GPT-4) **2:** according to Joseph Richardson, "plain single teeth, made for the purpose, are arranged and soldered to a plate properly fitted to the mouth, after which different mineral compounds, made to represent the natural gums, roof, etc., are applied to the plate and teeth in a plastic state, then carved and trimmed in proper form, and by means of a strong furnace heat these compounds, which are called the body and the gum enamel, are fused, thus producing a continuous gum, root, and rugae of the mouth, without seam or crevice." The technique is attributed to Dr. John Allen (American)

Richardson J. A practical treatise on mechanical dentistry. Philadelphia: Lindsay & Blakiston, 1880:307-35.

continuous loop wire clasp \kon-tĭn′yōō-us lōōp wīr klăsp\ *obs***:** attributed to J. Wright Beach, DDS, this clasp assembly was used to completely encircle a tooth, particularly "a straight sided" tooth, by means of one wire. If the retained was not continuous, it was described as an *open loop wire clasp*

Roach FE. Partial dentures. The Dental Summary 1915:35:203-10.

continuous spectrum \kon-tĭn′yōō-us spĕk′trum**:** a spectrum or section of the spectrum in which radiations of all wavelengths are present; opposed to line spectra or band spectra

[1]con·tour \kŏn′tōōr\ *n* (1662)**:** an outline, especially of a curving or irregular figure: the line representing this outline; the general form or structure of something—*usage:* see HEIGHT OF CONTOUR, TRANSITIONAL CONTOUR

[2]con·tour \kŏn′tōōr\ *adj* (1844)**:** following contour lines or forming furrows or ridges along them; made to fit the contour of something

[3]con·tour \kŏn′tōōr\ *vt* (1871)**:** to shape the contour of; to shape so as to fit contours; to construct in conformity to a contour

con·tra·be·vel \kŏn′tra-bĕv′el\ *n* (20c)**: 1:** an external bevel arising from the occlusal surface or edge of a tooth preparation and placed at an angle that opposes or contrasts the angle of the surface it arises from **2:** an external bevel arising from the occlusal surface or edge of a preparation—see BEVEL

con·trac·tion \kon-trăk′shun\ *n* (15c)**:** in muscle physiology, the development of tension in a muscle in response to a stimulus—*usage:* see ISOMETRIC C., ISOTONIC C., POSTURAL C.

con·trac·ture \kon-trăk′chur\ *n* (1658)**:** a permanent shortening of a muscle—see MUSCLE C., MYOFIBROTIC CAPSULAR C., MYOSTATIC C.

con·tra·lat·er·al \kŏn′tra-lăt′er-al\ *adj* (1882)**:** occurring on or acting in conjunction with similar parts on an opposite side

contralateral condyle: see NONWORKING SIDE CONDYLE

convergence angle \kon-vûr′jens ăng′gel**: 1.** the taper of a crown preparation **2.** the angle, measured in degrees, formed between opposing axial walls when a tooth or teeth are prepared for crowns or fixed dental prostheses. *Usage-* this term is best described as the *total occlusal convergence*

co·or·di·na·tion \kō-ôr′dn-ā′shun\ *n* (1643)**:** smooth, controlled symmetrical movement

[1]cope \kōp\ *n* (bef.12c)**:** the upper half of any flask used in casting; the upper or cavity side of a denture flask used in conjunction with the *drag* or lower half of the flask—see DRAG

[2]cope \kōp\ *v***:** to dress, cover, or furnish with a cope; to cover, as if with a cope or coping

[1]cop·ing \kō′pĭng\ *n***: 1:** a long, enveloping ecclesiastical vestment **2a:** something resembling a cope (as by concealing or covering) **2b:** coping

[2]cop·ing \kō′pĭng\ *n* (ca. 1909)**:** a thin covering or crown—*usage:* see C. IMPRESSION, TRANSFER C.

coping impression \kō′pĭng ĭm-prĕsh′an**:** an impression, usually encompassing an entire dental arch, that uses metal or resin copings placed on prepared teeth. The copings are repositioned before the pouring of a working cast

coping pick-up impression: see COPING IMPRESSION

coping prosthesis *obs***:** see OVERDENTURE

copolymer resin \kō-pŏl′a-mer**:** polymers formed from more than one type of molecular repeat unit

copper band \kŏp′er bănd**:** a copper cylinder employed as a matrix for making an impression

cor·al·i·form \kŏr′al-ĭ′fôrm\ *adj***:** having the form of coral; branched like a coral; often with reference to certain types of hydroxylapatite implant materials

core \kôr, kōr\ *n* (14c)**:** the center or base of a structure

co·ro·nal \kôr′a-nal, kōr′-, ka-rō′nal\ *adj* (15c)**: 1:** of or relating to a corona or crown **2:** or relating to any longitudinal plane or section that passes through a body at right angles to the median plane **3:** pertaining to the crown of a tooth

coronal plane \ka-rō-nal plān**:** lying in the direction of the coronal suture, of or relating to the frontal plane that passes through the long axis of a body

coronoid maxillary space \kôr′a-noid′, kŏr′- măk′sa-lĕr′ē spās**:** the region

between the medial aspect of the coronoid process of the mandible and the buccal aspect of the tuberosity of the maxilla, bounded anteriorly by the zygomatic arch

coronoid process \kôr′a-noid′, kŏr′- prō-sĕs\: the thin triangular rounded eminence originating from the anterosuperior surface of the ramus of the mandible—see HYPERPLASIA OF THE C.P.

coronoidectomy: surgical removal of the coronoid process

co·ro·no·plas·ty \kŏr′a-nō-plăs′tē\ *n* (20c): alteration or change in morphology of the coronal portion of natural teeth by the use of abrasive instruments

corrected cast: see ALTERED CAST

corrective wax: see DENTAL IMPRESSION WAX

correlated color temperature \kôr′a-lā′tid kŭl′er tĕm′per-a-chōōr\: the term describing the color of white light sources. Specifically, it is the temperature of the Planckion (black body) radiator that produces the chromaticity most similar to that produced by the light source expressed in degrees Kelvin or in mired; it is measured in degrees Kelvin, to which a black body must be raised to provide the closest match, in chromaticity, to a particular light source

cor·rode \ka-rōd\ *vt* (15c): **1:** deterioration of a metal due to an electrochemical reaction within its environment **2:** to eat away by degrees as if by gnawing **3:** to wear away gradually usually by chemical action

cor·ro·sion \ka-rō′zhen\ *n* (15c): the action, process, or effect of corroding; a product of corroding; the loss of elemental constituents to the adjacent environment

cor·ro·sive \ka-rō′sĭv\ *adj* (14c): tending or having the power to corrode

cortical bone \kôr′tĭ-kal\: the peripheral layer of compact osseous tissue

Costen's syndrome [James Bray Costen, American otolaryngologist, 1895-1962]: *eponym* for TEMPOROMANDIBULAR DISORDERS

Costen JB. A syndrome of ear and sinus symptoms dependent upon disturbed functions of the temporomandibular joint. Ann Otol Rhinol Laryngol, 1934;43:1-15.

coun·ter·die \koun′ter-dī\ *n, obs*: the reverse image of a die; usually made of a softer and lower fusing metal than the die (GPT-1)

coup·ling \kŭp′lĭng\ *n*: a device that serves to link or connect the ends of adjacent parts or objects

coupling lug \kŭp′lĭng lŭg\: a small projecting part of a larger member; a projection or a casting to which a bolt or other part may be attached

covalent bond \kō-vā′lĕnt bŏnd\ *n* (1939): a chemical bond between two atoms or radicals formed by the sharing of a pair (single bond), two pairs (double bond), or three pairs (triple bond) of electrons—called also *primary bond*

cover screw: see HEALING SCREW

cranial base \krā′nē-al bās\: the inferior part of the skull that is thought to be relatively stable throughout life and is used in cephalometrics as a landmark from which to measure changes due to growth, time, or treatment

cranial prosthesis \krā′nē-al prŏs-thē-sĭs\: a biocompatible, permanently implanted replacement (maxillofacial prosthesis) for a portion of the skull bones; an artificial replacement for a portion of the skull bones—called also *cranial implant, cranioplasty prosthesis, skull plate*

craniofacial defects \krā′nē-ō-fā′shal dē′fĕkts, dĭ′fĕkts\: malformations associated with the head and face craniofacial dysjunction fracture: see LE FORT III FRACTURE

craniomandibular articulation \krā′nē-ō-măn-dĭb′ya-lar ăr-tĭk′ya-lā′shun\: both temporomandibular joints functioning together as a bilateral sliding hinge joint connecting the mandible to the cranium—***syn*** TEMPOROMANDIBULAR JOINTS

cra·ter *n*: in periodontics, a saucer shaped defect of soft tissue or bone

[1]craze \krāz\ *vb.* **craz·ed** \krāzd\; **craz·ing** \krā′zĭng\ *vt* (14c): to produce minute cracks on the surface or glaze of; to develop a mesh of fine cracks

[2]craze \krāz\ *n* (1534): a crack in a surface or coating (as of glaze or enamel)

[1]creep \krēp\ *vi* **crept** \krĕpt\; **creep·ing** \krēp′ĭng\ (12c): to slip or gradually shift position; to change shape permanently due to prolonged stress or exposure to high temperature

[2]creep \krēp\ *n* (1818): the slow change in dimensions of an object due to prolonged exposure to high temperature or stress

crep·i·ta·tion \krĕp′ĭ-tā′shun\ *n*: a crackling or grating noise in a joint during movement, liken to the throwing of fine salt into a fire or rubbing hair between the fingers; the noise made by rubbing together the ends of a fracture

crep·i·tus *n*: see CREPITATION, JOINT C.

crest \krĕst\ *n* (14c): a ridge or prominence on a part of a body; in dentistry, the most coronal portion of the alveolar process

crest of the ridge \krĕst ŭv tha rĭj\: the highest continuous surface of the residual ridge—not necessarily coincident with the center of the ridge

crevicular epithelium \krĕ′vĭ-kyōō′lar ĕp′a-thē′lē-um\: the non-keratinized epithelium of the gingival crevice

crevicular fluid \krĕ′vĭ-cyōō′lar flōō′id\: the fluid that seeps through the crevicular epithelium; this is usually increased in the presence of inflammation

cribriform plate \krĭb′ra-fôrm\ *obs*: in dentistry, the alveolar bone proper

crist·o·bal·ite \krĭs′tō-băl′līt\ *n*: an allotropic form of crystalline silica used in dental casting investments

cross arch balance: see C.A.B. ARTICULATION

cross arch balanced articulation \krôs, krŏs ärch băl′ansd är-tĭk′ya-lā′shun\: the simultaneous contact of the buccal and lingual cusps of the working side maxillary teeth with the opposing buccal and lingual cusps of the mandibular teeth, concurrent with contact of the nonworking side maxillary lingual cusps with the mandibular buccal cusps

cross arch stabilization \krŏs, krôs ärch stā′ba-lī′zā-shun\: resistance against dislodging or rotational forces obtained by using a partial removable dental prosthesis design that uses natural teeth on the opposite side of the dental arch from the edentulous space to assist in stabilization

cross bite: see REVERSE ARTICULATION

cross bite teeth: see REVERSE ARTICULATION TEETH

cross bite occlusion: see REVERSE ARTICULATION

cross pinning \krôs, krŏs pĭn′ing\: the augmentation achieved in retention of a cast restoration by the placement of a pin through the axial wall of a dental casting into tooth dentin

cross tooth balance: see BALANCED ARTICULATION, CROSS TOOTH BALANCED ARTICULATION

cross tooth balanced articulation \krôs, krŏs tōōth băl′ansd är-tĭk′ya-lā′shun\: the harmonious contact of opposing working side buccal and lingual cusps

[1]crown \kroun\ *n* (12c)**: 1:** the highest part, as the topmost part of the skull, head or tooth; the summit; that portion of a tooth occlusal to the dentinoenamel junction or an artificial substitute for this **2:** an artificial replacement that restores missing tooth structure by surrounding part or all of the remaining structure with a material such as cast metal, porcelain, or a combination of materials such as metal and porcelain

[2]crown \kroun\ *vt* (12c)**:** to place on the head, as to place a crown on a tooth, dental implant or tooth substitute—*usage*: implies fabrication of a restoration for a tooth on a natural tooth, dental implant and/or dental implant abutment

crown flask \kroun flăsk**:** a sectional, box like case in which a sectional mold is made of artificial stone or plaster of parts for the purpose of processing dentures or other resinous restorations

crown fracture \kroun frăk′chur**:** micro or macroscopic cleavage in the coronal portion of a tooth

crown-implant ratio: the physical relationship between the portion of the implant-supported restoration within alveolar bone compared with the portion not within the alveolar bone, frequently determined by radiographic examination

crown lengthening *slang*: see LENGTHENING OF THE CLINICAL CROWN

crown-root ratio \kroun-rōōt rā′shō, rā′shē-ō′**:** the physical relationship between the portion of the tooth within alveolar bone compared with the portion not within the alveolar bone, as determined by radiograph

crown slitter \kroun slĭt′er\ *obs*: a mechanical device used to slit the axial surface of a swayed artificial crown to facilitate its removal [GPT-4]

cru·ci·ble \krōō′sa-bal\ *n* (15c)**:** a vessel or container made of any refractory material (frequently porcelain) used for melting or calcining any substance that requires a high degree of heat

crucible former \krōō′sa-bal fôr′mer**:** the base to which a sprue former is attached while the wax pattern is being invested in refractory investment; a convex rubber, plastic, or metal base that forms a concave depression or crucible in the refractory investment

CT: *acronym* for *Computerized Tomography*

crypt \krĭpt\ *n* (1789)**: 1:** a chamber wholly or partly underground **2:** in anatomy, a pit, depression or simple tubular gland

cuff \kŭf\ *n* (14c)**:** something that encircles; a band about any body

cul-de-sac \kŭl-dĭ-săk\ *n* (1738)**:** a blind pouch or tubular cavity closed at one end

cumulative dose \kyōōm′ya-lā′tĭv, -ya-la-tĭv dōs**:** the total accumulated dose resulting from a single or repeated exposure to radiation of the same region or of the whole body; if used in area monitoring, it represents the accumulated radiation exposure over a given period of time

cure *vb* (14c)**:** see POLYMERIZE

[1]curve \kûrv\ *adj* (15c)**:** bent or formed into a curve

[2]curve \kûrv\ *vb* **curved** \kûrvd**; curv·ing** \kûrv′ing\ *vi* (1594)**:** to take a turn, change, or deviation from a straight line or plane surface without angularity or sharp breaks; a non-angular deviation from a straight line or surface—see REVERSE C.

curve of Monson \kûrv ŭv Mŏn-son\ [George S. Monson, St. Paul, Minnesota, U.S. dentist, 1869-1933]**:** *eponym* for a proposed ideal curve of occlusion in which each cusp and incisal edge touches or conforms to a segment of the surface of a sphere 8 inches in diameter with its center in the region of the glabella

Monson GS. Occlusion as applied to crown and bridgework. J Nat Dent Assoc 1920;7:399-417.

Monson GS. Some important factors which influence occlusion. J Nat Dent Assoc 1922;9:498-503.

curve of occlusion \kûrv ŭv a-klōō′shun**:** the average curve established by the incisal edges and occlusal surfaces of the anterior and posterior teeth in either arch

curve of Pleasure \kûrv ŭv Plĕzh′er\ [Max A. Pleasure, New York, U.S. dentist, 1903-1965]**: 1:** *eponym* for a helicoid curve of occlusion that, when viewed in the frontal plane, conforms to a curve that is convex from the superior view, except for the last molars which reverse that pattern **2:** in excessive wear of the teeth, the obliteration of the cusps and formation of either flat or cupped-out occlusal surfaces, associated with reversal of the occlusal plane of the premolar, first and second molar teeth (the third molars being generally unaffected), whereby the occlusal surfaces of the mandibular teeth slope facially instead of lingually and those of the maxillary teeth incline lingually—***syn*** ANTIMONSON CURVE, FREQUENCY CURVE, PROBABILITY CURVE, REVERSE CURVE

Pleasure MA. Prosthetic occlusion—a problem in mechanics. J Am Dent Assoc and Dent Cosmos 1937;24:1330-8.

Pleasure MA. Practical full denture occlusion. J Am Dent Assoc Dent Cosmos 1938;25:1606-17.

curve of Spee [Ferdinand Graf Spee, Prosector of Anatomy, Kiel, Germany, 1855-1937]**:** *eponym* for ANTEROPOSTERIOR CURVE

Spee FG. Die Verschiebrangsbahn des Unterkiefers am Schadell. Arch Anat Physiol (Leipz) 1890;16:285-94.

curve of Wilson [George H. Wilson, Cleveland, Ohio, U.S. dentist, 1855-1922]**: 1:** *eponym* for the MEDIOLATERAL CURVE **2:** in the theory that occlusion should be spherical, the curvature of the cusps as projected on the frontal plane expressed in both arches; the curve in the lower arch being concave and the one in the upper arch being convex. The curvature in the lower arch is affected by an equal lingual inclination of the right and left molars so that the tip points of the corresponding cross-aligned cusps can be placed into the circumferences of a circle. The transverse cuspal curvature of the upper teeth is affected by the equal buccal inclinations of their long axes

Wilson GH. A manual of dental prosthetics. Philadelphia Lea & Febiger, 1911:22-37.

cur·vi·lin·ear \kûr′va-lĭn′ē-er\ *adj* (1710)**:** consisting of or bounded by curved lines; represented by a curved line

cusp *n***:** cone-shaped protuberance on the crown of a tooth that forms the occlusal surface

cusp angle \kŭsp ăng′gal**:** the angle made by the average slope of a cusp with the cusp plane measured mesiodistal or buccolingually

cusp-fossa articulation scheme: an occlusal arrangement where the maxillary and mandibular centric cusps articulate with the opposing fossae in maximum intercuspation

cusp height \kŭsp hīt**:** the perpendicular distance between the tip of a cusp and its base plane

cusp-marginal ridge articulation scheme: an occlusal arrangement where the mandibular second premolar

buccal cusp and mandibular molar mesiobuccal cusps articulate with the opposing occlusal embrasures in maximum intercuspation

cusp plane \kŭsp plān\: the plane determined by the two buccal cusp tips and the highest lingual cusp of a molar

cusp plane angle \kŭsp plān ăng′gal\: the incline of the cusp plane in relation to the plane of occlusion

cuspal interference: see DEFLECTIVE OCCLUSAL CONTACT

cuspid guidance: see CANINE PROTECTED ARTICULATION

cuspid guided articulation: see CANINE PROTECTED ARTICULATION

cuspid lift: see CANINE PROTECTED ARTICULATION

cuspid lifted articulation: see CANINE PROTECTED ARTICULATION

cuspid protected occlusion: see CANINE PROTECTED ARTICULATION

cuspid rise: see CANINE PROTECTED ARTICULATION

cuspid rise articulation: see CANINE PROTECTED ARTICULATION

cuspless teeth \kŭsp′les tēth\: teeth designed without cuspal prominence on the occlusal surface—see NONANATOMIC TEETH, ZERO-DEGREE TEETH

custom anterior guide table: used for transferring to an articulator the contacts of anterior teeth when determining their influence on border movements of the mandible. Acrylic resin is molded by the articulator pin to record and preserve this information—*comp* MECHANICAL ANTERIOR GUIDE TABLE *see also* ANTERIOR GUIDE TABLE

custom tray \kŭs′tum trā\: an individualized impression tray made from a cast recovered from a preliminary impression. It is used in making a final impression

cy·ano·acryl·ate \sī′a-nō-ăk′ra-lāt\ *n* (20c): a single component, moisture activated, thermoplastic group of adhesives characterized by rapid polymerization and excellent bond strength

D

Davis crown [Wallace Clyde Davis, Lincoln, Nebraska, U.S. dentist (1866-1950)] *obs*: *eponym* for a dental restoration supported by a dowel in the root canal over which was cemented a porcelain tube tooth in direct contact with the root face of the tooth. A later modification involved a gold casting that improved the fit between the root and artificial tooth

Davis WC. Essentials of operative dentistry. 1st ed. Lincoln, Neb.: Author as publisher, 1911.

Davis WC. Essentials of operative dentistry. 2nd ed. St. Louis: The C V Mosby Co., 1916.

de·bride·ment \dā′brēd-mäN′, dĭ-brēd′ment\ *n* (ca. 1842): the removal of inflamed, devitalized, contaminated tissue or foreign material from or adjacent to a lesion

deciduous dentition: see PRIMARY DENTITION

de·cor·ti·ca·tion \dē-kôr′tĭ-kā′shun\ *n* (ca. 1623): **1:** a process of removing the outer covering (as in enamel, bark, husks, etc.) from something **2:** surgical removal of the cortex of an organ, an enveloping membrane or fibrinous covering—**de·cor·ti·cate** \dē-kôr′tĭ-kāt\ *vt*—**de·cor·ti·cat·or** \dē-kôr′tĭ-kā′tor\ *n*

decreased occlusal vertical dimension \dĭ-krēsd a-klōō′sal vûr′tĭ-kal dĭ-mĕn′shun\: a reduction in the distance measured between two anatomic points when the teeth are in occlusal contact

deep bite: see VERTICAL OVERLAP

deep heat therapy: see DIATHERMY

defective color vision \dĭ-fĕk′tĭv kŭl′er vĭzh′un\: the condition in which color discrimination is significantly reduced in comparison with the normal trichromat. The forms of color defective vision can be divided into three main groups—dichromatic vision, anomalous trichromatic vision, and monochromatic vision—see COLOR BLINDNESS, COLOR DEFICIENCY

definitive cast \dĭ-fĭn′ĭ-tĭv kăst\: a replica of the tooth surfaces, residual ridge areas, and/or other parts of the dental arch and/or facial structures used to fabricate a dental restoration or prosthesis; called also *final cast*

defective occlusal contact \dĭ-fĕk′tĭv a-klōō′sal kŏn′tăkt′\ *obs*: contact that is capable of guiding the mandible from its original path of action into a different path of motion or capable of disturbing the relation between a denture base and its supporting tissues (GPT-1)

definitive obturator \dĭ-fĭn′ĭ-tĭv ŏb′ta-rā′ter\: a maxillofacial prosthesis that replaces part or all of the maxilla and associated teeth lost due to surgery or trauma *Editorial note: a definitive obturator is made when it is deemed that further tissue changes or recurrence of tumor are unlikely and a more permanent prosthetic rehabilitation can be achieved; it is intended for long- term use*

definitive palatal lift prosthesis: see PALATAL LIFT PROSTHESIS

definitive prosthesis \dĭ-fĭn′ĭ-tĭv prŏs-thē′sĭs\: any dental or maxillofacial prosthesis designed for long-term use

definitive speech aid prosthesis: see SPEECH AID PROSTHESIS

de·flec·tion \dĭ-flĕk′shun\ *n* (1605): **1:** a turning aside or off course **2:** a continuing eccentric displacement of the mandibular midline incisal path symptomatic of restriction in movement

deflective occlusal contact \dĭ-flĕk′tĭv a-klōō′sal kŏn′tăkt\: a contact that displaces a tooth, diverts the mandible from its intended movement, or displaces a removable denture from its basal seat—*usage*: see OCCLUSAL DISHARMONY, OCCLUSAL PREMATURITY

de·for·ma·tion \dē′fôr-mā′shun, dĕf′-er-\ *n* (15c): the change of form or shape of an object

de·gas \dē-găs′\ *vt*; **de·gassed** \dē-găsd′\ *pt., pp*; **de·gassing** \dē-găs′ing\ *ppr* (1920): **1:** to remove gas from an object or substance **2:** the name commonly used to denote the first heat cycle (oxidation cycle) in fabrication of a metal ceramic restoration that removes surface impurities from the metallic component and produces surface oxides prior to the application of opaque porcelain

degenerative arthritis: see OSTEOARTHRITIS

degenerative joint disease: see OSTEOARTHRITIS

de·glu·ti·tion \dē′glōō-tĭsh′un\ *n* (1650): the act of swallowing

de·hisce \dĭ-hĭs′\ *vt*; **de·hisced** \dĭ-hĭsd\; **de·hisc·ing** \dĭ-hĭs′sing\ (1658): to split or peal down along a natural line; to discharge the contents by so splitting

de·his·cence \dĭ-hĭs′sens\ *n* (ca. 1828): an act or instance of dehiscing, i.e., separation of wound margins

delayed dentition \dĭ-lād′ dĕn-tĭsh′en\: the eruption of the first teeth of the primary dentition or the permanent dentition considerably later than the normally expected time (after the thirteenth month of life for the primary dentition and after the seventh year of

life for the permanent dentition in humans)

delayed dis-occlusion: see DELAYED DISCLUSION

delayed disclusion \dĭ-lād′ dĭs-klōō′–shun\: deferred separation of the posterior teeth due to the anterior guidance

de·liv·er·y: see PLACEMENT

delta E \dĕl′ta Ē\: total color difference computed by use of a color difference equation. It is generally calculated as the square root of the sums of the squares of the chromaticity difference and the lightness difference. It signifies the difference between sample and standard

de·min·er·al·iza·tion \dē-mĭn′er-ă-lī-zā′shun\ *n* (ca. 1903) **1:** loss of minerals (as salts of calcium) from the body **2:** in dentistry, decalcification, usually related to the dental caries process

de·nas·al·i·ty \dē-nā-zăl′ĭ-tē\ *n*: the quality of the voice when the nasal passages are obstructed to prevent adequate nasal resonance during speech–see HYPONASALITY

de·ner·va·tion \dē-nûr-vā′shun\ *n* (1905): resection of or removal of the nerves to an organ or part

den·tal \dĕn′tl\ *adj* (1594): of or pertaining to the teeth

dental arch \dĕn′tl arch\: the composite structure of the natural teeth and alveolar bone

dental articulation \dĕn′tl är-tĭk′ya-lā′shun\: the contact relationships of maxillary and mandibular teeth as they move against each other–*usage:* this is a *dynamic* process

dental biomechanics \dĕn′tl bī′ō-mĭ-kăn′iks\: the relationship between the biologic behavior of oral structures and the physical influence of a dental restoration–*syn* DENTAL BIOPHYSICS

dental cast \dĕn′tl kăst\: a positive life size reproduction of a part or parts of the oral cavity

dental casting investment \dĕn′tl kăs′tĭng ĭn-vĕst′ment\: a material consisting principally of an allotrope of silica and a bonding agent. The bonding substance may be gypsum (for use in lower casting temperatures) or phosphates and silica (for use in higher casting temperatures)

dental dysfunction \dĕn′tl dĭs-fŭngk′shun\: abnormal functioning of dental structures; partial disturbance or functional impairment of a dental organ

dental element \dĕn′tl ĕl′a-ment\: *slang* for a dental prosthesis that receives part or all support/retention from one or more endosteal, eposteal or transosteal dental implants

dental engineering \dĕn′tl ĕn′ja-nîr′ing\ *obs*: **1:** the application of physical, mechanical, and mathematical principles to dentistry **2:** the application of engineering principles to dentistry (GPT-4)

dental esthetics \dĕn′tl ĕs-thĕt′ĭks, ĭs\: the application of the principles of esthetics to the natural or artificial teeth and restorations

dental geriatrics \dĕn′tl jĕr′ē-ăt′rĭks\: **1:** the branch of dental care involving problems peculiar to advanced age and aging **2:** dentistry for the aged patient–see GERODONTICS, GERODONTOLOGY

dental implant \dĕn′tl ĭm-plănt\: 1. a prosthetic device made of alloplastic material(s) implanted into the oral tissues beneath the mucosal or/and periosteal layer, and on/or within the bone to provide retention and support for a fixed or removable dental prosthesis; a substance that is placed into or/and upon the jaw bone to support a fixed or removable dental prosthesis 2. the portion of an implant that provides support for the dental implant abutment(s) through adaptation upon (eposteal), within (endosteal), or through (transosteal) the bone–*usage:* although dental implants may be classified by their silhouette or geometrical form (i.e., fin, screw, cylinder, blade, basket, root form, etc.) generally dental implants are classified based on their anchorage component as it relates to the bone that provides support and stability. Thus, there are three basic types of dental implants: *eposteal* dental implants, *endosteal* dental implants, and *transosteal* dental implants. Some dental implants possess both eposteal and endosteal components (by design or subsequent anchorage change); the decision as to what anchorage system provides the most support at initial placement determines which category is used to best describe the dental implant; the dental implant(s) provide bony support via the dental implant attachment while the dental implant abutment(s) connect the dental implant to the fixed or removable dental prosthesis–see also DENTAL IMPLANT ABUTMENT, ENDOSTEAL DENTAL IMPLANT, EPOSTEAL DENTAL IMPLANT, TRANSOSTEAL DENTAL IMPLANT–*comp* MUCOSAL INSERT

dental implant abutment \ĭm′plănt′ a-bŭt′ment\: the portion of a dental implant that serves to support and/or retain any fixed or removable dental prosthesis–*usage:* frequently dental implant abutments, especially those used with endosteal dental implants, are changed to alter abutment design or use before a definitive dental prosthesis is fabricated. Such a preliminary abutment is termed an *interim (dental implant) abutment*. The abutment chosen to support the definitive prosthesis is termed a *definitive (dental implant) abutment*. Dental implant abutments frequently are described by their form (i.e., cylindrical, barrel), material (i.e., ceramic, titanium, zirconia ceramic), or special design factors (i.e., internal hex lock, external hex lock, spline)

dental implant attachment \ĭm′plănt′ a-tăch′ment\: 1. the biochemical/mechanical interconnection between the dental implant and the tissues to which it is attached 2. *slang* expression for the means of retention of the dental implant abutment to the dental implant

dental implant analog: a replica of the entire dental implant, not intended for human implantation

dental implant loading: the process of placing axial or tangential force on a dental implant usually associated with the intentional exposure of the dental implant either at the time of initial surgical placement of the dental implant or subsequent surgical exposure. Such forces may come from any of a variety of sources including intentional or/and unintentional occlusal loading, unintentional forces from the tongue or other oral tissues, food bolus, as well as alveolar/osseous deformation. Generally application of intentional occlusal forces may be termed *immediate loading, progressive loading,* or *delayed loading*–see AXIAL LOADING

dental implant system \ĭm′plănt sĭs′tem\ (1993): dental implant components that are designed to mate together. An implant system can represent a specific concept, inventor, or patent. It consists of the necessary parts and instruments to complete the implant placement and abutment components

dental impression \děn′tl ĭm-prĕsh′en\: a negative imprint of an oral structure used to produce a positive replica of the structure to be used as a permanent record or in the production of a dental restoration or prosthesis—see IMPRESSION

dental impression wax \děn′tl ĭm-prĕsh′en wăks\: any thermoplastic wax used to make impressions for dental use

dental plaster \děn′tl plăs′ter\: the beta-form of calcium sulfate hemihydrate. It is a fibrous aggregate of fine crystals with capillary pores that are irregular in shape and porous in character

dental prosthesis \děn′tl prŏs-thē′sis\: an artificial replacement (prosthesis) of one or more teeth (up to the entire dentition in either arch) and associated dental/alveolar structures. Dental prostheses usually are subcategorized as either *fixed dental prostheses* or *removable dental prostheses*—see also FIXED DENTAL PROSTHESIS, REMOVABLE DENTAL PROSTHESIS; *comp* to MAXILLOFACIAL PROSTHESIS, ANCILLARY PROSTHESIS

dental prosthetic laboratory procedures \děn′tl prŏs-thĕt′ik lăb′ra-tôr′ē prasē′jerz\: the steps in the fabrication of a dental prosthesis that do not require the presence of the patient for their completion

dental senescence \děn′tl sĭ-nĕs′enz\: that condition of the teeth and associated structures in which there is deterioration due to aging or premature aging processes

dental shade selection: see TOOTH COLOR SELECTION

dental stone \děn′tl stōn\: the alpha-form of calcium sulfate hemihydrate with physical properties superior to the beta-form (dental plaster). The alpha-form consists of cleavage fragments and crystals in the form of rods or prisms, and is therefore more dense than the beta-form

den·tate \děn′tāt′\adj (1760): having teeth or pointed conical projections

den·tin \děn′tĭn\ *n* (1840): a calcareous material similar to but harder and denser than bone that comprises the principle mass of the tooth—**den·tin·al** \děn-tē′nal\ *adj;* also spelled **den·tine** \děn′tēn\

dentin porcelain *obs*: see BODY PORCELAIN

den·ti·tion \děn-tĭsh′on\ *n* (1615): the teeth in the dental arch

dentofacial orthopedics \děn′tō-fā′shal ôr′tha-pē′dĭks\: the branch of dentistry that treats abnormal jaw and tooth relationships

den·to·form \děn′tō-fôrm\: having the likeness of a tooth; a tooth-like substitute

den·tu·lous \děn′cha-lus\ *adj* (1926): **1:** possessing natural teeth **2:** a condition in which natural teeth are present in the mouth—***syn*** DENTATE

den·ture \děn′chur\ *n* (1874): an artificial substitute for missing natural teeth and adjacent tissues—*usage:* see COMPLETE D., DIAGNOSTIC D., DUPLICATE D., EXTENSION BASE REMOVABLE DENTAL PROSTHESIS., FIXED DENTAL PROSTHESIS., IMMEDIATE D., INTERIM D., OVERDENTURE, PARTIAL D., PROVISIONAL D., REMOVABLE DENTAL PROSTHESIS., ROTATIONAL PATH REMOVABLE PARTIAL D., TRANSITIONAL D., TREATMENT D., TRIAL D., UNILATERAL REMOVABLE DENTAL PROSTHESIS

denture adhesive \děn′chur ăd-hē′sĭv\: a material used to adhere a denture to the oral mucosa

denture basal surface: see DENTURE BASE

denture base \děn′chur bās\: the part of a denture that rests on the foundation tissues and to which teeth are attached—usage: see TINTED D.B.

denture base material \děn′chur bās mă-tîr′ē-al\: any substance of which a denture base may be made

denture base saddle \děn′chur bās săd′l\ *obs*: **1:** the part of a denture that rests on the oral mucosa and to which the teeth are attached **2:** the part of a complete or removable partial denture that rests on the basal seat and to which the teeth are attached (GPT-4)—see DENTURE BASE

denture bearing area: see DENTURE FOUNDATION AREA

denture border \děn′chur bôr′der\: **1:** the margin of the denture base at the junction of the polished surface and the impression surface **2:** the peripheral border of a denture base at the facial, lingual, and posterior limits

denture characterization \děn′chur kăr′ak-ter-ĭ-zā′shun\: modification of the form and color of the denture base and teeth to produce a more lifelike appearance

denture curing \děn′chur kyōōr′ing\ *obs*: the process by which the denture base materials are hardened to the form of a denture mold (GPT-4)—see DENTURE PROCESSING

denture design \děn′chur dĭ-zīn\ *obs*: a planned visualization of the form and extent of a dental prosthesis arrived at after study of all factors involved (GPT-4)

denture esthetics \děn′chur ĕs-thĕt′ĭks\: the effect produced by a dental prosthesis that affects the beauty and attractiveness of the person

denture flange \děn′chur flănj\: the part of the denture base that extends from the cervical ends of the teeth to the denture border

denture flask: see CASTING FLASK, CROWN FLASK

denture foundation \děn′chur foun-dā′shun\: the oral structures available to support a denture

denture foundation area \děn′chur foun-dā′shun âr′ē-a\: the surfaces of the oral structures available to support a denture

denture occlusal surface \děn′chur a-klōō′săl sûr′fas\: the portion of the surface of a denture that makes contact with its antagonist

denture packing \děn′chur păk′ing\ *substand*: the act of pressing a denture base material into a mold within a refractory flask- see DENTURE RESIN PACKING

denture placement: see PLACEMENT

denture polished surface \děn′chur pŏl′ĭsht\: the portion of the surface of a denture that extends in an occlusal direction from the border of the denture and includes the palatal surface. It is the part of the denture base that is usually polished, and it includes the buccal and lingual surfaces of the teeth

denture processing \děn′chur prosĕs′ing\ *substand*: **1:** the means by which the denture base materials are polymerized to the form of a denture **2:** the conversion of the wax pattern of a denture or a portion of a denture into resin or other material

denture prognosis \děn′chur prŏg-nō′sĭs\ *obs*: an opinion or judgment given in advance of treatment for the prospects for success in the fabrication of dentures and for their usefulness (GPT-4)

denture prosthetics \děn′chur prŏs-thĕt′iks\ *obs*: **1:** the replacement of the natural teeth in the arch and their associated parts by artificial

substitutes **2:** the art and science of the restoration of an edentulous mouth (GPT-4)—see COMPLETE DENTURE PROSTHODONTICS

denture resin packing \děn′chur rĕz′ĭn păk′ing**:** filling and pressing a denture base material into a mold within a refractory flask

denture retention \děn′chur rĭ-tĕn′shun**: 1:** the resistance in the movement of a denture away from its tissue foundation especially in a vertical direction **2:** a quality of a denture that holds it to the tissue foundation and/or abutment teeth—see DENTURE STABILITY

denture service \děn′chur sûr′vĭs**:** the procedures that are involved in the diagnosis and subsequent fabrication and maintenance of artificial substitutes for missing natural teeth and associated structures

denture space \děn′chur spās**: 1:** the portion of the oral cavity that is or may be occupied by the maxillary and/or mandibular denture(s) **2:** the space between and around the residual ridges that is available for dentures **3:** the area occupied by dentures where formerly the teeth, alveolar bone, and surrounding soft and hard tissues were located

denture stability \děn′chur sta-bĭl′ĭ-tē**: 1:** the resistance of a denture to movement on its tissue foundation, especially to lateral (horizontal) forces as opposed to vertical displacement (termed denture retention) **2:** a quality of a denture that permits it to maintain a state of equilibrium in relation to its tissue foundation and/or abutment teeth—see DENTURE RETENTION

denture supporting area: see DENTURE FOUNDATION AREA

denture supporting structures \děn′chur sa-pôr′tĭng strŭk′churz\ *obs***:** the tissues (teeth and/or residual ridges) that serve as the foundation for removable partial or complete dentures (GPT-4)

denture surfaces: see DENTURE POLISHED SURFACE

den·tur·ism \děn′chur-izum\ *n***:** the fabrication and delivery of removable dentures by non-dentists

den·tur·ist \děn′chur-ist\ *n* (1965)**: 1:** any non-dentist who makes, fits, and repairs removable dentures directly for the public **2:** a non-dentist licensed to provide complete dentures directly to the public

de·pas·siv·a·tion \dē-păs′sĭ-vā′shun\ *n***:** loss of corrosion protection due to damage or removal of the protective oxide surface film on a passivated metal

de·pro·gram·mer \dē-prō′grăm′er\ n**:** various types of devices or materials used to alter the proprioceptive mechanism during mandibular closure

determinants of mandibular movement \dĭ-tûr′ma-nent**:** those anatomic structures that dictate or limit the movements of the mandible. The anterior determinant of mandibular movement is the dental articulation. The posterior determinants of mandibular movement are the temporomandibular articulations and their associated structures

de·tru·sion \dē-trōō′shun\ *n***:** downward movement of the mandibular condyle

deuteranomalous vision \dōō′ter-a-nŏm′a-lus, dyōō′-ter-a-nŏm′a-lus vĭzh′on**:** a form of anomalous trichromatism in which the viewer requires more green in a mixture of red and green to match spectral yellow than does a normal trichromat. The relative spectral visual sensitivity does not differ noticeably from normal. Hue discrimination is poor in the red to green region of the spectrum

deu·ter·an·opia \dōō′ter-a-nō′pē-a, dyōō′-\ *n* (ca. 1901)**:** green color blindness

developmental anomaly \dĭ-vĕl′op-mĕn′tl a-nŏm′a-lē**:** unusual sequelae of development; a deviation from normal shape or size

developmental dysmorphia \dĭ-vĕl′op-mĕn′tl dĭs′môr′fē-a**:** anomaly of growth seemingly related to extrinsic interference from contiguous or adjacent structures

developmental dysplasia \dĭ-vĕl′op-mĕn′tl dĭs-plā′zha,-sē-a**:** any abnormality of growth or disharmony between parts due to growth

developmental hyperplasia \dĭ-vĕl′op-mĕn′tl hī′per-plā′zha**:** excessive growth development

developmental hypoplasia \dĭ-vĕl′op-mĕn′tl hī′pō-plā′zha**:** diminution in growth development

de·vest \dĭ-vĕst\ *vb***:** the retrieval of a casting or prosthesis from an investing medium

de·vi·a·tion \dē′vē-ā′shun\ *n* (15c)**:** with respect to movement of the mandible, a discursive movement that ends in the centered position and is indicative of interference during movement

de·vice \dĭ-vīs\ *n***:** something developed by the application of ideas or principles that are designed to serve a special purpose or perform a special function-see RESTORATION

de·vit·ri·fi·ca·tion \dē-vĭt′ra-fĭ-kā′shun\ *n* (1832)**:** to eliminate vitreous characteristics partly or wholly; to crystallize

di·ag·no·sis \dī′ag-nō′sis\ *n;* **di·ag·no·ses** \dī′ag-nō′sez\ *pl* (ca. 1861)**:** the determination of the nature of a disease

[1]di·ag·nos·tic \dī′ag-nŏs′tik\ *n* (1625)**:** the practice of diagnosis

[2]di·ag·nos·tic \dī′ag-nŏs′tik\ *adj* (1625)**:** relating to or used in diagnosis

diagnostic cast \dī′ag-nŏs′tik kăst**:** a life-size reproduction of a part or parts of the oral cavity and/or facial structures for the purpose of study and treatment planning

diagnostic denture \dī′ag-nŏs′tik dĕn′chur**:** an interim removable dental prosthesis placed for the purpose of evaluation and planning later therapy

diagnostic index: see PROSTHODONTIC DIAGNOSTIC INDEX

diagnostic mounting: see MOUNTING

diagnostic occlusal adjustment: an evaluation of the process and implications of subtractive tooth adjustment on articulator-mounted casts for the determination of the benefits and consequences of an occlusal adjustment

diagnostic occlusal prosthesis: a removable dental prosthesis, usually made of acrylic resin, that includes an overlay of the occlusal surfaces, designed to evaluate a patient's response to extensive restorative intervention

diagnostic radiation \dī′ag-nŏs′tik rā′dē-ā′shun**:** the use of radiographs for the determination of the nature of a disease

diagnostic setups: see TOOTH ARRANGEMENT

diagnostic splint: see OCCLUSAL DEVICE

diagnostic study cast: see DIAGNOSTIC CAST

diagnostic tooth preparation: preparations on dental casts performed to evaluate and optimize definitive tooth preparations

diagnostic waxing: waxing of intended restorative contours on dental casts for the purpose of evaluation and planning restorations

diagnostic wax up: see TOOTH ARRANGEMENT

diarthrodial joint \dī′är-thrō-dē-al\: a freely moving joint

di·ar·thro·sis \dī′är-thrō′sĭs\ *n* (1578): a specialized articulation permitting more or less free movement; a synovial joint

di·a·ste·ma \dī′a-stē′ma\ *n, pl* **-ma·ta** \-ma-ta\ (1854): a space between two adjacent teeth in the same dental arch

dia·ther·my \dī′a-thûr′mē\ *n* (1909): tissue resistance generated heat resulting from high-frequency electric current

di·a·tor·ic \dī′a-tôr′ik\ *adj*: a channel placed in denture teeth to serve as a mechanical means of retaining the teeth in a chemically dissimilar denture base material

dichromatic vision \dī′krō-măt′ĭk vĭzh′en\: defective color vision characterized by the interpretation of wavelengths from the red portion of the spectrum matching a given green. There are two known sub classifications. One requires red light to be approximately 10 times brighter than the red selected by the other to achieve a similar color mismatch

di·chro·ma·tism \dī-krō′ma-tĭz′um\ *n* (1884): a form of defective color vision in which a mixture of only two can match all colors. In dichromatic vision, the spectrum is seen as comprising only two regions of different hue separated by an achromatic band. Dichromatic vision can be subdivided into three types: protanopia, deuteranopia, and tritanopia

die \dī\ *n* (14c): the positive reproduction of the form of a prepared tooth in any suitable substance

die spacer \dī spās′er\: an agent applied to a die to provide space for the luting agent in the finished casting

differential diagnosis \dĭf′a-rĕn′shal dī′ag-nō′sĭs\: the process of identifying a condition by comparing the signs and symptoms of all pathologic processes that may produce similar signs and symptoms

dilaceration \dĭl-ăs′a-rā′shun\: **1:** a tearing apart **2:** in dentistry, a condition due to injury of a tooth during its development and characterized by a band or crease at the junction of the crown and root, or alternatively by tortuous roots with abnormal curvatures

dimensional stability \dī-mĕn′shun-l stabĭl′ĭ-tē\: the ability of a material to retain its size and form

dimensions of color \dĭ-mĕn′shunz ŭv kŭl′er\: terms used to describe the three dimensional nature of color. In the Munsell Color Order System, the dimensions are named hue, value, and chroma. These are used to describe the color family (hue), the lightness/darkness (value), and the purity or strength (chroma)

direct bone impression \dĭ-rĕkt, dī- bōn ĭm-prĕsh′on\: a negative likeness of bone from which overlying tissues have been reflected

direct lift technique: a means of fabricating porcelain labial margins where by porcelain is condensed directly onto the die—*comp* PORCELAIN WAX TECHNIQUE

direct pulp capping \dĭ-rĕkt, dī- pŭlp kăp′ing\: application of a material to exposed vital pulp to protect it and promote healing

direct retainer \dĭ-rĕkt, dī- rĭ-tā′ner\: that component of a partial removable dental prosthesis used to retain and prevent dislodgment, consisting of a clasp assembly or precision attachment

direct retention \dĭ-rĕkt, dī- rĭ-tĕn′shun\: retention obtained in a partial removable dental prosthesis by the use of clasps or attachments that resist removal from the abutment teeth

dis·ar·tic·u·la·tion \dĭs′är-tĭk′ya-lā′shun\ *n*: separation of joint parts

disc \dĭsk\ *n*: var. spelling of disk

disk-condyle complex \dĭsk-kŏn′dīl, -dl kŏm′plĕks′\: the condyle and its disk articulation that functions as a simple hinge joint

disk \dĭsk\ *n* (1664): with respect to the temporomandibular joint, the avascular intraarticular tissue—spelled also *disc*

disk degeneration \dĭsk dĭ-jĕn′a-rā′shun\: degenerative changes in the temporomandibular joint articular disk

disk derangement \dĭsk dĭ-rānj′ment\: an abnormal relationship of the articular disk to the condyle, fossa, and or/and eminence

disk detachment: a peripheral separation of the disk from its capsular, ligamentous, or osseous attachments

disk dislocation: see DISK DERANGEMENT

disk displacement: see DISK DERANGEMENT

disk displacement with reduction \dĭsk dĭs-plās′ment wĭth rĭ-dŭk′shun\: disk displacement in which the temporomandibular joint disk is displaced at rest (usually in an anterior-medial direction) but resumes a normal position on mandibular movement, usually accompanied by a clicking sound

disk displacement without reduction \dĭsk dĭs-plās′ment wĭth-out rĭ-dŭk′shun\: disk displacement in which the temporomandibular joint disk is displaced at rest and does not resume a normal position on mandibular movement—see CLOSED LOCK

disk interference \dĭsk ĭn′ter-fĭr′ens\: interference with mandibular movement due to disk related pathosis and/or dysfunction

disk locking \dĭsk lŏk′ing\: disk derangement that will not reduce or restore to its normal place or relationship

disk perforation \dĭsk pûr′fa-rā′shun\: a circumscribed tear in the articular disk, generally as the result of degenerative thinning in the central portion, usually with longstanding increased compressive forces, permitting communication between the superior and inferior joint spaces. There is no disruption at the peripheral attachments to the capsule, ligaments, or bone

disk prolapse \dĭsk prō-lăps\: rotation of the disk forward on the condyle

disk space \dĭsk spās\: the radiolucent area on a temporomandibular joint radiograph between the mandibular condyle and the articular fossa

disk thinning \dĭsk thĭn′ing\: degenerative decrease in disk thickness, usually as the result of long standing increased compressive forces

diskectomy: excision of the intraarticular disk

dis·clu·sion *vb*: see DISOCCLUSION

dis·junc·tor \dĭs-jŭngk′tor\ *n*: any component of a prosthesis that serves to allow movement between two or more parts

dislocated fracture \dĭs′lō-kā′tĭd frăk′chur\: a fracture of a bone near an articulation, with displacement of the condyloid process out of the articular fossa

dis·lo·ca·tion \dĭs′lō-kā′shun\ *n* (15c): the state or act of being dislocated, as displacement of one or more bones at a joint—*usage:* see CONDYLAR D., FUNCTIONAL D., MANDIBULAR D., PARTIAL D.

dis·oc·clude: see DISOCCLUSION

dis·oc·clu·sion \dĭs′a-klōō′zhen\ *vb*: separation of opposing teeth during eccentric movements of the mandible—see DELAYED D., IMMEDIATE D.

displacement of the mandible \dĭs-plās′ment ŭv tha măn′da-bl**:** any abnormal relationship of the mandible when at rest

dis·tal \dĭs′tal\ *adj* (1808)**:** remote; farther from the point of reference; away from the median sagittal plane of the face following the curvature of the dental arch

distal extension partial denture: see EXTENSION BASE PARTIAL REMOVABLE DENTAL PROSTHESIS

dis·to·c·clus·sion: see ANGLE'S CLASSIFICATION OF OCCLUSION

dis·to·ver·sion \dĭs′tō-vûr′zhun\ *vb***:** a deviation towards the distal

distraction of the condyle \dĭ-străk′shun ŭv tha kŏn′dīl, -dl**:** displacement of the condyle in and inferior direction

distraction osteogenesis: a procedure whereby a segment of the jaw is sectioned by osteotomy and gradually displaced by a controlled movement

distributed mandibular lateral translation: see PROGRESSIVE MANDIBULAR LATERAL TRANSLATION

disuse atrophy \dĭs-yōōs′ ăt′ra-fē**:** diminution in the size of a cell, tissue, organ, or part as a result of inactivity

di·ver·gence \dĭ-vûr′jens, dī-\ *n* (1656)**: 1:** a drawing apart as a surface extends away from a common point **2:** the reverse taper of walls of a preparation for a restoration—**di·ver·gen·cy** \dĭ-vûr′jen-sē\ *n, pl* **-cies** \-cēz\ (1709)

divergence angle \dĭ-vûr′jens ăng′gl\ (1998)**:** the sum of the angles of taper of opposing walls of a tooth preparation that diverge away from each other

docking device: see RADIATION CONE LOCATOR

Dolder bar [Eugene J. Dolder, Zurich, Switzerland prosthodontist]**:** *eponym* for one of many bar attachments that splint teeth or roots together while acting as an abutment for a partial removable dental prosthesis. The bar is straight with parallel sides and a round top. The sleeve or clip that fits over the bar gains retention by friction only. The bar may be of variable size and is pear shaped in cross section, as is its accompanying sleeve. This clip allows for some measure of rotational movement about the bar

Dolder EJ. The bar joint mandibular denture. J PROSTHET DENT 1961;11: 689-707.

donor site \dō′ner sīt**:** an area of the body from which a graft is taken

double lip: hyperplasia of the mucosa of the upper lip producing a fold of tissue that gives the appearance of duplication of the lip

double wire clasp \dŭb′al wīr klăsp\ *obs***:** a back-to-back wire circumferential clasp

dove·tail \dŭv′tāl′\ *n* (1565)**:** a widened portion of a prepared cavity used to increase retention and/or resistance

dow·el \dou′al\ *n, obs* (13c)**:** a post usually made of metal that is fitted into a prepared root canal of a natural tooth. When combined with an artificial crown or core, it provides retention and resistance for the restoration_ see POST AND CORE CROWN

dowel core crown: see POST AND CORE CROWN

dowel crown *obs***:** see DAVIS CROWN, RICHMOND CROWN

dowel pin \dou′al pĭn**:** a metal pin used in stone casts to remove die sections and replace them accurately in the original position

drag \drăg\ *n***:** the lower or cast side of a refractory flask to which the cope is fitted

draw \drô\ *vt* (bef. 12c)**:** the taper or convergence of walls of a preparation for a restoration; *slang*—DRAFT, DRAUGHT

dross \drŏs, drôs\ *n***: 1.** the solid scum formed on the surface of a metal when molten or melted, often formed from oxides of various metals but sometimes arising from impurities and waste materials, **2.** waste matter; refuge

duc·til·i·ty \dŭk-tĭl′ĭ-tē\ *n* (14c)**:** the ability of a material to withstand permanent deformation under a tensile load without rupture; ability of a material to be plastically strained in tension. A material is brittle if it does not have appreciable plastic deformation in tension before rupture

dum·my \dŭm′ē\ *n, pl* **dum·mies** \dŭm′ēz\ (1598) *obs***:** the replacement tooth or pontic in a fixed partial denture

duplicate denture \dōō′plĭ-kĭt dĕn′chur**:** a second denture intended to be a replica of the first

du·rom·e·ter \dōō′rŏm-ĭ-ter\ *n* (ca. 1890)**:** an instrument for measuring hardness

dwt: *abbr* [*denarius* + *weight*] pennyweight; called also *pennyweight*; a measurement of weight in the troy system equal to 24 grains, or 0.05 ounce. Its metric equivalent is 1.555 grams

dye \dī\ *n***:** a colorant that does not scatter light but absorbs certain wavelengths and transmits others

dynamic relations \dī-năm′ĭk rĭ-lā′shunz\ *obs***:** relations of two objects involving the element of relative movement of one object to another, as the relationship of the mandible to the maxillae (GPT-4)

dynamic splint: see FUNCTIONAL OCCLUSAL SPLINT

dys·es·the·sia \dĭs-ĕs-thē′zha, -zhē-a, ĭs-\ *n***:** an unpleasant abnormal sensation

dys·func·tion \dĭs-fŭngk′shun\ *n* (ca. 1916)**:** the presence of functional disharmony between the morphologic form (teeth, occlusion, bones, joints) and function (muscles, nerves) that may result in pathologic changes in the tissues or produce a functional disturbance

dys·geu·sia \dĭs-gyōō′zha, -zhē-a\ *n***:** any disturbance in the sense of taste

dys·ki·nes·ia \dĭs-kĭn′ĭs-zha, -ahē-a\ *n* (ca. 1706)**:** impairment of the power of voluntary movement resulting in fragmentary or incomplete movement—see also INCOORDINATION

dys·la·lia \dĭs-lā′lē-a\ *n***:** defective articulation due to faulty learning or to abnormality of the external speech organs and not due to lesions of the central nervous system

dys·ma·se·sis \dĭs-măs′ĭ-sĭs\ *n***:** difficulty in mastication

dys·os·to·sis \dĭs-ŏs′ta-sĭs\ *n***:** imperfect ossification

dysphagia \dĭs-plā′zha\ *n***:** difficulty in swallowing

dys·phon·ia \dĭs-fō′nē-a\ *n* (ca. 1706)**:** impairment in the voice; difficulty in speaking

dys·pla·sia \dĭs-plā′zha\ *n* (ca. 1923)**:** abnormality of development—see MANDIBULAR D., MAXILLOMANDIBULAR D.

dys·ton·ia \dĭs-tōn′ya\ *n***:** acute irregular tonic muscular spasms, often with contortions of the tongue, jaw, eyes, neck, and sometimes the entire body

E

earbow \îr-bō\ *n* (20c)**:** an instrument similar to a facebow that indexes to the external auditory meatus and registers the relation of the maxillary dental arch to the external auditory meatus and a horizontal reference plane. This instrument is used to transfer the maxillary cast to the articulator. The earbow

provides an average anatomic dimension between the external auditory meatus and the horizontal axis of the mandible—see FACEBOW

early closing click \ûr′lē klōs′ing klĭk\: a click emanating from the temporomandibular joint that occurs at the initiation of retrusive translation

early mandibular lateral translation \ûr′lē măn-dĭb′ya-lar\: the translatory portion of lateral movement in which the greatest portion occurs early in the forward movement of the nonworking side condyle as it leaves centric relation—see IMMEDIATE MANDIBULAR LATERAL TRANSLATION

early opening click \ûr′lē ō′pen-ing klĭk\: a temporomandibular joint click that occurs at initiation of the translation of the condyle(s)

EBA cement: *acronym* for *e*th oxy*b*enzoic *a*cid cement; reinforced zinc oxide-eugenol cement with part of the eugenol replaced by 2-ethoxybenzoic acid

eccentric \ĭk-sĕn′trĭk\ *adj* (14c): **1:** not having the same center **2:** deviating from a circular path **3:** located elsewhere than at the geometric center **4:** any position of the mandible other than that which is its normal position

eccentric checkbite: see ECCENTRIC INTEROCCLUSAL RECORD

eccentric interocclusal record \ĭk-sĕn′trĭk ĭn′ter-a-klōō′sal rĕk′erd\: a registration of any maxillomandibular position other than centric relationship

eccentric jaw record: see ECCENTRIC INTEROCCLUSAL RECORD

eccentric jaw relation \ĭk-sĕn′trĭk jô rĭ-lā′shun\ *obs*: any relationship between the jaws other than centric relation (GPT-4)

eccentric occlusion \ĭk-sĕn′trĭk a-klōō′shun\: an occlusion other than centric occlusion

eccentric position: see ECCENTRIC RELATION

eccentric record: see ECCENTRIC INTEROCCLUSAL RECORD

eccentric relation \ĭk-sĕn′trik rĭ-lā′shun\: any relationship of the mandible to the maxilla other than centric relation—see ACQUIRED E.R.

ec·top·ic \ĕk-tŏp′ĭk\ *adj* (1873): occurring in an abnormal position or in an unusual manner or form—**ec·top·i·cal·ly** \ĕk-tŏ′pĭk-lē\ *adv*

ectopic eruption \ĕk-tŏp′ik ĭ-rŭp′shun\: eruption of a tooth out of its normal place or position

ede·ma \ĭ-dē′ma\ *n* (15c): abnormal accumulation of fluid in the tissues

eden·tics \ē-dĕn′tiks\ *n, obs*: the art, science, and technique used in treating edentulous patients (GPT-4)

e·den·tu·late \ē-dĕn′cha-lāt\ *v, obs*: to remove all teeth

e·den·tu·lous \ē-dĕn′cha-lus\ *adj* (1782): without teeth, lacking teeth

edentulism \ē-dĕn′cha-lĭz-um\ (1998): the state of being edentulous; without natural teeth

edge to edge articulation \ĕj tōō ĕj är-tĭk′ya-lā′shun\: articulation in which the opposing anterior teeth meet along their incisal edges when the teeth are in maximum intercuspation

edge to edge bite: see EDGE TO EDGE ARTICULATION

edge to edge occlusion: see EDGE TO EDGE ARTICULATION

educationally qualified prosthodontist \ĕj′a-kā′shun-a-lē kwŏl′a-fīd prŏs′tha-dŏn′tĭst\: in the United States as defined by the American Board of Prosthodontics, a prosthodontist who has successfully completed an advanced educational program accredited by the ADA and is eligible to apply for examination by the American Board of Prosthodontics

e·las·tic \ĭ-lăs′tĭk\ *adj* (1653): susceptible to being stretched, compressed, or distorted and then tending to resume the original shape

elastic limit \ĭ-lăs′tĭk lĭm′it\: the greatest stress to which a material may be subjected and still be capable of returning to its original dimensions when such forces are released

elastic modulus \ĭ-lăs′tĭk mŏj′a-lus\: the stiffness or flexibility of a material within the elastic range. Within the elastic range, the material deforms in direct proportion to the stress applied as represented by Hooke's law

e·las·tic·i·ty \ĭ-lă-stĭs′ĭ-tē\ *n* (1664): the quality that allows a structure or material to return to its original form on removal of an external force—see MODULUS OF E.

e·las·to·mer \ĭ-lăs′ta-mer\ *n* (ca. 1934): a polymer whose glass transition temperature is below its service temperature (usually room temperature). These materials are characterized by low stiffness and extremely large elastic strains—**e·las·to·mer·ic** *adj*

elastomeric impression material: a group of flexible chemical polymers, which are either chemically or physically cross-linked. Generally, they can be easily stretched and rapidly recover their original dimensions when applied stresses are released

electrical discharge machining \ĭ-lĕk′trĭ-kal dĭs-chärj ma-shēn′ing\: **1.** the process by which metal(s) is (are) altered in form using electrical current through conductive objects brought into physical contact with the metal surface **2.** a precision metal removal process using an accurately controlled electrical discharge (a spark) to erode metal, usually performed in a liquid dielectric medium—***syn*** SPARK EROSION

e·lec·trode \ĭ-lĕk′trōd\ *n* (1834): **1:** a medium used between an electric conductor and the object to which it is to be applied **2:** an x-ray tube component from which electrons emanate or to which they are attracted. The positive electrode is the anode; the negative electrode is the cathode

electromagnetic spectrum \ĭ-lĕk′trō-măg-nĕt′ĭk spĕk′trŭm\: the range of energy waves that extend from gamma rays to radio waves. The eye is sensitive to a very narrow band of wavelengths between about 380 and 760 nm

electromagnetic wave \ĭ-lĕk′trō-măg-nĕt′ĭk wāv\: a disturbance that propagates outward from any electric charge that oscillates or is accelerated; far from the charge, it consists of vibrating electric and magnetic fields that move at the speed of light and are at right angles to each other and to the direction of motion

electromyographic biofeedback \ĭ-lĕk-trō-mī-ŏ′gra-fĭk bī′ō-fēd′băk\: an instrumental process that helps patients learn control over muscle tension levels previously under automatic control

e·lec·tro·my·og·ra·phy \ĭ-lĕk′trō-mī-ŏg′ra-fē\ *n* (1948): the graphic recording of the electrical potential of muscle—see NOCTURNAL E.

e·lec·tron \ĭ-lĕk′trŏn\ *n* (1891): the elemental unit of electricity. A stable elementary particle that is the negatively charged constituent of ordinary matter, having a mass of about 9.11 x 10^{-28} g (equivalent to 0.511 MeV) and a charge of about –1.602 x 10^{-19} Coulomb—called also *negative electron, negatron*

electron accelerator \ĭ-lĕk′trŏn ăk-sĕl′a-rā′ter\: a device used in radiation treatment that accelerates electrons to high energies

electron beam therapy \ĭ-lĕk′trŏn bēm thĕr′a-pē\: treatment by electrons accelerated to high energies by a machine such as the betatron

electron volt \ĭ-lĕk′trŏn vōlt\: a unit of energy equal to the energy acquired by an electron when it passes through a potential difference of 1 volt in a vacuum; it is equal to (1.602192 + 0.000007)x 10^{-19} volt. Abbreviated *eV*

e·lec·tro·plat·ing \ĭ-lĕk′tro-plā′tĭng\ *vt* (ca. 1864): the process of covering the surface of an object with a thin coating of metal by means of electrolysis

e·lec·tro·pol·ish·ing \ĭ-lĕk′trō-pŏl′ĭsh-ĭng\ *vt*: the electrolytic removal of a thin layer of metal to produce a bright surface

el·e·ments *slang* \ĕl′a-ment\ (1993): when used in reference to dental implants, component parts of a dental implant structure such as the dental implant, dental implant abutment, and abutment screw

elevator muscle \ĕl′a-vā′ter mŭs′el\: one of the musclăes that, on contracting, elevates or closes the mandible

e·lon·ga·tion \ĭ-lông′gā′shun\ *n* (14c): **1:** deformation as a result of tensile force application **2:** the degree to which a material will stretch before breaking **3:** the over eruption of a tooth

em·bed·ment \ĕm-bĕd-ment\ *n* (1794): 1. the process of using a ceramic powder mixed with water to surround a glass-ceramic casting. The purpose of the procedure is to prevent distortion and limit the shrinkage of the casting 2. with reference to the physics of threaded unions, localized plastic deformation which occurs in screw threads or the mated components when applying preload.

em·bou·chure \äm′bōō-shōōr\ *n* (1760): the position and use of the lips, tongue, and teeth in playing a wind instrument

em·bra·sure \ĕm-brā′zher\ *n* (1702): **1:** the space formed when adjacent surfaces flair away from one another **2:** in dentistry, the space defined by surfaces of two adjacent teeth; there are four embrasure spaces associated with each proximal contact area: occlusal/incisal, buccal, lingual, and gingival

em·brittle \ĕm-brĭt′l\ *vt*: to make brittle or plastic

emergence angle \ĭ-mûr′jens ăng′gel\ (1993): the angle of the dental implants' transitional contour as determined by the relation of the surface of the abutment to the long axis of the implant body

emergence profile \ĭ-mûr′jens prō′fīl\: the contour of a tooth or restoration, such as a crown on a natural tooth or dental implant abutment, as it relates to the adjacent tissues

EMG: *acronym* for *ElectroMyoGram*

em·i·nence \ĕm′i-nens\ *n* (15c): a prominence or projection, especially one on the surface of a bone

empty mouth movement \ĕmp′tē mouth mōōv′ment\: voluntary or reflex movements of the mandible when not engaged in incision or mastication

en·am·el \ĭ-năm′el\ *n* (15c): in dentistry, the hard, thin, translucent layer of calcified substance that envelopes and protects the dentin of the coronal aspect of the tooth; it is the hardest substance in the body—called also adamantine layer

enamel projection: an apical extension of enamel, usually toward a furcation in the roots

enamel projection \ĭ-năm′el pro-jĕk′shun\: An apical extension of enamel, usually toward a furcation in the roots

en·am·el·o·plas·ty *n*: see OCCLUSAL RESHAPING

en·ar·thro·sis \ĕn′ăr-thrō′sĭs\ *n* (1634): joints with a ball and socket arrangement (e.g., hip)

endodontic implants: see ENDODONTIC ENDOSTEAL DENTAL IMPLANT

endodontic endosteal dental implant \ĕn′dō-dŏn′tĭks ĕn-dŏs′tē-l dĕn′tl ĭm-plănt′\: a smooth and/or threaded pin implant that extends through the root canal of a tooth into periapical bone and is used to stabilize a mobile tooth, sometimes called an *endodontic stabilizer*

endodontic pin \ĕn′dō-dŏn′tĭk pĭn\ *obs*: a metal pin that is placed through the apex of a natural tooth into the bone to stabilize a mobile tooth (GPT-4)—see ENDODONTIC ENDOSTEAL DENTAL IMPLANT

endodontic stabilizer: see ENDODONTIC ENDOSTEAL DENTAL IMPLANT

en·dog·en·ous \ĕn-dŏj′a-nus\ *adj* (1830): developing or originating within the organism

en·do·scope \ĕn′da-skōp\ *n* (1861): a flexible or rigid thin tube used for examining the interior of a structure

endosseous blade implant: see BLADE ENDOSTEAL DENTAL IMPLANT

endosseous implant: see ENDOSTEAL DENTAL IMPLANT

endosteal dental implant \ĕn-dŏs′tē-l dĕn′tl ĭm-plănt′\: a device placed into the alveolar and/or basal bone of the mandible or maxilla and transecting only one cortical plate. The endosteal dental implant is composed of an anchorage component, termed the *endosteal dental implant*, which, ideally, is within the bone, and a retentive component, termed the *endosteal dental implant abutment*. The dental implant abutment connects to the dental implant (by means of screws, thread/screw interfacing, compression/luting agent etc. that can be termed *elements*), passes through the oral mucosa, and serves to support and/or retain the prosthesis (fixed dental prosthesis, removable dental prosthesis, maxillofacial prosthesis). The dental implant abutment may be for *interim* or *definitive* application—*usage:* interim abutment, definitive abutment. Descriptions of the dental implant or/and the dental implant abutment that use silhouette or geometric forms, such as cylinder, conical, pre-angled, angled, blade, basket, or endodontic, may be used as adjectives to enhance understanding of the geometry of any endosteal dental implant. Also, descriptive adjectives may be used to delineate the materials from which they are made, i.e. a *ceramic* dental implant abutment. *Interim* or *definitive dental implant abutments* may be composed of one or more individual component parts, each of which is termed an *element*. The dental implant abutment element(s) usually is (are) described by means of their geometric form, function or means of adaptation, i.e., screw, coping, cylinder, lug, friction fitting, press-fit. Hence multiple adjectives may be used to describe both the endosteal dental implant and abutment.—see also BASKET E.D.I., BLADE E.D.I., DENTAL IMPLANT, ENDODONTIC E.D.I., EPOSTEAL D.I., SCREW E.D.I., TRANSOSTEAL D.I.

endosteal dental implant (1998): that portion of the dental implant that provides the anchorage to the bone through the process of tissue integration

endosteal dental implant abutment \ĕn-dŏs′tē-l dĕn′tl ĭm-plănt′ a-bŭt′ment\ (1998): that portion of the dental implant which passes through the oral mucosa and provides connection between the endosteal dental implant body and the prosthesis

endosteal dental implant abutment element (s) \ĕn-dŏs′tē-l dĕn-tl ĭm-plănt a-bŭt′ment ĕl′a-ment\ (1998): any component used to secure either the dental implant abutment to the dental implant or the prosthesis to the dental implant abutment

endosteal dental implant \ĕn-dŏs′tē-l dĕn′tl ĭm-plănt′\ (1998) that portion of the dental implant that provides the anchorage to the bone through the process of tissue integration

end-to-end bite: see EDGE TO EDGE ARTICULATION

end-to-end occlusion: see EDGE TO EDGE ARTICULATION

entrance port \ĕn′trăns port\: the area of the surface of a patient or phantom on which a radiation beam is incident

envelope of function \ĕn′va-lōp ŭv fŭngk′shun\: the three-dimensional space contained within the envelope of motion that defines mandibular movement during masticatory function and/or phonation

envelope of motion \ĕn′va-lōp ŭv mō′shun\: the three-dimensional space circumscribed by mandibular border movements within which all unstrained mandibular movement occurs

epithelial attachment: see JUNCTIONAL EPITHELIUM

epithelial cuff \ĕp′a-thē′lē-al kŭf\: a term used to describe the relationship between the mucosal and the dental implant. The use of this term implies a close adherence, but not necessarily a biochemical attachment, between the implant and mucosa

ep·i·the·li·um \ĕp′a-thē′-lē-um\ *n, pl* **-lia** \-lē-a\ (1748): the mucosal tissue serving as the lining of the intraoral surfaces. It extends into the gingival crevice and adheres to the tooth at the base of the crevice–see CREVICULAR E, JUNCTIONAL E.

ep·i·the·li·za·tion \ĕp′a-thē′lĭ-zā′shun\ *n* (ca. 1934): the process of becoming covered with or converted to epithelium–**ep·i·the·lize** \ĕp′a-thē′līz\ *vt*

eposteal dental implant \ĕp′ŏs′tē-al dĕn′tl ĭm-plănt′\: any dental implant that receives its primary support by means of resting upon the bone–*usage:* a subperiosteal dental implant that conforms to the superior surface of an edentulous area of alveolar bone is an *eposteal dental implant.* Any retaining screws or other *elements* that may secure the *eposteal framework* to the alveolar bone and pass through the bone represent endosteal dental implant components. Should the eposteal framework penetrate the alveolar bone, technically, the framework becomes an *endosteal dental implant*–*usage:* an eposteal dental implants' support system has, heretofore, been termed the *implant frame, implant framework,* or *implant substructure;* however, this is an integral component of that dental implants' form and is not subservient to any other component–see ENDOSTEAL DENTAL IMPLANT, SUBPERIOSTEAL DENTAL IMPLANT, TRANSOSTEAL DENTAL IMPLANT

epoxy resin \ĕp′ŏk′sē, ĭ-pŏk′- rĕz′ĭn\: a resin characterized by the reactive epoxy or ethyloxyline groups that possess unique characteristics in terms of adhesion to metals, woods, and glasses

epoxy resin die \ĕp′ŏk′sē, ĭ-pŏk′- rĕz′ĭn dī\: a reproduction formed in epoxy resin

epulis fissuratum: overgrowth of intraoral tissue resulting from chronic irritation

equalization of pressure \ĭ-kwĭl′a-zā′shun ŭv prĕsh′ur\: the act of equalizing or evenly distributing pressure

equil·i·brate \ĭ-kwĭl′a-brāt\ *v* **-brat·ed** \-brā′tĭd\ ; **-brat·ing** \-brā′tĭng\ *vt* (1635): to bring or to place in equilibrium

equil·i·bra·tion \ĭ-kwĭl′a-brā′shun\ *n* (1635): **1:** the act or acts of placing a body in a state of equilibrium **2:** the state or condition of being in equilibrium–*usage:* see MANDIBULAR E., OCCLUSAL E.

equil·i·bra·tor \ĭ-kwĭl′a-brā′tor\ *n* (19c) *obs*: an instrument or device used in achieving or helping maintain a state of equilibrium (GPT-4)

equi·lib·ri·um \ē′kwa-lĭb′rē-um, ĕk′wa-\ (1608): **1:** a state of even adjustment between opposing forces **2:** that state or condition of a body in which any forces acting on it are so arranged that their product at every point is zero **3:** a balance between active forces and negative resistance

e·ro·sion \ĭ-rō′zhun\ *n* (1541): **1:** an eating away; a type of ulceration **2:** in dentistry, the progressive loss of tooth substance by chemical processes that do not involve bacterial action producing defects that are sharply defined, wedge-shaped depressions often in facial and cervical areas–*comp* ABFRACTION, ABRASION, ATTRITION

Essig splint [Norman S. Essig, DDS, Prof. of Prosthodontics, Temple University School of Dentistry]: *eponym* for a stainless steel wire passed labially and lingually around a segment of the dental arch and held in position by individual ligature wires around the contact areas of the teeth; it is used to stabilize fractured or repositioned teeth and the involved alveolar bone. Variously ascribed to V. H. Jackson, DDS, (N.Y.), C. J. Essig, DDS, N. S. Essig, DDS (Pa.), or W. H. Atkinson, DDS

Essig CJ, ed. The American textbook of prosthetic dentistry. Philadelphia: Lea Brothers and Co., 1896:187, 208.

Essig NS. Prosthetic dentistry. Brooklyn: Dental Items of Interest Publishing Co., 1937.

es·thet·ic \ĕs-thĕt′ĭk\: **1:** pertaining to the study of beauty and the sense of beautiful. Descriptive of a specific creation that results from such study; objectifies beauty and attractiveness, and elicits pleasure **2:** pertaining to sensation *var of* AESTHETIC

esthetic reshaping \ĕs-thĕt′ĭk rē-shāp′ĭng\: the physical modification of the surfaces of teeth to improve appearance

es·thet·ics \ĕs-thĕt′ĭks\ *adj* (1798): **1:** the branch of philosophy dealing with beauty **2:** in dentistry, the theory and philosophy that deal with beauty and the beautiful, especially with respect to the appearance of a dental restoration, as achieved through its form and/or color. Those subjective and objective elements and principles underlying the beauty and attractiveness of an object, design or principle–see DENTAL E., DENTURE E.–**aes·thet·i·cal·ly** *adj*

Estlander's operation [Jakob August Estlander, Finnish surgeon, 1831-1881]: *eponym* for a lip switch operation. A triangular flap of tissue borrowed from the lower lip is transferred to the upper lateral lip

[1]etch \ĕch\ *vb,vt* (1634): **Ia** to produce a retentive surface, especially on glass or metal, by the corrosive action of an acid

lb: to subject to such etching **2:** to delineate or impress clearly

[2]etch \ĕch\ *n* (1896)**: 1:** the effect or action of an etching acid on a surface **2:** a chemical agent used in etching

etch·ant \ĕch′ănt\ *n***:** an agent that is capable of etching a surface

etch·ing \ĕch′ing\ *vt* (1632)**: 1:** the act or process of selective dissolution **2:** in dentistry, the selective dissolution of the surface of tooth enamel, metal, or porcelain through the use of acids or other agents (etchants) to create a retentive surface

ethylene oxide \ĕth′a-lēn ŏk′sīd′**:** a bactericidal agent occurring as a colorless gas with a pleasant ethereal odor; the chemical in gas sterilization systems used for many items that cannot be sterilized in a high heat system; used as a disinfectant, especially for disposable equipment

etiologic factors \ē′tē-ō-lŏj′ĭk făk′tors**:** the elements or influences that can be assigned as the cause or reason for a disease or lesion—see LOCAL E.F., SYSTEMIC E.F.

e·ti·ol·o·gy \ē′tē-ŏl′a-jē\ *n* (1555)**: 1:** the factors implicated in the cause or origin of a disease or disorder **2:** the study or theory of the factors causing disease

e·vis·cer·a·tion \ĭ-vĭs′a-rā′shun\ *n***:** removal of the viscera or contents of a cavity. In ophthalmology, the removal of the contents of the eyeball, leaving the sclera

e·vul·sion \ĭ-vŭl′shun\ *n* (1611)**:** extraction; removed, usually of a sudden nature

ex·am·in·a·tion \ĭg-zăm′a-nā′shun\ *n* (14c)**:** scrutiny or investigation for the purpose of making a diagnosis or assessment

excoriate \ex-skor-ee-ayt**:** to wear off the skin; to abrade

excoriation\: a scratch or abrasion of the skin

ex·cur·sion \ĭk-skûr′shun\ *n* (1577)**: 1:** a movement outward and back or from a mean position or axis; also, the distance traversed **2:** in dentistry, the movement occurring when the mandible moves away from maximum intercuspation

ex·cur·sive \ĭk-skûr′sĭv\ *adj* (1673)**:** constituting a digression; characterized by digression

excursive movement \ĭk-skûr′sĭv mōōv′ment**:** movement occurring when the mandible moves away from maximum intercuspation

ex·en·ter·a·tion \ĭk-zĕn′ta-rā′shun\ *n***:** removal of an organ. Used in connection with the eye, an *orbital exenteration* denotes the removal of the entire eye and surrounding structures

exercise prosthesis \ĕk′ser-sīz′ prŏth′ĭ-sĭs**:** a temporary, removable dental prosthesis, usually without teeth and always without occluding contact, used for the purpose of reconditioning the supporting structures (especially the residual ridge) by means of light, intermittent biting pressure applied against bilaterally interposed fingers

exostosis: bony projection extending beyond the normal contour of a bony surface

expansion prosthesis \ĭk-spăn′shun prŏth′ĭ-sĭs**:** a maxillofacial prosthesis used to expand the lateral segment of the maxilla in a unilateral or bilateral cleft of the soft and hard palates and alveolar processes

ex·po·sure \ĭk-spō′zher\ *n* (1606)**: 1:** the act of laying open, as a surgical or dental exposure **2:** in radiology, a measure of the roentgen rays or gamma radiation at a certain place based on its ability to cause ionization. The unit of exposure is the roentgen, called also exposure dose—see ROENTGEN RAY

ex·ten·sion \ĭk-stĕn′shun\ *n* (15c)**: 1:** the movement by which the two elements of any jointed part are drawn away from each other, the process of increasing the angle between two skeletal levers having end-to-end articulation with each other. The opposite of flexion **2:** in maxillofacial prosthetics, that portion of a prosthesis added to fill a defect or provide a function not inherent in a dental restoration, e.g., palatal extension, pharyngeal extension—see SECTION

extension base partial removable dental prosthesis \ĭk-stĕn′shun bās pär′shal rĭ-mōō′va-bal dĕn′tl prŏs-thē′sĭs**:** a removable dental prosthesis that is supported and retained by natural teeth only at one end of the denture base segment and in which a portion of the functional load is carried by the residual ridge

extension bridge: see CANTILEVER FIXED DENTAL PROSTHESIS

extension outline \ĭk-stĕn′shun out′līn\ *obs***: 1:** the outline of the area of the entire basal seat of a denture **2:** the outline on the surface of a cast or mucous membrane that includes the entire area to be covered by a denture (GPT-1)

external oblique ridge \ĭk-stûr′nal ō-blēk′ rĭj**:** a smooth ridge on the buccal surface of the body of the mandible that extends from the anterior border of the ramus, with diminishing prominence, downward and forward to the region of the mental foremen. This ridge changes very little in size and direction throughout life

ex·tir·pate \ĕk′stir-pāt′\ *vt.* **-pat·ed** \-pā′tĭd\ **-pat·ing** \-pā′tĭng\ (1539)**:1.** To pull up or out, to destroy completely. **2.** To cut out by surgery.—**ex·tir·pa·tion** \ĕk′stir-pā′shun\ *n.*

extracapsular ankylosis \ĕk′stra-kăp′sa-lar ăng′ka-lō′sĭs**:** ankylosis due to rigidity of any structure external to the joint capsule

extracapsular disorder \ĕk′stra-kăp′sa-lar dĭs-ôr′der**:** a problem associated with the masticatory system in which the etiological factors are located outside of the temporomandibular joint capsule

ex·tra·coro·nal \ĕk′stra-kôr′a-nal, kŏr′-, ka-rō′nal\ *adj***:** that which is outside or external to, the crown portion of a natural tooth; e.g., an extracoronal preparation, restoration, partial or complete crown

extracoronal attachment: any prefabricated attachment for support and retention of a removable dental prosthesis. The male and female components are positioned outside the normal contour of the abutment tooth—*see* INTRACORONAL ATTACHMENT, PRECISION ATTACHMENT

extracoronal retainer \ĕk′stra-kôr′a-nal, kŏr′-, ka-rō′nal rĭ-tā′ner**:** that part of a fixed dental prosthesis uniting the abutment to the other elements of a prosthesis that surrounds all or part of the prepared crown

extraoral tracing \ĕk′stra-ôr′al, ōr′-trā′sĭng**:** a tracing of mandibular movements made by means of devices that extend outside the oral cavity; a tracing made outside the oral cavity

ex·tra·ver·sion: see LABIOVERSION

ex·tir·pate *vt* **-pat·ed**; **-pat·ing** (1539)**: 1:** to pull up or out; to destroy completely **2:** to cut out by surgery—**ex·tir·pa·tion** *n*

ex·trin·sic \ĭk-strĭn′sĭk\ *adj* (1613)**:** external, extraneous, as originating from or on the outside—**ex·trin·si·cal·ly** *adv*

extrinsic coloring \ĭk-strĭn′sĭk kŭl′or-ĭng**:** coloring from without; applying color to the external surface of a prosthesis

ex·tru·sion \ĭk-strōō′zhun\ *n* (1540)**:** the movement of teeth beyond the natural occlusal plane that may be accompanied by a similar movement of their supporting tissues

ex·u·date \ĕks′yōō-dāt′\ *n***: 1.** exuded molten material **2.** any fluid that gradually passing through tissues. *Inflammatory exudate* is a fluid with a high content of serum proteins and leukocytes, formed as a reaction to tissue injury

F

fab·ri·ca·tion \făb′rĭ-kā′shun\ *n* (1670)**:** the building, making, or constructing of a restoration

face form \fās form\ *obs***: 1:** the outline form of the face **2:** the outline form of the face from an anterior view, sometimes described geometrically as square, tapering, ovoid, or by various combinations of these basic forms (GPT-4)—see FACIAL FORM

facebow \fās bō**:** a caliper-like instrument used to record the spatial relationship of the maxillary arch to some anatomic reference point or points and then transfer this relationship to an articulator; it orients the dental cast in the same relationship to the opening axis of the articulator. Customarily the anatomic references are the mandibular condyles transverse horizontal axis and one other selected anterior point; called also *hinge bow*—see EARBOW, KINEMATIC F.

facebow fork \fās bō fork**:** that component of the facebow used to attach the occlusion rim to the facebow

facebow record \fās bō rĕk′erd**:** the registration obtained by means of a facebow

facebow transfer: the process of transferring the facebow record of the spatial relationship of the maxillary arch to some anatomic reference point or points and transferring this relationship to an articulator

fac·et \făs′ĭt\ *n* (1625)**:** a small, planar surface on any hard body—see WEAR FACET—*usage:* the French spelling of facet, *facette,* has continued to confuse the profession regarding pronunciation

facial \fā′shal\ *adj***:** the surface of a tooth or other oral structure approximating the face (including both the lips and cheeks)

facial augmentation implant prosthesis \fā′shal ôg′mĕn-tā′shun ĭm-plănt prŏth′ĭ-sĭs**: 1:** a maxillofacial prosthesis made of implantable biocompatible material generally onlayed upon an existing bony area beneath the skin tissue to fill in or selectively raise portions of the overlaying facial skin tissues to create acceptable contours. Although some forms of pre made surgical implants are commercially available, the facial augmentation implant prosthesis is usually custom made for surgical implantation for each individual patient due to the irregular or extensive nature of the facial deficit **2:** an implantable biocompatible material generally laid upon an existing bony area beneath the skin tissues to fill in or selectively raise portions of the overlaying facial skin tissues to create acceptable contours (GPT7)—called also *facial implant*

facial form \fā′shal form**:** the outline form of the face from an anterior view

facial moulage \fā′shal mōō-läzh**:** a negative reproduction (impression) of the face that records soft tissue and bony contours of the face. It is used for diagnostic purposes or to create a prosthesis or implant—see COMPLETE F.M., MOULAGE, SECTIONAL F.M.

facial profile \fā′shal prō′fīl**:** the outline form of the face from a lateral view

facial prosthesis \fā′shal prŏth′ĭ-sĭs**:** a maxillofacial prosthesis that artificially replaces a portion of the face lost due to surgery, trauma, or congenital absence—called also *extraoral prosthesis, prosthetic dressing*

facial prosthetic adhesive \fā′shal prŏs-thĕt′ĭk ăd-hē′sĭv**:** a material used to adhere a facial prosthesis to the skin

fac·ing \fā′sĭng\ *n* (1566)**:** a veneer of any restorative material used on a natural tooth or prosthesis as a restoration to simulate a natural tooth

failure \fa-tēg′ fāl′yer**:** in dental materials, fracture of any physical material due to cyclic loading and unloading characterized by fracture below its ultimate tensile strength

Farrar appliance [William B. Farrar, Alabama, U.S. dentist]**:** a type of occlusal device used to position the mandible anteriorly; used in the treatment of some types of temporomandibular joint disk disorders

Farrar WB. A clinical outline of temporomandibular joint diagnosis and treatment. 7th ed. Montgomery: Walker Printing Co., 1983

Farrar device: C. L. Goddard includes descriptions and illustrations of several devices used to retract teeth and " . . . for many other purposes" that are attributed to J. N. Farrar, DDS. Farrar also is credited with various "push- and pull-jacks" for tooth movement, and "appliances" for moving roots forward and backward

Essig CJ, ed. The American textbook of prosthetic dentistry. 1st ed. Philadelphia: Lea Brothers and Co., 1986:153-209.

fa·tigue \fa-tēg′**:** the breaking or fracturing of a material caused by repeated cyclic or applied loads below the yield limit; usually viewed initially as minute cracks followed by tearing and rupture; also termed *brittle failure* or *fracture* <metal ~>—see FAILURE

feeding aid \fē′dĭng ād\ *obs***:** an ancillary prosthesis that closes the oral-nasal cavity defect, thus enhancing sucking and swallowing, and maintains the right and left maxillary segments of infants with cleft palates in their proper orientation until surgery is performed to repair the cleft—called also *feeding appliance, feeding prosthesis*

feeding appliance *obs***:** see FEEDING AID

feeding prosthesis \fē′dĭng prŏs-thē′sĭs\ *obs***:** a ancillary prosthesis constructed for newborns with cleft palates to permit normal sucking and feeding—see FEEDING AID

feld·spar \fĕld′spär, fĕl′-\ *n* (1757)**: 1:** any one of a group of minerals, principally aluminosilicate of sodium, potassium, calcium, or barium, that are essential constituents of nearly all crystalline rocks **2:** a crystalline mineral of aluminum silicate with sodium, potassium, barium, and/or calcium; a major constituent of some dental porcelains

feld·spath·ic \fĕld-spăth′ĭk, fĕl′-\ *adj* (ca. 1828)**:** related to or containing feldspar; used especially with reference to porcelain glaze

feldspathic porcelain: porcelain fabricated from the natural mineral group feldspar. The material is composed of compounds of oxygen with lighter metals and nonmetals and is predominantly an amorphous (noncrystalline) matrix with one or more crystalline phases (such as leucite $K_2O_Al_2O_3_4SiO_2$)

fer·rule \fĕr′al\ *n* (15c)**: 1:** a metal band or ring used to fit the root or crown of a tooth **2:** any short tube or bushing for making a tight joint

[1]fes·toon \fĕ-stōōn\ *n* (1630)**: 1:** any decorative chain or strip hanging between two points **2:** in dentistry, carvings in the base material of a denture that simulate the contours of the natural tissues that are being replaced by the denture

[2]fes·toon \fĕ-stōōn\ *vt* (1800)**:** to shape into festoons

FGP: *acronym* for *Functionally Generated Path*

fi·bro·in·te·gra·tion \fī′brō-ĭn′tĭ-grā′shun\ *n* (1982)**:** see FIBROUS INTEGRATION

fibroosseous integration: see FIBROUS INTEGRATION

fi·bro·sis \fī-brō′sĭs\ *n* (1873)**:** the formation of fibrous tissue; fibroid or fibrous degeneration

fi·brous \fī′brus\ *adj* (1626)**:** composed of or containing fibers

fibrous adhesion \fī′brus ăd-hē′zhun**:** a fibrous band or structure by which parts abnormally adhere

fibrous ankylosis \fī′brus ăng′ka-lō′sĭs**:** reduced mobility of a joint due to proliferation of fibrous tissue

fibrous integration \fī′brus ĭn′tĭ-grā′shun**:** the presence of a layer of intervening fibrous connective tissue between a dental implant and the adjacent bone indicative of failed osseointegration

field \fēld\ *n* (bef. 12c)**: 1:** an area or open space, as an operative field or visual field **2:** a range of specialization or knowledge, study, or occupation

fil·ter \fĭl′ter\ *n* (1563)**:** in radiology, a solid screen insert, usually of varying thicknesses and different metals (aluminum, copper, tin) placed to filter out photons of longer wavelengths

final flask closure \fī′nal flăsk klō′zher**:** the last closure of a dental flask before polymerizing, after trial packing of the mold with a restorative material

final impression \fī′nal ĭm-prĕsh′on**:** the impression that represents the completion of the registration of the surface or object

fine \fīn\ *adj* (13c)**: 1:** free from impurities **2:** of a metal: having a stated proportion of pure metal in its composition, expressed in parts per thousand > a gold coin 0.9265

fine·ness \fīn′nĕs′\ *n***:** the proportion of pure gold in a gold alloy; the parts per 1000 of gold

finish \fĭn′ĭsh\ *n* (1779)**:** to put a final coat or surface on; the refinement of form prior to polishing

finish junction: the path of union of a dental restoration with the tooth

finish line \fĭn′ĭsh līn\ *n* (1899)**: 1:** a line of demarcation determined by two points **2** *(obs)* the peripheral extension of a tooth preparation **3:** the planned junction of different materials **4:** *(obs)* the terminal portion of the prepared tooth

fir·ing \fīr′ĭng**:** the process of porcelain fusion, in dentistry, specifically to produce porcelain restorations

first stage dental implant surgery \fûrst dĕn′tal ĭm-plănt sûr′ja-rē**:** the initial surgical procedure in dental implant placement. For eposteal dental implants, this refers to the reflection of the oral mucosa, the impression made of the surgically exposed bone and usually an interocclusal record made to fabricate the implant body followed by surgical closure. For an endosteal implant, this refers to the reflection of the oral mucosa and investing tissues, preparation of the implantation site (i.e., removal of alveolar bone and, occasionally, tapping), placement of the dental implant body, and surgical closure of the overlying investing soft tissues—*comp* SECOND STAGE DENTAL IMPLANT SURGERY

Fischer's angle [Rudolf Fischer, Swiss dentist, Zurich, Switzerland]**:** *eponym* for the angle formed by the intersection of the protrusive and nonworking side condylar paths as viewed in the sagittal plane

Fischer R. Beziehungen zwischen den Kieferbewegungen und der Kauflachenform der Zuhne. Schweizerische Monataschrift fur Zahnheilkunde Zurich 1926;74.

Fischer R. Die Offnungsbewegungen des Unterkiefers und ibre Wiedergabe am Artikulator. Schweizerische Monateschrift fur Zahnheilkunde 1935;45:867-99.

fis·sure \fĭsh′ur\ *n* (15c)**:** any cleft or grove, normally present or otherwise; a cleft or deep ditch in the surface of a tooth, usually due to imperfect fusion of adjoining enamel lobes. Distinguished from a groove or sulcus—called also enamel fissure

fissured fracture \fĭsh′urd frăk′shur**:** a fracture that extends partially through a bone with displacement of the bony fragments

fistula \fĭs′cha-la\ *n, pl* **-las** \-lăs\ or **-lea** \lēa\ (14c)**:** a pathologic or abnormal passage resulting from incomplete healing; a communication between two internal organs or one that leads from an internal organ to the surface of a body; usually designated according to the parts it communicates with, as *oral-nasal f.*

fit \fĭt\ *v,* **fit·ted** \fĭt′ĭd\, also **fit** \fĭt\; **fit·ting** \fĭt′ĭng\ *vt* (1586)**: 1:** to be suitable or to be in harmony with **2a:** to conform correctly to the shape or size of **2b:** to insert or adjust until correctly in place; to make or adjust to the correct size or shape, i.e., to adapt one structure to another, as the adaptation of any dental restoration to its site, in the mouth

fix \fĭks\ *vt* (14c)**:** to make firm, stable, or stationery, to attach to another object so that separation of the parts cannot be accomplished without breaking of the mechanical and/or chemical bonds that hold the parts in spatial relationship with each other

fixed \fĭkst\ *adj* (14c)**:** securely placed or fastened; stationary; not subject to change; immobile

fixed bridge: see FIXED DENTAL PROSTHESIS

fixed movable bridge \fĭkst mōōv′va-bal brĭj\ *obs***:** a fixed partial denture having one or more nonrigid connectors

fixed partial denture \fĭkst pär′shal dĕn′chur**:** see FIXED DENTAL PROSTHESIS

fixed dental prosthesis retainer \fĭkst dĕn′tl prŏs-thē′sĭs rĭ-tā′ner**:** the part of a fixed dental prosthesis that unites the abutment(s) to the remainder of the restoration

fixed dental prosthesis \fĭkst dĕn′tl prŏs-thē′sĭs**:** any dental prosthesis that is luted, screwed or mechanically attached or otherwise securely retained to natural teeth, tooth roots, and/or dental implant abutments that furnish the primary support for the dental prosthesis. This may include replacement of one to sixteen teeth in each dental arch. If a metallic or ceramic component is included within the fixed dental prosthesis, that component is termed the *framework*. *Ed note:* Dental prostheses (fixed dental prostheses, removable dental prostheses) as well as maxillofacial prostheses can be supported and retained in part or whole by dental implants. Terminology to assist in describing the means of retention, support and dental materials should

be limited to concatenation of three and no more than four adjectives to provide clarity. Descriptive terminology (modifiers) expressed as adjectives to each fixed dental prosthesis may include such items as the *method of retention, composition, nature of support, design characteristics,* and/or *form of anchorage*

Simon H, Yanase RT. Terminology for Implant Prostheses. Int J Oral Maxillofac Implants 2003; 18:539-543.

fixed prosthodontics \fĭkst prŏs′thadŏn′tĭks\: the branch of prosthodontics concerned with the replacement and/or restoration of teeth by artificial substitutes that not readily removed from the mouth

[1]fix·ture \fĭks′chur\ *n*: something that is fixed or attached, as a structural part or a permanent appendage

[2]fix·ture \fĭks′chur\ *substand* (1982): an endosteal dental implant_see ENDOSTEAL DENTAL IMPLANT, DENTAL IMPLANT

fixture cover \fĭks′chur kŭv′er\ *substand* (1982): the component placed over a dental implant during the healing phase to prevent tissue from proliferating into the internal portion of the implant body–see COVER SCREW

flabby tissue \flăb′ē tĭsh′ōō\ *obs*: excessive movable tissue (GPT-4)

[1]flange \flănj\ *n* (ca 1688): a rib or rim used for strength, for guiding or attachment of another object–see BUCCAL F., DENTURE F., LABIAL F.

[2]flange \flănj\ *vt*, **flang·ed** \flănjd\; **flang·ing** \flănj′ing\ (ca. 1864): to furnish with a flange

flange contour \flănj kŏn′tōōr\ *obs*: the design of the flange of a denture (GPT-4)

[1]flask \flăsk\ *n*: a metal case or tube used in investing procedures–see CASTING F., CROWN F.

[2]flask \flăsk\ *v*: to flask or surround; to invest

flask closure \flăsk klō′zher\: the procedure of bringing two halves, or parts, of a flask together–see FINAL F.C., TRIAL F.C.

flask·ing \flăsk′ing\ *vt* (20c): **1:** the act of investing in a flask **2:** the process of investing the cast and a wax replica of the desired form in a flask preparatory to molding the restorative material into the desired product

flipper *obs*: see INTERIM PROSTHESIS; PROVISIONAL PROSTHESIS

flowing composite resin \flō′ā′bel kŏmpŏz′ĭt rĕz′ĭn\ (1998): composite resin that is less highly filled than conventional composite resin and has improved wettability

flu·o·res·cence \flŏŏ-rĕs′ens\ *n* (1852): a process by which a material absorbs radiant energy and emits it in the form of radiant energy of a different wavelength band, all or most of whose wavelengths exceed that of the absorbed energy. Fluorescence, as distinguished from phosphorescence, does not persist for an appreciable time after the termination of the excitation process

flu·o·res·cent \flŏŏ-rĕsent\ *adj* (1853): having or relating to fluorescence

fluoride gel carrier \flŏŏr′īd jĕl kăr′ēer\ (20c): a ancillary prosthesis which covers the teeth in either dental arch and is used to apply topical fluoride in close proximity to tooth enamel and dentin for several minutes daily. Generally considered essential for all patients with any natural dentition who undergo oral radiation therapy to assist in prevention of extensive secondary dental decay–*syn* FLUORIDE APPLICATOR

flux \flŭks\ *n* (14c): **1:** in physics, the rate of flow of a liquid, particles or energy **2:** in ceramics, an agent that lowers the fusion temperature of porcelain **3:** in metallurgy, a substance used to increase fluidity and to prevent or reduce oxidation of a molten metal **4:** any substance applied to surfaces to be joined by brazing, soldering or welding to clean and free them from oxides and promote union

FMA: *acronym* for *Frankfort Mandibular plane Angle*

foil \foil\ *n* (14c): an extremely thin, pliable sheet of metal, usually of variable thickness–see GOLD F., PLATINUM F., TINFOIL

force \fôrs\ *n* (14c): an agency or influence that, when exerted on a body, tends to set the body into motion or to alter its present state of motion. Force applied to any material causing deformation of that material–see MASTICATORY F., OCCLUSAL F.

forces of mastication \fôrs-es ŭv măs′tĭkā′shun\ *obs*: the motive force created by the dynamic action of the muscles during the physiologic act of mastication (GPT-4)

[1]form \form\ *n* (13c): the shape or configuration of anything, as distinguished from its material

[2]form \form\ *vt* (13c): to give shape, to mold, to adapt

for·nix \fôr′nĭks\ *n, pl* for **for·ni·ces** \fôr′nĭ-sĕz\ (1681): an anatomical arch or fold

forward protrusion \fôr′werd prōtrōō′zhun\ *obs*: a protrusion forward of centric position (GPT-3)

fossa \fŏs′a\ *n, pl* **fossae** \fŏs′ē′\ (1771): an anatomical pit, groove, or depression

foundation restoration \foun-dā′shun rĕs′ta-rā′shun\: the core buildup portion of a natural tooth restoration

foveae palatinae \fō′vē-ē′ păl′a-tīn-ē\: two small pits or depressions in the posterior aspect of the palatal mucosa, one on each side of the midline, at or near the attachment of the soft palate to the hard palate

[1]frac·ture \frăk′chur\ *n* (15c): the process or act of breaking; state of being broken–see AVULSION F., BLOWOUT F., CEMENTUM F., CLOSED REDUCTION OF A F., COMMINUTED F., COMPLICATED F., DISLOCATED F., FISSURED F., GREENSTICK F., GUERIN'S F., IMPACTED F., INDIRECT F., INTRACAPSULAR F., MIDFACIAL F., OPEN F., PYRAMIDAL F., ROOT F., SECONDARY F., SIMPLE F., SPONTANEOUS F., SUBCONDYLAR F., SUBPERIOSTEAL F.

[2]frac·ture \frăk′chur\ *v*, **frac·tured** \frăk′churd\; **frac·tur·ing** \frăk′churĭng\ *vt* (1612): to cause a fracture in; to break, rupture, or tear

fracture strength \frăk′chur strĕngkth\: strength at fracture based on the original dimensions of the specimen

frame·work \frām′wûrk\ *n* (1644): 1. an interior or imbedded, openwork or structural frame used to support some other object or objects 2. the skeletal portion of prosthesis (usually metal, sometimes ceramic) around which and to which are attached the remaining portions of the prosthesis to produce a finished restoration–*usage:* for dental prostheses, the *framework* may be any metal or combination of metals or ceramic material, with various forms including designed slots, incorporated corrective angulation patterns etc. which provide rigidity to a dental prosthesis. Such a framework can be made in whole or made of component parts. Frequently used to anchor a prosthesis to natural teeth (by cementation) or dental implant abutments (by cementation, mechanical undercuts, screws) or both

Frankfort mandibular plane angle \Frăngk′fort măn′dĭ-bū′lăr plān ăng′gal\: *eponym* for the angle formed by the intersection of the Frankfort horizontal plane with the mandibular plane

Frankfort horizontal plane \Frăngk′fort hôr′ĭ-zŏn′tl plān\: **1:** *eponym* for a plane established by the lowest point on the margin of the right or left bony orbit and the highest point on the margin of the right or left bony auditory meatus **2:** a horizontal plane represented in profile by a line between the lowest point on the margin of the orbit to the highest point on the margin of the auditory meatus; adopted at the 13th General Congress of German Anthropologists (the "Frankfort Agreement") at Frankfort am Main, 1882, and finally by the International Agreement for the Unification of Craniometric and Cephalometric Measurements in Monaco in 1906; called also *auriculo-orbital plane, eye-ear plane, Frankfort horizontal (FH), Frankfort horizontal line*

Frankfort plane: see FRANKFORT HORIZONTAL PLANE

free gingival \frē jĭn′ja-va\: **1:** the part of the gingiva that surrounds the tooth and is not directly attached to the tooth surface

free gingival groove: the line demarcating the junction between free and attached gingival tissue

free gingival margin \frē jĭn′ja-val mär′jĭn\: the unattached gingiva surrounding the teeth in a collar-like fashion and demarcated from the attached gingiva by a shallow linear depression, termed the *free gingival groove*

free mandibular movement \frē măn-dĭb′ya-lar mōōv′ment\: **1:** any mandibular movement made without interference **2:** any uninhibited movement of the mandible

free support \frē sa-pôrt\ *obs*: support that does not permit translation of the beam perpendicular to its axis and presumably offers no restraint to the tendency of the beam to rotate at the support (GPT-4)

freedom in intercuspal position: see INTERCUSPAL CONTACT AREA

freeway space *obs*: see INTEROCCLUSAL REST SPACE

frem·i·tus \frĕm′ĭ-tus\ *n* (1879): a vibration perceptible on palpation; in dentistry, a vibration palpable when the teeth come into contact

frenectomy: surgical excision of a frenum

fren·u·lum \frĕn′ya-lem\ *n, pl* **-la** \lă\ (1706): a connecting fold of membrane serving to support or retain a part

fren·um \frē′num\ *n, pl* **fren·ums** \frē′numz\ or **fre·na**: see FRENULUM

frictional attachment \frĭk′shun-al a-tăch′ment\: a precision or semiprecision attachment that achieves retention by metal to metal contact, without springs, clips or other mechanical means of retention—see PRECISION ATTACHMENT

friction retained pin \frĭk′shun rĭ-tānd pĭn\: a metal rod driven into a hole drilled into dentin to enhance retention; retained solely by dentinal elasticity

[1]frit \frĭt\ *n* (1662): **1:** the calcined or partly fused matter of which glass is made **2:** a mass of fused porcelain obtained by firing the basic constituents and plunging them into water while hot. The frit is ground to make porcelain powders

[2]frit \frĭt\ *vt* **fri·tted** \frĭ-tĭd\; **frit·ing** \frĭ′tĭng\ (1805): **1:** to prepare substances for glass by heating; to fuse **2:** to convert into a fritĭ

frontal plane \frŭn′tl\: any plane parallel with the long axis of the body and at right angles to the median plane, thus dividing the body into front and back parts. So called because this plane roughly parallels the frontal suture of the skull

fulcrum line \fŏŏl′krum līn\: **1.** a theoretical line passing through the point around which a lever functions and at right angles to its path of movement **2:** an imaginary line, connecting occlusal rests, around which a partial removable dental prosthesis tends to rotate under masticatory forces. The determinants for the fulcrum line are usually the cross arch occlusal rests located adjacent to the tissue borne components—see F.L. OF A REMOVABLE PARTIAL DENTURE, RETENTIVE F.L.

fulcrum line of a removable dental prosthesis \fŏŏl′krum līn ŭv a rĭ-mōōv′va-bal dĕn′tl prŏs-thē′sĭs\: a theoretical line around which a removable dental prosthesis tends to rotate

full denture: see COMPLETE DENTURE

full denture prosthetics \fŏŏl dĕn′chur prŏs-thĕt′ĭks\ *obs*: **1:** the replacement of the natural teeth in the arch and their associated parts by artificial substitutes **2:** the art and science of the restoration of an edentulous mouth (GPT-4)—see COMPLETE DENTURE PROSTHODONTICS

full thickness graft \fŏŏl thĭk-nes\: a transplant of epithelium consisting of skin or mucous membrane with a minimum of subcutaneous tissue

full veneer crown: see COMPLETE CROWN

fully adjustable articulator \fŏŏl′ē a-jŭst-a′bal är-tĭk′ya-lā′tor\: an articulator that allows replication of three dimensional movement of recorded mandibular motion—called also Class IV articulator

fully adjustable gnathologic articulator \fŏŏl′ē a-jŭst-a′bal năth′ō-lŏj′ik är-tĭk′ya-lā′tor\: an articulator that allows replication of three dimensional movement plus timing of recorded mandibular motion—called also *Class IV articulator*

functional articulation \fŭngk′sha-nal är-tĭk′ya-lā′shun\: the occlusal contacts of the maxillary and mandibular teeth during mastication and deglutition

functional chew-in record \fŭngk′sha-nal chōō-ĭn rĕk′ord\ *obs*: a record of the movements of the mandible made on the occluding surface of the opposing occlusion rim by teeth or scribing studs and produced by simulated chewing movements (GPT-4)

functional dislocation \fŭngk′sha-nal dĭs′lō-kā′shun\: dislocation of the articular disk of the temporomandibular joint due to a seriously impaired disk-condyle complex function

functional jaw orthopedics \fŭngk′sha-nal jô ôr′tha-pē′dĭks\: use of orthodontic prostheses that rely on the patient's own musculature for force application and that attempt to alter the skeletal structure of the face

functional mandibular movements' \fŭngk′sha-nal măn-dĭb′ū-lar mōōv′ments\: all normal, proper, or characteristic movements of the mandible made during speech, mastication, yawning, swallowing, and other associated movements

functional occlusal harmony \fŭngk′sha-nal a-klōō′sal här′ma-nē\ *obs*: the occlusal relationship of opposing teeth in all functional ranges and movements that will provide the greatest masticatory efficiency without causing undue strain or trauma on the supporting tissues (GPT-4)

functional occlusion \fŭngk′sha-nal a-klōō′shun\ *obs*: the contacts of the maxillary and mandibular teeth during mastication and deglutition (GPT-4)

functional record \fŭngk′sha-nal rĕk′ord\: a record of lateral and protrusive movements of the mandible made on the surfaces of an occlusion rim or other recording surface

functional occlusal splint \fŭngk′sha-nal a-klōō′sal splĭnt\: a device that directs the movements of the mandible by controlling the plane and range of motion

functional wax: see DENTAL IMPRESSION WAX

functionally generated path \fŭngk′sha-na-lē jĕn′a-rāt′ĭd păth\: a registration of the paths of movement of the occlusal surfaces of teeth or occlusion rims of one dental arch in plastic or other media attached to the teeth or occlusal rims of the opposing arch

functioning condyle: see WORKING SIDE CONDYLE

fur·ca·tion \fûr′kā′shun\ *n*: the anatomic region of a multirooted tooth where the roots diverge

G

gag \găg\ *n* (1553): **1:** an involuntary contraction of the muscles of the soft palate or pharynx that results in retching **2:** a surgical device for holding the mouth open

galvanic skin response \găl-văn′ĭk\: the change in the electrical resistance of the skin in response to diverse stimuli

galvanic stimulation \găl-văn′ik stĭm′ya-lā′shun\: stimulation of muscles through the application of varying amplitudes and pulsations of electrical current; used in the treatment of muscle disorders

gal·van·ism \găl′va-nĭz′um\ *n* (1797): accelerated corrosion of a metal due to electrical contact with a more noble metal in a corrosive electrolyte. The resulting current flow can produce nerve stimulation, unpleasant tastes, and other physiological reactions commonly associated with this term

ga·vage \ga-väzh′\ *n* (1889): forced feeding especially through a tube passed into the stomach

generated occlusal path: see FUNCTIONALLY GENERATED PATH

ge·nial \jī-nĭ′al\ *adj* (1566): pertaining to the chin

genial tubercles \jī-nĭ′al tōō′ber-kalz, tyōō-\: mental spines; rounded elevations (usually two pairs) clustered around the midline on the lingual surface of the lower portion of the mandibular symphysis. These tubercles serve as attachments for the genioglossus and geniohyoid muscles

ge·nio·plasty \jī-nĭ′ō-plăs′tē\ *n*: **1:** a surgical procedure performed to alter the contour of the mandibular symphysis **2:** plastic surgery of the chin

geriatrics \jĕr′ē-ăt′r′ks\ *n, pl but sing in constr* (1909): the branch of medicine that treats all problems peculiar to the aging patient, including the clinical problems of senescence and senility—see DENTAL G., GERODONTICS, GERODONTOLOGY

gerodontics \jĕr′a-dŏn′tĭks\ *n, pl but sing in constr*: the treatment of dental problems of aging persons; also spelled *geriodontics*

gerodontology \jĕr′a-dŏn-tŏl′a-jē\ *n*: the study of the dentition and dental problems in aged or aging persons

Gillett bridge [Henry W. Gillett] *obs*: *eponym* for a partial removable dental prosthesis utilizing a Gillett clasp system, which was composed of an occlusal rest notched deeply into the occlusal-axial surface with a gingivally placed groove and a circumferential clasp for retention. The occlusal rest was custom made in a cast restoration

Kennedy E. The techniques of Gillett clasps in partial denture construction. Brooklyn: Dental Items of Interest Publishing Co., 1928:292-317.

Cohn LA. The physiologic basis for tooth fixation in precision-attached partial dentures. J PROSTHET DENT 1956;6:220-44.

gin·gi·va \jĭn′ja-va, jĭn-jī-\ *n, pl* **-vae** \-vē′\: the fibrous investing tissue, covered by epithelium, which immediately surrounds a tooth and is contiguous with its periodontal membrane and with the mucosal tissues of the mouth—see ATTACHED G., FREE G., MARGINAL G.

gingival crevice \jĭn′ja-val krĕv′ĭs\: a shallow fissure between the marginal gingiva and the enamel or cementum. It is bounded by the tooth surface on one side, the crevicular epithelium on the other, and the coronal end of the junctional epithelium at its most apical point—called also *gingival sulcus*

gingival denture contour \jĭn′ja-val dĕn′chur kŏn′tōōr\: the form of the denture base or other material around the cervical regions of prosthetic teeth

gingival displacement \jĭn′ja-val dĭs-plās′ment\: the deflection of the marginal gingiva away from a tooth

gingival embrasure: the space between adjacent teeth that is cervical to the interproximal contact area

gingival porcelain: a porcelain blend used for the cervical portion of a ceramic restoration comp BODY PORCELAIN, INCISAL PORCELAIN

gingival retraction: see GINGIVAL DISPLACEMENT

ginglymoarthrodial joint: any joint, such as the temporomandibular joint, capable of both hinging and gliding articulation

ginglymus joint \jĭn′gla-mŭs joint\: a hinge joint

gin·gly·mus \jĭn′gla-mŭs\ *n*: a type of synovial joint which allows movement in one plane only (i.e., forward and backward), such as the hinge of a door; called also ginglymoid or hinge joint

ginglymus joint \jĭn′gla-mŭs joint\: a hinge joint

glare \glâr\ *v* (13c): the disturbance of the sensitivity of the eye, experienced when portions of the field of view have a brightness or intensity greatly in excess of that of the average for the field of view

glass-ceramic \glăs sa-răm′ik\: a solid material, crystalline and partly glassy, formed by controlled crystallization of a glass

glass ionomer \glăs ī′a-nō′mer\ (1998): a cement, luting or restorative agent composed of an acid-soluble glass, polyacrylic acid, and water that sets via an acid-base reaction

glaze \glāz\ *vb* **glazed** \glāzd\; **glaz·ing** \glā′zĭng\ *vt* (14c): **1:** to cover with a glossy, smooth surface or coating **2:** the attainment of a smooth and reflective surface **3:** the final firing of porcelain in which the surface is vitrified and a high gloss is imparted to the material **4:** a ceramic veneer on a dental porcelain restoration after it has been fired, producing a nonporous, glossy or semiglossy surface—see NATURAL G., OVERGLAZE

glenoid fossa: the concavity in the temporal bone by the zygomatic arch that receives the mandibular condyle

gliding movement: see TRANSLATION

gliding occlusion \glī′dĭng a-klōō′zhun\ *obs*: used in the sense of designating

contacts of teeth in motion (GPT-4)—see ARTICULATION

glos·sal·gia \glô′sal-ja\ *n*: pain in the tongue

glos·so·py·nia \glô′sō-pĭn′ya\ *n*: painful or burning tongue

glos·sec·to·my \glô′sĕk′ta-mē\ *n*: partial or total resection of the tongue

glos·so·plas·ty \glô′sa-plăs-tē\ *n*: plastic surgery of the tongue

glos·so·py·ro·sis \glô′sa-pĭ-rō′sĭs\ *n*: a form of paresthesia characterized by pain, burning, itching, and stinging of the mucosa of the tongue, without noticeable lesions; called also burning tongue

gnath·ic \năth′ĭk\ *adj* (1882): of or pertaining to the jaw or cheek

gnath·ion \năth′ēon\ *n*: the lowest bony point, in the median plane of the mandible

gnath·o·dy·na·mo·me·ter \năth′a-dīn-ă-mŏm′a-ter\ *n*: **1:** an instrument for measuring the force exerted in closing the jaws **2:** an instrument used for measuring biting pressure

gnath·ol·o·gy \năth′ŏl-a-gē\ *n*: the science that treats the biology of the masticatory mechanism as a whole: that is, the morphology, anatomy, histology, physiology, pathology, and the therapeutics of the jaws or masticatory system and the teeth as they relate to the health of the whole body, including applicable diagnostic, therapeutic, and rehabilitation procedures

Goddard's linear occlusion (William H. Goddard, Louisville, Kentucky, U.S. dentist, 1808-1883): see LINEAR OCCLUSION

Golden Proportion: the ratio between succeeding terms in a mathematical progression (called the Fibonacci series [Leonardo Pisano: *nickname* Fibonacci, Italian Mathematician, c1170-c1240]) in which each number is the sum of the two immediately preceding it (i.e., 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, and so on). The ratio converges on approximately 1.618 to 1. Claims have been made that the Golden Proportion exists in natural dentitions in the ratio of the widths of incisors and canines as seen from the facial surfaces

gold foil \gōld\: **1:** pure gold rolled into extremely thin sheets **2:** a precious-metal foil used in restoration of carious or fractured teeth

gothic arch tracer \gŏth′ik arch trā′ser\ *obs*: the device that produces a tracing that resembles an arrowhead or a gothic arch. The device is attached to the opposing arches. The shape of the tracing depends on the relative location of the marking point and the tracing table. The apex of a properly made tracing is considered to indicate the most retruded, unstrained relation of the mandible to the maxillae, i.e., centric relation (GPT-4)—see CENTRAL BEARING TRACING DEVICE

gothic arch tracing: see CENTRAL BEARING TRACING

graft \graft\ *n* (14c): a tissue or material used to repair a defect or deficiency—see ALLOGRAFT, ALLOPLASTIC G., AUTOGENOUS G., AUTOGRAFT, FULL THICKNESS G., HETEROGRAFT, HOMOGRAFT, ISOGRAFT, SPLIT-THICKNESS G., XENOGENIC G.

Grassman's laws [author unknown]: *eponym* for three empirical laws that describe the color-matching properties of additive mixtures of color stimuli **1:** to specify a color match, three independent variables are necessary and sufficient **2:** for an additive mixture of color stimuli, only their tri-stimulus values are relevant, not their spectral compositions **3:** in an additive mixture of color stimuli, if one or more components of the mixture are gradually changed, the resulting tri-stimulus values also change gradually. (Laws do not hold for all observing conditions)

GRAY \grā\: a unit of absorbed radiation dose equal to 100 RADS. Abbreviated *Gy*

greenstick fracture \grēn-stĭk\ *n* (1885): a fracture in which the break in the bone is not complete. The bone appears to be bent on one side while the other side of the bone is broken

Griffith flaws: *eponym*—see MICROCRACK

grinding-in \grīn′dĭng-ĭn\ *obs*: a term used to denote the act of correcting occlusal disharmonies by grinding the natural or artificial teeth (GPT-1)—see OCCLUSAL RESHAPING

groove \grōōv\ *n*: a long narrow channel or depression, such as the indentation between tooth cusps or the retentive features placed on tooth surfaces to augment the retentive characteristics of crown preparations

group function \grōōp fŭngk′shun\: multiple contact relations between the maxillary and mandibular teeth in lateral movements on the working side whereby simultaneous contact of several teeth acts as a group to distribute occlusal forces

Guerin's fracture [Alphonse Francois Marie Guerin, French surgeon, 1816-1895]: *eponym*—see LE FORT I FRACTURE

guid·ance \gīd′ns\ *n* (1590): **1:** providing regulation or direction to movement; a guide **2:** the influence on mandibular movements by the contacting surfaces of the maxillary and mandibular anterior teeth **3:** mechanical forms on the lower anterior portion of an articulator that guide movements of its upper member—see ADJUSTABLE ANTERIOR G., ANTERIOR GUIDANCE, CONDYLAR G.

guide pin \gīd pĭn\: the component of a dental implant system that is placed within the surgically prepared osseous site for an endosteal implant. It assists in determination of location and angulation of the site relative to other soft tissue or bony landmarks

guide plane \gīd plān\ *obs*: **1:** the plane developed in the occlusal surfaces of the occlusion rims (viz., to position the mandible in centric relation) **2:** a plane which guides movement (GPT-4)

guide table \gīd tā′bal\: the anterior element of an articulator on which the incisal pin rests. It may be custom contoured or mechanically adjusted—see ANTERIOR G.T.

guided tissue regeneration \gī′dĭd tĭsh′ōō rĭ-jĕn′a-rā′shun\: any procedure that attempts to regenerate lost periodontal structures or alveolar process through differential tissue responses. Barrier techniques, using synthetic materials that may or may not resorb, to exclude epithelial ingrowth *(periodontal regeneration)* or connective tissue ingrowth *(alveolar process regeneration)* that is believed to interfere with regeneration

guiding occlusion \gī′dĭng a-klōō′shun\ *obs*: used in the sense of designating contacts of teeth in motion (GPT-4)

guiding planes \gī′dĭng plānz\: vertically parallel surfaces on abutment teeth or/and dental implant abutments oriented so as to contribute to the direction of the path of placement and removal of a removable dental prosthesis

guiding surfaces: see GUIDING PLANES

gum contour \gŭm kŏn′tŏŏr′\ *obs*: form of supporting structures of the teeth or

of the flanges of dentures around the teeth (GPT-1)

gums \gŭmz\ *n, obs*: the fibrous and mucosal covering of the alveolar process or ridge (GPT-4)—see GINGIVA

Gunning's splint [Thomas Brian Gunning, English-born American dentist, 1813-1889]: *eponym* for a device fabricated from casts of edentulous maxillary and mandibular arches to aid in reduction and fixation of a fracture. His initial work described four types of splints used in treating jaw fractures (1866-67), which allowed openings for saliva flow, nourishment, and speech—called also *occlusal splint*

Fraser-Moodie W. Mr. Gunning and his splint. Br J Oral Surg 1969; 7:112-5.

gus·ta·tion \gŭ-stā′shun\ *n* (1599): the act of perceiving taste

gyp·sum \jĭp′sum\ *n* (14c): the natural hydrated form of calcium sulfonate, $CaSO_4$ $2H_2O$ gypsum dihydrate

gypsum-bonded investment: any casting investment with gypsum as a binder, also containing cristobalite or quartz as a refractory material. The cristobalite and quartz are responsible for the thermal expansion of the mold during wax elimination. Because gypsum is not chemically stable at temperatures exceeding 650° C (1200° F), these investments are typically restricted to castings of conventional Type II, III, and IV gold alloys

H

habitual centric: see MAXIMAL INTERCUSPAL POSITION

habitual occlusion: see MAXIMAL INTERCUSPAL POSITION

Hader bar [after the Swiss tool and die technician, Helmut Hader]: *eponym* for a rigid bar connecting two or more abutments, which, when viewed in cross section, resembles a keyhole, consisting of a rectangular bar with a rounded superior (occlusal) ridge that creates a retentive undercut for the female clip within the removable prosthesis

Breim SL., Renner RP. An overview of tissue bars. Gen Dent 1982: 406-15.

hamular notch: see PTERYGOMAXILLARY NOTCH

Hanau's Quint [Rudolph L. Hanau, (1881-1930) Buffalo, New York, U.S. engineer, born Capetown, South Africa]: rules for balanced denture articulation including incisal guidance, condylar guidance, cusp length, the plane of occlusion, and the compensating curve described by Rudolph Hanau in 1926

Hanau R. Articulation defined, analyzed, and formulated. J Am Dent Assoc 1926;13:1694-709

hard palate \hard păl′ĭt\: the bony portion of the roof of the mouth

healing abutment: see INTERIM ENDOSTEAL DENTAL IMPLANT ABUTMENT

healing component: see INTERIM ENDOSTEAL DENTAL IMPLANT ABUTMENT

healing screw \hē′lĭng skrōō\: the component of an endosteal dental implant system used to seal, usually on an interim basis, the dental implant body during the healing phase after surgical placement. The purpose of the healing screw is to maintain patency of the internal threaded section for subsequent attachment of the abutment during the second stage surgery

heel *n*: see DISTAL

height of contour \hīt ŭv kŏn′tōr′\: a line encircling a tooth and designating its greatest circumference at a selected axial position determined by a dental surveyor; a line encircling a body designating its greatest circumference in a specified plane

hemi·glos·sec·to·my \hĕm′ĭ-glô-sĕk′ta-mē\ *n*: resection of one side of the tongue

hemi·sec·tion \hĕm′ĭ-sĕk′shun\ *n*: the surgical separation of a multirooted tooth, especially a mandibular molar, through the furcation in such a way that a root and the associated portion of the crown may be removed

hemostatic agent: any chemical, such as aluminum chloride or ferric sulfate, that acts to control soft-tissue hemorrhage. Used during impression making and restoration delivery

heterograft \hĕt′a-rō-grăft′\ *n*: a graft taken from a donor of another species—called also *xenograft*

heterotopic pain \hĕt′er-a-tă′pĭk pān\: a general term designating pain felt in an area other than the true originating site

high fusing ceramic: a ceramic with a maturation or fusion range of 1290° to 1370° C (2350° to 2500° F)

high fusing solder: any soldering alloy formulated to melt at approximately 1100° C (2012° F) used to form connectors before ceramic application

high lip line \hī lĭp līn\: the greatest height to which the inferior border of the upper lip is capable of being raised by muscle function

high noble metal alloy: as classified by the American Dental Association (1984) any dental casting alloy with at least 60% noble metal (Au, Pt, Pd, Rh, Ru, Ir, Os) by weight with at least 40% gold

American Dental Association: Classification system for cast alloys. J Am Dent Assoc 1984; 109:766.

hinge axis: see TRANSVERSE HORIZONTAL AXIS

hinge axis of the mandible: see TRANSVERSE HORIZONTAL AXIS

hinge axis point: see POSTERIOR REFERENCE POINTS

hinge bow: see KINEMATIC FACEBOW

hinge joint \hĭnj joint\: a ginglymus joint; a joint that allows motion around one axis

hinge movement: see TRANSVERSE HORIZONTAL AXIS

hinge position \hĭnj pa-zĭsh′an\ *obs*: the orientation of parts in a manner permitting hinge movement between them (GPT-4)

homograft \hō′ma-grăft′\ *n* (1923): a graft taken from one human and transplanted to another—called also *allograft*

horizontal axis of the mandible: see TRANSVERSE HORIZONTAL AXIS

horizontal plane \hôr′ĭ-zŏn′tl, hŏr- plān\: any plane passing through the body at right angles to both the median and frontal planes, thus dividing the body into upper and lower parts; in dentistry, the plane passing through a tooth at right angles to its long axis

horizontal plane of reference \hôr′ĭ-zŏn-tl, hŏr′- plān ŭv rĕf′er-ans, rĕf′rans\: a horizontal plane established on the face of the patient by one anterior reference point and two posterior reference points from which measurements of the posterior anatomic determinants of occlusion and mandibular motion are made

horizontal overlap \hôr′ĭ-zŏn-tl, hŏr′-ō′ver-lăp′\: the projection of teeth beyond their antagonists in the horizontal plane

horizontal reference plane: see HORIZONTAL PLANE OF REFERENCE

horseshoe plate \hôrs′shōō, hôrsh′- plāt\ *obs*: a horseshoe or V-shaped removable prosthesis

host site: see RECIPIENT SITE

hue \hyōō\ *n* (bef. 12c)**:** often referred to as the basic color, hue is the quality of sensation according to which an observer is aware of the varying wavelengths of radiant energy. The dimension of color dictated by the wavelength of the stimulus that is used to distinguish one family of color from another—as red, green, blue, etc. The attribute of color by means of which a color is perceived to be red, yellow, green, blue, purple, etc. White, black, and grays possess no hue

Munsell AH. A color notation. Baltimore: Munsell Color Co. Inc, 1975:14-6.

hunk bite *obs***:** see INTEROCCLUSAL RECORD

hybrid \hī′brĭd**: 1.** anything of mixed origin **2.** offspring of two plants or animals of different genus or species

hybrid denture \hī′brĭd dĕn′chur**:** *slang* for any modification or alteration in the usual form of a dental prosthesis

hybrid ionomer \hī′brĭd ī′a-nō′mĕr**:** a conventional glass ionomer that has been modified to include methacrylate groups in the liquid component. It may contain photo initiators. Setting is by an acid-base reaction with light and dual cure polymerization ***syn***—RESIN-MODIFIED GLASS IONOMER

hybrid prosthesis \hī′brĭd prŏs-thē′sĭs**:** *slang* for a nonspecific term applied to any prosthesis that does not follow conventional design. Frequently it is used to describe a dental prosthesis that is composed of different materials, types of denture teeth (porcelain, plastic, composite), variable acrylic denture resins, differing metals or design etc. It may refer to a fixed dental prostheses, removable dental prostheses, or maxillofacial prostheses

hydrocolloid \hī′dra-kŏl′oid\ *n* (1916)**:** a colloid system in which water is the dispersion medium; those materials described as a colloid sol with water that are used in dentistry as elastic impression materials—see IRREVERSIBLE H., REVERSIBLE H.

hydroxyapatite ceramic \hī-drŏk′sē-ăp′a-tīt sa-răm′ĭk**:** a composition of calcium and phosphate in physiologic ratios to provide a dense, nonresorbable, biocompatible ceramic used for dental implants and residual ridge augmentation

hygienic pontic \hī′jē-ĕn′ĭk, hī-jĕn′-pŏn′tĭk**:** a pontic that is easier to clean because it has a domed or bullet shaped cervical form and does not overlap the edentulous ridge

hygroscopic expansion \hī′gra-skŏp′ĭk ĭk-spăn′shun**:** expansion due to the absorption of moisture

hyp·al·ge·sia \hī′păl-gē-a\ *n***:** diminished sensitivity to pain

hy·per·ac·tiv·i·ty \hī′per-ăk′tĭv′ĭ-tē\ *n* (1867)**:** excessive motor activity. It is frequently, but not necessarily, associated with internal tension or a neurologic disorder. Usually the movements are more rapid than customary for the person

hy·per·al·ges·ia \hī′per-ăl-gē′sē-a\ *n***:** increased sensitivity or sensibility to pain—see PRIMARY H.

hyperbaric chamber \hī′per-băr′ĭk**:** an area in which a patient may be subjected to pressure of ambient gases greater than 1 atmosphere

hyperbaric oxygenation \hī′per-băr′ĭk ŏk′sĭ-ja-nā′shun**:** the administration of oxygen under greater than atmospheric pressure; called also hyperbaric oxygen therapy

hy·per·ce·men·to·sis \hī′per-sĭ-mĕn′tō′sĭs\ *n***:** an excessive deposition of cementum

hy·per·es·the·sia \hī′per-ĭs-thē′zha\ *n* (1849)**:** increased sensitivity to stimulation

hy·per·na·sal·i·ty \hī′per-nā-zăl′ĭ-tē\ *n***:** a perceived voice quality in which the nasal cavity acts as a resonating cavity for non-nasal sounds. Generally associated with palatopharyngeal inadequacy

hy·per·os·mia \hī′per-ŏz′mē-a\ *n***:** abnormally increased sensitivity to odors

hy·per·pla·sia \hī′per-plā′zha\ *n* (1861)**:** the abnormal multiplication or increase in the number of normal cells in normal arrangement in a tissue

hyperplasia of the coronoid process: pathologic growth of the coronoid process of the mandible after normal growth has ended—called also *osteoma of the coronoid*

hyperplastic tissue \hī′per-plăs′tik tĭsh′ōō**:** excessive tissue proliferation, usually as a response to chronic irritation

hy·per·tro·phy \hī-pûr′tra-fē\ *n* (1834)**:** an enlargement or overgrowth of an organ or tissue beyond that considered normal as a result of an increase in the size of its constituent cells and in the absence of tumor formation

hy·po·don·tia \hī′pa-dŏn′zha\ *n***:** congenital absence of one or more, but not all, of the normal complement of teeth

hy·po·es·the·sia \hī′pō-ĭs-thē′zha\ *n***:** diminished sensitivity to stimulation

hy·po·geu·sia \hī′pa-jē′us-ē′a\ *n***:** diminished acuteness of the sense of taste—called also *hypogeusesthesia*

hy·po·na·sal·i·ty \hī′pō-nā-zăl′ĭ-tē\ *n***:** reduced nasal resonance usually from obstruction in the nasopharynx or nasal passages resulting in an alteration of *m, n,* and *-ng* sounds

hy·po·pla·sia \hī′pō-plā′zha\ *n* (1889)**:** defective or incomplete development of an organ or tissue

hys·ter·e·sis *n***:** the lagging or delay in the effect of a system's change. In dentistry, the affect of cooling and reheating of a casting investment can cause casting inaccuracy because the refractory and binder will not revert to their original forms

I

i·at·ro·gen·ic \ī-ăt′ra-jĕn′ĭk\ *adj* (1924)**:** resulting from the activity of the clinician; applied to disorders induced in the patient by the clinician

I-bar clasp: see CLASP

id·io·path·ic \ĭd′ē-ō-păth′ĭk\ *adj* (1669)**:** self-originated; of unknown causation

idling condyle: see NONWORKING SIDE CONDYLE

il·lum·inance \ĭ-lōō′ma-nans\ *n* (ca. 1938)**: 1:** density of luminous flux on a surface **2:** luminous flux incident per unit area of a surface

il·lum·inant \ĭ-lōō′ma-nant\ *adj* (15c)**:** mathematical description of the relative spectral power distribution of a real or imaginary light source, that is, the relative energy emitted by a source at each wave length in its emission spectrum—see CIE STANDARD ILLUMINANT

im·bi·bi·tion *n***:** the act or process of imbibing or absorbing. In dentistry, an example is the dimensional change caused in hydrocolloid impression materials if they are stored in water

imbrication lines: lines in the dentin caused by changes in mineralization during formation. Also called *incremental lines of von Ebner* [Anton Gilbert Victor von Ebner, Austrian histologist, 1842-1925]

immediate denture \ĭ-mē′dē-ĭt dĕn′chur**:** any removable dental prosthesis fabricated for placement immediately following the removal of a natural tooth/teeth

immediate disocclusion \ĭ-mē′dē-ĭt dĭs′a-klōō′shun\: instantaneous separation of the posterior teeth due to the anterior guidance

immediate insertion denture: see IMMEDIATE DENTURE

immediate lateral translation: see IMMEDIATE MANDIBULAR LATERAL TRANSLATION

immediate mandibular lateral translation \ĭ-mē′dē-ĭt măn-dĭb′ya-lar lăt′ar-al trăns-lā′shun\: the translatory portion of lateral movement in which the nonworking side condyle moves essentially straight and medially as it leaves the centric relation position- see also EARLY MANDIBULAR LATERAL TRANSLATION; PROGRESSIVE MANDIBULAR LATERAL TRANSLATION

immediate obturator: see SURGICAL OBTURATOR

immediate replacement denture: see IMMEDIATE DENTURE

immediate side shift: see IMMEDIATE MANDIBULAR LATERAL TRANSLATION

immediate temporary obturator: see SURGICAL OBTURATOR

impacted fracture \ĭm-păk′tĭd\: a fracture in which one fragment is driven into another portion of the same or an adjacent bone

[1]im·plant \ĭm-plănt′\ *vt* (1890): to graft or insert a material such as an alloplastic substance, an encapsulated drug, or tissue into the body of a recipient

[2]im·plant \ĭm-plănt′\ *n* (1809): any object or material, such as an alloplastic substance or other tissue, which is partially or completely inserted or grafted into the body for therapeutic, diagnostic, prosthetic, or experimental purposes—see DENTAL IMPLANT

implant connecting bar *slang*: *usage*—a connecting bar is not an implantable device. It receives support and stability from the dental implant(s) through the dental implant abutments and is termed a *framework*

implant crown \ĭm′plănt′ kroun\ *slang*: *usage*—a crown or fixed dental prosthesis is not an implantable device. The prosthesis receives support and stability from the dental implant see DENTAL IMPLANT, DENTAL PROSTHESIS, CROWN

implant dentistry \ĭm′plănt′ dĕn′tĭ-strē\ (1993): the selection, planning, development, placement, and maintenance of restoration(s) using dental implants

implant denture \ĭm′plănt′ dĕn′chur\ *slang*: *usage*—a denture is not an implantable device. Dental prostheses (fixed dental prostheses, removable dental prostheses) as well as maxillofacial prostheses can be supported and retained in part or whole by dental implants. Terminology to assist in describing the means of retention, support and dental materials should be limited to concatenation of three and no more than four adjectives to provide clarity. Descriptive terminology *(modifiers)* expressed as adjectives to each dental prosthesis may include the *method of retention, composition, nature of support, design characteristics,* and *form of anchorage*—See also PROSTHESIS

Simon H, Yanase RT. Terminology for Implant Prostheses. Int J Oral Maxillofac Implants 2003; 18:539-543.

implant fixture: see DENTAL IMPLANT BODY

implant infrastructure \ĭm′plănt′ ĭn′fra-strŭk′chur\ *slang*: *usage*—while a dental implant may have an infrastructure, the proper geometric reference to such an area of the implant is referenced relative to the long axis of the dental implant, in this case, the *inferior* portion of the dental implant

implant interface \ĭm′plănt′ ĭn′ter-fās\: the junction of the surface of a dental implant and the surrounding host tissues—see FIBROUS INTEGRATION, OSSEOUS INTEGRATION

implant prosthesis \ĭm′plănt′ prŏs-thē′sĭs\ *slang*: *usage*- a prosthesis is not an implantable device. Dental prosthesis such as crown and other fixed dental prostheses, removable dental prostheses as well as maxillofacial prostheses can be supported and retained in part or whole by dental implants. Terminology to assist in understanding the means of retention and support should be limited to concatenation of three and no more than four adjectives to provide clarity. Descriptive terminology may include the *method of retention, composition, nature of support, design characteristics,* and *form of anchorage*

Simon H, Yanase RT. Terminology for Implant Prostheses. Int J Oral Maxillofac Implants 2003; 18:539-543.

implant prosthodontics \ĭm′plănt′ prŏs′tha-dŏn′tĭks\: the phase of prosthodontics concerning the replacement of missing teeth and/or associated structures by restorations that are attached to dental implants

implant substructure \ĭm′plănt′ sŭb′strŭk′chur\ *slang*: the metal *framework* of a eposteal dental implant that is embedded beneath the soft tissues, in contact with the bone, and stabilized by means of endosteal screws. The periosteal tissues retain the framework to the bone. The framework supports the prosthesis, frequently by means of dental implant abutments and other superstructure components

implant surgery \ĭm′plănt′ sûr′ja-rē\ (1993): the phase of implant dentistry concerning the selection, planning, and placement of the implant body and abutment

im·plan·tol·o·gy \ĭm′plăn-tŏl′a-gē\ *obs*: a term historically conceived as the study or science of placing and restoring dental implants—see IMPLANT DENTISTRY, IMPLANT SURGERY, IMPLANT PROSTHODONTICS

im·ple·ment *n*: see DEVICE

im·pres·sion \ĭm-prĕsh′an\ *n* (14c): a negative likeness or copy in reverse of the surface of an object; an imprint of the teeth and adjacent structures for use in dentistry—see ALTERED CAST PARTIAL DENTURE I., DENTAL I., DIRECT BONE I., I. AREA, I. MATERIAL, I. TRAY, MASTER I., PARTIAL DENTURE I., PRELIMINARY I., SECTIONAL I., TUBE I.

impression area \ĭm-prĕsh′an âr′ē-a\: the surface that is recorded in an impression

impression compound: *slang*: see MODELING PLASTIC I.C.

impression coping \ĭm-prĕsh′an kō′pĭng\ (1998): **1:** that component of a dental implant system used to provide a spatial relationship of an endosteal dental implant to the alveolar ridge and adjacent dentition or other structures. Impression copings can be retained in the impression or may require a transfer (termed an *impression transfer procedure*) from intraoral usage to the impression after attaching the analog or replicas **2:** any device that registers the position of the dental implant or dental implant abutment relative to adjacent structures; most such devices are indexed to assure reproducible three dimensional location

impression material \ĭm-prĕsh′an mă-tîr′ē-al\: any substance or combination of substances used for making an impression or negative reproduction

impression post *substand*: see IMPRESSION COPING

impression surface \ĭm-prĕsh′an sûr′fas\ *obs*: the portion of the denture surface that has its contour determined by the impression (GPT-4)–see IMPRESSION AREA

impression technique \ĭm-prĕsh′an tĕk′nēk\ *obs*: a method and manner used in making a negative likeness (GPT-4)

impression tray \ĭm-orĕsh′an trā\: **1:** a receptacle into which suitable impression material is placed to make a negative likeness **2:** a device that is used to carry, confine, and control impression material while making an impression

impression wax: see DENTAL IMPRESSION WAX

incisal guidance \ĭn-sī′zal gīd′ans\: **1:** the influence of the contacting surfaces of the mandibular and maxillary anterior teeth on mandibular movements **2:** the influences of the contacting surfaces of the guide pin and guide table on articulator movements

incisal guide \ĭn-sī′zal gīd\ *obs*: the part of an articulator that maintains the incisal guide angle (GPT-4)–see ANTERIOR GUIDE TABLE

incisal guide angle \ĭn-sī′zal gīd ăng′gal\: **1:** anatomically, the angle formed by the intersection of the plane of occlusion and a line within the sagittal plane determined by the incisal edges of the maxillary and mandibular central incisors when the teeth are in maximum intercuspation **2:** on an articulator, that angle formed, in the sagittal plane, between the plane of reference and the slope of the anterior guide table, as viewed in the sagittal plane

incisal guide pin: see ANTERIOR GUIDE PIN

incisal guide table: see ANTERIOR GUIDE TABLE

incisal porcelain: a porcelain blend used for the incisal portion of a ceramic restoration–*comp* BODY PORCELAIN, GINGIVAL PORCELAIN

incisal reduction: the amount of tooth preparation at the incisal edge–*comp* INCISAL REDUCTION, OCCLUSAL REDUCTION

incisal rest \ĭn-sī′zal rĕst\: a rigid extension of a removable partial denture that contacts a tooth at the incisal edge

incisal restoration \ĭn-sī′zal rĕs′tarā′shun\: any restoration extending along the incisal edge of a tooth

incisive foramen \ĭn-sī′sĭv fôr′man\: a foramen located in the midline on the anterior of the hard palate. It transmits the nasopalatine nerves and vessels–called also *nasopalatine foramen*

incisive papilla \ĭn-sī′sĭv pa-pĭl′a\: the elevation of soft tissue covering the foramen of the incisive or nasopalatine canal

inclined plane \ĭn-klīnd plān\: any of the inclined cuspal surfaces of a tooth

incomplete cleft palate \ĭn′kam-plē′tĭd klĕft păl′ĭt\: a cleft involving only a part of the hard or/and soft palate

in·co·or·di·na·tion \ĭn-kō-ôr′dn-ā′shun\ *n* (1876): inability to move in a smooth, controlled, symmetrical movement

in·dex \ĭn′dĕks′\ *n* (1571): a core or mold used to recordĭ or maintain the relative position of a tooth or teeth to one another, to a cast, or to some other structure

indirect fracture \ĭn′dĭ-rĕkt′, -dī-\: a fracture at a point distant from the primary site of injury due to secondary forces

indirect pulp capping \ĭn′dĭ-rĕkt′, -dī-pŭlp kăp′ĭng\: a procedure that seeks to stimulate formation of reparative dentin by placing a material over sound or carious dentin

indirect retainer \ĭn′dĭ-rĕkt′, -dī- rĭ-tā′ner\: the component of a partial removable dental prosthesis that assists the direct retainer(s) in preventing displacement of the distal extension denture base by functioning through lever action on the opposite side of the fulcrum line when the denture base moves away from the tissues in pure rotation around the fulcrum line

indirect retention \ĭn′dĭ-rĕkt′, -dī- rĭ-tĕn′shun\: the effect achieved by one or more indirect retainers of a partial removable denture prosthesis that reduces the tendency for a denture base to move in an occlusal direction or rotate about the fulcrum line

in·du·rate \ĭn′da-rāt,–dya-\ *vb* **-rat·ed** \rā′tĭd\; **-rat·ing** \rā′tĭng\ (1538): to make hard–**in·du·ra·tion** \ĭn′da-rā′shun\ *n*–**in·du·ra·tive** \ĭn′da-rā′tĭv\ *adj*

in·du·rat·ed \ĭn′da-rā′tĭd\ *adj* (1604): having become firm or hard, especially by an increase in fibrous elements

in·fra·bulge \ĭn′fra-bŭlj\ *n*: that portion of the crown of a tooth apical to the survey line

infrabulge clasp \ĭn′fra-bŭlj klăsp\: a removable partial denture retentive clasp that approaches the retentive undercut from a cervical or infrabulge direction

in·fra·erup·tion \ĭn′fra-ĭ-rŭp′shun\ *n*: failure in eruption of a tooth to the established plane of occlusion

infrared soldering: joining the components of a fixed dental prosthesis with a specially designed unit that uses infrared light as its heat source–*comp* OVEN SOLDERING

in·fra·oc·clu·sion \ĭn′fra-a-klōō′shun\ *n*: malocclusion in which the occluding surfaces of teeth are below the normal plane of occlusion

infrared radiation \ĭn′fra-rĕd\: electromagnetic radiation of wavelengths between 760 nm and 1000 nm

in·fra·struc·ture \ĭn′fra-strŭk′chur\ *n*: a metal or ceramic framework onto which a second framework or prosthesis will be placed

ingot \ĭng′gat\ *n*: **1:** a mold in which metal is cast **2:** a mass of metal cast into a shape convenient for storage and measure that can be re melted for later casting

initial occlusal contact \ĭ-nĭsh′al a-klōō′sal kŏn′tăkt\: during closure of the mandible, the first or initial contact of opposing teeth between the arches

injection molding \ĭn-jĕk′shun mōl′dĭng\: the adaptation of a plastic material to the negative form of a closed mold by forcing the material into the mold through appropriate gateways–see COMPRESSION MOLDING

in·lay \ĭn-lā′, ĭn′lā′\ *n* (1667): a fixed intracoronal restoration; a dental restoration made outside of a tooth to correspond to the form of the prepared cavity, which is then luted into the tooth

inlay wax: see CASTING WAX

in·ser·tion *vb*: see PLACEMENT

instantaneous axis of rotation \ĭn′stantā′nē-as ăk′sĭs ŭv rō-tā′shun\: the hypothetical center of rotation of a moving body, viewed in a given plane, at any point in time; for any body that has planar motion, there exists, at any instant, some points that have zero velocity and will be fixed at a given instant. The line joining these points is the *instantaneous axis of rotation.* The intersection of this line with the plane of motion is called the *instantaneous center of rotation*

in·stru·ment \ĭn′stra-ment\ *n*: a tool or implement, especially one used for

delicate work or for artistic or scientific purposes—see DEVICE

in·tagl·io \ĭn-tăl′yō, -täl′-\ *n, pl* **-ios** \-yōs\ (1644): **1:** an incised or engraved figure in stone or any hard material depressed below the surface of the material such that an impression from the design would yield an image in relief **2:** something carved in intaglio

intaglio surface \ĭn-tăl′yō, täl′- sûr′fas\: the portion of the denture or other restoration surface that has its contour determined by the impression; the interior or reversal surface of an object

integration: see FIBROUS I., OSSEOUS I., TISSUE I.

interalveolar space: see INTERARCH DISTANCE

interarch distance \ĭn′ter-ärch\: the interridge distance; the vertical distance between the maxillary and mandibular dentate or edentate arches under specified conditions—see REDUCED I.D.

interarch expansion device: see TRISMUS APPLIANCE

interceptive occlusal contact: see DEFLECTIVE OCCLUSAL CONTACT

in·ter·con·dy·lar \ĭn′ter-kŏn′da-lar\ *adj*: situated between two condyles

intercondylar axis: see CONDYLAR AXIS

intercondylar distance \ĭn′ter-kŏn′da-lar dĭs′tans\: the distance between the rotational centers of two condyles or their analogues

intercuspal contact \ĭn′ter-kŭs′păl kŏn′tăkt\: the contact between the cusps of opposing teeth

intercuspal contact area \ĭn′ter-kŭs′păl kŏn′tăkt âr′ē-a\: the range of tooth contacts in maximum intercuspation

intercuspal occlusion: see MAXIMAL INTERCUSPAL POSITION

intercuspal position: see MAXIMAL INTERCUSPAL POSITION

in·ter·cus·pa·tion \ĭn′ter-kŭs-pā′shun\ *n, obs*: the interdigitation of cusps of opposing teeth (GPT-4)

in·ter·den·tal \ĭn′ter-dĕn′tl\ *adj*: between the proximal surfaces of the teeth within the same arch

interdental gingival void: any interproximal soft tissue loss due to periodontal disease, traumatic, mechanical or chemical preparation or crown lengthening procedures

interdental papilla \ĭn′ter-dĕn′tl pa-pĭl′a\: a projection of the gingiva filling the space between the proximal surfaces of two adjacent teeth

interdental space: see DIASTEMA, INTERARCH DISTANCE, and INTERPROXIMAL SPACE

interdental splint \ĭn′ter-dĕn′tl splĭnt\: a splint for treatment of fractures and consisting of a metal or acrylic resin prostheses wired to the teeth in the maxilla and mandible and joined to keep the segments immovable—see GUNNING'S SPLINT

interdigitated occlusion: see MAXIMAL INTERCUSPAL POSITION

in·ter·dig·i·ta·tion *n*: see MAXIMAL INTERCUSPAL POSITION

in·ter·fer·ence \ĭn′ter-fîr′ans\ *n* (1783): in dentistry, any tooth contacts that interfere with or hinder harmonious mandibular movement

interim denture: see INTERIM PROSTHESIS

interim endosteal dental implant abutment \ĭn′ter-ĭm ĕn-dŏs′tē-al dĕn′tl ĭm′plănt′ a-bŭt′ment\: any dental implant abutment used for a limited time to assist in healing or modification of the adjacent tissues

interim obturator \ĭn′ter-ĭm ŏb′ta-rā′tor\: a maxillofacial prosthesis which is made following completion of initial healing following surgical resection of a portion or all of one or both maxillae; frequently many or all teeth in the defect area are replaced by this prosthesis. This prosthesis replaces the *surgical obturator* which is usually inserted at or immediately following the resection. Generally, an interim obturator is made to facilitate closure of the resultant defect after initial healing has been completed. *Editorial Note: Unlike the surgical obturator, which usually is made prior to surgery and frequently revised in the operating room during surgery, the interim obturator is made when the defect margins are clearly defined and further surgical revisions are not planned. It is a provisional prosthesis . . . Also, it frequently must be revised (termed an* obturator prosthesis modification*) during subsequent dental procedures (i.e. restorations, gingival surgery, etc.) as well as to compensate for further tissue shrinkage before a* definitive obturator *prosthesis is made.*

interim ocular prosthesis \ĭn′ter-ĭm ŏk′ya-lar prŏs-thē′sĭs\: an interim replacement generally made of clear acrylic resin for an eye lost due to surgery or trauma. No attempt is made to reestablish esthetics—*syn* CONFORMER, EYE SHELL, SHELL, OCULAR CONFORMER

interim palatal lift prosthesis: see PALATAL LIFT PROSTHESIS

interim prosthesis \ĭn′ter-ĭ prŏs-thē′sĭs\: a fixed or removable dental prosthesis, or maxillofacial prosthesis, designed to enhance esthetics, stabilization and/or function for a limited period of time, after which it is to be replaced by a definitive dental or maxillofacial prosthesis. Often such prostheses are used to assist in determination of the therapeutic effectiveness of a specific treatment plan or the form and function of the planned for definitive prosthesis—***syn*** PROVISIONAL PROSTHESIS, PROVISIONAL RESTORATION

interlock \ĭn′ter-lŏk\ *n* (1874): a device connecting a fixed unit or a removable dental prosthesis to another fixed unit

interlocking cast core: a foundation restoration for an endodontically treated, multirooted tooth that comprises multiple castings to engage divergent roots

intermaxillary fixation: see MAXILLOMANDIBULAR FIXATION

intermaxillary relation: see MAXILLOMANDIBULAR RELATIONSHIP

intermediary jaw movement \ĭn′ter-mē′dē-ĕr′ē jô mōōv′ment\ *obs*: all movements between the extremes of mandibular excursions (GPT-3)

intermediate abutment \ĭn′ter-mē′dē-ĭt a-bŭt′ment\: a natural tooth located between terminal abutments that serve to support a fixed or removable dental prosthesis

internal attachment: see PRECISION ATTACHMENT

internal connector \ĭn-tûr′nal ka-nĕk′tor\: a nonrigid connector of varying geometric designs using a matrix to unite the members of a fixed partial denture

internal derangement \ĭn-tûr′nal dĭ-rānj′ment\: with respect to the temporomandibular joint, a deviation in position or form of the tissues within the capsule of the temporomandibular joint; an abnormal relationship of the disk to the condyle, fossa, and/or eminence

internal rest: see PRECISION REST

interocclusal \ĭn′ter-a-klōō′sal\ *adj*: between the occlusal surfaces of opposing teeth

interocclusal clearance \ĭn′ter-a-klōō′sal klîr′ans\: **1:** the arrangement in which

the opposing occlusal surfaces may pass one another without any contact **2:** the amount of reduction achieved during tooth preparation to provide for an adequate thickness of restorative material

interocclusal distance \ĭn′ter-a-klōō′sal dĭs′tans**:** the distance between the occluding surfaces of the maxillary and mandibular teeth when the mandible is in a specified position

interocclusal gap *obs***:** see INTEROCCLUSAL DISTANCE

interocclusal record \ĭn′ter-a-klōō′sal rĕk′ard**:** a registration of the positional relationship of the opposing teeth or arches; a record of the positional relationship of the teeth or jaws to each other

interocclusal rest space \ĭn′ter-a-klōō′sal rĕst spās**:** the difference between the vertical dimension of rest and the vertical dimension while in occlusion

interproximal contact \ĭn′ter-prŏk′sa-mal kŏn′tăkt**:** the area of a tooth that is in close association, connection, or touch with an adjacent tooth in the same arch

interproximal space \ĭn′ter-prŏk′sa-mal spās**:** the space between adjacent teeth in a dental arch. It is divided into the *embrasure space,* occlusal to the contact point, and the *septal space,* gingival to the contact point

interradicular space: the space between roots of adjacent teeth in a dental arch

interridge distance: see INTERARCH DISTANCE

interrupted bridge \ĭn′ta-rŭp′tĭd brĭj\ *obs***:** a fixed dental prosthesis with one or more nonrigid connectors

intracapsular adhesion \ĭn′tra-kăp′sa-lar ăd-hē′zhen**:** adhesions occurring within the joint capsule, resulting in reduced mobility

intracapsular ankylosis \ĭn′tra-kăp′sa-lar ăng′ka-lō′sĭs**:** diminished joint motion due to disease, injury, or surgical procedure within a joint capsule

intracapsular disorder \ĭn′tra-kăp′sa-lar dĭs-ôr′der**:** a problem associated with the masticatory system in which the etiological factors are located within the temporomandibular joint capsule

intracapsular fracture \ĭn′tra-kăp′sa-lar frăk′chur**:** a fracture of the condyle of the mandible occurring within the confines of the capsule of the temporomandibular joint—called also *intraarticular fracture*

in·tra·con·dy·lar \ĭn′tra-kŏn′dĭ′lar\ *adj***:** within the condyle

in·tra·cor·o·nal \ĭn′tra-kôr-a-nal\ *adj***: 1:** within the confines of the cusps and normal proximal/axial contours of a tooth **2:** within the normal contours of the clinical crown of a tooth

intracoronal attachment: any prefabricated attachment for support and retention of a removable dental prosthesis. The male and female components are positioned within the normal contour of the abutment tooth—see EXTRACORONAL ATTACHMENT, PRECISION ATTACHMENT

in·tra·mu·co·sal \ĭn′tra-myōō-kō′sal\ *adj***:** situated, formed by, or occurring within the mucosa

intramucosal implant: see MUCOSAL INSERT

intramucosal insert: see MUCOSAL INSERT

in·tra·or·al \ĭn′tra-ôr′al\ *adj***:** within the mouth

intraoral tracing \ĭn′tra-ôr′al trā′sĭng**:** a tracing made within the oral cavity—see ARROW POINT TRACING

in·tra·os·seo·us \ĭn′tra-ŏs′ē-us\ *n***:** within bone

intrinsic coloring \ĭn-trĭn′zĭk, -sĭk kŭl′arĭng**:** coloring from within; the incorporation of a colorant within the material of a prosthesis or restoration

in·tru·sion \ĭn-trōō′zhen\ *vb***:** movement of a tooth in an apical direction

invariant color match \ĭn-vâr′ē-ant kŭl′ar măch**:** a perfect color match under all light conditions

inverted cusp tooth \ĭn-vŭr′tĭd kŭsp tōōth\ *obs***:** a nonanatomic posterior porcelain denture tooth that had circular indentations where cusps would normally be located

in·vest \ĭn-vĕst′\ *vb***:** to surround, envelop, or embed in an investment material—see VACUUM INVESTING

in·vest·ing \ĭn-vĕs′tĭng\ *v***:** the process of covering or enveloping, wholly or in part, an object such as a denture, tooth, wax form, crown, etc. with a suitable investment material before processing, soldering, or casting

in·vest·ment *n***:** see DENTAL CASTING I., REFRACTORY I.

investment cast \ĭn-vĕst′ment kăst**:** a cast made of a material that will withstand high temperature without disintegration—*comp* REFRACTORY CAST

ion exchange strengthening \ī′an, ī′ŏn′ĭks-chănj′ strĕngk′tha-nĭng**:** the chemical process whereby the surface of a glass is placed in compression by the replacement of a small ion by a larger one while maintaining chemical neutrality

ionizing radiation \ī′a-nī′zĭng rā′dē-ā-shun**:** any radiation capable of displacing electrons from atoms or molecules thereby producing ions

ir·i·des·cent \ĭr′ĭ-dĕs′ant\ *adj* (1796)**:** colors produced by interference, refraction, or diffraction

irreversible hydrocolloid \ĭr′ĭ-vûr′sa-bal hī′dra-kŏl′oid′**:** a hydrocolloid consisting of a sol of alginic acid having a physical state that is changed by an irreversible chemical reaction forming insoluble calcium alginate—called also *alginate, dental alginate*

is·chem·ia \ĭ-skē′mē-a\ *n* (ca. 1860)**:** local and temporary deficiency of blood, chiefly resulting from the contraction of a blood vessel

iso·graft \ī′sa-grăft\ *n* (1909)**:** a graft from one individual to another with the same genetic basis, as in twins—called also *isogeneic graft, syngraft*

isometric contraction \ī′sa-mĕt′rĭk kontrăk′shun**:** muscular contraction in which there is no change in the length of the muscle during contraction

isotonic contraction \ī′sa-tŏn′ĭk kontrăk′shun**:** muscular contraction in which there is a shortening of the length of the muscle while the muscle maintains a constant tension

iso·tope \ī′sa-tōp′\ *n* (ca 1913)**:** a chemical element having the same atomic number as another but possessing a different atomic mass

J

jacket crown: see CERAMIC CROWN, RESIN CROWN

Jackson crib clasp [V. H. Jackson, New York, N.Y., dentist] *obs***:** a one-piece clasp bent to engage the mesial and distal interproximal undercuts in adjacent natural teeth. Usually it was made by hand bending of a straight wire of appropriate dimensions

Kennedy E. The Jackson crib clasp technique in partial denture construction. Brooklyn: Dental Items of Interest, 1928.

Essig CJ. The American textbook of prosthetic dentistry. Philadelphia: Lea Brothers and Co., 1896:185-7.

Jackson magnet [Thomas R. Jackson, U.S. dentist]**:** *eponym* for permanent

magnetic alloy magnets using rare earth metals adapted for oral use

Jackson TR. New rare earth magnetic technology: the Jackson solid state attachment system. Trends Tech Contemp Dent Lab 1986;5:31-9.

jaw \jô\ *n* (14c)**:** the bony structure bearing the teeth—see MANDIBLE, MAXILLA

jaw malposition \jô măl′pa-zĭsh′an\ *obs***:** any abnormal position of the mandible (GPT-3)

jaw movement: see MANDIBULAR MOVEMENT

jaw record: see MAXILLOMANDIBULAR RELATIONSHIP RECORD

jaw relation: see MAXILLOMANDIBULAR RELATIONSHIP

jaw relation record: see MAXILLOMANDIBULAR RELATIONSHIP RECORD

jaw repositioning: see MANDIBULAR REPOSITIONING

jig \jĭg**:** a device used to maintain mechanically the correct positional relationship between a piece of work and a tool or between components during assembly or alteration

joint \joint\ *n* (13c)**:** the place of union of two or more bones—see ARTHRODIAL J., COMPOUND J., DIARTHRODIAL J., GINGLYMOUS J., SIMPLE J., TEMPOROMANDIBULAR J.

joint crepitus \joint krĕp′ĭ-tŭs**:** the grating sensation caused by the rubbing together of the bony surfaces of joints—called also *articular crepitus*

junctional epithelium \jŭngk′shun-al ĕp′a-thē′lē-um**:** a single or multi-layer of non-keratinizing cells adhering to the tooth surface at the base of the gingival crevice—called also *epithelial attachment*

jump case *slang***:** see REBASE, RELINE

K

ka·olin \kā′a-lĭn\ *n* (1727)**:** fine, usually white, clay that is used in ceramics and refractory materials as a filler or extender

keep·er \kē′par\ *n* (14c)**:** any one of various devices used for keeping something in position—*usage:* in dentistry, this is usually construed to mean a magnetized alloy attached to one element of a restoration to which a magnet may adhere

Kelly's syndrome [Ellsworth Kelly, U.S. prosthodontist]**:** see COMBINATION SYNDROME

Kelly E. Changes caused by a mandibular removable partial denture opposing a maxillary complete denture. J PROSTHET DENT 1972;27:140-50.

Kelvin temperature [Thomson W. (Lord Kelvin), Scottish mathematician and physicist (1824-1907)]**:** absolute temperature indicated by the symbol K. Zero Kelvin = 273° C

Kennedy bar [Edward Kennedy, U.S. dental surgeon]**:** see CONTINUOUS BAR CONNECTOR

Kennedy E. Partial denture construction. Brooklyn: Dental Items of Interest, 1928.

Kennedy bar connector [Edward Kennedy, U.S. dental surgeon]**:** see CONTINUOUS BAR CONNECTOR

Kennedy E. Partial denture construction. Brooklyn: Dental Items of Interest, 1928.

Kennedy classification of removable partial dentures [Edward Kennedy, U.S. dental surgeon, variably dated 1923, 1925, and 1928]**:** a classification of partially edentulous arches divisible into four classes. Class 1: a bilateral edentulous areas located posterior to the remaining natural teeth. Class II: a unilateral edentulous area located posterior to the remaining natural teeth. Class III: a unilateral edentulous area with natural teeth located both anterior and posterior to it. Class IV: a single bilateral edentulous area located anterior to the remaining natural teeth. Edentulous areas, in addition to those determining the main types, were designated as *modification spaces*. O. C. Applegate's Rules govern application of the Kennedy system

Kennedy E. Partial denture construction. Brooklyn: Dental Items of Interest, 1928.

ker·a·tin \kĕr′a-tĭn\ *n* (1847)**:** a protein present in all cuticular (cornified) structures of the body, such as hair, epidermis, horns, and the organic matrix of the enamel of the teeth

ker·a·tin·i·za·tion \kĕr′a-tĭn-ĭ-zā-shun\ *n***:** the process of maturation of keratinocytes. The formation of a protein layer (keratin) on the surface of some epithelia

keratinized gingival \kĕr′a-tī-nīzd jĭn′ja-va**:** the oral surface of the gingiva extending from the mucogingival junction to the gingival margin. In gingival health, the coronal portion of the sulcular epithelium may also be keratinized. The pattern of keratinization may be *ortho*-or *para*-

key and keyway attachment: see ATTACHMENT

key·way \kē′wā′\ *n***:** an interlock using a matrix and patrix between the units of a fixed dental prosthesis. It may serve two functions: 1) to hold the pontic in the proper relationship to the edentulous ridge and the opposing teeth during occlusal adjustment on the working cast (during application of any veneering material) and 2) to reinforce the connector after soldering

kinematic axis \kĭn′a-măt′ĭk ăk′sĭs**:** the transverse horizontal axis connecting the rotational centers of the right and left condyles

kinematic facebow \kĭn′a-măt′ĭk fās-bō**:** a facebow with adjustable caliper ends used to locate the transverse horizontal axis of the mandible

kinematics \kĭn′a-măt′ĭks**:** the phase of mechanics that deals with the possible motions of a material body

Kingsley splint \Kĭngz′lē′ splĭnt\ [Norman William Kingsley, U.S. dentist, 1829-1913] *obs***:** *eponym* for a maxillary splint used to apply traction to reduce and immobilize maxillary fractures and immobilize them through wings attached to a head device by elastics. C. L. Goddard cites Dr. Kingsley as first using "the occipital appliance" in 1866

Essig CJ. The American textbook of prosthetic dentistry. Philadelphia: Lea Brothers and Co., 1896:204.

Kingsley NW. Oral deformities. 1866:134.

Knoop hardness number: (KHN) a measure of hardness obtained with a diamond pyramid indenter and rhombic base with included angles of 172.5° and 130°. *KHN* is the ratio of the applied load to the area of the indentation

F Knoop, CG Peters, WB Emerson. A sensitive pyramidal-diamond tool for indentation measurements. J Res Natl Bur Stands (U.S.) 1939; 23:39-61

Knoop hardness tests [Frederick Knoop, U.S. engineer, U.S. Department of Commerce]**:** *eponym* for a surface hardness test using a diamond stylus. It is used for harder materials and is characterized by the diamond or rhomboid shaped indentation. The indentation micro-hardness test uses a rhombic-based pyramidal diamond indenter. The long diagonal of the resulting indentation is measured to determine

the hardness. This test is suitable for most classes of materials including brittle and elastomeric

Knoop F, Peters CG, Emerson WB. A sensitive pyramidal diamond tool for indentation measurements. J Res Nat Bur Stand 1939;12:39-45.

Kubelka-Munk scattering coefficient [authors unknown]: eponym for the multiple (diffuse) scattering coefficient for a unit of thickness and concentration of scattering material in a medium of a different refractive index as used in the Kubelka-Munk Equation. It is the rate of increase of reflectance of a layer over black, as thickness is increased. Hence, the assumption is made that the entire scattering is in the backward or reverse direction from that of the incident diffuse light

Kubelka P. New contributions to the optics of intensely light scattering materials. Part 1. J Opt Soc Am 1948;38:448-57.

Kubelka-Munk theory [authors unknown]: *eponym* for a theory describing the optical behavior of materials containing small particles that scatter and absorb radiant energy. It is widely used for color matching

Kubelka P, Munk F. Ein Beitrag zur Optik der farbenstriche. Z Tech Phys 1931;12:593-601.

L

lab·i·al \lā′bē-al\ *adj* (1594): **1:** of or pertaining to the lip **2:** toward the lip

labial bar: see LABIAL BAR CONNECTOR

labial bar connector \lā′bē-al bär ka-nĕk′tor\: a major connector located labial to the dental arch

labial flange \lā′bē-al flănj\: the portion of the flange of a denture that occupies the labial vestibule of the mouth

labial splint \lā′bē-al splĭnt\: a device of plastic, metal, or both, made to conform to the outer aspect of the dental arch and used in the management of jaw and facial injuries

labial vestibule \lā′bē-al vĕs′ta-byōōl\: the portion of the oral cavity that is bounded on one side by the teeth, gingiva, and alveolar ridge (in the edentulous mouth, the residual ridge) and on the other by the lips anterior to the buccal frenula

la·bio·ver·sion \lā′bē-ō-vûr′shun\ *n*: labial position of a tooth beyond the normal arch form

lamina dura \lăm′a-na dŭr′a\: the layer of compact bone forming the wall of a tooth alveolus

land area \lănd âr′ē-a\: the portion of a dental cast that extends beyond the impression's replica surface laterally that defines the area between the end of the replica's surface and the cast

lap \lăp\ *vb* **lap·ped** \(lăpd\; **lap·ping** \lă′pĭng\ *vt* (14c) **1a:** to fold over or around something; to wind about **1b:** to envelop entirely **2:** to fold over in successive layers **3:** to place over and cover a part of another **4a:** to dress smooth or to polish to a high degree **4b:** to fit or shape by working two surfaces together with or without abrasives until a very close fit is achieved—**lap·per** \lă′per\ *n*

laser \lā′zer\ n (1957): *acronym* for Light Amplification by Simulated Emission of Radiation: a device that transforms light of various frequencies into an intense, small, and nearly non-divergent beam of monochromatic radiation, within the visible range

laser therapy \lā′zer thĕr′a-pē\: the use of laser energy in the treatment of tissue pathosis

laser welding \lā′zer wĕl′dĭng\: the joining of metal components through the use of heat generated with a laser beam

late closing click \lāt klō′zĭng klĭk\: the sound emanating from the temporomandibular joint that occurs just prior to termination of closure in some patients with anteriorly displaced disks

late opening click \lāt ō′pa-nĭng klĭk\: the sound emanating from the temporomandibular joint that occurs just prior to termination of opening in some patients with anteriorly displaced disks

lat·er·al \lăt′ar-al\ *adj* (15c): **1:** positions either right or left of the midsagittal plane **2:** denotes a position farther from the median plane or midline of the body or structure

lateral checkbite: see LATERAL INTEROCCLUSAL RECORD

lateral condylar inclination \lăt′ar-al kŏn′da-lar ĭn′kla-nā′shun\: the angle formed by the path of the moving condyle within the horizontal plane compared with the median plane (anterior-posterior movement) and within the frontal plane when compared with the horizontal plane (superior-inferior movement)—see LATEROTRUSION

lateral condylar path \lăt′ar-al kŏn′da-lar păth\: the path of movement of the condyle-disk assembly in the joint cavity when a lateral mandibular movement is made

lateral incisor \lăt′ar-al ĭn-sī′zor\: the second incisor

lateral interocclusal record \lăt′ar-al ĭn′ter-a-klōō′sal rĕk′ard′\: a registration of the positional relationship of opposing teeth or arches made in either a right or left lateral position of the mandible

lateral mandibular movement: see MANDIBULAR LATERAL TRANSLATION

lateral mandibular relation \lăt′ar-al măn-dĭb′ya-lar rĭ-lā′shun\: the relationship of the mandible to the maxillae in a position to the left or right of the midsagittal plane

lateral movement \lăt′ar-al mōōv′ment\ *obs*: a movement from either right or left of the midsagittal plane (GPT-4)

lateral protrusion: see LATEROPROTRUSION

lateral relation \lăt′ar-al rĭ-lā′shun\ *obs*: the relation of the mandible to the maxillae when the lower jaw is in a position to either side of centric relation (GPT-4)

lateral side shift: see MANDIBULAR TRANSLATION

lat·ero·de·tru·sion \lăt′ar-ō-de-trōō′zhun\ *n*: lateral and downward movement of the condyle on the working side—see LATEROTRUSION

lat·ero·pro·tru·sion \lăt′ar-al-prō-trōō′zhun\ *n*: a protrusive movement of the mandibular condyle in which there is a lateral component

lat·ero·re·tru·sion \lăt-ar-ō-rĭ-trōō′shun\ *n*: lateral and backward movement of the condyle on the working side

lat·ero·sur·tru·sion \lăt-ar-ō-sûr-trōō′shun\ *n*: lateral and upward movement of the condyle on the working side—see LATEROTRUSION

lat·ero·tru·sion \lăt-ar-ō-trōō′shun\ *n*: condylar movement on the working side in the horizontal plane. This term may be used in combination with terms describing condylar movement in other planes, for example, *laterodetrusion, lateroprotrusion, lateroretrusion,* and *laterosurtrusion*

Le Fort fracture [Leon Clement Le Fort, French surgeon, 1829-1893]: *eponym* for a midfacial fracture, classified into three categories (I, II, III)

Le Fort I fracture: *eponym* for a horizontal segmented fracture of the alveolar process of the maxilla, in which the

teeth are usually contained within the detached portion

Le Fort II fracture: *eponym* for a pyramidal fracture of the midfacial skeleton with the principal fracture lines meeting at an apex at or near the superior aspect of the nasal bones

Le Fort III fracture: *eponym* for a craniofacial dysjunction fracture in which the entire maxilla and one or more facial bones are completely separated from the craniofacial skeleton

leaf gauge \lēf gāj\: a set of blades or leaves of increasing thickness used to measure the distance between two points or to provide metered separation

lengthening of the clinical crown \lĕngk′tha-nĭng ŭv tha klĭn′ĭ-kal kroun\: a surgical procedure designed to increase the extent of supragingival tooth structure for restorative or esthetic purposes by apically positioning the gingival margin, removing supporting bone, or both

LET: *acronym* for *Linear Energy Transfer*: the energy dissipation of ionizing radiation over a given linear distance. Highly penetrating radiations such as gamma rays cause low ion concentration and thus have a relatively low LET, x-rays and beta particles exhibit intermediate LET, and alpha particles have a high LET

light \līt\ *n* (bef. 12c): the aspect of electromagnetic radiation of which the human observer is aware through the visual sensations that arise from the stimulation of the retina of the eye

light source \līt sors\: an object that emits light or radiant energy to which the human eye is sensitive. The emission of a light source can be described by the relative amount of energy, emitted at each wavelength in the visible spectrum; the emission may be described in terms of its correlated color temperature

light·ness \līt′nĭs\ *n* (bef. 12c): **1:** achromatic dimension necessary to describe the three-dimensional nature of color, the others being hue and saturation. The lightness dimension may also be called brightness. In the Munsell Color Order System, the lightness dimension is called value **2:** perception by which white objects are distinguished from gray and light objects from dark ones; equivalent to shading in grays

lim·bus \lĭm′bas\: a border or interface especially if marked by a difference in color or structure between adjoining parts

line angle \līn ang′gal\: the point of convergence of two planes in a cavity preparation

linear coefficient of thermal expansion: the fractional change in length of a given material per degree change in temperature

line of occlusion \līn ŭv a-klōō′shun\: the alignment of the occluding surfaces of the teeth as viewed in the horizontal plane—see OCCLUSAL PLANE

linear occlusion \lĭn′ē-ar a-klōō′shun\: the occlusal arrangement of artificial teeth, as viewed in the horizontal plane, wherein the masticatory surfaces of the mandibular posterior artificial teeth have a straight, long, narrow occlusal form resembling that of a line, usually articulating with opposing monoplane teeth.

Frush JP. Linear occlusion. Ill Dent J 1966;35:788-94.

lin·gual \lĭng′gwal\ *adj* (15c): pertaining to the tongue; next to or toward the tongue

lingual apron: see LINGUAL PLATE

lingual bar: see LINGUAL BAR CONNECTOR

lingual bar connector \lĭng′gwal bär ka-nĕk′tor\: a major connector of a partial removable dental prosthesis located lingual to the dental arch

lingual flange \lĭng′gwal flănj\: the portion of the flange of a mandibular denture that occupies the alveololingual sulcus

lingual inclination \lĭng′gwal ĭn-kla-nā′shun\: deviation of the coronal portion of a tooth from the vertical plane toward the tongue

lingual plate \lĭng′gwal plāt\: the portion of the major connector of a partial removable dental prosthesis contacting the lingual surfaces of the natural teeth—also spelled *linguoplate*

lingual rest \lĭng′gwal rĕst\: a metallic extension of a partial removable dental prosthesis framework that fits into a prepared depression within an abutment tooth's lingual surface

lingual rest seat \lĭng′gwal rĕst sēt\: the depression prepared on the lingual surface of an abutment tooth to accept the metal rest of a partial denture (the lingual rest)

lingual splint \lĭng′gwal splĭnt\: a dental splint conforming to the inner aspect of the dental arch

lingual strap: see LINGUAL PLATE

lingualized occlusion \lĭng′gwa-līzd a-klōō′shun\: first described by S. Howard Payne, DDS, in 1941, this form of denture occlusion articulates the maxillary lingual cusps with the mandibular occlusal surfaces in centric working and nonworking mandibular positions. The term is attributed to Earl Pound

Payne SH. A posterior set-up to meet individual requirements. Dent Digest 1941;47:20-22.

Pound E. Utilizing speech to simplify a personalized denture service. J PROSTHET DENT 1970;24:586-600.

lin·guo·c·clu·sion \lĭng′gwa-a-klōō′shun\ *n*: an occlusion in which a tooth or group of teeth is located lingual to its normal position

lin·guo·ver·sion \lĭng′gwa-vûr′zhun, -shun\ *n*: lingual or palatal position of a tooth beyond the normal arch form

lip line: see HIGH L.L., LOW L.L.

lip switch operation \lĭp swĭch ŏp′a-rā′shun\: tissues borrowed from one lip and transferred to the other; also used to describe a *modified vestibuloplasty procedure*—see also ABBE FLAP, ESTLANDER'S OPERATION

Kiethley JL, Gamble JW: The lip switch: a modification of Kazanjian's labial vestibuloplasty. J Oral Surg 36:701-705,1978

loading: see IMMEDIATE LOADING; PROGRESSIVE LOADING

lobe \lōb\ *n* (1525): a curved or rounded projection or division, especially of a body organ or part

local etiologic factors \lō′kal ē′tē-a-lŏj′ĭk făk′tarz\: the environmental influences that may be implicated in the causation, modification, and/or perpetuation of a disease entity

localization film \lō′ka-lĭ-zā′shun fĭlm\: a radiograph made with radiopaque markers to localize the position of a body (i.e., a tumor) relative to external landmarks

long axis \lŏng ăk′sĭs\: a theoretical line passing lengthwise through the center of a body

long centric articulation: see INTERCUSPAL CONTACT AREA

longitudinal axis: see SAGITTAL AXIS

lost-wax casting technique: —also called *investment casting*. The casting of a metal into a mold produced by surrounding *(investing)* an expendable *(wax)* pattern with a refractory slurry

that sets at room temperature, after which the pattern is removed through the use of heat

low lip line \lō lĭp līn\: **1:** the lowest position of the inferior border of the upper lip when it is at rest **2:** the lowest position of the superior border of the lower lip during smiling or voluntary retraction

lower impression \lō′ar ĭm-prăsh′an\ *slang*: an impression of the mandibular jaw or dental structures (GPT-4)—see MANDIBULAR IMPRESSION

lower ridge slope \lō′ar rĭj slōp\ *obs*: **1:** the slope of the mandibular residual ridge in the second and third molar region as seen from the buccal side (GPT-1) **2:** the portion of the lower residual ridge, either lingual, labial, or buccal, between the crest of the ridge and the mucobuccal fold or flexion line of the peripheral tissues (GPT-1)

Lucia jig [Victor O. Lucia, U.S. prosthodontist]: *eponym*—see ANTERIOR PROGRAMMING DEVICE

Lucia VO. Treatment of the edentulous patient. Chicago: Quintessence, 1986.

lug \lŭg\ *n*: something that projects away from an object and is generally used as a support or for connection to a body

lu·mi·nance \lōō′ma-nans\ *n* (1880): the intensity of light per unit area

[1]lute \lōōt\ *n* (15c): a substance, such as cement or clay, used for placing a joint or coating a porous surface to make it impervious to liquid or gas—see CEMENT

[2]lute \lōōt\ *vt;* **lut·ed** \lōō′tĭd\; **lut·ing** \lōō′tĭng\: to fasten, attach, or seal—see CEMENT

luting agent: any material used to attach or cement indirect restorations to prepared teeth

lux·a·tion *n* (1552): an abnormal anterior displacement of the mandibular condyle out of the glenoid fossa that is self-reducing

M

mac·ro·glos·sia \măk′rō-glŏ′zha\ *n*: excessive size of the tongue

mac·ula \măk′ya-la\ *n, pl* **mac·ula** (1863): a patch of tissue that is altered in color but usually not elevated; usually characteristic of various diseases

maintenance dose \mān′ta-nans dōs\: the quantity of a drug necessary to maintain a normal physiologic state or a desired blood or tissue level of drug

major connector \mā′jar ka-năk′tor\: the part of a partial removable dental prosthesis that joins the components on one side of the arch to those on the opposite side

mal·a·lign·ment: see MALOCCLUSION

mal·le·a·ble \măl′ē-a-bal\ *adj* (14c): capable of being extended or shaped with a hammer or with the pressure of rollers

mal·oc·clu·sion \măl′a-klōō′shun\ *n* (1888): **1:** any deviation from a physiologically acceptable contact between the opposing dental arches **2:** any deviation from a normal occlusion—see ANGLE'S CLASSIFICATION OF OCCLUSION

mam·e·lon \măm′a-lŏn\ *n*: one of three tubercles sometimes found on the incisal edges of incisor teeth—**mam·e·lon·at·ed** \măm′a-la-nā′tĭd\ *v,* **mam·e·lon·a·tion** \măm′a-la-nā′shun\ *n*

man·di·ble \măn′da-bal\ *n* (15c): the lower jawbone

man·dib·u·lar \măn-dĭb′ya-lar\ *adj*: of or pertaining to the mandible

mandibular anteroposterior ridge slope \măn-dĭb′ya-lar ăn′ter-pŏ-stîr′ē-ar rĭj slōp\: the slope of the crest of the mandibular residual ridge from the third molar region to its most anterior aspect in relation to the lower border of the mandible as viewed in profile

mandibular axis: see SAGITTAL AXIS, TRANSVERSE HORIZONTAL AXIS, VERTICAL AXIS

mandibular condyle: the articular process of the mandible, called also the *head of the mandible*—see also CONDYLE

mandibular dislocation \măn-dĭb′ya-lar dĭs′lō-kā′shun\: a non-self-reducing displacement of the mandibular condyle out of the glenoid fossa

mandibular dysplasia \măn-dĭb′ya-lar dĭs-plā′zha\: disharmony in size or form between the right and left halves of the mandible

mandibular equilibration \măn-dib′ya-lar ē′kwa-lĭb′rē-ā′shun\: **1:** the act or acts performed to place the mandible in equilibrium **2:** a condition in which all of the forces acting on the mandible are neutralized

mandibular glide \măn-dib′ya-lar glīd\ *obs*: the side to side, protrusive, and intermediate movement of the mandible occurring when the teeth or other occluding surfaces are in contact (GPT-4)

mandibular guide plane prosthesis: see MANDIBULAR RESECTION PROSTHESIS

mandibular hinge position \măn-dĭb′ya-lar hĭnj pa-zish′an\ *obs*: the position of the mandible in relation to the maxilla at which opening and closing movements can be made on the hinge axis (GPT-4)

mandibular impression \măn-dĭb′ya-lar ĭm-prăsh′an\: an impression of the mandibular jaw or dental structures

mandibular lateral translation: see MANDIBULAR TRANSLATION

mandibular micrognathia \măn-dĭb′ya-lar mī′krō-nā′thē′a\: an abnormally small mandible with associated recession of the chin

mandibular movement \măn-dĭb′ya-lar mōōv′ment\: any movement of the lower jaw

mandibular nerve \măn-dĭb′ya-lar nûrv\: the third division of the trigeminal nerve that leaves the skull through the foremen ovale and provides motor innervation to the muscles of mastication, to the tensor veli palatini m., the tensor tympani m., the anterior belly of the digastric m., and the mylohyoid m. It also provides the general sensory innervation to the mandibular teeth and gingivae, the floor of the mouth, the epithelium of the anterior two thirds of the tongue, and the skin of the lower portion of the face

mandibular orthopedic repositioning prosthesis \măn-dĭb′ya-lar ôr′tha-pē′dĭk rē′pa-zĭsh′a-nĭng prŏs-thē′sĭs\: a removable dental prosthesis that creates a different, yet temporary, dental occlusal position that guides the mandible to close into a predetermined and altered position

mandibular plane \măn-dĭb′ya-lar plān\: in cephalometrics, a plane that passes through the inferior border of the mandible

mandibular protraction \măn-dĭb′ya-lar prō′trăk′shun, pra-\: a type of facial anomaly in which gnathion lies anterior to the orbital plane—see ANGLE'S CLASSIFICATION OF OCCLUSION

mandibular relationship record \măn-dĭb′ya-lar rĭ-lā′shun-shĭp\: any registration of the relationship of the mandible to the maxillae

mandibular repositioning \măn-dĭb′ya-lar rē′pa-zĭsh′a-nĭng\: guidance of the mandible to cause closure in a predetermined, altered position

mandibular resection \măn-dĭb′ya-lar rĭ-sĕk′shun\: the surgical removal of a portion or all of the mandible and the related soft tissues—called also *mandibulectomy*

mandibular resection prosthesis \măn-dĭb′ya-lar rĭ -sĕk′shun prŏs-thē′sĭs\: a maxillofacial prosthesis used to maintain a functional position for the jaws (maxillae and mandible), improve speech and deglutition following trauma or/and surgery to the mandible or/and adjacent structures —*syn* MANDIBULAR GUIDE PLANE PROSTHESIS, MANDIBULAR RESECTION PROSTHESIS WITH GUIDE, MANDIBULAR RESECTION PROSTHESIS WITHOUT GUIDE, RESECTION PROSTHESIS

mandibular rest position: see PHYSIOLOGIC REST POSITION

mandibular retraction \măn-dĭb′ya-lar rĭ-trăk′shun\: a type of facial anomaly in which gnathion lies posterior to the orbital plane—see also ANGLE'S CLASSIFICATION OF OCCLUSION

mandibular side shift: see MANDIBULAR TRANSLATION

mandibular staple \măn-dĭb′ya-lar stā′pal\: a transosteal dental implant placed from the inferior border of the mandible with posts (abutments) that extend through the mucosa into the oral cavity in the mandibular anterior region—called also *transmandibular staple*

mandibular tracing \măn-dĭb′ya-lar trā′sĭng\: a graphic representation or record of the movements of the mandible within a given plane

mandibular translation \măn-dĭb′ya-lar trăns-lā′shun\: the translatory (mediolateral) movement of the mandible when viewed in the frontal plane. While this has not been demonstrated to occur as an immediate horizontal movement when viewed in the frontal plane, it could theoretically occur in an essentially pure translatory form in the early part of the motion or in combination with rotation in the latter part of the motion or both—see also EARLY MANDIBULAR LATERAL TRANSLATION, IMMEDIATE MANDIBULAR LATERAL TRANSLATION, PROGRESSIVE MANDIBULAR LATERAL TRANSLATION

mandibular trismus \măn-dĭb′ya-lar trĭz′mas\: reduced mobility of the mandible resulting from tonic contracture of the masticatory muscles

mandibulectomy \măn-dĭb′ū-lĕk′ta-mē\ *n*: the removal of part or the entire mandible

man·drel \măn′dral\ also **man·dril** \măn′dral\ *n* (1790): **1a:** usually a tapered or cylindrical axle, spindle, or arbor placed in a hole to support it during machining **1b:** a metal bar which serves as a core about which material may be cast, molded, compressed, forged, bent or shaped **2:** the shaft and bearings on which a tool is mounted

Maryland bridge: see RESIN-BONDED PROSTHESIS

Livaditis, GJ, Thompson, VP: Etched castings: an improved retentive mechanism for resin-bonded retainers JPD 1982; 47-52

mar·gin \mär′jĭn\ *n* (14c): the outer edge of a crown, inlay, onlay, or other restoration. The boundary surface of a tooth preparation and/or restoration is termed the *finish line* or *finish curve*

marginal gingiva \mär′ja-nal jĭn′ja-va\: the most coronal portion of the gingiva; often used to refer to the free gingiva that forms the wall of the gingival crevice in health

marginal ridge \mär′ja-nal rĭj\: a component of the tooth structure forming the occlusal proximal margin of a premolar or molar

mask·ing \măs′kĭng\ *n*: the process of applying an opaque covering to camouflage the metal component of a prosthesis

master cast: see DEFINITIVE CAST

master impression \măs′tar ĭm-prĕsh′an\: the negative likeness made for the purpose of fabricating a prosthesis

masticating cycles \măs′tĭ-kā′tĭng sī′kalz\ *obs*: the patterns of mandibular movements formed during the chewing of food (GPT-1)

mas·ti·ca·tion \măs′tĭ-kā′shun\ *n* (1649): the process of chewing food for swallowing and digestion

masticatory apparatus: see MASTICATORY SYSTEM

masticatory cycle \măs′tĭ-ka-tôr′ē, -tōr′ē sī′kal\: a three dimensional representation of mandibular movement produced during the chewing of food

masticatory efficiency \măs′tĭ-ka-tôr′ē, -tōr′ē ĭ-fĭsh′an-sē\: the effort required achieving a standard degree of comminution

masticatory force \măs′tĭ-ka-tôr′ē fôrs, fōrs\: the force applied by the muscles of mastication during chewing

masticatory movements' \măs′tĭ-ka-tôr′ē mōōv′mentz\: mandibular movements used for chewing food—see MASTICATORY CYCLE

masticatory mucosa: see MUCOSA

masticatory muscle \măs′tĭ-ka-tôr′ē mŭs′al\: muscles that elevate the mandible to close the mouth (temporalis m., superficial and deep masseter m., medial pterygoid m.)—see ELEVATOR MUSCLE

masticatory pain \măs′tĭ-ka-tôr′ē pān\: discomfort about the face and mouth induced by chewing or other use of the jaws but independent of local disease involving the teeth and mouth

masticatory performance \măs′tĭ-ka-tôr′ē par-fôr′mans\: a measure of the comminution of food attainable under standardized testing conditions

masticatory system \măs′tĭ-ka-tôr′ē sĭs′tam\: the organs and structures primarily functioning in mastication. These include the teeth with their supporting structures, craniomandibular articulations, mandible, positioning and accessory musculature, tongue, lips, cheeks, oral mucosa, and the associated neurologic complex

ma·trix \mā′trĭks\ *n, pl* **ma·tri·ces** \mā′trĭ-sēz′\ (15c): **1:** a mold or impression in which something is formed **2:** the portion of an attachment system that receives the patrix

max·il·la \măk-sĭl′a\ *n, pl* **max·il·lae** \măk-sĭl′ē\ (15c): the irregularly shaped bone that, with its contralateral maxilla, forms the upper jaw. It assists in the formation of the orbit, the nasal cavity, and the hard palate; it contains the maxillary teeth

maxillary impression \măk′sa-lĕr′ē\: an impression of the maxillary jaw or dental structures

maxillary micrognathia \măk′sa-lĕr′ē mī′krō-nă-thē′a\: abnormally small maxillae with associated retraction of the middle third of the face

maxillary protraction \măk′sa-lĕr′ē prō-trăk′shun, pra-\: a type of facial anomaly in which subnasion lies anterior to the orbital plane

maxillary resection \măk′sa-lĕr′ē rĭ-sĕk′shun\: the surgical removal of a part or all of the maxilla—called also *maxillectomy*

maxillary sinus \măk′sa-lĕr′ē sī′nas\: the anatomic space located superior to the posterior maxillary alveolus

maxillary tuberosity \măk′sa-lĕr′ē tōō′ba-rŏs′ĭ-tē\: the most distal portion of the maxillary alveolar ridge

max·il·lec·to·my \măk′sa-lĕk′ta-mē\ *n*: the removal of part or all of the maxilla—called also *maxillary resection*

max·il·lo·fa·cial \măk′sa-la-fā′shul\ *adj*: pertaining to the dental arches, the face, head and neck structures

maxillofacial prosthesis \măk′sa-la-fā′shul prŏs-thē′sĭs\: any prosthesis used to replace part or all of any stomatognathic and/or craniofacial structure. *Editorial Note:* the taxonomy for maxillofacial prostheses may include modifiers (adjectives) to provide descriptive evidence of the nature of the prosthesis including *anatomic location, retention, support,* time, *materials,* and *form.* Frequently, the means of *retention* is used, and may encompass descriptive adjectives such as the adjacent tissue, teeth, dental/craniofacial implants or a combination of such, thus appropriate terminology can include *tissue retained MP, tooth retained MP, implant retained MP, tissue/implant retained MP.* Descriptive terminology may also be included to delineate *time* utilization for the prosthesis such as *surgical, interim* and *definitive.*

maxillofacial prosthetic adhesive \măk′sa-la-fā′shul prŏs-thĕt′ĭk ăd-hē′sĭv\: a material used to adhere external maxillofacial prostheses to skin and associated structures around the periphery of an external anatomic defect

maxillofacial prosthetics \măk′sa-la-fā′shul prŏs-thĕt′iks\: the branch of prosthodontics concerned with the restoration and/or replacement of the stomatognathic and craniofacial structures with prostheses that may or may not be removed on a regular or elective basis

maxillomandibular dysplasia \măk′sa-la-măn-dĭb′ya-lar dĭs-plā′zha,-zhē-a\: disharmony between one jaw and the halves of the mandible

maxillomandibular fixation: fastening together of the maxillary and mandibular teeth, as ĭfor immobilization of a mandibular fracture—*syn* IMF

maxillomandibular record: see MAXILLOMANDIBULAR RELATIONSHIP RECORD

maxillomandibular registration: see MAXILLOMANDIBULAR RELATIONSHIP RECORD

maxillomandibular relation: see MAXILLOMANDIBULAR RELATIONSHIP

maxillomandibular relationship \măk′sa-la-măn-dĭb′ya-lar rĭ-lā′shun-shĭp′\: any spatial relationship of the maxillae to the mandible; any one of the infinite relationships of the mandible to the maxillae

maxillomandibular relationship record \măk′sa-la-măn-dĭb′ya-lar rĭ-lā′shun-shĭp′ rĕk′ard′\: a registration of any positional relationship of the mandible relative to the maxillae. These records may be made at any vertical, horizontal, or lateral orientation

maxillomandibular registration: see MAXILLOMANDIBULAR RELATIONSHIP RECORD

maximal intercuspal contacts \măk′sa-mal ĭn′ter-kŭs′pal′ kŏn′tăkts′\: tooth contact in the maximum intercuspal position

maximal intercuspal position \măk′sa-mal ĭn′ter-kŭs′pal′ pa-zĭsh′an\: the complete intercuspation of the opposing teeth independent of condylar position, sometimes referred to as the best fit of the teeth regardless of the condylar position—called also *maximal intercuspation—comp* CENTRIC OCCLUSION

mean foundation plane \mēn foun-dā′shun plān\ *obs*: the mean of the various irregularities in form and inclination of the basal seat (GPT-4)

me·a·tus \mē-ā′tus\ *n, pl* **me·a·tus·es** or **me·a·ti** (1665): a natural body passage; a general term for any opening or passageway in the body

mechanical anterior guidance table: an adjustable articulator component that guides the articulator pin's movement to simulate lateral and anterior guidance during mandibular movement—*comp* CUSTOM ANTERIOR GUIDE TABLE *see also* ANTERIOR GUIDE TABLE:

mechanically balanced occlusion \mĭ-kăn′ĭ-ka′lē băl′ansd a-klōō′shun\ *obs*: a balanced occlusion without reference to physiologic considerations, as on an articulation (GPT-4)

median line \mē′dē-an līn\: the centerline dividing a body into the right and left

median mandibular point \mē′dē-an măn-dĭb′a-lar point\ *obs*: a point on the anteroposterior center of the mandibular ridge in the median sagittal plane (GPT-4)

median plane \mē′dē-an plān\: an imaginary plane passing longitudinally through the body, from front to back, and dividing it into left and right halves

median relation \mē′dē-an rĭ-lā′shun\ *obs*: any jaw relation when the mandible is in the median sagittal plane (GPT-4)

median retruded relation: see CENTRIC RELATION

mediolateral curve \mē′dē-ō-lăt′ar-al kûrv\: in the mandibular arch, that curve (viewed in the frontal plane) which is concave above and contacts the buccal and lingual cusp tips of the mandibular molars; in the maxillary arch, that curve (viewed in the frontal plane) which is convex below and contacts the buccal and lingual cusp tips of the maxillary molars.

me·di·o·tru·sion \mē′dē-ō-trōō′zhun\ *n*: a movement of the condyle medially—see NONWORKING SIDE

mem·brane \mĕm′brān\ *n* (15c): **1**: a thin soft pliable sheet or layer, especially of plant or animal origin **2**: a thin layer of tissue that lines a cavity, envelops a vessel or part, or separates a space or organ

me·nis·cus \ma-nĭs′kas\ *n, pl* **me·nis·ci** \ma-nĭs′ī\: see DISK

meniscectomy: excision of the intraarticular disk. see DISKECTOMY

me·si·al \mē′zē-al\ *adj* (1803): near or toward the centerline of the dental arch; toward the median sagittal plane of the face, following the curvature of the dental arch

mesial drift \mē′zē-al drĭft\: movement of teeth toward the midline

me·sio·clu·sion *n*: any occlusion in which the mandibular teeth articulate with the maxillary teeth in a position anterior to normal—***syn*** ANTERIOR OCCLUSION, MESIO-OCCLUSION

mesioversion \mē′zē-ō-vûr′zhun, -shun\: with reference to a tooth, nearer than normal in its position toward the median line of the face, along the dental arch

[1]**met·al** \mĕt′l\ *n* (13c): any strong and relatively ductile substance that provides electropositive ions to a corrosive environment and that can be polished to a high luster. Characterized by metallic atomic bonding

[2]**met·al** \mĕt′l\ *vt* **-aled** or **-alled**; **-al·ing** or **-al·ling** (1610): to cover or furnish with metal

metal base \mĕt′l bās\: the metallic portion of a denture base forming a part or the entire basal surface of the denture. It serves as a base for the attachment of the resin portion of the denture base and the teeth

metal ceramic restoration \mĕt′l sa-răm′ĭk rĕs-ta-rā′shun\: a tooth or/and implant retained fixed dental prosthesis that uses a metal substructure upon which a ceramic veneer is fused—see COLLARLESS M.C.R.

metal collar: a narrow band of highly polished metal immediately adjacent to the facial/buccal margin on a metal-ceramic restoration—*comp* PORCELAIN LABIAL MARGIN

metal insert teeth \mĕt′l ĭn-sûrt tēth\: artificial denture teeth containing metal cutting edges; teeth designed to contain metal cutting edges in the occlusal surface

metal saddle \mĕt′l săd′l\ *obs*: a metal denture base (GPT-4)

met·a·mer \mĕt′a-mer′\ *n*: one of a pair of objects whose colors match when viewed in a described way but do not match under all viewing conditions

metameric pair \mĕt′a-mer′ik pâr\: a pair of objects whose colors match when viewed in a described way, but which do not match if the viewing conditions are changed. Thus a metameric pair of samples exhibit the same tristimulus values for a described set of viewing conditions (observer, light source, geometry of the illumination and viewing arrangement) but have different spectral distributions. Hence, they exhibit a match that is conditional

me·tam·er·ism \ma-tăm′a-rĭz′um\ *n.* (1877): pairs of objects that have different spectral curves but appear to match when viewed in a given hue exhibit metamerism. Metamerism should not be confused with the term's *flair* or *color constancy,* which apply to apparent color change exhibited by a single color when the spectral distribution of the light source is changed or when the angle of illumination or viewing is changed

methyl methacrylate resin \měth′al měth-ăk′ra-lāt rĕz′ĭn\: a transparent, thermoplastic acrylic resin that is used in dentistry by mixing liquid methyl methacrylate monomer with the polymer powder. The resultant mixture forms a pliable plastic termed *dough,* which is packed into a mold prior to initiation of polymerization

mi·cro·crack \mī′krō-krăk\ *n*: in porcelain, one of the numerous surface flaws that contribute to stress concentrations and results in strengths below those theoretically possible

mi·cro·gnath·ia \mī′krō-nā′thē-a\ *n*: a congenital or acquired condition characterized by an abnormally small jaw—see MANDIBULAR M., MAXILLARY M.

mi·cro·glos·sia \mī′krō-glô′zha\ *n*: presence of a small tongue

mi·cro·max·il·lae *n*: see MAXILLARY MICROGNATHIA

mi·cro·sto·mia \mī′krō-stôm′ya\ *n*: an abnormally small oral orifice

mi·cro·tia \mī′krō-sha\ *n*: a developmental anomaly characterized by hypoplasia or aplasia of the pinna of the ear, associated with an impatent or absent external auditory meatus

midfacial deficiency \mĭd-fā′shul dĭ-fĭsh′an-sē\: failure of the mid-third of the face, including the maxilla, to grow in proportion to the upper and lower thirds

midfacial fracture \mĭd-fā′shul frăk′chur\: fractures of the zygomatic, maxillary, nasal, and associated bones

mid-opening click \mĭd-ō′pa-nĭng klĭk\: the abnormal sound emanating from the temporomandibular joint that occurs during mid protrusive translation of the condyles

MIE theory: the theory that relates the scattering of a single spherical particle in a medium to the diameter of the particle, the difference in refractive index between the particle and the medium, and the wavelength of radiant energy in the medium that is incident on the particle. This theory relates to the direct observation of the scattering of a single particle as compared with the Kubelka-Munk Theory and also takes into account the absorption that the particle may also exhibit

[1]mill \mĭl\ *n*: a machine or device used for working or forming materials into a desired form, to blend materials, or to perform other mechanical operations

[2]mill \mĭl\ *vt* (1570): **1**: to subject to an operation or process in a mill; to grind **2**: to shape or dress by means of instruments

mill in \mĭl ĭn\ *v*: **1**: the procedure of refining occluding surfaces through the use of abrasive materials—see SELECTIVE GRINDING **2**: the machining of boxes or other forms in cast restorations to be used as retainers for fixed or removable prostheses

milled in curve *obs*: see MILLED IN PATH

milled in path \mĭld ĭn păth\: a contour pattern carved into the occlusal surface of an occlusion rim during various mandibular movements by teeth or studs placed in the opposing arch

mill·ing \mĭl′ĭng\ *v*: the machining of proximal boxes, recesses, or other forms on cast restorations to be used as retainers for fixed or removable prostheses

milling in \mĭl′ĭng ĭn\ *obs*: the procedure of refining or perfecting the occlusion of teeth by the use of abrasives between their occluding surfaces while the dentures are rubbed together in the mouth or on the articulator (GPT-3)—see MILL IN

minor connector \mī′nar ka-nĕk′tor\: the connecting link between the major connector or base of a partial removable dental prosthesis and the other units of the prosthesis, such as the clasp assembly, indirect retainers, occlusal rests, or cingulum rests

mixed dentition \mĭkst dĕn-tĭsh′an\: a stage of development during which the primary and permanent teeth function together in the mouth—***syn*** TRANSITIONAL DENTITION

MMF: *acronym* for *Maxillo Mandibular Fixation*

mo·bile \mō′bal, -bēl, -bīl\ *adj* (15c): capable of moving or being moved; movable—

mod·el \mŏd′l\ *n* (1575): a facsimile used for display purposes; a miniature representation of something; an example for imitation or emulation; see CAST

modeling composition *obs*: see MODELING PLASTIC IMPRESSION COMPOUND

modeling compound *obs*: see MODELING PLASTIC IMPRESSION COMPOUND

modeling plastic: see MODELING PLASTIC IMPRESSION COMPOUND

modeling plastic impression compound \mŏd′lĭng plăs′tĭk ĭm-prĕsh′an kŏm-pound′\: a thermoplastic dental impression material composed of wax, rosin, resins, and colorants

modeling wax \mŏd′lĭng wăks\: a wax suitable for making patterns in the fabrication of nonmetallic restorations

modes of appearance \mōdz ŭv a-pîr′ans\: various manners in which

colors can be perceived, depending on spatial distributions and temporal variations of the light causing the sensation

modified cast: see ALTERED CAST

modified ridge lap \mŏd′a-fīd′ rĭj lăp\: a ridge lap surface of a pontic that is adapted to only the facial or buccal aspect of the residual ridge

mod·i·fi·er \mŏd′a-fī′ar\ *n*: a substance that alters or changes the color or properties of a substance

mo·dio·lus \mō-dī′a-las\ *n*: the area near the corner of the mouth where eight muscles converge that functionally separates the labial vestibule from the buccal vestibule

modulus of elasticity \mŏj′a-las ŭv ĭ-lă-stĭs′ĭ-tē, ē-lă-\: in metallurgy, the coefficient found by dividing the unit stress, at any point up to the proportional limit, by its corresponding unit of elongation (tension) or strain. A ratio of stress to strain. As the modulus of elasticity rises, the material becomes more rigid

modulus of resilience \mŏj′a-las ŭv rĭ-zĭl′yans\: the work or energy required to stress a cubic inch of material (in one direction only) from zero up to the proportional limit of the material, measured by the ability of the material to withstand the momentary effect of an impact load while stresses remain within the proportional limit

mold \mōld\ *n* (13c): **1:** a cavity in which a substance is shaped, as a matrix for casting metal or plastics; a negative form in which an object is cast or shaped **2:** the size and shape of an artificial tooth or teeth

mold chart \mōld chart\: an illustration of the manufacturer's shapes and sizes of denture teeth

mold guide \mōld gīd\: a selection of denture teeth demonstrating the molds offered by a manufacturer

monochromatic vision \mŏn′a-krō-măt′ĭk vĭsh′an\: vision in which there is no color discrimination

mon·o·mer \mŏn′a-mar\ *n* (1914): a chemical compound that can undergo polymerization; any molecule that can be bound to a similar molecule to form a polymer

mon·o·plane \mŏn′a-plān\ *adj*: an arbitrary plane for the arrangement of denture teeth that is flat both medial-laterally and anterior-posteriorly

monoplane articulation \mŏn′a-plān ăr-tĭk′ya-lā′shun\: the arrangement of teeth by which they are positioned in a single plane

monoplane occlusion \mŏn′a-plān a-klōō′shun\: an occlusal arrangement wherein the posterior teeth have masticatory surfaces that lack any cuspal height

Monson curve: see CURVE OF MONSON

MORA device: *acronym* for *Mandibular Orthopedic Repositioning Appliance,* a type of removable dental prosthesis with a modification to the occlusal surfaces used with the goal of repositioning the mandible to improve neuro-muscular balance and jaw relationship

Gelb H. Clinical management of head, neck and TMJ pain and dysfunction. Philadelphia: W B Saunders Co, 1977:314.

mother matrix mold \mŭth′ar mā′trĭks mōld\ *obs*: a negative form, usually in sections, used for positive casts (GPT-1)

mou·lage \mōō-läzh′\ *n* (1902): **1:** the negative impression of a body structure **2:** an impression or cast made for use, especially as evidenced in a criminal investigation **3:** impression or reverse likeness of a part that produces a model when converted to a positive replica, i.e., by means of plaster

[1]mount·ing \moun′tĭng\ *v*: the laboratory procedure of attaching a cast to an articulator or cast relater

[2]mount·ing \moun′tĭng\ *n*: the relationship of dental casts to each other and the instrument to which they are attached; see also—SPLIT-CAST M.

mounting ring: see MOUNTING PLATE

mounting plate \moun′tĭng plāt\: removable metal or resin devices that attach to the superior and inferior members of an articulator, which are used to attach casts to the articulator

mouth guard \mouth gard\: a removable dental prosthesis made of resilient material which is useful in reducing mouth injuries and protecting the teeth and surrounding structures from injury

mouth protector: see MOUTH GUARD

mouth rehabilitation \mouth rē′ha-bĭl′ĭ-tā′shun\ *obs*: restoration of the form and function of the masticatory apparatus to as near normal as possible (GPT-4)

mouth stick \mouth stĭk\: a device held in the mouth by a disabled person that aids in performing certain functions

MRI: *acronym* for *Magnetic Resonance Imaging*

mucobuccal fold \myōō′kō-bŭk′al fōld\: the line of flexure of the mucous membrane as it passes to the cheek

mucogingival: see MUCOGINGIVAL JUNCTION

mucogingival junction \myōō′kō-jĭn′ja-val, jĭn′jī-\: the junction of gingiva and alveolar mucosa

mucolabial fold \myōō′kō-lā′bē-al\: the line of flexure of the oral mucous membrane as it passes from the maxillary or mandibular alveolar ridge to the lip

mu·co·peri·os·te·um \myōō′kō-pĕr′ē-ŏs′tē-am\ *n*: a term synonymous with a full-thickness flap implying the inclusion of both mucosa and periosteum during flap elevation

mu·co·sa \myōō-kō′sa\ *n* (1880): a mucous membrane comprised of epithelium, basement membrane, and lamina propria—see ALVEOLAR M., ORAL M.

mucosal implant: see MUCOSAL INSERT

mucosal insert \myōō-kō′sal ĭn-sûrt\: any metal form attached to the tissue surface of a removable dental prosthesis that mechanically engages undercuts in a surgically prepared mucosal site—called also *button implant, intramucosal insert, mucosal implant*

mu·co·si·tis \myōō′kō-sī′tĭs\ *n*: inflammation of the mucous membrane

mu·co·sta·tic \myōō′kō-stăt′ĭk\ *adj*: the state of the oral mucosa when external forces are not displacing it

muf·fle \mŭf′al\ *n*: the portion of a furnace, usually removable or replaceable, in which material may be placed for processing without direct exposure to heating element

Munsell chrome [Alfred H. Munsell, Massachusetts, U.S. artist and teacher, 1858-1918]: *eponym* for the Munsell color system chrome, which is that quality by which a strong color is distinguished from one that is weak. The departure of a color sensation from that of white or gray; the intensity of a distinctive hue color intensity—see also SATURATION

Munsell color order system [Alfred H. Munsell, Massachusetts, U.S. artist and teacher, 1858-1918]: *eponym* for a color order system; developed in 1905, it places colors in an orderly arrangement encompassing the three attributes of hue, value, and chrome

Munsell AH. A color notation. Baltimore: Munsell Color Co., 1975:14-6.

Munsell hue [Alfred H. Munsell, Massachusetts, U.S. artist and teacher, 1858-1918]: *eponym* for that quality by which one color family is distinguished from another, as red from yellow, and green from blue or purple. The dimension of color determined by wavelength

Munsell value [Alfred H. Munsell, Massachusetts, U.S. artist and teacher, 1858-1918]: *eponym* for the relative brightness of a color. The quality of grayness in comparison to white (high value) and black, (low value); in the Munsell color system, the value of a color is determined by which gray on the value scale it matches in lightness/darkness (black is assigned a value of zero; white a value of 10)

mus·cle \mŭs′al\ *n* (14c): an organ that by contraction produces movements of an animal; a tissue composed of contractile cells or fibers that effect movement of an organ or part of the body

muscle contraction \mŭs′al kan-trăk′shun\: the shortening and development of tension in a muscle in response to stimulation

muscle contracture \mŭs′al kan-trăk′chur\: a condition of high resistance to passive stretching of a muscle resulting from fibrosis of the tissues supporting the muscle or the joint; sustained increased resistance to passive stretch with reduced muscle length

muscle hyperalgesia \mŭs′al hī′par-ăl-gē′sha\: increased sensitivity to pain in a muscle evoked by stimulation at the site of pain in the muscle

muscle hypertenseness \mŭs′al hī′par-tĕns′nĕs\ *obs*: increased muscular tension that is not easily released but that does not prevent normal lengthening of the muscles involved (GPT-4)

muscle hypertonicity: increased contractile activity in some motor units driven by reflex arcs from receptors in the muscle and/or alpha motor neurons of the spinal cord

muscle marking: see BORDER MOLDING

muscle relaxant \mŭs′al rī-lăk′sant\: a drug or therapy that diminishes muscle tension

muscle spasm \mŭs′al spăz′am\: a sudden involuntary contraction of a muscle or group of muscles attended by pain and interference with function. It differs from muscle splinting in that the contraction is sustained even when the muscle is at rest and the pain/dysfunction is present with passive and active movements of the affected part—called also *myospasm*

muscle spasticity \mŭs′al spă-zĭs′ĭ-tē\: increased muscular tension of antagonists preventing normal movement and caused by an inability to relax (a loss of reciprocal inhibition)

muscle-splinting \mŭs′al-splĭnt′ĭng\ *slang*: involuntary contraction (rigidity) of muscles occurring as a means of avoiding the pain caused by movement of the part (resistance to passive stretch). The involved muscle(s) relaxes at rest

muscle-trimming *slang*: see BORDER MOLDING

muscular atrophy \mŭs-kya′lar ăt′ra-fē\: a wasting of muscular tissue, especially due to lack of use

muscular splinting \mŭs-kya′lar splĭnt′ĭng\: contraction of a muscle or group of muscles attended by interference with function and producing involuntary movement and distortion; differs from *muscle spasm* in that the contraction is not sustained when the muscle is at rest

musculoskeletal pain \mŭs′kya-lō-skĕl′ĭ-tl pān\: deep, somatic pain that originates in skeletal muscles, facial sheaths, and tendons (myogenous pain), bone and periosteum (osseous pain), joint, joint capsules, and ligaments (arthralgic pain), and in soft connective tissues

mush bite \mŭsh bīt\ *obs*: a maxillomandibular relationship record made in a softened material, frequently beeswax, without the benefit of record bases—see INTEROCCLUSAL RECORD

mutually protected articulation \myōō′chōō-al-lē pra-tĕk′tĭd ăr-tĭk′ya-lā′shun\: an occlusal scheme in which the posterior teeth prevent excessive contact of the anterior teeth in maximum intercuspation, and the anterior teeth disengage the posterior teeth in all mandibular excursive movements. Alternatively, an occlusal scheme in which the anterior teeth disengage the posterior teeth in all mandibular excursive movements, and the posterior teeth prevent excessive contact of the anterior teeth in maximum intercuspation

mutually protected occlusion: see MUTUALLY PROTECTED ARTICULATION

my·al·gia \mī-ăl′jē-a\ *n* (1860): pain in a muscle or muscles

my·co·tic \mī-kō′tĭk\ *n*: pertaining to a mucosis; caused by fungi

mylohyoid concavity \mī′la-hoid kŏn-kăv′ĭ-tē\: the fossa in the mandible below the mylohyoid line in the molar region

mylohyoid groove or canal \mī′la-hoid grōōv ôr ka-năl′\: the groove in the mandible running downward and forward toward the submandibular fossa, which contains the mylohyoid muscle, nerve, and vessels

mylohyoid region \mī′la-hoid rē′jan\ *obs*: the region on the lingual surface of the mandible marked by the mylohyoid ridge and the attachment of the mylohyoid muscle (GPT-4)

mylohyoid ridge \mī′la-hoid rĭj\: an oblique ridge on the lingual surface of the mandible that extends from the level of the roots of the last molar teeth and that serves as a bony attachment for the mylohyoid muscles forming the floor of the mouth

my·o·cen·tric \mī′ō sĕn′trĭk\ *adj*: that terminal point in space in which, with the mandible in rest position, subsequent colonic muscle contraction will raise the mandible through the interocclusal space along the myocentric (muscle balanced) trajectory. Also described as the initial occlusal contact along the myocentric trajectory (isotonic closure of the mandible from rest position)

Jankelson B. Dent Clin North Am 1979;23:157-68.

Jankelson BR, Polley ML. Electromyography in clinical dentistry. Seattle: Myotronica Research Inc, 1984:52.

myofascial trigger point \mī′a-fāsh′al trĭg′ar point\: a hyperirritable spot, usually within a skeletal muscle or in the muscle fascia, that is painful on compression and can give rise to characteristic referred pain, tenderness (secondary hyperalgesia), and autonomic phenomena

myofibrotic capsular contracture \mī′a-fī-bra′tĭk kăp′sa-lar kan-trăk′chur\: muscle contracture resulting from the formation of excessive fibrous tissue within the muscle or its sheath

my·o·func·tion·al \mī′a-fŭngk′sha-nal\: relating to the function of muscles. In dentistry, the role of muscle function in the cause or correction of muscle related problems

myofunctional therapy \mī′a-fŭngk′sha-nal thĕr′a-pē\: the use of exercises to

improve the action of a group of muscles used as an adjunct to orthodontic or craniomandibular dysfunction treatment

myogenous pain \mī′a-jēn′ŭs\: deep somatic musculoskeletal pain originating in skeletal muscles, fascial sheaths, or tendons

Myo-monitor \mī′ō mon′ē tĕr\: a digital electronic pulse generator specifically optimized for bilateral transcutaneous electrical neural stimulation of the stomatognathic system; an electrical device introduced in 1969 by Bernard Jankelson, DDS as a means of applying muscle relaxation as a prerequisite to obtain an occlusal position that would sustain a relaxed musculature

Jankelson B, Radke JO. The Myo-monitor: its use and abuse. Quintessence Int 1978;9:47-52.

Jankelson B, Sparks S. Crane PF, Radke JC. Neural conduction of the Myo-monitor stimulus: a quantitative analysis. J PROSTHET DENT 1975;34:245-53.

Jankelson BR. Neuromuscular dental diagnosis and treatment. St. Louis: Ishiyaki Euro America Intl, 1990:73-7.

myostatic contracture \mī′a-stăt′ĭk kantrăk′chur\: muscle contracture resulting from reduced muscle stimulation

my·o·si·tis \mī′a-sī-tĭs\ *n* (ca. 1819): inflammation of muscle tissue

my·o·spasm *n*: see MUSCLE SPASM

my·o·ton·ia \mī′a-tō′nē-a\ *n* (1896): increased muscular irritability and contractility with decreased power of relaxation; tonic muscle spasms

N

NA: *acronym* for *NAsion;* a cephalometric landmark located where the intranasal and nasofrontal sutures meet

nano·me·ter \năn′a-mē′tar\ *n* (1963): unit of length to measure the wavelength of light. It is equivalent to 1 x 10^{-9} M or 10 angstroms. 1 *nm* = 1/1,000,000 *mm*

narrative report \năr′a-tĭv\: a complete description of the clinical findings, diagnosis, and treatment rendered for a given patient

nasal grimace \nā′zal grĭm′ĭs, grī-măs′\: movements in the tissue of the nares reflecting the attempts of the oronasal system to compensate for palatopharyngeal insufficiency

nasal prosthesis \nā′zal prŏs-thē′sĭs\: a removable maxillofacial prosthesis that artificially restores part or the entire nose—***syn*** ARTIFICIAL NOSE

nasal turbulence \nā′zal tûr′bya-lans\: the excessive "noise" or air passing over resistance in the nasal passages

nasal septal prosthesis \nā′zal sĕp′tal prŏs-thē′sĭs\: a maxillofacial prosthesis used to occlude (obturate) a hole within the nasal septal wall—***syn*** SEPTAL BUTTON, SEPTAL PLUG

nasal spine \nā′zal spīn\: a sharp bony protuberance of the lower margin of the anterior aperture of the nares formed by the forward prolongation of the two maxillae

nasal stent \nā′zal stĕnt\: a removable intranasal maxillofacial prosthesis used to support the form of the nose

na·sal·i·ty \nā-zăl′ĭ-tē\ *n* (1656): the quality of speech sounds when the nasal cavity is used as a resonator

nas·ion \nā′zhun\ *n*: a bony cephalometric landmark at which the nasofrontal suture is bisected by the midsagittal plane

nasion relator: an adjustable arbitrary facebow component that engages the outer point of intersection between the nasion-sella line and the soft tissue profile to stabilize the bow while recording the position of the maxillary teeth

nas·o·phar·ynx \nā′zō-făr′ĭngks\ *n* (1877): the part of the pharynx situated above the soft palate

natural color system \năch′ar-al, năch′ral kul′ar sĭs′tam\: a color order system derived by Anders Hard that defines six color perceptions using the concept of percentage for localizing nuances within the three part system. The six perceptions are white, black, red, green, yellow, and blue. The dimensions of hue, blackness or whiteness, and chrome are used to relate colors within this system

natural dentition \năch′ar-al, năch′ral dĕn-tĭsh′an\: the natural teeth, as considered collectively, in the dental arch, which may be deciduous, permanent, or mixed

natural glaze \năch-ar-al, năch′ral glāz\: the production of a glazed surface by the vitrification of the material itself and without addition of other fluxes or glasses

neck of the condylar process \nĕk ŭv tha kŏn′dah lĕr prŏ sĕs\: the constricted inferior portion of the mandibular condylar process that is continuous with the ramus of the mandible; that portion of the condylar process that connects the mandibular ramus to the condyle

ne·cro·sis \na-krō′sĭs, nĕ-\ *n, pl* **ne·cro·ses** \sēz\ (1665): localized death of living tissue

needlepoint tracing: see CENTRAL BEARING TRACING DEVICE

Nesbit prosthesis [Norman Nesbit, dentist, Boston, Massachusetts, U.S.] *obs*: *eponym* for a unilateral partial removable dental prosthesis design that Dr. Nesbit introduced in 1918

neu·ral·gia \nŏŏ-răl′ja\ *n* (ca. 1822): neurogenous pain felt along the peripheral distribution of a nerve trunk

neu·ri·tis \nŏŏ-rī′tĭs\ *n* (1840): inflammation of a nerve

neurogenous pain \nŏŏ-rŏj′a-nŭs pān\: pain that is generated within the nervous system as a result of some abnormality of neural structures

neuromuscular dysfunction: a collective term for muscle disorders of the masticatory system with two observable major symptoms: pain and dysfunction. Common observations include muscle fatigue, muscle tightness, myalgia, spasm, headaches, decreased range of motion and acute malocclusion. The five types of masticatory muscle disorders include protective co-contraction *(muscle splinting),* local muscle soreness *(noninflammatory myalgia),* myofascial pain *(trigger point myalgia),* myospasm *(tonic contraction myalgia),* and chronic centrally mediated myalgia *(chronic myositis)*

Okeson, Management of Temporomandibular Disorders and Occlusion. (4th Ed pp 180-82)

neu·rop·a·thy \nŏŏ′rŏp-ă-thē\ *n* (1857): a general term used to designate an abnormality or pathologic change in a peripheral nerve

neutral zone \nōō′tral, nyōō′- zōn\: the potential space between the lips and cheeks on one side and the tongue on the other; that area or position where the forces between the tongue and cheeks or lips are equal

neu·tro·oc·clus·ion: see ANGLE'S CLASSIFICATION OF OCCLUSION

nickel-chromium alloy: a low density, large grained base metal dental casting alloy with prominent dendritic structure, composed of up to 30% Cr and 70% Ni with trace elements that may include small amounts of Mo, Mn, Si, C,

and Al. Chromium, by its passivation effect insures corrosion resistance of the alloy. Increased nickel content tends to result in reduced strength, hardness, modulus of elasticity and fusion temperature while ductility may increase

ni·dus \nī′das\ *n, pl* **ni·di** \dī′\ or **ni·dus·es** (1742)**:** a place or substance in an animal or plant where bacteria or other organisms lodge and multiply

night guard *slang***:** see OCCLUSAL DEVICE

NMR: *acronym* for *Nuclear Magnetic Resonance;* a radiologic procedure that gives images in any plane without radiation or any biologic after effect by picking up signals from resonating hydrogen nuclei

noble metal \nō′bal mĕt′l**:** those metal elements that resist oxidation, tarnish, and corrosion during heating, casting, or soldering and when used intraorally; examples include gold and platinum—*comp* BASE METAL

noble metal alloy: as classified by the American Dental Association (1984) any dental casting alloy containing a minimum of 25% by weight of Au, Pt, or/and Pd

American Dental Association: Classification system for cast alloys. J Am Dent Assoc 1984; 109:766.

no·ci·cep·tive \na-sĭ-sĕp′tĭv\ *adj* (1904)**:** receiving injury; applicable to a neuron receptive to painful sensations

nociceptive pathway \na-sĭ-sĕp′tĭv păth′wā′, päth′-**:** an afferent neural pathway that mediates pain impulses

no·ci·cep·tor \na-sĭ-sĕp′tor\ *n***:** a sensory receptor preferentially sensitive to noxious or potentially noxious stimuli

nocturnal electromyography \nŏk-tûr′nal ĭ-lĕk′trō-mī-ŏg′ra-fē**:** electromyographic registrations made during sleep

nonadjustable articulator \nŏn-a-jŭst′ă-bal är-tĭk′ya-lā′tor**:** an articulator that does not allow adjustment to replicate mandibular movements—see also CAST RELATOR

nonarcon articulator: 1: any articulator which broadly replicates the three dimensional motions of the left and right condylar compartments **2.** any articulator design in which the condylar element (analog) is not part of the lower member of the articulator and may be used to simulate the three dimensional motions of the left and right condylar compartments

nonanatomic teeth \nŏn-a-nō′tŏm-ĭk tēth**:** artificial teeth with occlusal surfaces that are not anatomically formed. The term *nonanatomic* as applied to artificial posterior teeth, and especially their occlusal forms, means that such teeth are designed in accordance with mechanical principles rather than from the viewpoint of anatomic replication. I. R. Hardy, DDS, first introduced nonanatomic teeth with flat occlusal surfaces set to a flat occlusal plane

Sears VH. Thirty years of nonanatomic teeth. J PROSTHET DENT 1953; 3:596-617

Hardy IR. Technique for use of nonanatomic acrylic posterior teeth. Dent Digest 1942;48:562-6.

nonfunctioning condyle: see NONWORKING SIDE CONDYLE

nonpivoting condyle: see NONWORKING SIDE CONDYLE

nonprecious metal: see BASE METAL

non·re·sorb·able \nŏn-rē-sŏrb′a-bal\ *adj***:** the property exhibited by substances that demonstrate relatively limited in-vivo degradation

nonrigid connector \nŏn-rĭj′ĭd ka-nĕk′tor**:** any connector that permits limited movement between otherwise independent members of a fixed dental prosthesis

nonworking side \nŏn-wûr′kĭng sīd**:** that side of the mandible that moves toward the median line in a lateral excursion. The condyle on that side is referred to as the *nonworking side condyle*

nonworking side condyle \nŏn-wûr′kĭng sīd kŏn′dĭl**:** the condyle on the nonworking side

nonworking side condyle path \nŏn-wûr′kĭng sīd kŏn′dĭl păth**:** the path the condyle traverses on the nonworking side when the mandible moves in a lateral excursion, which may be viewed in the three reference planes of the body

nonworking side interference \nŏn-wûr′kĭng sīd ĭn′tar-fîr′ans**:** undesirable contacts of the opposing occlusal surfaces on the nonworking side

nonworking side occlusal contacts \nŏn-wûr′kĭng sīd a-klōō′sal kŏn′tăkts′**:** contacts of the teeth on the side opposite to the side toward which the mandible moves in articulation

notch *n***:** see PTERYGOMAXILLARY N.

noxious stimulus \nŏk′shas stĭm′ya-las**:** a tissue damaging stimulus

nu·ance \nōō-äns′, nyōō-, nōō′äns′, nyōō′-\ *n,* **nu·anced** *adj* (1781)**: 1:** a subtle distinction or variation, such as in tone or color **2:** a subtle quality **3:** delicate shading

null detector \nŭl dĭ-tĕk′tor**:** a detector of the point at which there is no color difference between two samples. The human eye is an excellent null detector; it is considerably less trustworthy in estimating how large a given difference is

O

oblique ridge \ō-blēk′, a-blēk′ rĭj**:** the elevation in the enamel that runs obliquely across the occlusal surface of a maxillary molar

ob·tun·dent \ŏb-tŭn′dant\ *n***:** an agent or remedy that lessens or relieves pain or sensibility

ob·tu·ra·tor \ŏb′ta-rā′tar\ *n* (ca. 1727)**: 1:** a maxillofacial prosthesis used to close a congenital or acquired tissue opening, primarily of the hard palate and/or contiguous alveolar/soft tissue structures (GPT7) **2:** that component of a prosthesis which fits into and closes a defect within the oral cavity or other body defect **3:** a maxillofacial prosthesis used to close, cover or maintain the integrity of the oral and nasal compartments resulting from a congenital, acquired or developmental disease process, i.e., cancer, cleft palate, osteoradionecrosis of the palate. The prosthesis facilitates speech and deglutition by replacing those tissues lost due to the disease process and can, as a result, reduce nasal regurgitation and hypernasal speech, improve articulation, deglutition and mastication. An obturator prosthesis is classified as *surgical, interim* or *definitive* and reflects the intervention time period used in the maxillofacial rehabilitation of the patient. Prosthetic restoration of a defect often includes use of a surgical obturator, interim obturator, and definitive obturator—see DEFINITIVE O., INTERIM O., SURGICAL O.—*comp* SPEECH AID PROSTHESIS

obturator prosthesis modification \ŏb′ta-rā′tar prŏs-thē′sĭs mŏd′a-fĭ-kā′shun**:** revision or alteration of an existing obturator (surgical, interim, or definitive); possible revisions include relief of the denture base due to tissue compression, augmentation of the seal

or border regions to effect adequate sealing or separation between the nasal and oral cavities

oc·clude \a-klōōd′\ *vb* **oc·clud·ed; oc·clud·ing** *vt* (1597): **1:** to bring together; to shut **2:** to bring or close the mandibular teeth into contact with the maxillary teeth

occluded gas porosity \a-klōō′dĭd găs pa-rŏs′ĭ-tē\: porosity produced in castings due to the inability of gasses in the mold to escape

oc·clud·er \a-klōōd′ar\ *n*: a name given to some articulators—see CAST RELATOR

occluding centric relation record \a-klōōd′ĭng sĕn′trĭk rĭ-lā′shun rĕk′ard\ *obs*: a registration of centric relation made at the established occlusal vertical dimension (GPT-4)

occluding frame \a-klōōd′ĭng frām\ *obs*: a name given to a device for relating casts to each other for the purpose of arranging teeth (GPT-1)

occluding jaw record \a-klōō′dĭng jô rĕk′ard\: the registration of centric relation made at the occlusal vertical dimension

occluding relation \a-klōōd′ĭng rĭ-lā′shun\ *obs*: the jaw relation at which the opposing teeth occlude (GPT-4)

oc·clu·sal \a-klōō′zal, -sal\ *adj* (1897): pertaining to the masticatory surfaces of the posterior teeth, prostheses, or occlusion rims

occlusal adjustment \a-klōō′zal, -sal a-jŭst′mant\: **1:** any change in the occlusion intended to alter the occluding relation **2:** any alteration of the occluding surfaces of the teeth or restorations—see also OCCLUSAL RESHAPING

occlusal analysis \a-klōō′zal,-sal a-năl′ĭ-sĭs\: an examination of the occlusion in which the interocclusal relations of mounted casts are evaluated

occlusal balance \a-klōō′zal, -sal băl′ans\: a condition in which there are simultaneous contacts of opposing teeth or tooth analogues (i.e., occlusion rims) on both sides of the opposing dental arches during eccentric movements within the functional range

occlusal clearance: see INTEROCCLUSAL CLEARANCE

occlusal contact \a-klōō′zal, -sal kŏn′tăkt′\: **1:** the touching of opposing teeth on elevation of the mandible **2:** any contact relation of opposing teeth—see DEFLECTIVE O.C, INITIAL O.C

occlusal correction: see OCCLUSAL ADJUSTMENT, OCCLUSAL RESHAPING

occlusal curvature \a-klōō′zal, -sal kûr′va-chōōr′, -char\: the curve of the dentition in which the occlusal surfaces lie, when viewed in the frontal and sagittal planes

occlusal device \a-klōō′zal, -sal dĭ-vīs′\: any removable artificial occlusal surface used for diagnosis or therapy affecting the relationship of the mandible to the maxillae. It may be used for occlusal stabilization, for treatment of temporomandibular disorders, or to prevent wear of the dentition

occlusal disharmony \a-klōō′zal, -sal dĭs-hăr′ma-nē\: a phenomenon in which contacts of opposing occlusal surfaces are not in harmony with other tooth contacts and/or the anatomic and physiologic components of the craniomandibular complex

occlusal dysthesia \a-klōō′zal, -sal dĭs-thē′zha\: unusual sensory perceptions during occlusal contact

occlusal embrasure \a-klōō′zal, -sal ĕm-brā′zhar\: the interdental space that is coronal to the contact area

occlusal equilibration \a-klōō′zal, -sal ĭ-kwĭl′a-brā′shun\: the modification of the occlusal form of the teeth with the intent of equalizing occlusal stress, producing simultaneous occlusal contacts or harmonizing cuspal relations

occlusal facet: see WEAR FACET

occlusal force \a-klōō′zal, -sal fôrs, fōrs\: the result of muscular force applied on opposing teeth; the force created by the dynamic action of the muscles during the physiologic act of mastication; the result of muscular activity applied to opposing teeth

occlusal form \a-klōō′zal, -sal form\ *obs*: the form the occlusal surface of a tooth or a row of teeth (GPT-4)

occlusal harmony \a-klōō′zal, -sal hăr′ma-nē\ *obs*: a condition in centric and eccentric jaw relation in which there are no interceptive or deflective contacts of occluding surfaces (GPT-4)

occlusal interference \a-klōō′zal, -sal ĭn′tur-fîr′ans\: any tooth contact that inhibits the remaining occluding surfaces from achieving stable and harmonious contacts

occlusal path \a-klōō′zal, -sal păth, path\ *obs*: **1:** a gliding occlusal contact **2:** the path of movement of an occlusal surface (GPT-4)

occlusal pattern \a-klōō′zal, -sal păt′arn\: the form or design of the masticatory surfaces of a tooth or teeth based on natural, modified anatomic or non-anatomic teeth

occlusal pivot \a-klōō′zal, -sal pĭv′at\: an elevation placed on the occlusal surface, usually in the molar region, designed to act as a fulcrum, thus limiting mandibular closure and inducing mandibular rotation

occlusal plane \a-klōō′zal,-sal plān\: **1:** the average plane established by the incisal and occlusal surfaces of the teeth. Generally, it is not a plane but represents the *planar mean* of the curvature of these surfaces **2:** the surface of wax occlusion rims contoured to guide in the arrangement of denture teeth **3:** a flat metallic plate used in arranging denture teeth—comp to CURVE OF OCCLUSION

occlusal position \a-klōō′zal, -sal pa-zĭsh′an\ *obs*: the relationship of the mandible and maxillae when the jaw is closed and the teeth are in contact; this position may or may not coincide with centric occlusion (GPT-4)

occlusal prematurity \a-klōō′zal, -sal prē′ma-tyōōr′ĭ-tē, -tōōr′-, -chōōr′-\: any contact of opposing teeth that occurs before the planned intercuspation

occlusal pressure \a-klōō′zal, -sal prĕsh′ar\ *obs*: any force exerted on the occlusal surfaces of teeth (GPT-4)

occlusal reduction: the quantity (usually measured in millimeters) of tooth structure that is removed to establish adequate space for a restorative material between the occlusal aspect of the tooth preparation and the opposing dentition

occlusal reshaping \a-klōō′zal, -sal rē-shāp′ĭng\: the intentional alteration of the occlusal surfaces of teeth to change their form

occlusal rest \a-klōō′zal, -sal rĕst\: a rigid extension of a partial removable dental prosthesis that contacts the occlusal surface of a tooth or restoration, the occlusal surface of which may have been prepared to receive it—see REST SEAT

occlusal rest arm \a-klōō′zal, -sal rĕst ärm\ *obs*: a minor connector used to attach an occlusal rest to a major part of a removable partial denture (GPT-1)

occlusal rim: see OCCLUSION RIM

occlusal splint: see OCCLUSAL DEVICE

occlusal stability \a-klōō′zal, -sal sta-bĭl′ĭ-tē\: the equalization of contacts that prevents tooth movement after closure

occlusal stop: see OCCLUSAL REST

occlusal strength: see MASTICATORY FORCE

occlusal surface \a-klōō′zal, -sal sûr′fas\ *obs:* a surface of a posterior tooth or occlusion rim that is intended to make contact with an opposing occlusal surface (GPT-1)

occlusal system \a-klōō′zal, -sal sĭs′tam\ *obs:* the form or design and arrangement of the occlusal and incised units of a dentition or the teeth on a denture (GPT-4)

occlusal table \a-klōō′zal, -sal tā′bal\: the portion of the occlusal surfaces of posterior teeth that lies within the perimeter of the cusp tips and marginal ridges; the functional portion(s) of the occlusal surface(s) of a posterior tooth (teeth)

occlusal trauma \a-klōō′zal, -sal trou′ma, trô′-\: trauma to the periodontium from functional or parafunctional forces causing damage to the attachment apparatus of the periodontium by exceeding its adaptive and reparative capacities. It may be self-limiting or progressive—see PRIMARY O.T., SECONDARY O.T.

occlusal vertical dimension \a-klōō′zal, -sal vûr′tĭ-kal dĭ-mĕn′shun\: the distance measured between two points when the occluding members are in contact

occlusal wear \a-klōō′zal, -sal wâr\: loss of substance on opposing occlusal units or surfaces as the result of attrition or abrasion

occlusion \a-klōō′shun\ *n* (1645): **1:** the act or process of closure or of being closed or shut off **2:** the static relationship between the incising or masticating surfaces of the maxillary or mandibular teeth or tooth analogues—see CENTRIC O., COMPONENTS OF O., ECCENTRIC O., LINE OF O., LINEAR O., MONOPLANE O., PATHOGENIC O., SPHERICAL FORM OF O.—*comp* ARTICULATION

occlusion analysis \a-klōō′shun a-năl′ĭ-sĭs\ *obs:* a systematic examination of the masticatory system with special consideration to the effect of tooth occlusion on the teeth and their related structures (GPT-4)

occlusion record \a-klōō′shun rĕk′ard\ *obs:* a registration of opposing occluding surfaces made at any maxillomandibular relationship (GPT-4)

occlusion rim \a-klōō′shun rĭm\: occluding surfaces fabricated on interim or final denture bases for the purpose of making maxillomandibular relation records and arranging teeth—called also *record rim*

occult cleft palate \a-kŭlt′, ŏ-kŭlt′, ōk′ŭlt′ klĕft păl′ĭt\: a separation of muscle in the soft palate with mucous membrane covering the defect. This is often characterized by a notch in the hard palate, bifurcation of the uvula, displaced musculature, and an attenuated raphe—*syn* SUBMUCOUS CLEFT PALATE

oc·tant: \′äktənt\ Latin *octant-,octans* half quadrant, from *octo* eight **1:** the position or aspect of a celestial body (as the moon or a planet) when halfway between conjunction or opposition and quadrature **2:** an instrument used for observing altitudes of a celestial body from a moving ship or aircraft and having a maximum angle of 45 degrees between its reflecting mirrors—comp SEXTANT

ocular prosthesis \ŏk′ya-lar prŏs-thē′sĭs\: a maxillofacial prosthesis that artificially replaces an eye missing as a result of trauma, surgery, or congenital absence. The prosthesis does not replace missing eyelids or adjacent skin, mucosa or muscle—***syn*** ARTIFICIAL EYE, GLASS EYE—*comp* INTERIM OCULAR PROSTHESIS

o·don·tal·gia \ō-dŏn′tăl-ja\ *n:* toothache; pain in a tooth

odontogenous pain \ō-dŏn-taj′a-nus pān\: deep somatic pain originating in the dental pulp and/or periodontal ligament

o·don·to·graph \ō-dŏn′ta-grăf\ *n:* a device used to demonstrate irregularities occurring in the surface of tooth enamel

o·don·to·plasty \ō-dŏn′ta-plăs-tē\: the reshaping of a portion of a tooth

ol·i·go·don·tia \ŏl′ĭ-gō-dŏn′cha\: the formation of less than a full complement of teeth; many such teeth are smaller than normal

on·lay \ŏn′lā, ôn′-\: a restoration that restores one or more cusps and adjoining occlusal surfaces or the entire occlusal surface and is retained by mechanical or adhesive means

onlay graft \ŏn′lā, ôn- grăft\ (1998): augmentation of the height or width of the alveolar ridge with autologous bone or bone substitutes placed beneath the periosteum

o·pac·i·ty \ō-păs′ĭ-tē\ *n* (1611): the quality or state of a body that makes it impervious to light

o·paque \ō-pāk′\ *adj* (1641): the property of a material that absorbs and/or reflects all light and prevents any transmission of light

opaque dentin: modified body porcelain with increased opacity, used where fewer translucencies are required such as in the gingival area of a pontic or incisal mamelon to mimic existing anatomic features of adjacent natural teeth

opaque modifier: colored dental porcelain formulated to be selectively mixed with opaque porcelain to increase the saturation of the desired pigment

opaque porcelain: the first porcelain layer applied in the metal-ceramic technique to the underlying metal framework to establish the bond between the porcelain and metal while simultaneously masking the dark color of the metallic oxide layer. Opaque porcelain provides the primary source of color for the completed restoration

open bite *slang:* see OPEN OCCLUSAL RELATIONSHIP; APERTOGNATHIA

open fracture \ō′pan frăk′chur\: any fracture in which there is an external wound leading to a break in the bone; called also *compound fracture*

open occlusal relationship \ō′pan a-klōō′zal, -sal rĭ-lā′shun-shĭp′\: the lack of tooth contact in an occluding position—see ANTERIOR O.O.R., POSTERIOR O.O.R.

opening movement \ō′pa-nĭng\ *obs:* movement of the mandible executed during jaw separation; movement executed during jaw separation (GPT-1)—see ENVELOPE OF MOTION

oral flora \ôr′al, ōr′- flôr′a, flōr′a\: the various bacterial and other microscopic forms of life inhabiting the oral cavity

oral mechanism \ôr′al, ōr′- mĕk′a-nĭz′um\: the functioning structures of the oral cavity

oral orifice \ôr′al, ōr′- ôr′a-fĭs, ŏr′-\: the longitudinal opening of the mouth between the lips that provides the entrance to the oral cavity

oral mucosa \ôr′al, ōr′- myōō-kō′sa\: the lining of the oral cavity

oral orthopedics \ôr′al, ōr′- ôr′tha-pē′dĭks\: **1:** a concept in dentistry concerned with postural relationships of the jaws, both normal and abnormal **2:** analysis of the harmful effects of an improper relationship of the mandible and the maxillae on dental and other related structures **3:** the diagnosis and

correction of such relationships and the treatment and/or prevention of disturbances resulting therefrom

orbital prosthesis \ôr′bĭ-tăl prŏs-thē′sĭs\: a maxillofacial prosthesis that artificially restores the eye, eyelids, and adjacent hard and soft tissues

orbiting condyle: see NONWORKING SIDE CONDYLE

organ of mastication \ôr′gan ŭv măs′tĭ-kā′shun\: the combination of all the structures involved in the reception, mastication, and deglutition of food

organic occlusion: see ANTERIOR PROTECTED ARTICULATION

or·i·fice \ôr′a-fĭs, ōr′-\ *n* (15c): an opening into a body cavity

oronasal fistula \ôr′a-nā′zal fĭs′cha-la\: a pathologic opening between the oral and nasal cavities

oro·phar·ynx \ôr′a-făr′ĭngks\ *n* (1887): the part of the pharynx lying between the soft palate and the upper edge of the epiglottis—called also *oral pharynx, pars oralis pharyngis, pharyngo oral cavity,* and *vestibule of the pharynx*

orthodontic band \ôr′tha-dŏn′tĭk\: a metal orthodontic device that holds a bracket or tube and encircles a tooth

orthognathic surgery: surgical repositioning of all or parts of the maxillae or mandible

or·tho·gnath·ous \ŏr′thŏg-năth′ĭk\ *adj*: pertaining to or characterized by minimal protrusion of the mandible or minimal prognathism

orthopedic craniofacial prosthesis \ôr-tha-pē′dĭk\ (1998): a dynamic orthopedic maxillofacial prosthesis used to maintain or position the craniofacial osseous segments that are malaligned due to trauma or craniofacial anomalies.

orthotic device \ôr-thŏ′tĭk dĭ-vīs′\: a device designed to brace, activate, or supplement a weakened limb or function

os·seo·in·te·gra·tion *n* [P.I. Branemark, ca. 1982]: see OSSEOUS INTEGRATION

os·se·ous \ŏs′ē-as\ *adj* (1707): bony

osseous integration \ŏs′ē-as ĭn′tĭ-grā′shun\ (1993): **1:** the apparent direct attachment or connection of osseous tissue to an inert, alloplastic material without intervening connective tissue **2:** the process and resultant apparent direct connection of an exogenous materials' surface and the host bone tissues, without intervening fibrous connective tissue present **3:** the interface between alloplastic materials and bone

os·si·fi·ca·tion \ŏs′a-fĭ-kā′shun\ *n* (1697): **1:** the natural process of bone formation; the hardening into a bony substance **2:** a mass of ossified tissue

os·te·i·tis \ŏs′tē-ī′tĭs\ *n* (ca. 1839): inflammation of bone

os·te·o·ar·thri·tis \ŏs′tē-ō-är-thrī′tĭs\ *n* (1878): chronic degeneration and destruction of the articular cartilage and/or fibrous connective tissue linings of the joint components and disks, leading to bony spurs, pain, stiffness, limitation of movement, and changes in bone morphology. Advanced conditions may involve erosions and disk degeneration with crepitus—*syn* DEGENERATIVE JOINT DISEASE

os·te·o·gen·e·sis \ŏs′tē-ō-jĕn′ĭ-sĭs\ *n*: development of bone; formation of bone

os·te·o·in·duc·tion \ŏs′tē-ō-ĭn-dŭk′shun\ *n*: the capability of chemicals, procedures, etc., to induce bone formation through the differentiation and recruitment of osteoblasts

os·te·o·in·te·gra·tion *n*: see OSSEOUS INTEGRATION

os·te·o·tome \ŏs′tē-ō-tōm\ *n*: a chisel for use in cutting bone

os·tec·to·my \ŏs-tĕk′tō-mē\ *n*: the excision of bone or a portion of a bone, usually by means of a saw or chisel, for the removal of a sequestrum, the correction of a deformity, or any other purpose

os·te·ot·o·my \ŏs′tē-ŏt′a-mē\ *n*: the surgical cutting of a bone; frequently used to also describe smoothing, leveling, or altering external contours of the bone- see ALVEOLECTOMY; ALVEOPLASTY

os·teo·po·ro·sis \ŏs′tē-ō-pa-rō′sĭs\ *n, pl* **-ro·ses** \-rō′sēz\ (1846): a medical condition characterized by a decrease in bone mass with diminished density and concurrent enlargement of bone spaces, which produces porosity and fragility—**osteoporotic** *adj*

outline form: the shape of the area of a tooth preparation that is included within the cavosurface margins

ovate pontic: a pontic that is shaped on its tissue surface like an egg in two dimensions, typically partially submerged in a surgically-prepared soft-tissue depression to enhance the illusion that a natural tooth is emerging from the gingival tissues

oven soldering: any soldering procedure using heat from a furnace to melt and refuse the solder as opposed to using a gas-air or gas-oxygen torch as the heat source

o·ver·bite \ō′var-bīt′\ *n, slang*: see VERTICAL OVERLAP

o·ver·clo·sure \ō′var-klō′zhar\ *n*: an occluding vertical dimension at a reduced interarch distance; an occluding vertical dimension that results in excessive interocclusal distance when the mandible is in the rest position; it results in a reduced interridge distance when the teeth are in contact

o·ver·den·ture \ō′var-dĕn′chur\ *n*: any removable dental prosthesis that covers and rests on one or more remaining natural teeth, the roots of natural teeth, and/or dental implants; a dental prosthesis that covers and is partially supported by natural teeth, natural tooth roots, and/or dental implants—called also *overlay denture, overlay prosthesis, superimposed prosthesis*

o·ver·glaze \ō′var-glāz\ *adj* (1879): the production of a glazed surface by the addition of a fluxed glass that usually vitrifies at a lower temperature

o·ver·hang \ō′var-hăng\ *n* (1864): excess restorative material projecting beyond a cavity or preparation margin

o·ver·jet *n, obs*: see HORIZONTAL OVERLAP

o·ver·jut *n, obs*: see HORIZONTAL OVERLAP

o·ver·lap *n, obs* (1726): see HORIZONTAL OVERLAP, VERTICAL OVERLAP

overlay denture: see OVERDENTURE

overlay prosthesis: see OVERDENTURE

P

pack \păk\ *vt* (14c): **1:** to make into a compact form **2:** to completely fill **3:** to crowd together **4:** to compress—**pack·a·bil·i·ty** \păk′a-bĭl′ĭ-tē\ *n*—**pack·able** \păk′a-bal\ *adj*

pack \păk\ *n*: any material used to protect tissue, fill space or prevent hemorrhage

packing \păk′ĭng\ *vt*: the act of filling a mold—see DENTURE P.

pain \pān\ *n* (13c): a subjective unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage—see ACUTE P., CHRONIC P., HETEROTOPIC P., MASTICATORY P., MUSCULOSKELETAL P., MYOGENOUS

P., NEUROGENOUS P., ODONTOGENOUS P., PRIMARY P., PROJECTED P., SECONDARY P., VASCULAR P., VISCERAL P.

palatal augmentation prosthesis \păl′a-tal ôg′mĕn-tā′shun prŏs-thē′sĭs\: a removable maxillofacial prosthesis which alters the hard and/or soft palate's topographical form adjacent to the tongue. It allows reshaping of the hard palate to improve tongue/palate contact during speech and swallowing due to impaired tongue mobility as a result of surgery, trauma, or neurological/motor deficits

palatal bar: see PALATAL BAR CONNECTOR

palatal bar connector \păl′a-tal bär ka-nĕk′tōr\: a major connector of a removable dental prosthesis that crosses the palate and is characterized by being relatively narrow anterior and posteriorly

palatal cleft \păl′a-tal klĕft\: **1:** an opening in the roof of the mouth and/or in the functional soft palate. A deformity of the palate from improper union of the maxillary process with the median nasal process during the second month of intrauterine development **2:** a cleft in the palate between the two palatal processes. If both the hard and soft palate are involved, it is termed *uranostaphyloschisis;* if only the soft palate is divided, it is termed *uranoschisis*—see CLEFT PALATE, COMPLETE CLEFT PALATE, OCCULT CLEFT PALATE

palatal drop prosthesis: see PALATAL AUGMENTATION PROSTHESIS

palatal expansion \păl′a-tal ĭk-spăn′shun\: the lateral movement of the maxillae to increase palatal width

palatal incompetence \păl′a-tal ĭn-kŏm′pĭ-tans\: the inability of an anatomically intact soft palate to effect a functional palatopharyngeal closure

palatal insufficiency \păl′a-tal ĭn′sa-fĭsh′an-sē\: an anatomical inadequacy of the soft palate in which the palatopharyngeal sphincter is incomplete

palatal lift prosthesis \păl′a-tal lĭft prŏs-thē′sĭs\: a maxillofacial prosthesis which elevates the soft palate superiorly and aids in restoration of soft palate functions which may be lost due to an acquired, congenital or developmental defect. A *definitive palatal lift* is usually made for patients whose experience with a diagnostic palatal lift has been successful, especially if surgical alterations are deemed unwarranted. An *interim palatal life prosthesis* is usually made as a diagnostic aid to assess the level of possible improvement in speech intelligibility. Some clinicians believe use of a palatal lift may stimulate an otherwise flaccid soft palate to increase functional activity, subsequently lessening its need.

palatal lift prosthesis modification \păl′a-tal lĭft prŏs-thē′sĭs\: alterations in the adaptation, contour, form, or function of an existing palatal lift necessitated due to tissue impingement, lack of function, poor clasp adaptation, or the like

palatal plate \păl′a-tal plāt\: a major connector of a removable dental prosthesis that covers a significant portion of the palatal surface

palatal seal: see POSTPALATAL SEAL

palatal stent: see SURGICAL STENT

palatal strap \păl′a-tal străp\ *slang*: a maxillary major connector of a removable dental prosthesis having an anterior/posterior dimension of 13 to 20 mm that directly or obliquely traverses the palate and is generally located in the area of the second premolar and first molar

palatal vault \păl′a-tal volt\: **1:** the deepest and most superior part of the palate **2:** the curvature of the palate

pal·ate \păl′ĭt\ *n* (14c): see HARD P., SOFT P.

pal·a·to·gram \pă-lĭt′a-grăm\ *n*: a graphic representation of the area of the palate contacted by the tongue during a specified activity, usually speech

palatopharyngeal closure \pă-lĭt′a-fa-rĭn′jē-al, -jal, -făr′ĭn-jē′al klō′zhur\: a sphincteric action sealing the oral cavity from the nasal cavity during swallowing and phonation by the synchronous movement of the middle third of the soft palate in a superior and posterior direction, the lateral pharyngeal wall medially, and the posterior walls of the pharynx anteriorly—***syn*** VELOPHARYNGEAL CLOSURE

palatopharyngeal inadequacy \pă-lĭt′a-fa-rĭn′jē-al, -jal, -făr′ĭn-jē′al ĭn-ăd′ĭ-kwa-sē\: a condition where there is lack of effective closure between the soft palate and one or more of the pharyngeal walls during swallowing or speech sounds that require high intraoral pressure. Nasal reflux escape of air during speech or hypernasality may result. This lack of closure may be due to palatopharyngeal incompetence, insufficiency or from lack of movement of the pharyngeal walls—see PALATOPHARYNGEAL INCOMPETENCE, PALATOPHARYNGEAL INSUFFICIENCY

palatopharyngeal incompetence \pă-lĭt′a-fa-rĭn′jē′al ĭn-kŏm′pĭ-tans\: the inability of an anatomically intact soft palate to contribute to a functional palatopharyngeal closure usually due to disease or trauma of a neurogenic or muscular nature—see PALATOPHARYNGEAL INADEQUACY, PALATOPHARYNGEAL INSUFFICIENCY

palatopharyngeal insufficiency \pă-lĭt′a-fa-rĭn′jē′al ĭn′sa-fĭsh′an-sē\: an acquired or congenital anatomic defect of the soft palate that makes the palatopharyngeal sphincter incomplete—see PALATOPHARYNGEAL INADEQUACY, PALATOPHARNYGEAL INCOMPETENCE

palatopharyngeal sphincter \pă-lĭt′a-fa-rĭn′-jē′al sfĭngk′tar\: the functional sphincter that separates the nasopharynx and oropharynx during swallowing and phonation, formed by the posterior and superior movement of the middle third of the soft palate, the anterior movement of the posterior pharyngeal wall, and the medial movement of the lateral pharyngeal walls—see PALATOPHARYNGEAL CLOSURE—*syn* VELOPHARYNGEAL SPHINCTER

palatorrhaphy: surgical repair of a cleft palate

pal·lia·tive \păl′ē-ā′tĭv\ *adj* (1543): affording relief but not a cure

pal·pate \păl′pāt′\ *vt* **pal·pat·ed** \păl-pā′tĭd\; **pal·pat·ing** \păl-pā′tĭng\ (1849): to examine by touch—**pal·pa·tion** \păl-pā′shun\ *n*

panoramic radiograph \păn′a-răm′ĭk rā′dē-ō-grăf′\: a tomogram of the maxilla and mandible taken with a specialized machine designed to present a panoramic view of the full circumferential lengths of the maxilla and mandible on a single film—called also *orthopantograph*

panoramic radiography \păn′a-răm′ĭk rā′dē-ŏg′ra-fē\: a method of radiography by which a continuous radiograph of the maxillary and/or mandibular dental arches and their associated structures may be obtained

Panorex *adj—trademark* (1966): see PANORAMIC RADIOGRAPH

pan·to·gram *n*: see PANTOGRAPHIC TRACING

pan·to·graph \păn′ta-gräf′\ *n* (1723): **1:** an instrument used for copying a planar figure to any desired scale **2:** in dentistry, an instrument used to graphically record in, one or more planes, paths of mandibular movement and to provide information for the programming of an articulator

pantographic tracing \păn′ta-gräf′ĭk trā′sĭng\: a graphic record of mandibular movement usually recorded in the horizontal, sagittal and frontal planes as registered by styli on the recording tables of a pantograph or by means of electronic sensors

pa·pil·la \pa-pĭl′a\ *n, pl* **pa·pi·llae** \-pĭl′ē\ (1713): any small, nipple-shaped elevation—see INCISIVE P., INTERDENTAL P.

para·func·tion \păr′a-fŭngk′shun\ *adj*: disordered or perverted function

par·al·lax \păr′a-lăks′\ *n*: a difference in the perceived location of an object when observed from two different points not on a straight line with the object

parallel attachment: see PRECISION ATTACHMENT

par·al·lel·o·me·ter \păr′a-lĕ-lŏm′ĭ-tar\ *n*: **1:** an instrument used for determining the exact parallel relationships of lines, structures, and surfaces in dental casts and prostheses **2:** an apparatus used for making one object parallel with another object, as in paralleling attachments and abutments for fixed dental prostheses or precision attachments for removable dental prostheses

pa·ral·y·sis \pă-răl′ĭ-sĭs\ *n* (1525): loss or impairment of motor function as the result of a trauma or pathosis

paresthesia \păr′ĭs-thē′zha\ *n*: lacking normal sensation, such as tingling or burning; morbid or perverted sensation; abnormal sensation

partial coverage restoration: —*see* PARTIAL VENEER CROWN

partial denture \pär′shal dĕn′chur\: a removable dental prosthesis or a fixed dental prosthesis that restores one or more but not all of the natural teeth and/or associated parts and may be supported in part or whole by natural teeth, dental implant supported crowns, dental implant abutment(s), or other fixed dental prostheses and/or the oral mucosa; *usage:* a partial denture can be described as a *fixed dental prosthesis* or *removable dental prosthesis* based on the patient's capability to remove or not remove the prosthesis. If the prosthesis is a fixed dental prosthesis that can only be removed by a clinician, i.e., a fixed dental prosthesis (FDP) supported by dental implants that has been retained by means of a mechanical system [i.e., screw(s)], this prosthesis is also termed a *fixed dental prosthesis.* Adjectives (modifiers) may be added to the clinical description of the dental prosthesis, if needed, to designate the means of mechanical retention, i.e., a *screw retained fixed dental prosthesis.* Any such prosthesis luted to dental implants (in the same manner as luting a fixed dental prosthesis to natural teeth) needs no additional designation as to its means of retention—see BILATERAL DISTAL EXTENSION REMOVABLE D.P., FIXED D.P., REMOVABLE D.P., UNILATERAL REMOVABLE D.P., PROSTHESIS

partial denture construction \pär′shal dĕn′chur kon-strŭk′shun\ *obs*: the science and techniques of designing and constructing partial dentures (GPT-4)

partial denture impression \pär′shal dĕn′chur ĭm-prĕsh′an\ *coll*: a negative likeness of a part or all of a partially edentulous arch *Editorial note: the impression is made of the denture bearing areas, teeth, implant abutments etc, not of the removable dental prosthesis*

partial denture rest \pär′shal dĕn′chur rĕst\: a rigid extension of a fixed or removable dental prosthesis that prevents movement toward the mucosa and transmits functional forces to the teeth or dental implant

partial denture retention \pär′shal dĕn′chur rĭ-tĕn′shun\: the ability of a removable dental prosthesis to resist movement away from its foundation area and/or abutments

partial dislocation \pär′shal dĭs′lō-kā′shun\: displacement of the articular disk resulting in a seriously impaired disk-condyle complex function

partial veneer crown \pär′shal va-nîr′ kroun\: a restoration that restores all but one coronal surface of a tooth or dental implant abutment, usually not covering the facial surface

partitive color mixing \pär′tĭ-tĭv\: color mixing in which both additive and subtractive principles are involved. The eye interprets tiny dots of subtractive color too small to be individually resolved at the viewing distance. The resultant color will be the average of the colors used

Passavant's pad: see PASSAVANT'S RIDGE

Passavant's ridge [Philip Gustav Passavant, German surgeon, 1815-1893]: *eponym* for a prominence on the posterior wall of the nasal pharynx formed by contraction of the superior constrictor muscle of the pharynx during swallowing. Contraction occurs at the level of the plane of the hard palate—called also *Passavant's bar, Passavant's cushion, Passavant's pad, and Passavant's ridge*

Passavant PG. Uber die Verschliesung des Schlunmdes beim Sprechen, (Virchows) Arch Path Anat (Berlin) Virchows 1869;1-31.

pas·si·vate \păs′ĭ-vāt\ *vt* **-at·ed**; **-at·ing** (1913): **1:** to render inactive or less reactive **2:** to protect against contamination by coating or surface treating

pas·si·va·tion \păs′ĭ-vā′shun\ *n*: a process whereby metals and alloys are made more corrosion resistant through surface treatment. This process produces a thin and stable inert oxide layer on the external surfaces—called also *passive corrosion conditioning*

pas·sive \păs′ĭv\ *adj* (14c): **1:** not active or in operation; inert; latent **2:** resistant to corrosion **3:** existing or occurring without being active, direct, or open

pas·si·vi·ty \pă-sĭv′ĭ-tē\ *n* (14c): the quality or condition of inactivity or rest assumed by the teeth, tissues, and denture when a removable dental prosthesis is in place but not under masticatory pressure

pat·ent \păt′nt\ *adj* (14c): open or unobstructed path of dislodgment: the specific direction in which a removable dental prosthesis may be dislodged

path of insertion: see PATH OF PLACEMENT

path of placement \păth, path ŭv plās′mant\: the specific direction in which a prosthesis is placed on the abutment teeth or dental implant(s)

path of withdrawal: —*see* PATH OF PLACEMENT

pathogenic occlusion \păth′a-jĕn′ĭk\: an occlusal relationship capable of producing pathologic changes in the stomatognathic system

pat·tern \păt′urn\ *n* (14c): a form that is used to make a mold; a model for making a mold—see OCCLUSAL P.

pa·trix \pa-trĭks\ *n, pl* **pa·trices** \pa-trē′sĭz**:** **1:** a pattern or die used in type founding to form a matrix **2:** the extension of a dental attachment system that fits into the matrix

pawl \pôl\ *n* (1626)**:** a pivotal tongue or bolt on one part of a machine that is adapted to fall into notches or spaces on another part so as to permit motion in only one direction, i.e., a ratchet wheel

pear-shaped area: see PEAR-SHAPED PAD

pear-shaped pad \pâr-shāpd păd**:** the most distal extension of attached keratinized mucosa overlying the mandibular ridge crest formed by the scarring pattern after extraction of the most posterior molar. It should be differentiated from the retromolar area

pediatric speech aid prosthesis \pē′dē-ăt′rĭk spēch ād prŏs-thē′sĭs**:** a temporary or interim maxillofacial prosthesis used to close a defect in the hard and/or soft palate of an infant or child. It may replace tissue lost due to developmental or surgical alterations. It is necessary for the production of intelligible speech. Normal lateral growth of the palatal bones necessitates replacement of this prosthesis occasionally. Intermittent revisions of the obturator section can assist in maintenance of palatal pharyngeal closure (termed a *speech aid prosthesis modification*). Frequently, such prostheses are not fabricated before the deciduous dentition is fully erupted since clasp retention is often essential—***syn*** BULB, CLEFT PALATE APPLIANCE, NASOPHARYNGEAL OBTURATOR, OBTURATOR, PROSTHETIC SPEECH AID, SPEECH APPLIANCE, SPEECH BULB

pedicle graft: a skin flap sustained by a blood-carrying stem from the donor site during transfer; in periodontal surgery, a flap used to increase the width of attached gingiva, or to cover a root surface, by moving the attached gingiva, which remains joined at one side, to an adjacent position and then suturing the free end

peg lateral \pĕg lăt′ar-al**:** an undersized, tapered maxillary lateral incisor

pellucid \pa-lōō′sĭd\ *adj***:** admitting maximum pedage of light without diffusion or distortion; reflecting light evenly from all surfaces

pen·ny·weight *n***:** a unit of mass in the Troy system used to measure precious metals and equivalent to 1.555 grams. Defined also as 24 grains in the *p.* and 12 *p.* in the Troy Oz. Abbr: *dwt* (from Latin *denarius,* a small silver coin). The abbreviation *pwt* is also sometimes seen in publications

perceived color \par-sēvd′ kŭl′ar**:** attribute of visual perception that can be described by color names: white, gray, black, yellow, orange, brown, red, green, blue, purple, etc., or by a combination of names

per·cus·sion \pur-kŭsh′an\ *n* (1544)**: 1:** the act of striking a part with sharp blows as an aid in diagnosing the condition of the underlying parts by means of the sound obtained **2:** in dentistry, striking a part with short, sharp blows as a diagnostic aid in evaluation of a tooth or dental implant by the sound obtained

per·i·ap·i·cal \pĕr′ĭ-ăp′ĭ-kal, ā′pĭ-\ *adj***:** relating to tissues surrounding the apex of a tooth, including the alveolar bone and periodontal ligament

peri-implantitis \pĕr′ĭ-ĭm-plăn-tī′tĭs\ *substand***:** a term used to describe inflammation around a dental implant, usually the dental implant abutment *Editorial note: peri-implantitis is a misnomer since the peri-implant mucosa, not the dental implant and/or dental implant abutment, is the inflamed entity. Suggested terminology may include acute or chronic gingivitis.*

perikymata: small transverse ridges on the surface of the enamel of permanent teeth that represent overlapping prism groups within the enamel

peri·mo·lysis \pĕr′ĭ-mŏl′ĭ-sĭs\ (1998)**:** acidic erosion of the teeth due to chronic gastric regurgitation.

House RC et al., Perimolysis: Unveiling the Surreptitious Vomiter, Oral Surg Oral Med Oral Path 1981 Feb 51(2): 152-155.

per·i·o·don·tal \pĕr′ē-ō-dŏn′tl\ *adj***:** pertaining to or occurring around a tooth

per·io·don·tom·e·try \pĕr′ē-ō-dŏn′tŏm′ĭ-trē\ *n***:** the measurement of tooth mobility

periosteum \pĕr′ē-ŏs′tē-am\ *n, pl***—tea** \tē-a\ (1597)**:** the membrane of connective tissue that closely invests all bones except at articular surfaces

per·i·ra·dic·u·lar \pĕr′ĭ-răd′ĭ-kyōō-lar\ *adj***:** around or surrounding a tooth root

peripheral seal: see BORDER SEAL

pe·riph·er·y *n, pl* **-eries** (1571)**:** see DENTURE BORDER

permanent dentition \pûr′ma-nant dĕn-tĭsh′an**:** the teeth that erupt after the primary dentition that do not shed under normal conditions

phantasmagoria \fan-taz-muh-GOR-ee-us\ *n***: 1:** an exhibition or display of optical effect and illusions **2a:** a constantly shifting complex succession of things seen or imagined, **2b.** a scene that constantly changes **3.** a bizarre or fantastic combination, collection or assemblage

pharyngeal flap \fa-rĭn′jē-al, -jal, făr′ĭn-jē′al**:** tissue elevated from the posterior pharyngeal wall and inserted into the soft palate to correct palatopharyngeal inadequacy

pharyngeal speech aid prosthesis: see DEFINITIVE OBTURATOR, INTERIM OBTURATOR, SURGICAL OBTURATOR

pharyngeal walls \fa-rĭn′jē-al, -jal, făr′ĭn-jē-ăl**:** posterior and lateral walls of the naso- and oropharynx

phar·ynx \făr′ingks\ *n, pl* **phar·yn·ges** \fa-rĭn′jēz\ (ca. 1693)**:** a funnel-shaped tube of muscle tissue between the mouth, nares, and the esophagus, which is the common pathway for food and air. The nasopharynx is above the level of the soft palate. The oropharynx lies between the upper edge of the epiglottis and the soft palate, whereas the laryngopharynx lies below the upper edge of the epiglottis and the openings into the esophagus and larynx

phosphate-bonded investment: any casting investment with a binder formed from magnesium oxide and mono-ammonium phosphate. The resulting colloidal multi molecular $(NH_4MgPO_4{\cdot}6H_2O)_n$ coagulates around MgO and fillers. This is combined with silica in the form of quartz, cristobalite or both in a concentration of about 80%. Upon heating the binder undergoes several changes believed to be responsible for increased strength at higher temperatures. These investments exhibit considerable thermal expansion and can be used when casting higher fusing metal-ceramic alloys and partial denture frameworks

phos·phor·es·cence \fŏs′fa-rĕs′ans\ *n* (1796)**:** a form of photoluminescence based on the properties of certain molecules to absorb energy (either near ultra violet or visible), and emit it in the form of visible radiation at a higher wavelength. Distinguished from fluorescence in that light continues to be

emitted for some time after the exciting energy has ceased—see FLUORESCENCE, LUMINANCE

pho·to·ac·tive \fō′tō-ăk′tĭv\ *adj*: reacting chemically to visible light or ultraviolet radiation—**pho·to·ac·ti·va·tion**

pho·tom·et·er \fō-tŏm′ĭ-ter\ *n* (1884): an instrument for the measurement of emitted, reflected, or transmitted light. For the measurement of luminous intensity, a visual receptor element (the eye) may be used in the measuring device or a physical receptor element may be used that can be related to the calculated response of a standard observer—see PHYSICAL P., VISUAL P.

pho·ton \fō′tŏn\ *n* (ca. 1922): a massless particle, the quantum of the electromagnetic field, carrying energy, momentum, and angular momentum—called also *light quantum*

photopic vision \fō-tŏp′ĭk vĭzh′an\: vision as it occurs under illumination sufficient to permit the full discrimination of colors. It is the function of the retinal cones and is not dependent on the retinal rods—called also daylight vision as contrasted with twilight or scotopic vision

photoreceptor process \fō′tō-rĭ-sĕp′tar prŏs′ĕs′, prō′sĕs′\: that specific process that is set in motion in a visual sensory end organ or other photic receptor by the incidence of its adequate stimulus, i.e., light

physical elasticity of muscle \fĭz′ĭ-kal ĭ-lă-stĭs′ĭ-tē, ē′lă- ŭv mŭs′al\ *obs*: the physical quality of muscle of being elastic; that is, yielding to active or passive physical stretch (GPT-4)

physical photometer \fĭz′ĭ-kal fō-tŏm′ĭ-ter\: a photometer in which the measurement is made by some physical or chemical effect instead of by visual methods

physiologically balanced occlusion \fĭz′ē-a-lŏj′ĭ-ka-lē băl′ansd a-klōō′zhun\ *obs*: a balanced occlusion that is in harmony with the temporomandibular joints and the neuromuscular system (GPT-4)

physiologic elasticity of muscle \fĭz′ē-a-lŏj′ĭk ĭ-lă-stĭs′ĭ-tē ŭv mŭs′al\ *obs*: the unique biologic quality of muscle of being capable of change and of resuming its size under neuromuscular control (GPT-4)

physiologic occlusion \fĭz′ē-a-lŏj′ik a-klōō′zhun\ *obs*: occlusion in harmony with the functions of the masticatory system (GPT-4)

physiologic rest position \fĭz′ē-a-lŏj′ĭk rĕst pa-zĭsh′un\: **1:** the mandibular position assumed when the head is in an upright position and the involved muscles, particularly the elevator and depressor groups, are in equilibrium in tonic contraction, and the condyles are in a neutral, unstrained position (GPT-1) **2:** the position assumed by the mandible when the attached muscles are in a state of tonic equilibrium. The position is usually noted when the head is held upright (GPT-1) **3:** the postural position of the mandible when an individual is resting comfortably in an upright position and the associated muscles are in a state of minimal contractual activity—*comp* OCCLUSAL VERTICAL DIMENSION, REST VERTICAL DIMENSION

physiologic \fĭz′ē-a-lŏj′ĭk\ or **physiological** \fĭz′ē-a-lŏj′ĭ-kal\ *adj* (1814): **1:** characteristic of or conforming to the innate function of a tissue or organ **2:** pertaining to organic processes or to functions in an organism or in any of its parts **3:** the opposite of pathologic

[1]pick·le \pĭk′al\ *n* (15c): a solution or bath for preserving or cleaning; any of various baths used in cleaning or processing

[2]pick·le \pĭk′al\ *vt* **pick·led** \pĭk′ald\ **pick·ling** \pĭk′lĭng\ (1552): to treat, preserve, or clean in or with an agent

pier \pîr\ *n*: an intermediate abutment for a fixed dental prosthesis

pier abutment: see INTERMEDIATE ABUTMENT

pig·ment \pĭg′mant\ *n* (14c): finely ground, natural or synthetic, inorganic or organic, insoluble dispersed particles (powder), which, when dispersed in a liquid vehicle, may provide, in addition to color, many other essential properties such as opacity, hardness, durability, and corrosion resistance. The term is used to include an extender, white or color pigments. The distinction between powders that are pigments and those that are dyes is generally considered on the basis of solubility—pigments being insoluble and dispersed in the material, dyes being soluble or in solution as used

pin \pĭn\ *n* (bef. 12c): a small cylindrical piece of metal—see ANTERIOR GUIDE P., CEMENTED P., FRICTION RETAINED P., SELF-THREADING P., STEINMANN'S P.

pin·hole *n*: a tooth preparation feature used to provide retention and resistance to displacement. Typically a 2-3 mm hole is prepared in the dentin

pinledge \pĭn′lĕj\ (1998): a partial veneer retainer preparation incorporating pins holes to provide retention

pin-retained cast metal core: a cemented cast foundation restoration for an extensively damaged vital tooth retained by cast tapered pins that are integral with the core. An extracoronal restoration is subsequently placed over the core

pin-retained restoration: a restoration for an extensively damaged vital tooth that in part relies on threaded or cemented pins placed in the dentin for its retention and resistance form

pivoting condyle: see WORKING SIDE CONDYLE

place·ment \plās′mant\ *v*: the process of directing a prosthesis to a desired location; the introduction of prosthesis into a patient's mouth—*substand* DELIVERY, INSERTION—called also *denture placement, prosthesis placement*

plane \plān\ *n* (1570): a flat surface defined by three points—see AXIS ORBITAL P., CAMPER'S P., CORONAL P., CUSP P., FRANKFORT HORIZONTAL P., FRONTAL P., HORIZONTAL P., INCLINED P., MANDIBULAR P., MEDIAN P., OCCLUSAL P.,SAGITTALP.

plane motion \plān mō′shun\: **1:** motion that is a combination of rotation and translation in a given plane. The motion is described by instantaneous centers of rotation. When the center of rotation is fixed, the body is rotating **2:** the combined motions of translation and rotation of a rigid body within a given plane

plane of occlusion: see OCCLUSAL PLANE

plane of reference \plān ŭv rĕf′ar-ans\: any plane with defined landmarks from which measurements can be made—see HORIZONTAL PLANE OF REFERENCE

plas·ter \plăs′tar\ *n*: a paste-like composition (usually of water, lime, and sand) that hardens on drying and is used for coating walls, ceilings, and partitions—*slang:* in dentistry, a colloquial term applied to dental plaster of paris

plaster of paris \plăs′tar ŭv păr′ĭs\ (15c): a white, powdery, slightly hydrated calcium sulfate made by calcination of gypsum, used for making casts and molds when combined with water to form a quick-setting paste

plaster wash \plăs′tar wŏsh, wôsh\ *obs*: a thin mix of plaster used to improve the accuracy of a preliminary impression (GPT-4)

[1]plas·tic \plăs′tĭk\ *adj* (1632): **1:** capable of being shaped or formed **2:** pertaining to the alteration or reformation of living tissues

[2]plas·tic \plăs′tĭk\ *n* (ca. 1909): any of numerous organic synthetic or processed materials that generally are thermoplastic or thermosetting polymers, usually of high molecular weight. They can be cast, extruded, molded, drawn, or laminated into films, filaments, and objects

plastic base \plăs′tĭk bās\ *obs*: a denture or record base made of a plastic material (GPT-4)

plate *n, slang*: see PROSTHESIS

platinum foil \plăt′n-um foil\: a precious-metal foil with a high fusing point that makes it suitable as a matrix for various soldering procedures as well as to provide an internal form for porcelain restorations during their fabrication

Pleasure curve [Max Pleasure, 1903-1965]: *eponym* for a curve of occlusion which, when viewed in the frontal plane, conforms to a line that is convex in the cephalic direction, except when viewed through the molar region

plunger cusp \plŭn′jer kŭsp\: a cusp that tends to force food into interproximal areas

po·gon·ion \pa-gōn′yun\ *n*: the most anterior point on the mandible

point A \point Ā\: a bony landmark representing the deepest point of the premaxillary concavity between the anterior nasal spine and prosthion as viewed on a lateral cephalometric radiograph

point angle \point ăng′gal\: in the development of a cavity preparation, that place of convergence of three planes or surfaces—*comp* LINE ANGLE

point B: see SUPRAMENTALE

[1]pol·ish \pŏl′ĭsh\ *vb* (14c): to make smooth and glossy, usually by friction; giving luster; the act or process of making a denture or casting smooth and glossy

[2]pol·ish \pŏl′ĭsh\ *n* (1704): a smooth, glossy surface; having luster

polished denture surface \pŏl′ĭsht dĕn′chur sûr′fas\ *obs*: that portion of the surface of a denture that extends in an occlusal direction from the border of the denture and includes the palatal surfaces. It is that part of the denture base that is usually polished, and it includes the buccal and lingual surfaces of the teeth (GPT-4)

polished layer: see BEILBY LAYER

pol·ish·ing \pŏl′ĭsh-ĭng\ *v, obs*: **1:** to make smooth and glossy, usually by friction; to give luster to (GPT-1) **2:** *obs:* the act or process of making a denture or casting smooth and glossy (GPT-1)

polishing agents \pŏl′ĭsh-ĭng ā′jants\: any material used to impart luster to a surface

polycarboxylate cement: —*see* ZINC POLYCARBOXYLATE CEMENT

poly·eth·er \pŏl′ē-ē′thar\ *adj*: an elastomeric impression material of ethylene oxide and tetra-hydrofluro copolymers that polymerizes under the influence of an aromatic ester

poly·mer \pŏl′a-mar\ *n* (1866): a chemical compound consisting of large organic molecules built by repetition of smaller monomeric units

polymerization \pa-lĭ′ar-ī-zā′shun\ *n* (1872): the forming of a compound by the joining together of molecules of small molecular weights into a compound of large molecular weight

pol·ym·er·ize \pŏl′a-ma-rīz′, pa-lĭm′a-\ *vb*: to effect a chemical reaction by joining together individual molecules to form large molecules made up of many repeated units

poly(methyl methacrylate): a stable, hard transparent resin of marked clarity with a Knoop hardness number ranging from 18-20, a tensile strength of approximately 60 MPa, a density of 1.19 and a modulus of elasticity of approximately 2.4 GPa

poly·som·nog·raph·y \pŏl′ĭ-sŏm-ŏg′ră-fē\ *n*: the all-night recording of a variety of physiologic parameters (e g., brain waves, eye movements, muscle tonus, respiration, heart rate) as an aid in the diagnosis of sleep related disorders

poly·sul·fide \pŏl′ē-sŭl′fīd\ *n* (1849): an elastomeric impression material of polysulfide polymer (mercaptan) that cross-links under the influence of oxidizing agents such as lead peroxide

pon·tic \pŏn′tĭk\ *n*: an artificial tooth on a fixed dental prosthesis that replaces a missing natural tooth, restores its function, and usually fills the space previously occupied by the clinical crown

por·cel·ain \pôr′sa-lĭn, pōr′-\ *n* (known in Europe, ca. 1540): a ceramic material formed of infusible elements joined by lower fusing materials. Most dental porcelains are glasses and are used in the fabrication of teeth for dentures, pontics and facings, metal ceramic restorations including fixed dental prostheses, as well as all-ceramic restorations such as crowns, laminate veneers, inlays, onlays, and other restorations

porcelain fused to metal restoration: see METAL CERAMIC RESTORATION

porcelain jacket crown: —*see* ALL-CERAMIC RESTORATION

porcelain labial margin \pôr′sa-lĭn, pōr′-lā′bē-al mär′jĭn\: the extension of ceramic material to the finish line of the preparation without visible metal substructure in the marginal area—***syn*** PORCELAIN BUTT MARGIN

porcelain laminate veneer: a thin bonded ceramic restoration that restores the facial surface and part of the proximal surfaces of teeth requiring esthetic restoration

porcelain release agent: any coating to facilitate separation of unfired porcelain from a die

porcelain wax technique: application of a mixture of body porcelain and wax (approximately 6 : 1 ratio by weight) to the die to achieve optimal adaptation of a porcelain labial margin of a metal-ceramic restoration

po·ros·i·ty \pa-rŏs′ĭ-tē, pô-\ *n, pl* **-ties** (14c): **1:** the presence of voids or pores within a structure **2:** the state or quality of having minute pores, openings or interstices—see BACK PRESSURE P., OCCLUDED GAS P., SHRINK-SPOT P., SOLIDIFICATION P.

positional record \pa-zĭsh′a-nal rĕk′ard\: an intraoral or extraoral registration of a specified mandibular position

post and core crown \pōst-kôr,kōr kroun\: a restoration in which the crown and cast post are one unit

post-ceramic solder: **1.** a soldering procedure to join metal-ceramic restorations after final shaping and glazing of the ceramic veneer. Also used to join Type III or Type IV gold castings to metal-ceramic units. **2.** an alloy formulated for post-ceramic soldering

post dam: see POSTPALATAL SEAL

post dam area: see POSTPALATAL SEAL AREA

posterior \pŏ-stîr′ē-ar, pō-\ *adj* (1534): **1:** situated behind or in back of; caudal **2:** in human anatomy, dorsal

posterior bite collapse: see POSTERIOR OVERCLOSURE

posterior border jaw relation \pŏ-stîr′ē-ar, pō- bôr′dar jô rĭ-lā′shun\ *obs*: the most posterior relation of the mandible to the maxillae at any specific vertical relation (GPT-4)

posterior border movement \pŏ-stîr′ē-ar, pō- bôr′dar mōōv′mant\: movements of the mandible along the posterior limit of the envelope of motion

posterior border position \pŏ-stîr′ē-ar, pō- bôr′dar pa-zĭsh′an\: the most posterior position of the mandible at any specific vertical relation

posterior determinants of mandibular movement \pŏ-stîr′ē-ar, pō- dĭ-tûr′ma-nant ŭv măn′dĭb-ū-lar mōōv′mant\: the temporomandibular articulations and associated structures—see DETERMINANTS OF MANDIBULAR MOVEMENT

posterior determinants of occlusion: see DETERMINANTS OF MANDIBULAR MOVEMENT

posterior open bite *slang*: see POSTERIOR OPEN OCCLUSAL RELATIONSHIP

posterior open occlusal relationship \pŏ-stîr′ē-ar ō′pan a-klōō′zal rĭ-lā′shun-shĭp\: lack of posterior tooth contact in any occluding position of the anterior teeth

posterior opening movement \pŏ-stîr′ē-ar ō′pa-nĭng mōōv′mant\ *obs*: the opening movement of the mandible about the terminal hinge axis (GPT-4)

posterior overclosure \pŏ-stîr′ē-ar ō′var-klō′zher\: the loss of occluding vertical dimension as a result of the loss or drifting of posterior teeth

posterior palatal seal: see POSTPALATAL SEAL

posterior palatal seal area: see POSTPALATAL SEAL AREA

posterior reference points \pŏ-stĭr′ē-ar rĕf′ar-ans points\: two points, located one on each side of the face in the area of the transverse horizontal axis, which, together with an anterior reference point, establish the *horizontal reference plane*

posterior tooth form \pŏ-stĭr′ē-ar tōōth form\: the distinguishing contours of the occlusal surfaces of posterior teeth

postmenopausal atrophy \pōst-mĕn′a-pôz′al ăt′ra-fē\: atrophy of various tissues, such as oral mucosa, occurring after menopause

postpalatal seal \pōst-păl′a-tal sēl\: the seal area at the posterior border of a maxillary removable dental prosthesis

postpalatal seal area \pōst-păl′a-tal sēl âr′ē-a\: the soft tissue area at or beyond the junction of the hard and soft palates on which pressure, within physiologic limits, can be applied by a complete RDP to aid in its retention

postsurgical mandibular prosthesis: a maxillofacial prosthesis used to optimize intra/extraoral contours to improve speech and deglutition after mandibular or contiguous soft tissue surgery due to tumor ablation, or reconstruction of acquired or congenital defects, where mandibular continuity is maintained or reestablished

postsurgical maxillary prosthesis: a maxillofacial prosthesis used to optimize maxillary contours to improve speech and deglutition after a maxillary resection due to a tumor or reconstruction of acquired or congenital defects of the maxilla, where there is no oral-antral or oral-nasal communication

postsurgical prosthesis: see DEFINITIVE OBTURATOR, INTERIM OBTURATOR, POSTSURGICAL MANDIBULAR P., POSTSURGICAL MAXILLARY P.

postural contraction \pŏs′chur-al kan-trăk′shun\: that minimal tonic muscle activity necessary to resist the forces of gravity and thus maintain posture; maintenance of muscle tension (usually isometric) sufficient to maintain posture, dependent on muscle tone

postural position \pŏs′chur-al pa-zĭsh′an\: any mandibular relationship occurring during minimal muscle contraction

pour hole \pôr, pōr hōl\ *obs*: an aperture in investment or any other mold material leading to the prosthesis space into which prosthetic material is poured (GPT-4)

pre ceramic solder: **1.** a soldering procedure joining framework components of a metal-ceramic prosthesis prior to application of the ceramic veneer **2.** an alloy formulated for pre-ceramic soldering

precious metal \prĕsh′as mĕt′l\: a metal containing primarily elements of the platinum group, gold, and silver

precious metal alloy \prĕsh′as mĕt′l ăl′oi′, a-loi′\: an alloy predominantly composed of elements considered precious, i.e., gold, the six metals of the platinum group (platinum, osmium, iridium, palladium, ruthenium, and rhodium), and silver

precision attachment \prĭ-sĭzh′un a-tăch′mant\: **1:** a retainer consisting of a metal receptacle (matrix) and a closely fitting part (patrix); the matrix is usually contained within the normal or expanded contours of the crown on the abutment tooth/dental implant and the patrix is attached to a pontic or the removable dental prosthesis framework **2:** an interlocking device, one component of which is fixed to an abutment or abutments, and the other is integrated into a removable dental prosthesis in order to stabilize and/or retain it

precision rest \prĭ-sĭzh′un rĕst\: a prefabricated, rigid metallic extension (patrix) in a fixed or removable dental prosthesis that fits intimately into the box-type rest seat or keyway (matrix) portion of a precision attachment in a restoration

preextraction cast: see DIAGNOSTIC CAST

preliminary cast \prĭ-lĭm′a-nĕr′ē\: a cast formed from a preliminary impression for use in diagnosis or the fabrication of an impression tray

preliminary impression \prĭ-lĭm′a-nĕr′ē ĭm-prĕsh′an\: a negative likeness made for the purpose of diagnosis, treatment planning, or the fabrication of a tray

preload: the tension created in a screw, especially the fluked threadings, when tightened. An engineering term used in dentistry to describe the degree of tightness of a screw, usually in implant dentistry.

premature contact: see DEFLECTIVE OCCLUSAL CONTACT

pre·ma·tur·i·ty *n*: see DEFLECTIVE OCCLUSAL CONTACT

preoperative cast \prē-ŏp′ar-a-tĭv, -ŏp′ra-, -ŏp′a-rā- kăst\: a positive likeness of a part or parts of the oral cavity for the purpose of diagnosis and treatment planning—see DIAGNOSTIC CAST

preoperative record \prē-ŏp′ar-a-tĭv, -ŏp′ra-, -ŏp′a-rā- rĕk′ard\ *obs*: any record made for the purpose of study or treatment planning (GPT-4)

preoperative wax-up: a dental diagnostic procedure in which planned restorations are developed in wax on a diagnostic cast to determine optimal clinical and laboratory procedures necessary to achieve the desired esthetics and function—called also *diagnostic wax-up, preoperative waxing*

preprosthetic surgery \prē-prŏs-thĕt′ĭk sûr′ja-rē\: surgical procedures

designed to facilitate fabrication of a prosthesis or to improve the prognosis of prosthodontic care

pressure area \prĕsh′ar\: a region of mucosa that is being subjected to excessive pressure from a dental prosthesis

pressure indicating paste \prĕsh′ar ĭn′dĭ-kā-tĭng pāst\: any substance applied to a dental prosthesis, which, when seated on a structure, demonstrates the adaptation of the prosthesis to the structure it opposes

pressure relief \prĕsh′ar rĭ-lēf′\ *obs*: alteration of the denture-bearing surface of a denture to reduce force on the underlying tissues (GPT-4)

pressure welding \prĕsh′ar wĕl′dĭng\: bonding of two metals together by sufficiently large force applied perpendicular to the surface. Such force must be of magnitude to produce permanent distortions that expose a film-free metal contact

pretreatment records \prē-trēt′mant rĕk′ardz\: any records made for the purpose of diagnosis, recording of the patient history, or treatment planning in advance of therapy

primary colors \prī′mĕr′ē, -ma-rē kŭl′erz\: three basic colors used to make most other colors by mixture, either additive mixture of lights or subtractive mixture of colorants

primary colors (additive) \prī′mĕr′ē, -ma-rē kŭl′erz ăd′ĭ-tĭv\: three colored lights from which all other colors can be matched by additive mixture. The three must be selected so that no one of them can be matched by mixture of the other two. Generally, red, green, and blue are used. Additive primaries are the complements of the subtractive primaries

primary colors (subtractive) \prī′mĕr′ē, -ma-rē kŭl′erz sab-trăk′tĭv\: colors of three colorants or colored materials which, when mixed together subtract from one another, resulting in black or a very dark neutral color. Subtractive primaries are generally cyan, magenta, and yellow

primary dentition \prī′mĕr′ē dĕn-tĭsh′an\: the teeth that erupt first and are normally shed and replaced by permanent (succedaneous) teeth—***syn*** DECIDUOUS DENTITION

primary hyperalgesia \prī′mĕr′ē hī′par-ăl-gē′zha\: stimulation evoked primary pain due to lowered pain threshold

primary impression: see PRELIMINARY IMPRESSION

primary occlusal trauma \prī′mĕr′ē a-klōō′al trou′ma\: the effects induced by abnormal or excessive occlusal forces acting on teeth with normal periodontal support

primary pain \prī′mĕr′ē pān\: pain that identifies the true source of nociceptive input

pro·cess \prŏs′ĕs, prō′sĕs′\ *n, pl* **pro·ces·ses** (14c): **1:** in anatomy, a prominence or projection of bone **2a:** in dentistry, any technical procedure that incorporates a number of steps **2b:** the procedure of bringing about polymerization of dental resins for prostheses or bases—see DENTURE PROCESSING

processed denture base \prŏ′sĕsd dĕn′chur bās\: that portion of a polymerized dental prosthesis covering the oral mucosa of the maxillary and/or mandible to which artificial teeth will be attached by means of a second processing

process jig: see ANALOG

pro·file \prō′fīl′\ *n* (ca. 1656): an outline or contour, especially one representing a side view of a human head

profile record \prō′fīl rĕk′ard\: a registration or record of the facial profile of a patient—see also EMERGENCE PROFILE

prog·nath·ic \prŏg-năth′ĭk, -nā′thĭk\ *n*: a protruded position of the mandible in relation to the maxillae—called also *caput progeneum, exognathia, progenia, and prognathia*

prog·na·thism \prŏg-na-thĭz′um\ *n* (ca. 1864): an overgrowth of the mandible in an anteroposterior direction; a protrusion of the mandible in relation to the maxillae

prog·no·sis \prŏg-nō′sĭs\ *n* (1655): a forecast as to the probable result of a disease or a course of therapy

progressive loading \pra-grĕs′ĭv lō′dĭng\ (1998): the gradual increase in the application of force on a dental implant whether intentionally done with a dental prosthesis or unintentionally via forces placed by adjacent anatomic structures or parafunctional loading

progressive mandibular lateral translation \pra-grĕs′ĭv măn-dĭb′ya-lar lăt′ar-al trăns-lā′shun\: **1:** the translatory portion of mandibular movement when viewed in a specified body plane **2:** the translatory portion of mandibular movement as viewed in a specific body plane that occurs at a rate or amount that is directly proportional to the forward movement of the nonworking condyle—see MANDIBULAR TRANSLATION

progressive side shift: see MANDIBULAR TRANSLATION

projected pain \pra-jĕk′tĭd pān\: heterotopic pain felt in the anatomical peripheral distribution of the same nerve that mediates the primary pain

proportional limit \pra-pôr′sha-nal lĭm′ĭt\: that unit of stresses beyond which deformation is no longer proportional to the applied load

proprioception \prō′prē-ō-sĕp′shun\ *n* (1906): the reception of stimulation of sensory nerve terminals within the tissues of the body that give information concerning movements and the position of the body; perception mediated by proprioceptors

pros·the·sis \prŏs-thē′sĭs\ *n, pl* **-ses** \-sēz′\ (1900): **1:** an artificial replacement of an absent part of the human body **2:** a therapeutic device to improve or alter function **3:** a device used to aid in accomplishing a desired surgical result *Editorial note:* The taxonomy of the word *prostheses* is as complex as are the varieties of items made by humans for any utilitarian purpose. While classification of botanical or zoological species can be relatively precise due to the common nature of genetic derivation (including descriptions of genetic alterations), such is not the case with respect to many things made by humans. One has only to think about the range of forms used in the course of human history classified as "items of transportation" to be convinced of the complexity and frequently transient nature of such a mode as the automobile! With respect to dentistry, the noun *prosthesis* generally is described first by a *type* adjective (dental, maxillofacial or ancillary) (Figs. 1-4) and frequently second by use of one or more additional adjectives (termed *modifiers*) to clarify such matters as anatomic location, form, materials, means of retention, support, time of usage, or other items. Using coordinate adjectives (two or more adjectives separated by a comma, instead of by coordinating conjunctions) to assist in further description of the prosthesis is helpful but should generally be limited to three or at most four for convenience

in maintaining understanding of the noun *prosthesis*. Frequently, an adjective clause <*descriptor*> can be used following the word *prosthesis* to help clarify such issues as the nature of the support [i.e. tooth number(s), dental implant number(s)] available for the prosthesis. A *descriptor* is something (a word, phrase or characteristic feature) that serves to identify or describe; especially a word or phrase (as an index term) used to identify an item in an information retrieval system. Use of acronyms to describe a prosthesis is to be discouraged since such descriptors do not transfer between languages and thus can be easily misunderstood.

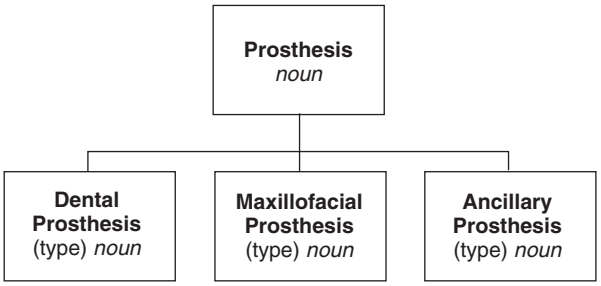


Fig. 1

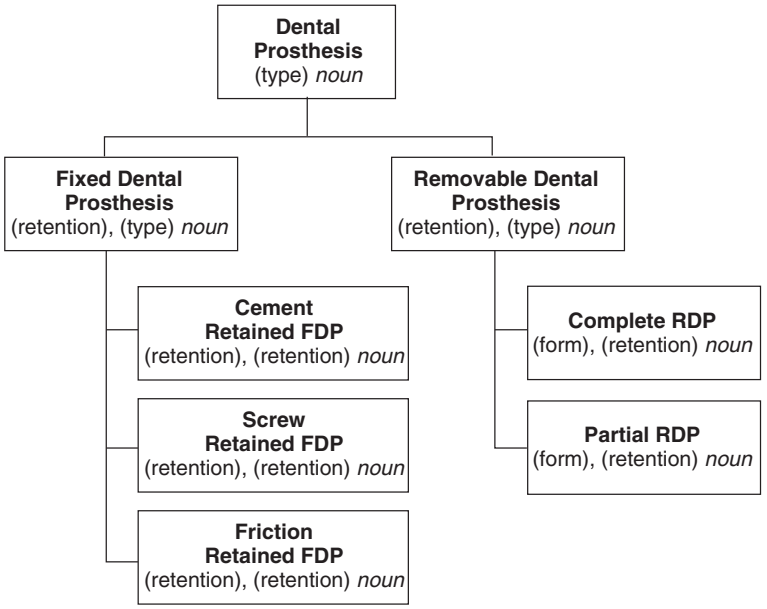


Fig. 2

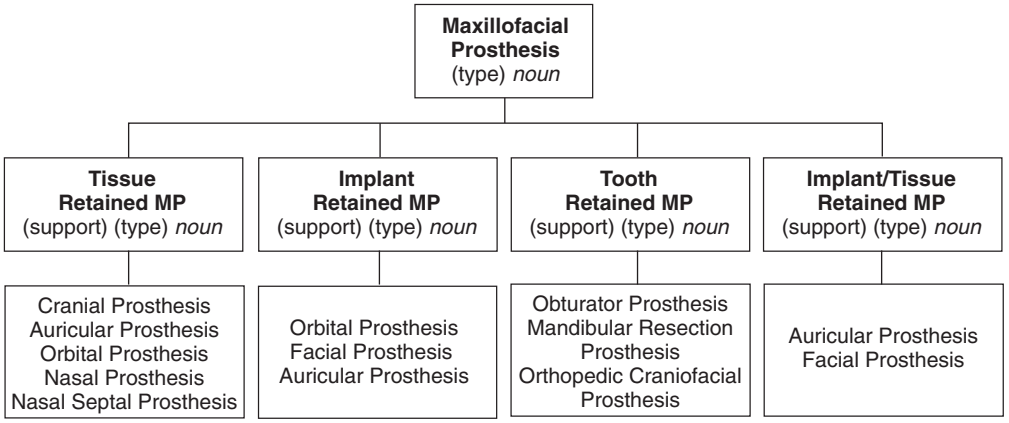


Fig. 3

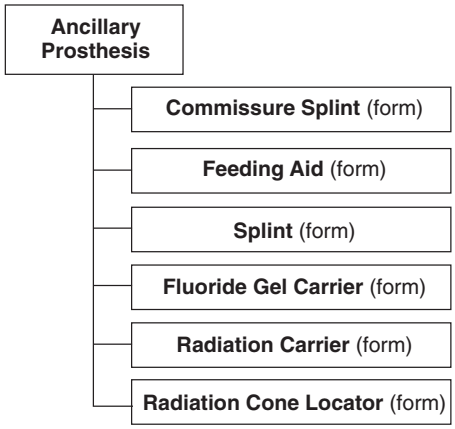


Fig. 4

{modifier} (type) **prosthesis** <descriptor>
coordinate adjective(s) noun adjective clause

Modifier: {anatomic location} i.e. maxillary, mandibular, inferior, superior
{form} i.e. complete, partial, splint, stent, carrier, bar, ovoid, round
{material} i.e. ceramic, metal, resin
{retention} i.e. cement, screw, friction, tissue, fixed, removable
{support} i.e. tooth, implant, tissue
{time} i.e. surgical, temporary, interim, definitive
{other} i.e. soft, zirconium

Type: (dental, maxillofacial, ancillary)

Descriptor: <support> tissue borne, implant borne, tooth/implant borne

Examples. . . .
dental prosthesis
maxillary, removable, partial, dental prosthesis
surgical, obturator, maxillofacial prosthesis
mandibular, fixed, partial, dental prosthesis on dental implants # 28, 30 and 31
cemented, fixed, partial, dental prosthesis on teeth # 12 and 14
cemented, fixed, partial, dental prosthesis on dental implant #12 and tooth #14
ceramic, fixed, partial, dental prosthesis on dental implants #3 and 5

To be avoided examples. . . .
rigid, interim, mandibular, removable, partial, dental prosthesis replacing teeth #23-30
hybrid prosthesis
hybrid denture prosthesis
interim plate

see also DEFINITIVE P., DENTAL P., INTERIM P., MAXILLOFACIAL P., PROVISIONAL P., SUPPLEMENTARY P., and SURGICAL P.

prosthesis placement: see PLACEMENT

prosthesis placement: see PLACEMENT

pros·thet·ic \prŏs-thĕt′ĭk\ *adj,* **pros·thet·i·cal·ly** \prŏs-thĕt′ĭ-kă-lē\ *adv* (ca. 1890)**:** relating to a prosthesis or prosthetics

prosthetic dentistry: see PROSTHODONTICS

prosthetic restoration \prŏs-thĕt′ĭk\ *obs***:** an artificial replacement for an absent part of the human body (GPT-4)

prosthetic speech aid: see ADULT SPEECH AID PROSTHESIS, PEDIATRIC SPEECH AID PROSTHESIS

pros·thet·ics \prŏs-thĕt′ĭks\ *n, pl but sing or pl in constr* (ca. 1894)**:** the art and science of supplying artificial replacements for missing parts of the human body—see also MAXILLOFACIAL P.

pros·the·tist \prŏs′thĭ-tĭst\ *n***:** a person involved in the construction of an artificial replacement for any part of the human body

pros·tho·don·tia *n***:** see PROSTHODONTICS

prosthodontic diagnostic index [American College of Prosthodontists ©, (2004)]**:** a clinical diagnostic index classification for 1) the edentulous patient, 2) the partially edentulous patient, and 3) the completely dentate patient. (see Appendix B, C and D) The classifications use specific diagnostic criteria to delineate treatment complexity into four classes: Class I (ideal or minimally compromised), Class II (moderately compromised), Class III (substantially compromised) or Class IV (severely compromised)

McGarry TJ, Nimmo A, Skiba JF, Ahlstrom RH, Smith CR, Koumjian JH. Classification system for complete edentulism. The American College of Prosthodontics. J Prosthodont. 1999 Mar;8(1):27-39.

McGarry TJ, Nimmo A, Skiba JF, Ahlstrom RH, Smith CR, Koumjian JH, Arbree NS. Classification system for partial edentulism. J Prosthodont. 2002 Sep;11(3):181-93.

McGarry TJ, Nimmo A, Skiba JF, Ahlstrom RH, Smith CR, Koumjian JH, Guichet GN; American College of Prosthodontics. Classification system for the completely dentate patient. J Prosthodont. 2004 Jun;13(2):73-82.

pros·tho·don·tics \prŏs′tha-dŏn′tĭks\ *n, pl but sing or pl in constr* (1947)**:** prosthodontics is the dental specialty pertaining to the diagnosis, treatment planning, rehabilitation and maintenance of the oral function, comfort, appearance and health of patients with clinical conditions associated with missing or deficient teeth and/or maxillofacial tissues using biocompatible substitutes—see FIXED PROSTHODONTICS, IMPLANT PROSTHODONTICS, MAXILLOFACIAL PROSTHETICS, REMOVABLE PROSTHODONTICS

pros·tho·don·tist \prŏs′tha-dŏn-tĭst\ *n* (1917)**: 1:** a specialist in prosthodontics **2:** a dentist who has successfully completed an advanced education program in prosthodontics that is accredited by the appropriate accrediting body. In the United States, that body is the Commission on Dental Accreditation of the American Dental Association—see BOARD-CERTIFIED P., BOARD-ELIGIBLE P., EDUCATIONALLY QUALIFIED P.

pro·ta·no·pia \prō′ta-nō′pē-a**:** a form of dichromatism in which red and blue-green stimuli are confused

protanomalous vision \prō′ta-nŏm′a-lŭs vĭzh′un**:** a form of color deficient vision in which the ability to perceive blue and yellow is retained. Hue discrimination is poor in the red to green region of the spectrum

pro·tru·sion \prō-trōō′zhan\ *n* (1646)**:** a position of the mandible anterior to centric relation—see LATEROPROTRUSION

pro·tru·sive \prō-trōō′sĭv, -zĭv\ *adj,* **pro·tru·sive·ly** \prō-trōō′sĭv-lē\ *adv,* **pro·tru·sive·ness** \prō-trōō′sĭv-nĕs\ *n* (1676)**:** thrusting forward; adjective denoting protrusion

protrusive checkbite: see PROTRUSIVE INTEROCCLUSAL RECORD

protrusive condyle path \prō-trōō′sĭv kŏn′dīl′, -dl păth**:** the path the condyle travels when the mandible is moved forward from its initial position

protrusive deflection \prō-trōō′sĭv dĭ-flĕk′shun**:** a continuing eccentric displacement of the midline incisal path on protrusion, symptomatic of a restriction of movement

protrusive deviation \prō-trōō′sĭv dē′vē-ā′shun**:** discursive movement on protrusion that ends in the centered position and is indicative of interference during movement

protrusive jaw relation \prō-trōō′sĭv jô rĭ-lā′shun\ *obs***:** a jaw relation resulting from a protrusion of the mandible (GPT-4)

protrusive interocclusal record \prō-trōō′sĭv ĭn′tar-a-klōō′zal rĕk′ard\: a registration of the mandible in relation to the maxillae when both condyles are advanced in the temporal fossa

protrusive movement: mandibular movement anterior to centric relation.

protrusive occlusion \prō-trōō′sĭv a-klōō′zhun\ *obs*: an occlusion of the teeth when the mandible is protruded (GPT-4)

protrusive record: see PROTRUSIVE INTEROCCLUSAL RECORD

protrusive relation \prō-trōō′sĭv rĭ-lā′shun\ *obs*: the relation of the mandible to the maxillae when the mandible is thrust forward (GPT-4)

provisional cementation: cementation of an interim or definitive restoration with a luting agent with weak retentive properties to facilitate the planned future removal of the restoration

provisional denture: see INTERIM PROSTHESIS

provisional prosthesis: see INTERIM PROSTHESIS

provisional restoration: see INTERIM PROSTHESIS

provisional splint \pra-vĭzh′a-nal splĭnt\: an interim device to stabilize teeth during diagnosis or therapy—*syn* INTERIM SPLINT

prox·i·mal \prŏk′sa-mal\ *adj* (1727): **1:** situated close to **2:** next to or nearest the point of attachment or origin, a central point especially, located toward the center of a body—*comp* DISTAL—**prox·i·mal·ly** *adj*

proximal contact: see INTERPROXIMAL CONTACT

pseudoisochromatic color tests \sōō′dō-ī′sa-krō-măt′ĭk kŭ′lar tĕsts\: tests for detecting color vision deficiency. The charts are made up of colored spots that yield a legible pattern (number, letter, figure, etc.,) for a normal observer but yield no legible pattern for observers with anomalous types of color vision

psy·cho·phys·i·cal \sī′kō-fĭz′ĭ-kal\ *adj* (1847): used to describe the sector of color science that deals with the relationship between physical description or specification of stimuli and the sensory perception arising from them

psychophysical color \sī′kō-fĭz′ĭ-kal kŭ′lar\: a specification of color stimulus in terms of operationally defined values, such as three tri-stimulus values

psychosomatic dentistry \sī′ka-sō-măt′ĭk dĕn′tĭ-strē\: **1:** dentistry that concerns itself with the mind-body relationship **2:** dentistry that acknowledges a relationship between the psychic and normal physiological functions

pterygoid notch: see PTERYGOMAXILLARY NOTCH

pterygoid plates \tĕr′ĭ-goid′ plātz\: broad, thin, wing-shaped processes of the spheroid bone separated by the pterygoid fossa. The inferior end of the medial plate terminates in a long curved process or hook for the tendon of the tensor veli palatini muscle. The lateral plate gives attachment to the medial and lateral pterygoid muscles

pterygomaxillary notch \tĕr′ĭ-ga-măk′sa-lĕr′ē nŏch\: the palpable notch formed by the junction of the maxilla and the pterygoid hamulus of the sphenoid bone

pulp \pŭlp\ *n*: the richly vascularized connective tissue of mesodermal origin with much innervation contained in the central cavity of the tooth

pulp capping \pŭlp kăp′ĭng\: application of a material to protect the pulp from external influences and promote healing, done either directly or indirectly

pulpectomy \pŭlp-ĕk′tō-mē\ *n*: the complete removal of the dental pulp

pulpitis \pŭl′pī-tĭs\ *n*: inflammation of the dental pulp

pulpotomy \pŭl-pa-ta′mē\ *n*: surgical amputation of the coronal portion of the dental pulp

[1]pum·ice \pŭm′ĭs\ *n* (15th cent.): **1:** a type of volcanic glass used as an abrasive. It is prepared in various grits and used for finishing and polishing **2:** a polishing agent, in powdered form, used for natural teeth and fixed and removable restorations

[2]pum·ice \pŭm′ĭs\ *vt* **pum·iced** \pŭm′ĭsd\ **pum·ic·ing** \pŭm′ĭ-sĭng\ (15th cent.): to finish or dress with pumice

pyramidal fracture \pĭr′a-mĭd frăk′chur\: a fracture of the midfacial bones, with the principal fracture lines meeting at an apex in the area of the nasion—called also *Le Fort II fracture*

Q

Q.D.: *acronym* for L. *Qad'que Di'e,* every day

Q.H.: *acronym* for L. *Qua'que Ho'ra,* every hour

Q.I.D.: *acronym* for L. *Qua'ter In Di'e,* four times a day

Q.L.: *acronym* for L. *Quan'tum Li'bet,* as much as desired

Q.Q.H.: *acronym* for L. *Qua'que Quar'ta Ho'ra,* every 4 hours

quadrant \kwŏd′rant\ *n* (15c): **1:** any of the four quarters into which something is divided by two real or imaginary lines that intersect each other at right angles **2:** in dentistry, one of the four sections of the dental arches, divided at the midline—see also SEXTANT, OCTANT

quartz \kwôrts\ *n* (ca. 1631): an allotropic form of silica; the mineral SiO_2 consisting of hexagonal crystals of colorless, transparent silicon dioxide

quick-cure resin: see AUTOPOLYMERIZING RESIN

R

RAD: *acronym* for *Radiation Absorbed Dose,* a unit of measurement of the absorbed dose of ionizing radiation. The biologic effect of one rad varies with the type of radiation tissue is exposed to—see also GRAY

radiation \rā′dē-ā′shun\ *n* (1570): the emission of electromagnetic waves, such as light, short wave, radio, ultraviolet, or x-rays, or particulate rays such as alpha, beta, and gamma rays

radiation carrier \rā′dē-ā′shun kăr′ē-ar\: an ancillary prosthesis used to administer radiation to confined areas by means of capsules, beads or needles of radiation emitting materials such as radium or cesium. Its function is to hold the radiation source securely in the same location during the entire period of treatment. Radiation oncologists occasionally request these devices to achieve a close approximation and controlled application of radiation to a tumor deemed amiable to eradication—***syn*** CARRIER PROSTHESIS, INTRACAVITY APPLICATOR, INTRACAVITY CARRIER, RADIATION APPLICATOR, RADIUM CARRIER, RADIOTHERAPY PROSTHESIS

radiation cone locator \rā′dē-ā′shun kōn lō′kātar\: an ancillary prosthesis used to direct and reduplicate the path of radiation to an oral tumor during a split course of irradiation—***syn*** CONE LOCATOR, DOCKING DEVICE

radiation shield \rā′dē-ā′shun shēld\: a intraoral ancillary prosthesis designed to shield adjacent tissues from radiation during orthovoltage treatment of malignant lesions of the head and neck

region—***syn*** LEAD SHIELD, RADIATION STENT, TONGUE PROTECTOR

radiation shield/positioner \rā′dē-ā′shun shēld/pa-zĭsh′nar**:** a custom made ancillary prosthesis to direct, align, and protect adjacent tissues during irradiation. The shield/positioner will prevent radiation damage to tissues that are unaffected by a tumor

radiation source device \rā′dē-ā′shun sôrs, sōrs dĭ-vīs′**:** custom made ancillary prosthesis to align a radiation source to a specific anatomic site

radiation source prosthesis: a custom made ancillary prosthesis to align a radiation source to a specific anatomic site. This prosthesis is used to carry or direct a radiation source to a tumor site

radiation stent: see RADIATION SHIELD

rad·i·cle \răd′ĭ-kal\ *n* (1671)**:** the lower part of the axis of an object

rad·ic·u·lar \ră-dĭ-kyōō′lar\ *adj* (1830)**:** pertaining to the root of a tooth

ra·di·o·gram *n***:** see RADIOGRAPH

[1]ra·di·o·graph \rā′dē-ō-grăf′\ *n* (1880)**:** an image produced on any sensitive surface by means of electromagnetic radiation other than light; a x-ray photograph

[2]ra·di·o·graph \rā′dē-ō-grăf′\ *vt* (1896)**:** to make a radiograph of

ra·di·o·lu·cent \rā′dē-ō-lōō′sant**:** permitting the passage of radiant energy with relatively little attenuation by absorption

ra·di·o·paque \rā′dē-ō-pāk′\ (1917)**:** a structure that strongly inhibits the passage of radiant energy

ramus endosteal implant \rā′mas ĕn-dŏs′tē-al ĭm-plănt′**:** an endosteal dental implant that is attached, in part, to the ramus of the mandible

ramus frame endosteal implant \rā′mas frām ĕn-dŏs′tē-al ĭm-plănt′**:** a dental implant design that consists of a horizontal intraoral supragingival abutment in the form of a bar and endosteal implant body segments that are placed into the rami and symphysis areas as one section (implants fabricated from one piece of metal), or two sections (implants of anterior and horizontal segments that are connected at the time of placement), or five sections (an implant consisting of five sections in which the endosteal implant body segments are independently placed and connected with fitted parts)

range of motion \rānj ŭv mō′shun**:** the range, measured in degrees of a circle, through which a joint can be extended or flexed. The range of the opening, lateral, and protrusive excursions of the temporomandibular joint

ra·phe \rā′fē\ *n* (1753)**: 1:** line of union of symmetrical parts **2:** a fibrous band or bands where paired muscles meet

re·at·tach·ment \rē-a-tăch′mant\ *n***:** in periodontics, the reunion of epithelial and connective tissues with root surfaces and bone such as occurs after incision or injury

re·base \rē-bās′\ *n***:** the laboratory process of replacing the entire denture base material on an existing prosthesis

receptor sites \rĭ-sĕp′tar sīts**:** specific sites at which molecular binding occurs that results in specific biologic responses

recipient site \rĭ-sĭp′ē-ant sīt**:** the site into which a graft or transplant material is placed

re·cip·ro·cal \rĭ-sĭp′ra-kal\ *adj, obs***:** the manner in which one part of a prosthesis is made to counter the effect created by another part (GPT-1)

reciprocal arm: see RECIPROCAL CLASP

reciprocal clasp \rĭ-sĭp′ra-kal klăsp**:** a component of the clasp assembly specifically designed to provide reciprocation by engaging a reciprocal guiding plane; it contacts the action of the clasp during removal and insertion of a partial removable dental prosthesis

reciprocal click \rĭ-sĭp′ra-kal klĭk**:** clicks emanating from the temporomandibular joint, one of which occurs during opening movement and the other during closing movement

re·cip·ro·ca·tion \rĭ-sĭp′ra-kā′shun\ *n* (1561)**: 1:** the mechanism by which lateral forces generated by a retentive clasp passing over a height of contour are counterbalanced by a reciprocal clasp passing along a reciprocal guiding plane **2:** a mutual exchange **3:** an alternating motion—**re·cip·ro·ca·tive** \rĭ-sĭp′ra-kā′tĭv\ *adj*

[1]re·cord \rĭ-kōrd\ *vb* (14c)**: 1:** to register data relating to specific conditions that exist currently or previously **2:** to register permanently by mechanical means, i.e., jaw relationships—see CENTRIC RELATION R., ECCENTRIC INTEROCCLUSAL R., INTEROCCLUSAL R., OCCLUDING JAW R., TERMINAL JAW RELATION R.

[2]re·cord \rĭ-kōrd\ *n* (14c)**: 1:** an official document **2:** a body of known or recorded facts about someone or something

record base \rĕk′ard bās**:** an interim denture base used to support the record rim material for recording maxillomandibular records

record rim \rĕk′ard rĭm**:** the occlusal surfaces fabricated on a record base for the purpose of making maxillomandibular relationship records and/or arranging teeth—called also *occlusion rim*

reduced interarch distance \rĭ-dōōsd′ ĭn′tar-ärch**:** an occluding vertical dimension that results in an excessive interocclusal distance when the mandible is in rest position and in a reduced interridge distance when the teeth are in contact—called also *overclosure*

re·duc·tion \rĭ-dŭk′shun\ *n* (1546)**:** the correction of a fracture or dislocation; the restoration by surgical or manipulative procedures of a part to its normal anatomic location

reference plane locator \rĕf′ar-ans, rĕf′rans plān lō′kā′tar**:** a device used to facilitate location of the horizontal reference plane on the face of a patient

re·flec·tance \rĭ-flĕk′tans\ *n* (1926)**:** the ratio of the intensity of reflected radiant flux to that of the incident flux. In popular usage, it is considered as the ratio of the intensity of reflected radiant flux to that reflected from a defined reference standard. Specular reflection is the angle of reflection equal to the angle of incidence. Surface reflection is associated with objects having optically smooth surfaces. These objects are usually termed *glossy*

re·flec·tion \rĭ-flĕk′shun\ (14c) *n***: 1:** the elevation and folding back of all or part of the mucosa to expose underlying structures **2:** the return of light or sound waves from a surface

re·frac·tion \rĭ-frăk′shun\ *n* (1603)**:** the deflection of light or energy waves from a straight path that occurs when passing obliquely from one medium into another in which its velocity is different

re·frac·tory \rĭ-frăk′ta-rē\ *adj* (1606)**:** difficult to fuse or corrode; capable of enduring high temperatures

refractory cast \rĭ-frăk′ta-rē kăst**:** a cast made of a material that will withstand high temperatures without disintegrating—called also *investment cast*

refractory die: any die material that is capable of enduring the high temperatures that occur during firing or casting procedures. The die is an integral part of the mold; the restoration is

directly cast, molded or fired onto the refractory die

refractory flask: see CASTING FLASK

refractory investment \rĭ-frăk′ta-rē ĭn-vĕst′mant**:** an investment material that can withstand the high temperatures used in soldering or casting

refractory mold \rĭ-frăk′ta-rē mōld**:** a refractory cavity into which a substance is shaped or cast

refractory prosthodontic patient: a patient unable to achieve treatment expectations despite the thoroughness or frequency of the treatment provided

re·gen·er·a·tion \rĭ-jĕn′a-rā′shun\ *n* (14c)**:** renewal or restoration of a body or bodily part after injury or as a normal process—see GUIDED TISSUE REGENERATION

reg·is·tra·tion \rĕj′ĭ-strā′shun\ *n* (1566)**: 1:** the making of a record of the jaw relationships present, or those desired, thus allowing their transfer to an articulator to assist in proper fabrication of a dental prosthesis **2:** a record made of the desired maxillomandibular relationship and used to relate casts to an articulator—see MAXILLOMANDIBULAR RELATIONSHIP RECORD

re·im·plan·ta·tion \rē-ĭm-plăn-tā′shun\ *n***:** the act of replacing a tooth in the same alveolar socket from which it had been removed, either surgically or as a result of trauma

re·lief \rĭ-lēf′\ *adj***:** the reduction or elimination of undesirable pressure or force from a specific region under a denture base. The creation of space in an impression tray for impression material

relief area \rĭ-lēf′ âr′ē-a**:** that portion of the dental prosthesis that is reduced to eliminate excessive pressure

relief chamber: see RELIEF AREA

re·line \rē-līn′\ *vt* (1851)**:** the procedures used to resurface the tissue side of a removable dental prosthesis with new base material, thus producing an accurate adaptation to the denture foundation area—*comp* REBASE

re·mod·el \rē-mŏd′l\ *vt***:** the morphologic change in bone as an adaptive response to altered environmental demands. The bone will progressively remodel where there is a proliferation of tissue and regressive remodeling when osteoclastic resorption is evident

remount cast \rē-mount′**:** a cast formed of a prosthesis for the purpose of mounting the prosthesis on an articulator

remount procedure \rē-mount′ pra-sē′jur**:** any method used to relate restorations to an articulator for analysis and/or to assist in development of a plan for occlusal equilibration or reshaping

remount record index \rē-mount′ rĕk′ard ĭn′dĕks′**:** a record of maxillary structures affixed to the mandibular member of an articulator useful in facilitating subsequent transfers

removable appliance: see REMOVABLE DENTAL PROSTHESIS

removable bridge: see REMOVABLE DENTAL PROSTHESIS

removable complete denture prosthesis: a removable dental prosthesis that replaces the entire dentition and associated structures of the maxillae or mandible

removable dental prosthesis \rĭ-mōō′va-bal prŏs-thē′sĭs**: 1:** any dental prosthesis that replaces some or all teeth in a partially dentate arch *(partial removable dental prostheses)* or edentate arch *(complete removable dental prostheses).* It can be removed from the mouth and replaced at will, **2:** any dental prosthesis that can be readily inserted and removed by the patient. The means of retention for such prostheses include *tissue retained RDP, tooth retained RDP, implant retained RDP* or *tooth and implant retained RDP. Editorial Note: examples of tissue retained removable dental prostheses include complete removable dental prostheses, interim prostheses and provisional prostheses devoid of any attachment to natural teeth; tooth retained partial removable dental prostheses include interim and definitive partial removable dental prostheses retained by clasps or/and other connector devices to natural teeth or/and dental implants*

removable die system: a segmented final cast system that permits accurate removal and replacement of dies of individually prepared teeth

removable partial denture prosthesis \rĭ-mōō′va-bal păr′shal dĕn′chur**:** any prosthesis that replaces some teeth in a partially dentate arch. It can be removed from the mouth and replaced at will—also called *partial removable dental prosthesis*

removable prosthodontics \rĭ-mōō′va-bal prŏs-tha-dŏn′tĭks**:** the branch of prosthodontics concerned with the replacement of teeth and contiguous structures for edentulous or partially edentulous patients by artificial substitutes that are readily removable from the mouth

rep·li·ca \rĕp′lĭ-ka\ *n* (1852)**: 1:** a reproduction or facsimile, especially by the makers, of an original **2:** a copy or duplicate, i.e., a duplicate of the surface of a component of a dental implant used to process a restoration

re·po·si·tion·ing \rē-pa-zĭsh′a-nĭng\ *adj***:** the changing of any relative position of the mandible to the maxillae, usually altering the occlusion of the natural or artificial teeth

repositioning splint \rē-pa-zĭsh′a-nĭng splĭnt\ *n***:** an intraoral maxillofacial prosthesis constructed to temporarily or permanently alter the relative position of the mandible to the maxillae

residual bone \rĭ-zĭj′ōō-al bōn**:** that component of maxillary or mandibular bone that remains after the teeth are lost

residual ridge \rĭ-zĭj′ōō-al rĭj**:** the portion of the residual bone and its soft tissue covering that remains after the removal of teeth

residual ridge crest \rĭ-zĭj′ōō-al rĭj krĕst**:** the most coronal portion of the residual ridge

residual ridge resorption \rĭ-zĭj′ōō-al rĭj rē-sôrb′shun, -zôrb′-**:** a term used for the diminishing quantity and quality of the residual ridge after teeth are removed

Ortman HR. Factors of bone resorption of the residual ridge. J PROSTHET DENT 1962;12:429-40.

Atwood DA. Some clinical factors related to rate of resorption of residual ridges. J PROSTHET DENT 1962;12:441-50.

re·sil·ient \rĭ-zĭl′yant\ *adj* (1674)**:** characterized or noted by resilience, as **a)** capable of withstanding shock without permanent deformation or rupture or **b)** tending to recover from or easily adjust to change ***syn*** ELASTIC—**re·sil·ient·ly** *adv*

resilient attachment \rĭ-zl′yant a-tăch′mant\ (1998)**:** an attachment designed to give a tooth borne/soft tissue borne removable dental prosthesis sufficient mechanical flexion to withstand the variations in seating of the prosthesis due to deformations of the mucosa and underlying tissues without placing excessive stress on the abutments

res·in \rĕz′ĭn\ *n* (14c)**: 1:** any of various solid or semisolid amorphous natural

organic substances that usually are transparent or translucent and brown to yellow; usually formed in plant secretions; are soluble in organic solvents but not water; are used chiefly in varnishes, inks, plastics, and medicine; and are found in many dental impression materials **2:** a broad term used to describe natural or synthetic substances that form plastic materials after polymerization. They are named according to their chemical composition, physical structure, and means for activation of polymerization—see AUTOPOLYMERIZING R., COPOLYMER R.

resin-bonded prosthesis \rĕz′ĭn-bŏn′dĭd prŏs-thē′sĭs**:** a fixed dental prosthesis that is luted to tooth structures, primarily enamel, which has been etched to provide mechanical retention for the resin cement. Early design incorporated perforations on the lingual plate (Rochette Bridge) through which the resin bonded material passed to achieve a mechanical lock; subsequently, use of acid etching of the metal plate (Maryland Bridge) eliminated the need for perforations.

Rochette, Alain L. Attachment of a splint to enamel of lower anterior teeth J Pros Dent 1973; 30: 418-423.

Livaditis, GJ, Thompson, VP.: Etched castings: an improved retentive mechanism for resin-bonded retainers J Pros Dent 1982; 47-52

resin-bonded splint \rĕz′ĭn bŏn′dĭd splĭnt**:** a fixed splint made of heavy wire, fibrous resin materials or/and cast metal that is bonded to the labial or lingual surface of natural teeth with an acid etch technique. It is used to stabilize traumatically displaced or periodontal compromised teeth

resin crown \rĕz′ĭn kroun**:** a resin restoration that restores a clinical crown without a metal substructure

resin-modified glass ionomer: a modified glass ionomer cement that incorporates polymerizing monomer and a cross-linking agent; this type of cement has a longer working time and is less sensitive to water contamination than conventional glass ionomer cements; also called *hybrid ionomer cement*

resin-retained prosthesis: see RESIN-BONDED PROSTHESIS

resin-veneered restoration: a fixed restoration that uses a metal framework on which an esthetic resin veneer is applied

resistance form \rĭ-zĭs′tans form**:** the features of a tooth preparation that enhance the stability of a restoration and resist dislodgment along an axis other than the path of placement

resorption \rē-sôrp′shun, zôrp′-\ *n* (1818)**:** the loss of tissue substance by physiologic or pathologic processes—see ALVEOLAR RESORPTION

rest \rĕst\ *n* (15c)**:** a projection or attachment, usually on the side of an object—see CINGULUM R., INCISAL R., LINGUAL R., OCCLUSAL R., PARTIAL DENTURE R., PRECISION R., SEMI-PRECISION R.

rest area: see REST SEAT

rest bite: see PHYSIOLOGIC REST POSITION

rest jaw relation \rĕst jô rĭ-lā′shun\ *obs***:** the habitual postural jaw relation when the patient is resting comfortably in an upright position and the condyles are in a neutral, unstrained position in the glenoid fossae (GPT-4)

rest occlusion: see PHYSIOLOGIC REST POSITION

rest position: see PHYSIOLOGIC REST POSITION

rest relation: see PHYSIOLOGIC REST POSITION

rest seat \rĕst sēt**:** the prepared recess in a tooth or restoration created to receive the occlusal, incisal, cingulum, or lingual rest

rest vertical dimension \rĕst vûr′tĭ-kal dĭ-mĕn′shun**:** the distance between two selected points (one of which is on the middle of the face or nose and the other of which is on the lower face or chin) measured when the mandible is in the physiologic rest position

res·to·ra·tion \rĕs′ta-rā′shun\ *n* (1660)**:** a broad term applied to any material or prosthesis that restores or replaces lost tooth structure, teeth, or oral tissues

re·tain·er \rĭ-tā′nar\ *n* (1540)**:** any type of device used for the stabilization or retention of a prosthesis—see DIRECT R., FIXED PARTIAL DENTURE R., INDIRECT R.

re·ten·tion \rĭ-tĕn′shun\ *n* (15c)**:** that quality inherent in the dental prosthesis acting to resist the forces of dislodgment along the path of placement—see DIRECT R., INDIRECT R.

retention arm \rĭ-tĕn′shun ärm**:** an extension that is part of a partial removable dental prosthesis and is used to aid in the fixation of the prosthesis; a part of a clasp

retention form \rĭ-tĕn′shun form**:** the feature of a tooth preparation that resists dislodgment of a crown in a vertical direction or along the path of placement

retention of the denture \rĭ-tĕn′shun ŭv the dĕn′chur\ *obs***:** the resistance of a denture to dislodgment (GPT-4)

retentive arm: see RETENTIVE CLASP

retentive circumferential clasp \rĭ-tĕn′tĭv sur-kŭm′fa-rĕn′shal klăsp**:** a circumferential clasp arm that is flexible and engages the infrabulge area of the abutment tooth at the terminal end of the arm

retentive clasp \rĭ-tĕn′tĭv klăsp**: 1:** a clasp specifically designed to provide retention by engaging an undercut **2:** a flexible segment of a partial removable dental prosthesis that engages an undercut on an abutment and that is designed to retain the prosthesis

retentive fulcrum line \rĭ-tĕn′tĭv fŭl′krum līn**: 1:** an imaginary line connecting the retentive points of clasp arms on retaining teeth adjacent to mucosa-borne denture bases **2:** an imaginary line, connecting the retentive points of clasp arms, around which the removable dental prosthesis tends to rotate when subjected to dislodging forces

retinal fovea \rĕt′n-al fō′vē-a**:** a small ellipse-shaped depression in the central region of the retina somewhat less than a degree of visual angle in maximum diameter and characterized by the sharpest cone vision. The fovea centralis is the normal center for visual fixation and attention

retrodiscal tissue \rĕt′rō-dĭs′kal tĭsh′ōō**:** a mass of loose, highly vascular and highly innervated, connective tissue attached to the posterior edge of the articular disk and extending to and filling the loose folds of the posterior capsule of the temporomandibular joint—called also *bilaminar zone*

ret·ro·gnath·ic \rĕt′rō-nā′thĭk\ *n***:** a retruded position of the mandible in relation to the maxillae

retromolar pad \rĕt′ra-mō′lar păd**:** a mass of tissue comprised of non-keratinized mucosa located posterior to the retromolar papilla and overlying loose glandular connective tissue. This freely movable area should be differentiated from the pear-shaped pad

retromylohyoid area \rĕt′rō-mī′lō-yoid âr-ē-a\ *obs***:** that area in the alveolingual sulcus just lingual to the retromo-

lar pad that extends down to the floor of the mouth and back to the retromylohyoid curtain. It is bounded anteriorly by the lingual tuberosity (GPT-4)

retromylohyoid space \rĕt′rō-mī′lō-yoid spās\: an anatomic area in the alveololingual sulcus just lingual to the retromolar pad bounded anteriorly by the mylohyoid ridge, posteriorly by the retromylohyoid curtain, inferiorly by the floor of the alveololingual sulcus, and lingually by the anterior tonsillary pillar when the tongue is in a relaxed position

retruded contact \rĭ-trōō′dĭd kŏn′tăkt\: contact of a tooth or teeth along the retruded path of closure. Initial contact of a tooth or teeth during closure around a transverse horizontal axis

retruded contact position \rĭ-trōō′dĭd kŏn′tăkt pa-zĭsh′an\: that guided occlusal relationship occurring at the most retruded position of the condyles in the joint cavities. A position that may be more retruded than the centric relation position

re·tru·sion \rĭ-trōō′shun\ *vb*: movement toward the posterior

re·tru·sive \rĭ-trōō′sĭv\ *adj*: denotes a posterior location

reverse articulation \rĭ-vûrs′ är-tĭk′ya-lā′shun\: an occlusal relationship in which the mandibular teeth are located facial to the opposing maxillary teeth; the maxillary buccal cusps are positioned in the central fossae of the mandibular teeth

reverse articulation teeth \rĭ-vûrs′ är-tĭk′ya-lā′shun tēth\: posterior teeth designed to accommodate the buccal cusps of the maxillary teeth positioned in the fossae of the mandibular teeth

reverse curve \rĭ-vûrs′ kŭrv\: a curve of occlusion defined by the cusp tips and incisal edges which, when viewed in the sagittal plane, is curved upward or in a cephalic manner—*comp* CURVE OF SPEE

reverse occlusal curve: see REVERSE CURVE

reverse swallow: see TONGUE THRUSTING

reversible hydrocolloid \rĭ-vûr′sa-bal hī′dra-kŏl′oid′\: colloidal gels in which the gelation is brought about by cooling and can be returned to the sol condition when the temperature is sufficiently increased

reversible splint \rĭ-vûr′sa-bal splĭnt\: any means of stabilizing teeth that does not irreversibly alter the structure of the teeth

Richmond crown [C.M. Richmond, U.S. dentist (1835-1902)] *obs*: **1:** a dowel-retained crown made for an endodontically treated tooth using a porcelain facing **2:** an artificial crown consisting of a metal base that fits the prepared abutment of the natural tooth and carries a post or pivot for insertion into the endodontically treated root canal: a porcelain facing reinforces the metal backing—called also *porcelain-faced dowel crown*

Richmond CM. New method of attaching gold crowns to natural roots of teeth. Am J Dent Sci 1878-79;12:425.

ridge \rĭj\ *n* (bef. 12c): an elevated body part; a long, narrow, raised crest—see ALVEOLAR R., CENTER OF THE R., CREST OF THE R., RESIDUAL R.

ridge augmentation \rĭj ôg′mĕn-tā′shun\: any procedure designed to enlarge or increase the size, extent, or quality of deformed residual ridge

ridge crest \rĭj krĕst\: the highest continuous surface of the residual ridge not necessarily coincident with the center of the ridge

ridge lap \rĭj lăp\: the surface of an artificial tooth that has been shaped to accommodate the residual ridge. The tissue surface of a ridge lap design is concave and envelops both the buccal and lingual surfaces of the residual ridge

ridge relation: see RIDGE RELATIONSHIP

ridge relationship \rĭj rĭ-lā′shun-shĭp\: the positional relationship of the mandibular residual ridge to the maxillary residual ridge

ridge resorption: see RESIDUAL RIDGE RESORPTION

ridge slope \rĭj slōp\ *obs*: the slope of the crest of the mandibular residual ridge from the third molar region to its most anterior aspect in relation to the inferior border of the mandible as viewed in profile (GPT-4)

rigid connector \rĭj′ĭd ka-nĕk′tar\: a cast, soldered, or fused union between the retainer(s) and pontic(s)

ring less investment technique: an investing technique that uses a removable paper or plastic cylindrical outer form permitting unrestricted expansion of the investment by comparison to the use of a steel casting ring

Roach clasp [Finnis Ewing (Frank) Roach, U.S. prosthodontist, educator, and inventor, (1865-1960)]: *eponym*—see INFRABULGE CLASP

Roach FE. Principles and essentials of bar clasp partial dentures. J Amer Dent Assoc 1930;17:124-38.

Rochette Bridge [Alain L. Rochette, French physician and dentist]: a resin-bonded fixed dental prosthesis incorporating holes within the metal framework and lutes to the lingual aspect of teeth adjacent to an edentulous space that replaces one or more teeth—see RESIN-BONDED PROSTHESIS

Rochette, Alain L. Attachment of a splint to enamel of lower anterior teeth JPD 1973; 30:418-23.

Rockwell hardness number: (RHN) a hardness measurement obtained from the depth of indentation after use of either a steel ball or conical diamond point. The Rockwell hardness number is designated to the particular indenter and load employed (Rockwell C, Rockwell M, etc.)

rod \rŏd\ *n* (bef. 12th cent.): the photoreceptor in the retina that contains a light-sensitive pigment capable of initiating the process of scotopic vision, i.e., low intensity for achromatic sensations only

[1]roent·gen \rĕnt′gan, -jan, rŭnt′-\ *adj* [W. C. Roentgen, German physicist (1845-1923)]: relating to x-rays

[2]roent·gen \rĕnt′gan, -jan, rŭnt′-\ *n* (ca. 1929): the international unit of measurement of x- or gamma radiation in air—*abb* r or R

roentgen ray \rĕnt′gan, -jan, rŭnt′- rā\ *n, often cap 1st R* (1898): **1:** the electromagnetic radiation [greater than 100eV] emitted from a highly evacuated tube, excited by the bombardment of the target anode with a stream of electrons from a heated cathode **2:** electromagnetic radiation produced by the excitation of the inner orbital electron of an atom

roent·gen·o·gram \rĕnt′gan-a-grăm, -jan-, rŭnt′-\ *n* (1904): a photograph made with x-rays

roent·gen·o·graph \rĕnt′gan-a-grăf, -jan-, rŭnt′-\ *n* (ca. 1905): a shadow image record made on a sensitized film or plate by roentgen rays

roentgenographic interpretation \rĕnt′gan-a-grăf′ĭk ĭn-tûr′prĭ-tā′shun\ *obs*: an opinion formed from the study of a roentgenograph (GPT-1)

root \rōōt, rŏŏt\ *n* (bef. 12c): the portion of the tooth apical to the cementoe-

namel junction that is normally covered by cementum and is attached to the periodontal ligament and hence to the supporting bone

root form endosteal dental implant \rōōt form ĭn-dŏs′tē-al dĕn′tl ĭm′plănt\: an endosteal dental implant shaped in the approximate form of a tooth root

root fracture \rōōt frăk′chur\: a microscopic or macroscopic cleavage of the root in any direction

rotating condyle: see WORKING SIDE CONDYLE

ro·ta·tion \rō-tā′shun\ *n* (1555): **1:** the action or process of rotating on or as if on an axis or center **2:** the movement of a rigid body in which the parts move in circular paths with their centers on a fixed line called the axis of rotation. The plane of the circle in which the body moves is perpendicular to the axis of rotation

rotation center \rō-tā′shun sĕn′tur\: a point around which all other points in a body move

rotation line *obs*: see FULCRUM LINE

rotational path removable partial denture \rō-tā′shun-al păth rē-mōōv′a-bal pär′shal dĕn′chur\: a partial removable dental prosthesis that incorporates a curved, arcuate, or variable path of placement allowing one or more of the rigid components of the framework to gain access to and engage an undercut area

rouge \rōōzh\ *n* (1753): a compound composed of ferric oxide and binders used for imparting a high luster to a polished surface, glass, metal, or gems

RPD: *acronym* for *Removable Partial Denture (now termed a Partial Removable Dental Prosthesis)*

RPI: *acronym* for *Rest, Proximal* Plate, and *I-BAR;* the clasp components of one type of partial removable dental prosthesis clasp assembly

ruga \rōō′ga\ *n, pl* **·gae** \-gē′, -gī\ (ca. 1775): an anatomic fold or wrinkle—usually used in the plural sense; the irregular fibrous connective tissue ridges located in the anterior third of the hard palate

rugae area: see RUGA

rugae zone: see RUGA

S

sad·dle *n, obs*: see DENTURE BASE

saddle pontic *obs*: a pontic with a broad concave facio-lingual area of contact with the residual ridge. It is also know as a *ridge lap pontic.* This type of pontic is known to be uncleanseable and result in tissue irritation at the area of contact with the ridge mucosa

sag·it·tal \săj′ĭ-tl\ *adj* (1541): situated in the plane of the cranial sagittal suture or parallel to that plane—*usage:* see SAGITTAL PLANE

sagittal axis \săj′ĭ-tl ăk′sĭs\: an imaginary anteroposterior line around which the mandible may rotate when viewed in the frontal plane

sagittal axis of the mandible: see SAGITTAL AXIS

sagittal plane \săj′ĭ-tl plān\: any vertical plane or section parallel to the median plane of the body that divides a body into right and left portions

sanitary bridge *obs*: see HYGIENIC PONTIC

sanitary pontic *obs*: a trade name originally designed as a manufactured convex blank with a slotted back. The name was used occasionaly as a synonym for a *hygienic pontic,* wherein the pontic does not contact the residual ridge

sat·u·ra·tion \săch′a-rā′shun\ *n* (1554): the attribute of color perception that expresses the degree of departure from gray of the same lightness. All grays have zero saturation

scaf·fold \skăf′ald\ *n* (14c): a supporting surface, either natural or prosthetic, that maintains the contour of tissue; a supporting framework

[1]scal·lop \skŏl′ap\ *n* (15c): one of a continuous series of circles

[2]scal·lop \skŏl′ap\ *vt* (1737): to shape, cut, or finish in scallops; segments or angular projections forming a border

scanning electron micrograph: a micrograph resulting from use of electron microscopy in which specimens are coated with heavy metal and scanned by an electron beam. The image is built up on a monitor screen (in the same way as the raster builds a conventional television image). The resolution is less than transmission electron microscopy, but preparation is easier (often by fixation followed by critical point drying), the depth of focus is relatively large allowing significant magnification and observation of the specimen surface

scattered radiation \skăt′ard rā′dē-ā′shun\: radiation that, during passage through a substance, has been deviated in direction. It may also have been modified by an increase in wavelengths. It is one form of secondary radiation

scat·ter·ing \skăt-a-rĭng\ *n* (14c): diffusion or redirection of radiant energy encountering particles of different refractive index; scattering occurs at any such interface, at the surface, or inside a medium containing particles

scattering coefficient \skăt′ar-ĭng kō′ĭ-fĭsh′ant\: single scattering coefficient of a particle in a medium of different refractive index, expressed as a ratio between scattering cross section and geometric cross section of the particle. It should properly be called scattering efficiency, but in popular use, called scattering coefficient

scotopic vision \ska-tō′pĭk vĭ′shun\: vision that occurs in faint light or dark adaptation and is attributable to the retinal rods. The maximum of the relative spectral visual sensitivity is shifted to 510 nm and the spectrum is seen uncolored

screw endosteal dental implant \skrōō ĭn-dŏs-tē-al dĕn′tl ĭm-plănt′\: **1:** any dental implant whose configuration resembles a screw **2:** any screw-shaped dental implant; it may be hollow or solid, and usually consists of the dental implant abutment and the dental implant

scribe \skrīb\ *vt;* **scrib·ed** \skrībd\ **scrib·ing** \skrī′bĭng\ (1678): to write, trace, or mark by making a line or lines with a pointed instrument

second stage dental implant surgery \sĕk′and stāj dĕn′tl ĭm-plănt sûr′ja-rē\: **1:** for eposteal dental implant surgery, the term refers to the procedure involving placement of the eposteal framework fabricated after the first stage implant surgery **2:** for endosteal dental implant surgery, after surgical reflection, the occlusal aspect of the dental implant is exposed, the cover screw is removed, and either the interim or definitive dental implant abutment is placed. After this, the investing tissues are (when needed) sutured

secondary bonds \sĕk′an-dĕr-ē bŏndz\: weak inter-atomic bonds arising from dipoles within atoms or molecules

secondary crown: see TELESCOPIC CROWN

secondary dentition: see PERMANENT DENTITION

secondary fracture \sĕk′an-dĕr-ē\: a fracture occurring as a consequence of

infection, necrosis or some other disease of the bone

secondary occlusal trauma \sĕk′an-dĕr-ē a-klōō′zal**:** the effects induced by occlusal force (normal or abnormal) acting on teeth with decreased periodontal support

secondary pain \sĕk′an-dĕr-ē pān**:** heterotopic pain and/or secondary hyperalgesia induced by deep somatic pain as a central excitatory effect

sec·tion \sĕk′shun\ *n.* the portion of a maxillofacial prosthesis that serves to fill a defect as a part of the prosthesis.

sectional facial moulage impression: a procedure used to record the soft tissue contours of a portion of the face. Occasionally several separate sectional impressions are made, and then reassembled to provide a full facial contour cast. The impression is utilized to create a partial facial moulage and generally is not reusable

sectional impression \sĕk′shun-al ĭm-prĕsh′an**:** a negative likeness that is made in sections

seg·ment \sĕg′mant\ *n* (1570)**:** any of the parts into which a body naturally separates or is divided either actually or by an imaginary line or plane

Seibert classification: the classification of residual alveolar ridge form into three categories identified as class I, II and III. Class I defects—faciolingual loss of tissue width with normal ridge height; class II defects—loss of ridge height with normal ridge width; class III defects—a combination of loss in both dimensions

Seibert JS Reconstruction of deformed, partially edentulous ridges, using full thickness onlay grafts. Part I. Technique and wound healing. Compend Contin Educ Dent 1983;4: 437-53

selective grinding: see OCCLUSAL RESHAPING

self-curing resin: see AUTOPOLYMERIZING RESIN

self-separating plaster \sĕlf-sĕp′a-rāt′ĭng plăs′tar\ *obs***:** an impression plaster that disintegrates in hot water (GPT-4)

self-threading pin \sĕlf-thrĕd′ĭng pĭn**:** a pin screwed into a hole prepared in dentin to enhance retention

sella turcica \sĕl-lă tŭr-sē′kă**:** a cephalometric landmark in the geometric center of the pituitary fossa of the spheroid bone; a bony anatomic landmark

semi-adjustable articulator \sĕm′ē-a-jŭst′a-bal är-tĭk′ya-lā-tor**:** an articulator that allows adjustment to replicate average mandibular movements—called also *Class III articulator*

semiprecious metal alloy \sĕm′ē-prĕsh′as mĕt′l ăl′oi′, a-loi′**:** an alloy composed of precious and base metals. There is no distinct ratio of components separating semiprecious alloys from another group

semiprecision attachment: a laboratory fabricated rigid metallic extension (patrix) of a fixed or removable dental prosthesis that fits into a slot-type keyway (matrix) in a cast restoration, allowing some movement between the components—*comp* PRECISION ATTACHMENT

semiprecision rest \sĕm′ē-prĭ-sĭzh′an rĕst**:** a rigid metallic extension of a fixed or removable dental prosthesis that fits into an intracoronal preparation in a cast restoration

senile atrophy: see AGE ATROPHY

separating medium \sĕp′a-rāt′ĭng mē′dē-am**: 1:** a coating applied to a surface and serving to prevent a second surface from adhering to the first **2:** a material, usually applied on an impression, to facilitate removal of the cast

sep·tum \sĕp′tum\ *n, pl* **sep·ta** \sĕp′ta\ (1726)**:** a dividing wall or membrane, especially between bodily spaces or masses

sequestrum: a portion of devitalized bone entirely separated from the adjacent vital bone

sequestrectomy: surgical removal of a sequestrum

setting expansion \sĕt′tĭng ĭk-spăn′shun**:** the dimensional increase that occurs concurrent with the hardening of various materials, such as plaster of paris, dental stone, die stone, and dental casting investment

setup *v, obs***:** see TOOTH ARRANGEMENT

sex·tant: \sekstənt*n* New Latin *sextant-, sextans,* from Latin, sixth part of anything, from *sextus* sixth +*-ant-,-ans* -ant**: 1:** the sixth part of a circle **2:** an instrument for measuring altitudes of celestial bodies from a moving ship or airplane with a maximum angle of 60 degrees between its reflecting mirrors **3:** in dentistry, a subdivision of the dental arch by adjacent tooth grouping. The maxillary and mandibular arches may be divided into a total of 6 areas termed *sextants.* In the maxilla, the right posterior sextant extends from tooth # 1-5, the anterior maxillary sextant extends from tooth #6-11, and the left posterior maxillary sextant extends from #12-16. The mandibular arch may be divided into three similar sextants: teeth # 17-21, # 22-27 and #28-32—*comp* OCTANT

shade \shād\ *n***: 1:** a term used to describe a particular hue, or variation of a primary hue, such as a greenish shade of yellow **2:** a term used to describe a mixture with black (or gray) as opposed to a tint that is a mixture with white—see TOOTH COLOR SELECTION

shade selection: see TOOTH COLOR SELECTION

shearing stress \shîr′ĭng strĕs**:** the internal induced force that opposes the sliding of one plane on an adjacent plane or the force that resists a twisting action

shellac base \sha-lăk′ bās\ *obs***:** a record base constructed using a shellac-based wafer that has been adapted to the cast with heat (GPT-4)

shell crown \shĕl kroun\ *obs***: 1:** an artificial full-veneer crown swaged from metal plate **2:** an artificial crown that is adapted like a shell or cap over the remaining clinical crown of a tooth; the space between the crown and the shell is filled with cement—called also *cap crown*

shim·stock *n***:** a thin (8-12 micrometer) strip of polyester film used to identify the presence or absence of occlusal or proximal contacts

shoulder finish line \shŏl′dar fĭn′ĭsh līn\ *n***:** a finish line design for tooth preparation in which the gingival floor meets the external axial surfaces at approximately a right angle

shrink-spot porosity \shrĭngk-spŏt pa-rŏs′ĭ-tē**:** an area of porosity in cast metal that is caused by shrinkage of a portion of the metal as it solidifies from the molten state without flow of additional molten metal from surrounding areas

side shift: see MANDIBULAR TRANSLATION

si·li·ca \sĭl′ĭ-ka\ *n* (ca 1301)**:** silicon dioxide occurring in crystalline, amorphous, and usually impure forms (as quartz, opal, and sand, respectively)

silica-bonded investment: a casting investment with ethyl silicate or a silica gel as a binder, the latter reverting to silica upon heating. This is combined with cristobalite or quartz as the refractory material. Such investments exhibit

considerable thermal expansion and can be used when casting higher fusing chromium alloys

silent period \sī′lant pir′ē-ad\: a momentary electromyographic decrease in elevator muscle activity on initial tooth contact presumably due to the inhibitory effect of stimulated periodontal membrane receptors

simple fracture \sim′pl frăk′chur\: a linear bony fracture that is not in communication with the exterior

simple joint \sim′pul joint\: a joint in which only two bones articulate

simulation film \sim′ya-lā′shun fĭlm\: radiographs made with the same field size, source-to-skin distance, and orientation as a therapy beam to mimic the beam and for visualization of the treated volume on a radiograph

single crystal sapphire \sing′gal krĭs′tal săf′ir\: a material composed of a single crystalline alpha aluminum oxide that is identical in crystalline structure to a gem sapphire

single denture construction \sing′gal dĕn′chur kun-strŭk′shun\ *obs*: the making of a maxillary or mandibular denture as distinguished from a set of complete dentures (GPT-1)

[1]sinter \sĭn′tar\ *n* (1780): a deposit formed by evaporation of lake or spring water

[2]sinter \sĭn′tar\ *vt* (1871): to cause to become a coherent mass by heating without melting

sinus tract: an abnormal passage from a pathological process to an external surface

sialorrhea: excessive flow of saliva

skia·graph \skī′a-grăf′, -gräf′\ *n* (1801) *obs*: **1:** a figure formed by shading in the outline of a shadow **2:** a radiograph—called also *skiagram* (GPT-1)

sleeper \slē′par\: *slang* for any dental implant body not used for support and stabilization of a dental prosthesis

sliding movement: see TRANSLATION

slotted attachment: see PRECISION ATTACHMENT

[1]sluice \slōōs\ *n* (14c): an artificial passage for water fitted with a valve or gate for stopping or regulating the flow

[2]sluice \slōōs\ *vb* **sluic·ed** \slōōsd\ **sluic·ing** \slōō′sĭng\ *vt* (1593): **1:** to draw off by or via a sluice **2:** to wash with or in water through or from a sluice **3:** to drench with a sudden flow

SNA angle: *acronym* for *Sella-Nasion-A* point—in cephalometrics, an angle measuring the anteroposterior relationship of the maxillary basal arch to the anterior cranial base; it shows the degree of maxillary prognathism

snap impression *obs*: see PRELIMINARY IMPRESSION

SNB angle: *acronym* for *Sella-Nasion-B* point—in cephalometrics, an angle showing the anterior limit of the mandibular basal arch in relation to the anterior cranial base

sock·et \sŏk′ĭt\ (15c): any opening or hollow that forms a holder for something, e.g., a tooth

soft palate \soft, sŏft păl′ĭt\: the movable part of the palatal anatomy posterior to the hard palate

soft palate obturator: see SPEECH AID PROSTHESIS

soft splint \soft, sŏft splĭnt\: a resilient device covering either the maxillary or the mandibular teeth for the purpose of preventing trauma to the dentition or acting as a deprogrammer

[1]sol·der \sŏd′ar\ *n* (15c): a fusible metal alloy used to unite the edges or surfaces owo pieces of metal; something that unites or cements

[2]sol·der \sŏd′ar\ *v*, **sol·der·ed** \sŏd′ard\ **sol·der·ing** \sŏd′ar-ĭng\ **sol·der·a·bil·i·ty** \sŏd′ar-ă-bĭl′ĭ-tē\ *n*—**sol·der·er** \sŏd′ar-er\ *n*: to unite, bring into, or restore to a firm union; the act of uniting two pieces of metal by the proper alloy of metals

soldering antiflux: a material, such as iron oxide (rouge) dissolved in a suitable solvent such as turpentine placed on a metal surface to confine the flow of molten solder

soldering flux: a material such as borax glass ($Na_2B_4O_7$) applied to a metal surface to remove oxides or prevent their formation in order to facilitate the flow of solder

soldering index: **1:** a mold used to record the relative position of multiple cast restorations prior to investing for a soldering procedure. **2:** a rigid resin connection between multiple cast restorations fixing their relative position prior to a soldering procedure

solidification porosity \sa-lĭd′a-fĭ-kā′shun pa-rŏs′ĭ-tē\: a porosity that may be produced by improper spruing or improper heating of either the metal or the investment

so·ma·to·pros·thet·ics \sō-măt′a-prŏs-thĕt′ĭks\ *n* (ca. 1950): the art and science of prosthetic replacement of external parts of the body that are missing or deformed

son·i·cate \sŏn′ĭ-kāt\ *vt* **-cat·ed** \-kā′tĭd\ **-cat·ing** \-kā′tĭng\ (1961): to disrupt (i.e. bacteria) by means of application of high frequency sound waves—**son·i·ca·tion** \sŏn′ĭ-kā′shun\ *n*

space \spās\ *n* (14c): a delimited, three-dimensional region; physical space independent of what occupies it—see DENTURE S., INTERPROXIMAL S., INTERRADICULAR S., RETROMYLOHYOID S.

space of Donders [F.C. Donders]: *eponym* for the space that lies above the dorsum of the tongue and below the hard and soft palates when the mandible and tongue are in the rest position

Donders FC. Ueber den Mechanismus des Saugens. Pflugers Archiv fur die Gesamte Physiologie Des Menschen Und Der Tiere. 1875;l0:91-4.

span length \spăn lĕngkth\: the length of a beam between two supports

spat·u·la \spăch′a-la\ *n* (1525): a flat-bladed instrument used for mixing or spreading materials

[1]spat·u·late \spăch′a-lĭt\ *adj* (1760): shaped like a spatula

[2]spat·u·late \spăch′a-lĭt\ *vt* **-ed**/**-ing**/**-s**: to work or treat with a spatula

spat·u·la·tion \spăch′a-lā′shun\ *v*: the manipulation of material with a spatula to produce a homogenous mass

speaking space \spē′kĭng spās\: the space that occurs between the incisal or/and occlusal surfaces of the maxillary and mandibular teeth during speech

spectral curve: see SPECTROPHOTOMETRIC CURVE

spectral reflection \spĕk′tral rĭ-flĕk′shun\: reflection in which the angle of reflection is equal to the angle of incidence. Associated with objects having optically smooth (glossy) surfaces—called also *mirrored reflection*

spec·tro·pho·tom·e·ter \spĕk′trō-fō-tŏm′ĭ-tar\ *n*: a photometry device for the measurement of spectral transmissions, reflectance, or relative emissions. Spectrophotometers are normally equipped with dispersion optics (prism or grating) to give a continuous spectral curve

spectrophotometric curve \spĕk′trō-fō-ta-mĕt′rĭk kûrv\: a curve measured on a spectrophotometer hence, a graph of relative reflectance or transmittance (or absorption) as the ordinate, plotted

versus wavelengths or frequency as the abscissa. The most common curves in the visible region use wavelength units of a nanometer, with the short wavelength to the left of the scale. The word *spectral* is frequently used in place of the longer *spectrophotometric,* but they are not necessarily synonymous

spec·trum \spĕk′trum\ *n*: **1:** band of colors produced when sunlight is passed through a prism **2:** spatial arrangements of components of radiant energy in order of their wavelengths, wave numbers, or frequency–**spec·tral** *adj*

speech aid \spēch ād\: any therapy or any instrument, apparatus, or device used to improve speech quality

speech aid prosthesis \spēch ād prŏs-thē′sĭs\: a removable maxillofacial prosthesis used to restore an acquired or congenital defect of the soft palate with a portion extending into the pharynx to separate the oropharynx and nasopharynx during phonation and deglutition, thereby completing the palatopharyngeal sphincter–***syn*** ADULT S.A.P., PEDIATRIC S.A.P.–called also *pharyngeal s.a.p, cleft palate prosthesis*

speech aid prosthesis modification \spēch ād prŏs-thē′sĭs mŏd′a-fĭ-kā′shun\: any revision of a pediatric or adult speech aid prosthesis not necessitating its replacement

speech articulation \spēch är-tĭk′ya-lā′shun\: **1:** the production of individual sounds in connected discourse **2:** the movement and placement during speech of the organs that serve to interrupt or modify the voiced or unvoiced air stream into meaningful sounds **3:** the speech function performed largely through the movements of the lower jaw, lips, tongue, and soft palate

speech bulb: see SPEECH AID PROSTHESIS

speech prosthesis: see SPEECH AID PROSTHESIS

spherical form of occlusion \sfĭr′ĭ-kal, sfĕr′- form ŭv a-klōō′shun\ *obs*: an arrangement of teeth that places their occlusal surfaces on the surface of an imaginary sphere (usually 8 inches in diameter) with its center above the level of the teeth (GPT-4)

sphinc·ter \sfĭngk′ter\ *n* (1578): a ring-like band of muscle fibers that constricts to close an orifice or passage

spider partial \spī′dar păr′shal\ *substand*: a unilateral partial removable dental prosthesis

[1]splint \splĭnt\ *n* (14c): **1:** a rigid or flexible device that maintains in position a displaced or movable part; also used to keep in place and protect an injured part **2:** a rigid or flexible material used to protect, immobilize, or restrict motion in a part–see ANDERSON S., CAP S., ESSIG S., FUNCTIONAL OCCLUSAL S., GUNNING'S S., INTERDENTAL S., KINGSLEY S., LABIAL S., LINGUAL S., PROVISIONAL S., RESIN-BONDED S., SOFT S., SURGICAL S., WIRE S.

[2]splint \splĭnt\ *v* (1543): to immobilize, support, or brace

splint·ing \splĭn′tĭng\ *v*: **1:** in dentistry, the joining of two or more teeth into a rigid unit by means of fixed or removable restorations or devices **2:** in physiology, prolonged muscle spasms that inhibit or prevent movement

split-cast method \splĭt-kăst měth′ad\ *obs*: **1:** a procedure for placing indexed casts on an articulator to facilitate their removal and replacement on the instrument **2:** the procedure of checking the ability of an articulator to receive or be adjusted to a maxillomandibular relation record (GPT-4)

split-cast mounting \splĭt-kăst moun′tĭng\: a method of mounting casts wherein the dental cast's base is sharply grooved and keyed to the mounting ring's base. The procedure allows verifying the accuracy of the mounting, ease of removal and replacement of the casts

split-dowel crown \splĭt-dou′al kroun\ *obs*: an artificial crown supported and retained by a dowel that was split longitudinally in an attempt to use spring retention in an undersized dowel space

split-thickness graft \splĭt-thĭk′nĭs grăft\: a transplant of skin or mucous membrane consisting of epithelium and a portion of the dermis

spontaneous anterior dislocation: see MANDIBULAR DISLOCATION

spontaneous fracture \spŏn-tā′nē-us frăk′chur\: a fracture occurring without any external injury trauma-also called *pathologic fracture*

spoon denture \spōōn\ *obs*: a maxillary provisional removable dental prosthesis, without clasps, whose palatal resin base resembles the shape of a spoon. The resin base does not contact the lingual surfaces of the teeth and is confined to the central portion of the palate. It was often used during periodontal treatment because the resin base extension did not promote plaque accumulation around the teeth and permitted surgical procedures to be performed

sports dentistry \sports, spōrts dĕn′tĭ-strē\: all aspects of dentistry, either preventive or therapeutic, directly or indirectly involved with sports and recreation

spot grinding: see OCCLUSAL RESHAPING

spring plate \sprĭng plāt\ *obs*: according to James Harrison Prothero, DDS, Emeritus Professor of Prosthetic Dentistry and Metallurgy at Northwestern University Dental School, Chicago, IL, "a spring plate was a denture molded over the cast of a mouth with teeth bearing the relation to each other as stated (*ed. note:* providing lingual undercuts), which would spring as it passes over the points of nearest approach of the teeth involved and resume its normal width without undue lateral pressure when firmly seated on the oral tissues"–called also *spring lock bridge*

sprue \sprōō\ *n* (1880): **1:** the channel or hole through which plastic or metal is poured or cast into a gate or reservoir and then into a mold **2:** the cast metal or plastic that connects a casting to the residual sprue button

sprue button \sprōō bŭt′n\: the material remaining in the reservoir of the mold after a dental casting

sprue former \sprōō fôr′mar\: a wax, plastic, or metal pattern used to form the channel or channels allowing molten metal to flow into a mold to make a casting

sprue pin: see SPRUE FORMER

stab·il·ize *vb* **-liz·ed**; **-liz·ing** *vt*, **stabilization** *v* (1861): **1:** to make firm, steadfast, stable **2:** to hold steady, as to maintain the stability of any object by means of a stabilizer

sta·bil·i·ty \stă-bĭl′ĭ-tē\ (15c): **1:** that quality of maintaining a constant character or position in the presence of forces that threaten to disturb it; the quality of being stable; to stand or endure **2:** the quality of a removable dental prosthesis to be firm, steady, or constant, to resist displacement by functional horizontal or rotational stresses **3.** resistance to horizontal displacement of a prosthesis–see DENTURE S., DIMENSIONAL S., OCCLUSAL S.

sta·b·i·li·za·tion \stā′ba-lī-zā′shun\ *n, obs*: the seating of a fixed or removable denture so that it will not tilt or be displaced under pressure (GPT-1)

stab·il·ize \stā′ba-līz′\ *vb* **-liz·ed** \līzd\ **-liz·ing** \lī-zĭng\ *vt,* **stabilization** \stā′ba-lĭ-zā′shun\ *v* (1861): **1:** to make firm, steadfast, stable **2:** to hold steady, as to maintain the stability of any object by means of a stabilizer

stabilized base plate: see STABILIZED RECORD BASE

stabilized record base \stā′ba-līzd rĕk′ard bās\: a record base lined with a material to improve its fit and adaptation to the underlying supporting tissues

stabilizing circumferential clasp arm \stā′ba-lī′zĭng sar-kŭm′fa-rĕn′shul klăsp ärm\: a circumferential clasp arm that is relatively rigid and contacts the height of contour of the tooth

[1]**stain** \stān\ *n* (1583): **1:** a soiled or discolored spot; a spot of color in contrast to the surrounding area **2:** a preparation used in staining **3:** in dentistry, the discoloration of a tooth surface or surfaces as a result of ingested materials, bacterial action, tobacco, and/or other substances. This may be intrinsic, extrinsic, acquired, or developmental

[2]**stain** \stān\ *vb* (14c): **1:** to suffuse with color **2:** to color by processes affecting chemically or otherwise the material itself **3:** in dentistry, to intentionally alter restorations through the application of intrinsic or extrinsic colorants to achieve a desired effect, best termed *characterization* or to *characterize* a restoration

stanch \stwnch\ *v*: **1:** to check or stop the flow of; *also:* to stop the flow of blood from (a wound) **2a:** to stop or check in its course **2b:** to make watertight: stop up

standard illuminant \stăn′dard ĭ-lōō′manant\: the illuminants A, B. C, D (and others) defined by the CIE in terms of their relative power distribution curves. "A" is an illuminant with a Planckion temperature of approximately 2854°K. It is intended to represent a common tungsten filament source. "B" approximates solar radiation—4870° K—and is obsolete. "C" is average daylight, 6740°K. "D" is daylight with the near ultraviolet source included

standard light source \stăn′dard līt sôrs, sōrs\: a reference light source whose spectral power distribution is known

standard observer \stăn′dard ob-zûr′vur\: a hypothetical observer with a visual response mechanism possessing the calorimetric properties defined by the CIE in 1931 as representative of the human population having normal color vision

standard of care: the level of care that reasonably prudent healthcare providers in the same or a similar locality would provide under similar circumstances

stat·ic \stăt′ĭk\ *adj*: related to bodies at rest or forces in equilibrium

static fatigue \stăt′ĭk fa-tēg\: the delayed failure of glass and ceramic materials resulting from stress enhanced chemical reactions aided by water vapor acting on surface cracks. Analogous to stress corrosion occurring in metals

static relation \stăt′ĭk rĭ-lā′shun\: the relationship between two parts that are not in motion

stay plate *n obj*: see INTERIM DENTAL PROSTHESIS

Steinmann's pin [Fritz Steinmann, Swiss surgeon, 1872-1932]: *eponym* for a firm metal pin that is sharpened on one end; used for the internal fixation of fractures

steam cleaning: the process of debris removal from a restoration, framework or dental prosthesis through use of pressurized steam

sten·o·sis \sta-nō′sĭs\ *n, pl* **-no·ses** (ca. 1860): a narrowing or constriction in the diameter of a passage or orifice—**ste·not·ic** \sta-nŏt′ĭk\ *adj*

stent \stĕnt\ *n* [Charles R. Stent, English dentist, 18??-1901]: *eponym* for any supplementary prosthesis used in conjunction with a surgical procedure to keep a skin graft in place; often modified with acrylic resin or dental modeling impression compound that was previously termed *Stent's mass;* also refers to any device or mold used to hold a skin graft in place or provide support for anastomosed structures—see NASAL S., SURGICAL S.

ste·reo·graph \stĕr′ē-ō-grăf′, stĭr′-\ *n* (1859): an instrument that records mandibular movement in three planes. Engraving, milling, or burnishing the recording medium by means of styli, teeth, abrasive rims, or rotary instruments thus obtains the registrations

stereographic record \stĕr′ē-a-grăf′ĭk\: an intra or extraoral recording of mandibular movement as viewed in three planes in which the registrations are obtained by engraving, milling, or burnishing the recording medium by means of studs, rotary instruments, styli, teeth, or abrasive rims

ster·ile \stĕr′al\ *adj* (1558): free from living microorganisms; aseptic

sterile technique \stĕr′al tĕk-nēk′\: a standard surgical technique in which an aseptic area is established and maintained, including proper sterilization of instruments, drapes, gowns, gloves, and the surgical area. With respect to dental implant placement, the systematic maintenance of asepsis with special emphasis on non-contamination of instruments and implant elements throughout an implant placement procedure

ster·il·i·za·tion \stĕr′a-lī-zā′shun\ *n*: the process of completely eliminating microbial viability

stip·ple \stĭp′al\ *vt* **stip·pled** \stĭ′puld\ **stip·pling** \stĭp′lĭng\ (1760): **1:** to engrave by means of dots or/and flicks **2:** to make small short touches that together produce an even or softly graded shadow **3:** to speckle or fleck—**stip·pler** \stĭp′lar\ *n*

stock tray *coll*: a metal prefabricated impression tray typically available in various sizes and used principally for preliminary impressions—*comp* CUSTOM TRAY

sto·ma \stō′ma\ *n, pl* **sto·ma·ta** \stō′ma-ta\, also **sto·mas** \stō′mäs\ (ca 1684): **1:** any simple bodily opening **2:** an artificial permanent opening usually made surgically

sto·mat·o·gnath·ic \stō-măt′a-nā′thĭk\ *n*: denoting the jaws and mouth collectively

stomatognathic system \stō-măt′a-nā′thĭk sĭs′tum\: the combination of structures involved in speech, receiving, mastication, and deglutition as well as parafunctional actions

sto·ma·tol·o·gy \stō′mă-tŏl′a-jē\ *n*: the study of the structures, functions, and diseases of the mouth

stone *n* : see DENTAL STONE

stone die: see MODEL, REPLICA

stop clasp \stŏp klăsp\ *obs*: as described by James Harrison Prothero, DDS, "the stop clasp was an early forerunner to the conventional clasp assembly by the addition of a lug (occlusal rest) to the retentive and reciprocal clasp assembly"

Prothero JH. Prosthetic dentistry. 2nd ed. Chicago: Medico-Dental Publishing Co., 1916:332.

strain \strān\: change in length per unit length when stress is applied; the change in length/original length

stress \strĕs\ *n* (14c): force per unit area; a force exerted on one body that presses on, pulls on, pushes against, or tends to invest or compress another body; the deformation caused in a body by such a force; an internal force that resists an externally applied load or force. It is normally defined in terms of mechanical stress, which is the force divided by the perpendicular cross sectional area over which the force is applied—see COMPRESSIVE S., SHEARING S., TENSILE S.

stress-bearing area: see STRESS-BEARING REGION

stress-bearing region \strĕs-bâr′ĭng\: **1.** the surfaces of oral structures that resist forces, strains, or pressures brought on them during function **2** the portion of the mouth capable of providing support for a denture—see also DENTURE FOUNDATION AREA

stress breaker: see STRESS DIRECTOR

stress concentration: an area or point of significantly higher stress associated with a structural discontinuity such as a crack or pore; a marked change in dimension of a structure

stress director \strĕs dĭ-rĕk′tar, dī-\: a device or system that relieves specific dental structures of part or all of the occlusal forces and redirects those forces to other bearing structures or regions

stress-strain curve: the graphic representation of the tensile or compressive stress and associated strain of a material

study cast *obs*: see DIAGNOSTIC CAST

stylus tracing \stī′lus trā′sĭng\: a planar tracing that resembles an arrowhead or gothic arch made by means of a device attached to the opposing arches. The shape of the tracing depends on the location of the marking point relative to the tracing table, i.e., in the incisal region as opposed to posteriorly. The apex of a properly made anterior tracing is considered to indicate the centric relation position, called also *arrow-point tracing, gothic arch tracing, needlepoint tracing*—see CENTRAL BEARING TRACING DEVICE

sub antral augmentation \sŭb′ăn-trăl ôg′mĕn-tā′shun\: augmentation of the antral floor with autologous bone or bone substitutes to provide a host site for dental implants—*called also,* SINUS LIFT, ANTHROPLASTY

subcondylar fracture \sŭb-kŏn′dĭ-lar frăk′chur\: a fracture beneath the condylar head and within the condylar neck

subdermal implant: see MUCOSAL INSERT

subgingival margin: the restoration margin or tooth preparation finish line that is located apical to the free gingival tissue

sub·lin·gual \sŭb′lĭng′gwal\ *adj* (1661): pertaining to the region or structures located beneath the tongue

sublingual crescent \sŭb′lĭng′gwal krĕs′ant\: the crescent shaped area on the anterior floor of the mouth formed by the lingual wall of the mandible and the adjacent sublingual fold. It is the area of the anterior alveolingual sulcus

sublingual fold \sŭb′lĭng′gwal fōld\: the crescent-shaped area on the floor of the mouth following the inner wall of the mandible and tapering toward the molar region. The sublingual gland and submaxillary duct form it

sublingual fossa \sŭb′lĭng′gwal fŏs′a\: a smooth depression on the lingual surface of the body of the mandible near the midline, above the mylohyoid line and below the alveolus. This fossa accommodates part of the sublingual gland

sub·lux·a·tion \sŭb′lŭk-sā′shun\ *n* (ca. 1688): an incomplete or partial dislocation that is self-reducing—see CONDYLAR SUBLUXATION

submersible endosteal implant *obj*: see ENDOSTEAL DENTAL IMPLANT

submersible implant *obj*: see ENDOSTEAL DENTAL IMPLANT

submucosal inserts: see MUCOSAL INSERT

submucous cleft palate: see OCCULT CLEFT PALATE

subocclusal connector \sŭb′a-klōō′zal kaněk′tar\: an interproximal nonrigid connector positioned apical to and not in communication with the occlusal plane

subocclusal surface \sŭb′a-klōō′zal sûr′fas\ *obs*: a portion of the occlusal surface of a tooth that is below the level of the occluding portion of the tooth (GPT-1)

subperiosteal dental implant \sŭb-pĕr′ē-ŏs′tē-al dĕn′tl ĭm-plănt′\: an eposteal dental implant that is placed beneath the periosteum while overlying the bony cortex—first attributed to Swedish Dentist, G.S. Dahl

Dahl, GS 1943. Om mojlighenten for implantation, kaken av metall skelett som bas eller retention for fasta eller avatagbara protesor, Odontol.Foren. Tidskr 51:440.

Goldberg, NI, and Gershkoff, A. 1949. The implant lower denture, Dent Digest 55:490.

Linkow, LI. 1984 Evolutionary Design Trends in the Mandibular Subperiosteal Implant, J Oral Implant 11:402-438.

subperiosteal dental implant abutment \sŭb-pĕr′ē-ŏs′tē-al dĕn′tl ĭm-plănt a-bŭt′mant\ *obs*: that portion of the implant that protrudes through the mucosa into the oral cavity for the retention or support of a crown or a fixed removable denture (GPT-4)—see ABUTMENT

subperiosteal dental implant substructure \sŭb-pĕr′ē-ŏs-tē-al ĭm-plănt sŭb′strŭk′chur\: a cast metal framework that fits on the residual ridge beneath the periosteum and provides support for a dental prosthesis by means of posts or other mechanisms protruding through the mucosa; the implant body

subperiosteal dental implant superstructure \sŭb-pĕr′ē-ŏs-tē-al dĕn′tl ĭm-plănt′ sōō′par-strŭk′chur\: the metal framework, usually within a removable dental prosthesis, that fits onto the dental implant abutment(s) and provides retention for artificial teeth and the denture base material of the prosthesis. It is a structural component of the fixed or removable dental prosthesis

subperiosteal fracture \sŭb-pĕr′ē-ŏs-tē-al frăk′chur\: a bony fracture occurring beneath the periosteum, without displacement

subtractive color system \sub-trăk′tĭv kŭ′lar sĭs′tum\: the system whereby light is removed by filtration or absorption from a white source. The primary colors of the subtractive system are magenta, cyan, and yellow—called also *pigment mixture color system*

subtractive primary colors \sub-trăk′tĭv prī′mĕr′ē, -ma-rē\: the primary colorant substances for pigment and filtering mixtures typically evoking responses of cyan (blue-green), magenta (red-blue), and yellow (red-green). The complementary colors of the subtractive primary colors are red,

green, and blue. Magenta is a mixture of red and blue and is the complement of green. Cyan is a mixture of blue and green and is the complement of red. Yellow is a mixture of red and green and is the complement of blue

suck-back porosity *coll*: a shrinkage void in a solidified casting opposite the location of the sprue attachment, resulting from a heat swell and localized lingering of molten metal after the casting, as a whole, has solidified

suction chamber \sŭk′shun chăm′bar\ *obs*: relief provided in the midline palatal area of a maxillary denture in an attempt to obtain additional retention by means of the theoretical vacuum created (GPT-4)

suction cup \sŭk′shun\ *obs*: a thin rubber disk, usually with a hole in its center, which fits over a button that is larger in diameter than the hole. This causes the disk to assume a cup shape. When applied to the tissue surface of a denture, the cup attaches itself to the mucous membrane by suction (GPT-1)

sulcular epithelium: see CREVICULAR EPITHELIUM

sul·cus *n*: see GINGIVAL CREVICE

superimposed prosthesis: see OVERDENTURE

superjacent \soo-per-JAY-sunt\ *adj*: lying above or upon; overlying

su·per·struc·ture \sōō′par-strŭk′chur\ *n*: the superior part of a fixed or removable dental prosthesis that includes the replacement teeth and associated gingival/alveolar structures

[1]sup·port \sa-pôrt, -pōrt\ *n* (14c): the foundation area on which a dental prosthesis rests. With respect to dental prostheses, the resistance to displacement away from the basal tissue or underlying structures

[2]sup·port \sa-pôrt, -pōrt\ *vt* (14c): to hold up, serve as a foundation, or prop for

supporting area \sa-pôrt′ĭng âr-ē′a\ *obs*: **1:** the surface of the mouth available for support of a denture (GPT-1) **2:** those areas of the maxillary and mandibular edentulous ridges that are considered best suited to carry the forces of mastication when the dentures are in function (GPT-1)

supporting cusps \sa-pôrt′ĭng kŭsps\: those cusps or incisal edges of teeth that contact in and support maximum intercuspation. Usually facial cusps of the mandibular posterior teeth, the maxillary palatal cusps, and the incisal edges of the mandibular anterior teeth

su·pra·bulge \sōō′pra-bŭlj\ *adj*: that portion of a tooth or crown that converges toward the occlusal surface, i.e., above the height of contour

suprabulge clasp \sōō′pra-bŭlj klăsp\: any partial removable dental prosthesis retentive clasp that approaches the retentive undercut from an occlusal or suprabulge direction

su·pra·erup·tion \sōō′pra-ĭ-rŭp′shun\ *n*: movement of a tooth or teeth above the normal occlusal plane

su·pra·gin·gi·val \sōō′pra-jĭn′ja-val\ *adj*: **1:** located above the gingiva **2:** that portion of a natural or artificial tooth that is coronal to the gingival crest

su·pra·men·tal·e \sōō′pra-mĕn′tāl\ *n*: a landmark representing the deepest point of the symphyseal cavity between infradentale and pogonion

su·pra·oc·clus·ion \sōō′pra-a-klōō′zhun\ *n*: malocclusion in which the occluding surfaces of teeth extend beyond the normal occlusal plane—called also *overeruption*

surface tension \sûr′fas tĕn′shun\: a property of liquids in which the exposed surface tends to contract to the smallest possible area, as in the spherical formation of drops. This is a phenomenon attributed to the attractive forces, or cohesion, between the molecules of the liquid

sur·fac·tant *n*: a surface active substance (as a detergent) applied to a substrate to facilitate its wetting by another material

surgical baseplate: see SURGICAL OBTURATOR

surgical guide: see SURGICAL PROSTHESIS, SURGICAL TEMPLATE

surgical maxillomandibular relation \sûr′jĭ-kal măk-sĭl′ō-măn-dĭb′ya-lar rĭ-lā′shun\: the establishing and recording of the correct vertical dimension and centric relation between a surgically exposed bone surface and opposite arch at the time of making a surgical bone impression

surgical obturator \sûr′jĭ-kal ŏb′ta-rā′tor\: a temporary maxillofacial prosthesis inserted during or immediately following surgical or traumatic loss of a portion or all of one or both maxillary bones and contiguous alveolar structures (i.e. gingival tissue, teeth). Frequent revisions of surgical obturators are necessary during the ensuing healing phase (approximately six months). Some dentists prefer to replace many or all teeth removed by the surgical procedure with the surgical obturator, while others do not replace any teeth. Further surgical revisions may require fabrication of another surgical obturator (i.e., an initially planned small defect may be revised and greatly enlarged after the final pathologic report indicates margins are not free of tumor)—see INTERIM OBTURATOR

surgical occlusion rim \sûr′jĭ-kal a-klōō′zhun rĭm\: an occlusion rim used in recording surgical maxillomandibular relations

surgical prosthesis \sûr′jĭ-kal prŏs-thē′sĭs\: any ancillary prosthesis prepared for insertion during a surgical procedure and intended for short-term use

surgical splint \sûr′jĭ-kal splĭnt\: any ancillary prosthesis designed to utilize existing teeth and/or alveolar processes as points of anchorage to assist in stabilization and immobilization of broken bones during healing. It is used to re-establish, as much as possible, normal occlusal relationships, during the process of immobilization. Frequently, an existing prosthesis (i.e. a patient's complete removable dental prosthesis) can be modified to serve as a surgical splint. Frequently surgical splints have arch bars added to facilitate intermaxillary fixation. Rubber elastics may be used to assist in this process. Circummandibular eyelet hooks can be utilized for enhanced stabilization with wiring to adjacent bone—***syn*** CAST METAL SPLINT, FENESTRATED SPLINT, GUNNING SPLINT, KINGSLEY SPLINT, LABIOLINGUAL SPLINT, MODIFIED GUNNING SPLINT

surgical stay plate: see SURGICAL OBTURATOR

surgical stent \sûr′jĭ-kal stĕnt\: named for the dentist who first described their use, Charles R. Stent, such ancillary prostheses are used to apply pressure to soft tissues to facilitate healing and prevent cicatrization or collapse—***syn*** COLUMELLAR STENT, PERIODONTAL STENT, SKIN GRAFT STENT

surgical template \sûr′jĭ-kal tĕm′plĭt\: **1:** a thin, transparent form duplicating the tissue surface of a dental prosthesis and used as a guide for surgically shaping the alveolar process **2:** a guide used to assist in proper surgical placement and

angulation of dental implants **3:** a guide used to assist in establishing the desired occlusion during orthognathic surgery

surface tension: a property of liquids in which the exposed surface tends to contract to the smallest possible area, as in the spherical formation of drops; this is a phenomenon attributed to the attractive forces, or cohesion, between the molecules of the liquid

sur·vey \sur-vā′, sûr′vā′\ *v*: **1:** to examine as to condition, value, or situation; to appraise **2:** to determine the form and position of a given entity by means of taking linear and angular measurements **3:** to inspect or scrutinize **4:** the procedure of locating and delineating the contour and position of the abutment teeth and associated structures before designing a removable partial denture (GPT-1) **sur·vey·ed**, **sur·vey·ing**

survey line \sûr′vā′ līn**:** a line produced on a cast by a surveyor marking the greatest prominence of contour in relation to the planned path of placement of a restoration

sur·vey·ing \sur-vā′ĭng\ *n***:** an analysis and comparison of the prominence of intraoral contours associated with the fabrication of a dental prosthesis

sur·vey·or \sur-vā′or\ *n* (15c)**:** a paralleling instrument used in construction of a dental prosthesis to locate and delineate the contours and relative positions of abutment teeth and associated structures

sut·ur·ing \sōō′chur-ĭng\ *vt* (1777)**:** the process of uniting the tissues separated by either a traumatic or a surgical wound in a specific manner using an appropriate material

[1]swage \swāj\ *n* (ca 1812)**:** any tool used for shaping metal by striking with a hammer or sledgehammer

[2]swage \swāj\ *vt* **swaged** \swājd\ **swag·ing** \swāj′ĭng\ (1881)**:** to shape a material by hammering or adapting it onto a die with a swage instrument

swallowing threshold \swŏl′ō-ĭng thrĕsh′ōld**:** the critical moment of reflex action initiated by sufficient stimulation before the act of deglutition

sympathetic nervous system \sĭm′pa-thĕt′ĭk nûr′vas sĭs′tum**:** the part of the autonomic nervous system that responds to dangerous or threatening situations by preparing a person physiologically for "fight or flight"—see PARASYMPATHETIC NERVOUS SYSTEM

symphysis \sĭm′fĭ-sĭs\ *n, pl* **-physes** (ca. 1578)**: 1:** a type of cartilaginous joint in which the opposed bony surfaces are firmly united by a plate of fibrocartilage **2:** the immovable dense midline articulation of the right and left halves of the adult mandible

symp·tom \sĭm′tum, sĭmp-\ *n* (14c)**:** subjective evidence of disease or physical disturbance; something that indicates the presence of a bodily disorder

syn·chro·ny \sĭng′kra-nē, sĭn′-\ *n* (1848)**:** the simultaneous appearance of two separate events

syn·drome \sĭn′drōm′\ n (1541)**:** a group of symptoms that occur together

synovial fluid \sĭ-nō′vē-al flōō′ĭd**:** a viscid fluid contained in joint cavities and secreted by the synovial membrane

synovial membrane: the articular membrane composed of specialized endothelial cells capable of producing synovial fluid filling the joint cavity surrounded by the membrane

systemic etiologic factors \sĭ-stĕm′ĭk ē′tē-ō-lŏj′ĭk făk′turs**:** generalized biologic factors that are implicated in the causation, modification, and/or perpetuation of a disease entity

T

ta·ble \tā′bal\ *n* (bef. 12c)**:** a flat surface; a raised horizontal surface—see GUIDE T., OCCLUSAL T.

ta·per: in dentistry, the convergence of two opposing external walls of a tooth preparation as viewed in a given plane. The extension of those average lines within that plane form an angle describe as the *angle of convergence*

tech·nic \tĕk′nĭk\ *n* (1855)**:** a detailed procedure in the fabrication of a prosthesis—spelled also *technique*

tech·nique \tĕk-nēk′\ *n* (1817)**:** a body of technical methods; a method of accomplishing a desired end; the method or procedure and its details

telescopic coping: see COPING

telescopic crown \tĕl′a-skŏp′ĭk kroun**:** an artificial crown constructed to fit over a coping (framework). The coping can be another crown, a bar or any other suitable rigid support for the dental prosthesis

telescopic denture: see OVERDENTURE

tem·plate \tĕm′plĭt\ *n* (1877)**: 1:** a pattern, mold, or gauge used as a guide to form a piece being made **2:** a curved or flat surface pattern that is used as an aid in arranging teeth—see also SURGICAL TEMPLATE

temporary base: see RECORD BASE

temporary denture: see INTERIM PROSTHESIS

temporary prosthesis: see INTERIM PROSTHESIS

temporary restoration: see INTERIM PROSTHESIS

temporomandibular articulation: see TEMPOROMANDIBULAR JOINT

temporomandibular disorders \tĕm′pa-rō′măn-dĭb′ya-lar dĭs-ôr′derz**: 1:** conditions producing abnormal, incomplete, or impaired function of the temporomandibular joint(s) **2:** *(obs)* a collection of symptoms frequently observed in various combinations first described by Costen (1934, 1937), which he claimed to be reflexes due to irritation of the auriculotemporal and/or chorda tympanic nerves as they emerged from the tympanic plate caused by altered anatomic relations and derangements of the temporomandibular joint associated with loss of occlusal vertical dimension, loss of posterior tooth support, and/or other malocclusions. The symptoms can include headache about the vertex and occiput, tinnitus, pain about the ear, impaired hearing and pain about the tongue—*acronym* TMD

temporomandibular dysfunction syndrome: see TEMPOROMANDIBULAR DISORDERS

temporomandibular joint \tĕm′pa-rō′măn-dĭb′ya-lar joint**: 1:** the articulation between the temporal bone and the mandible. It is a bilateral diarthrodial, bilateral ginglymoid joint **2:** the articulation of the condylar process of the mandible and the intraarticular disk with the mandibular fossa of the squamous portion of the temporal bone; a diarthrodial, sliding hinge (ginglymus) joint. Movement in the upper joint compartment is mostly translational, whereas that in the lower joint compartment is mostly rotational. The joint connects the mandibular condyle to the articular fossa of the temporal bone with the *temporomandibular disk* interposed

temporomandibular joint derangement: see INTERNAL DERANGEMENT

temporomandibular joint hypermobility \tĕm′pa-rō′măn-dĭb′ya-lar joint hī′par-mō′bĭl′ĭ-tē**:** excessive mobility of the temporomandibular joint

temporomandibular joint remodeling: see REMODEL

temporomandibular joint syndrome: see TEMPOROMANDIBULAR DISORDERS

TENS: *acronym* for *Transcutaneous Electrical Neural Stimulation*—see TRANSCUTANEOUS ELECTRICAL NEURAL STIMULATION

tensile stress \tĕn′sal, -sīl strĕs\: the internal induced force that resists the elongation of a material in a direction parallel to the direction of the stresses

ten·sion \tĕn′shun\ *n* (1533): the state of being stretched, strained, or extended

terminal hinge axis: see TRANSVERSE HORIZONTAL AXIS

terminal hinge position: see RETRUDED CONTACT POSITION

terminal jaw relation record \tûr′ma-nal jô rī-lā′shun rĕk′ard\: a record of the relationship of the mandible to the maxillae made in the terminal hinge position

therapeutic prosthesis: see RADIATION CARRIER

thermal expansion \thûr′mal ĭk-spăn′shun\: expansion of a material caused by heat

ther·mo·plas·tic \thûr′ma-plăs′tĭk\ *adj* (1883): a characteristic or property of a material that allows it to be softened by the application of heat and return to the hardened state on cooling—**ther·mo·plas·tic·i·ty** *n*

thread \′thred\ *n* (before 12c): **1:** a filament, a group of filaments grouped together, or a filamentous length formed by spinning and twisting short fibers into a continuous strand **2:** a projecting helical rib (as on a pipe) by which parts can be screwed together: a screw thread

thread crest: the top part of the thread; for *external* threads, the thread crest is the region of the thread which is on its outer surface, whereas for *internal* threads it is the region which forms the inner diameter

thread flank: the thread flanks join the thread roots to the crest of a screw

thread root: the bottom of the thread where it meets the shaft of the screw

thread run out: that portion at the end of a threaded shank which is not cut or rolled to full depth, but which provides a transition between full depth threads and the fastener shank

threaded post: any post used for the restoration of endodontically treated teeth that has a screw thread to engage radicular dentin

three-quarter crown *obs*: see PARTIAL VENEER CROWN

tic \tĭk\ *n* (ca. 1822): an intermittent, involuntary, spasmodic movement of a group of muscles, often without a demonstrable external stimulus

T.I.D.: acronym for L. Ter In Di′e, three times a day

tin·foil \tĭn′foil′\ *n* (15c): **1:** paper thin metal sheeting usually of a tin-lead alloy or aluminum (a misnomer) **2:** a base-metal foil used as a separating material between the cast and denture base material during flasking and polymerizing

tinners' joint: an overlapping folded joint between two abutting sheets of metal of uneven length in which the longer portion is first folded over the shorter after which the combined layers are folded over once more resulting in a quadruple layer of material. Originally used by tinsmiths to join sheets of tin. In dentistry, used to secure a thin platinum matrix that is applied to a die of a prepared tooth to support dental porcelain during firing

tin·ni·tus \tĭn′ĭtus\ *n* (1843): a noise in the ears, often described as ringing or roaring

tinted denture base \tĭnt′ĭd dĕn′chur bās\: a denture base with coloring that simulates the color and shading of natural oral tissues

tis·sue \tĭsh′ōō\ *n* (1771): **1:** the various cellular combinations that make up the body **2:** an aggregation of similarly specialized cells united in the performance of a particular function—see HYPERPLASTIC TISSUE

tissue-bearing area: see DENTURE FOUNDATION AREA

tissue displaceability \tĭsh′ōō dĭs-plās′a-bĭl′ĭ-tē\: **1:** the quality of oral tissues that permits them to be placed in other than a relaxed position **2:** the degree to which tissues permit displacement

tissue displacement \tĭsh′ōō dĭs-plās′mant\: the change in the form or position of tissues as a result of pressure. Frequently used to describe gingival tissue placement prior to impression making.

tissue integration \tĭsh′ōō ĭn′tĭ-grā′shun\: as clinically observed, the apparent direct and healthy attachment of living tissue to an alloplastic material, i.e., a dental implant—see OSSEOUS INTEGRATION

tissue molding: see BORDER MOLDING

tissue reaction \tĭsh′ōō rē-ăk′shun\: the response of tissues to an altered condition

tissue registration \tĭsh′ōō rĕj′ĭ-strā′shun\ *obs*: **1:** the accurate registration of the shape of tissues under any condition by means of a suitable material (GPT-1) **2:** an impression (GPT-1)

tissue trimming: see BORDER MOLDING

TMD: *acronym* for *TemporoMandibular Disorders*—see TEMPOROMANDIBULAR DISORDERS

to·mo·gram \tŏm′a-grăm\ *n* (1940): a radiograph made by using a tomograph

[1]to·mo·graph \tŏm′a-grăf\ *n*: a device for moving an x-ray source in one direction as the film moves in the opposite direction

[2]to·mo·graph \tŏm′a-grăf\ *n*: a radiograph produced from a machine that has the source of radiation moving in one direction and the film moving in the opposite direction

to·mo·gra·phy \tō-mŏg′ra-fē\ *n*: a general term for a technique that provides a distinct image of any selected plane through the body, while the images of structures that lie above and below that plane are blurred. Also, the term *body-section radiography* has been applied to the procedure, although the several ways of accomplishing it have been given distinguishing names

tongue habit \tŭng hăb′ĭt\: conscious or unconscious movements of the tongue that are not related to purposeful functions. Such habits may produce malocclusion or injuries to tissues of the tongue or the attachment apparatus of the teeth

tongue thrusting \tŭng thrŭst-ĭng\: the infantile pattern of suckle-swallow in which the tongue is placed between the incisor teeth or alveolar ridges during the initial stages of deglutition, resulting sometimes in an anterior open occlusion, deformation of the jaws, and/or abnormal function

tooth \tōōth\ *n, pl* **teeth** \tēth\ (bef. 12c): any hard calcified structure in the alveolar processes of the maxilla or mandible used for mastication of food, or a similar structure—see ANATOMIC T., CUSPLESS T., METAL INSERT T., NONANATOMIC T., REVERSE ARTICULATION T., TUBE T., ZERO-DEGREE T.

tooth arrangement \tōōth a-rănj′mant\: **1:** the placement of teeth on a denture

with definite objectives in mind **2:** the placement of teeth on trial bases—see ANTERIOR TOOTH ARRANGEMENT

tooth borne: see TOOTH SUPPORTED

tooth color selection \tōōth kŭl′ar sĭ-lĕk′shun**:** the determination of the color and other attributes of appearance of an artificial tooth or set of teeth for a given individual

tooth form \tōōth form**:** the characteristics of the curves, lines, angles, and contours of various teeth that permit their identification and differentiation—see ANTERIOR T.F., POSTERIOR T.F.

tooth placement: see TOOTH ARRANGEMENT

tooth preparation: 1. the process of removal of diseased and/or healthy enamel and dentin and cementum to shape a tooth to receive a restoration. **2.** the resulting prepared tooth

tooth selection \tōōth sĭ-lĕk′shun**:** the selection of a tooth or teeth of a shape, size, and color to harmonize with the individual characteristics of a patient

tooth size discrepancy \tōōth sīz dĭ-skrĕp′an-sē**:** abnormally sized teeth or groups of teeth

tooth supported \tōōth sa-pôr′tĭd**:** a term used to describe a dental prosthesis or part of a prosthesis that depends entirely on the natural teeth for support

tooth-supported base \tōōth-sa-pôr′tĭd bās**:** a dental prosthesis base that restores an edentulous region that has abutment teeth at each end for support. The tissue that it covers is not used for support

tooth-supported denture: see OVERDENTURE

tor·que \tôrk\ *n* (ca. 1884)**:** a twisting or rotary force. The movement of a system of forces producing rotation

tor·us \tôr′us\ *n, pl* **tori** \tôr′ī, tōr′ī\ (1563)**: 1:** a smooth rounded anatomical protuberance **2.** in dentistry, prominence (s) sometimes seen on the lingual surface of the mandible and the midline of the hard palate

total elasticity of muscle \tōt′l\ *obs***:** the combined effect of physical and physiologic elasticity of muscle (GPT-4)

tough·ness \tŭf′nĕs\ *n***:** the ability of a material to withstand stresses and strains without breaking

toxic dose \tŏk′sĭk**:** the amount of a drug that causes untoward symptoms in most persons

tox·ic·i·ty \tŏk-sĭs′ĭ-tē\ *n***:** the adverse reactions (dose-response-time relationships) of tissues to selected foreign substances resulting in unacceptable in-vivo interactions. The toxicity can be at the local or systemic level depending on the amount, rate of release, and specific type of substance available to the tissues

trac·er *n* (ca. 1552)**:** see ARROW-POINT T.

trac·ing \trā′sĭng\ *n* (15c)**: 1:** a line or lines scribed by a pointed instrument **2:** a traced copy of a drawing, photograph, radiograph, or similar entity—see ARROW POINT T., CEPHALOMETRIC T. EXTRAORAL T., INTRAORAL T., MANDIBULAR T., PAN TOGRAPHIC T., STYLUS T.

tracing device \trā′sĭng dĭ′vīs**:** a device that provides a central point of bearing, or support, between maxillary and mandibular occlusion rims or dentures. It consists of a contacting point that is attached to one occlusion rim or denture and a plate attached to the opposing occlusion rim or denture that provides the surface on which the bearing point rests or moves

transcranial oblique radiograph \trănskrā′nē-al ō-blēk′, a-blēk′ rā′dē-ō-grăf′**:** a flat radiographic projection in which the central beam travels across the cranium and through the temporomandibular joint on the opposite side showing an oblique lateral view of the condyle

transcutaneous electrical neural stimulation \trăns-kyōō-tā′nē-us ĭ-lĕk′trĭ-kal nōōr′al stĭm′yu-lā′shun**:** application of low-voltage electrical stimulation through the skin to nerves in order to interfere with the sensation of pain in the brain and increase blood flow to the region—*colloquial* TENS

trans·epi·the·li·al \trăns-ĕp′a-thē′lē-al\ *adj***:** penetrating or passing through the epithelium, as in a dental implant

transepithelial abutment \trăns-ĕp′a-thē′lē-al a-bŭt′mant\ *slang***:** the dental implant abutment that passes through the epithelium and attaches to the dental prosthesis—called also the *dental implant abutment*

transfer coping \trăns-fûr′, trăns′fur kō′pĭng**:** a metallic, acrylic resin, or other covering or cap used to position a die in an impression

transit dose \trăn′sĭt, -zĭt dōs**:** a measure of the primary radiation transmitted through the patient and measured at a point on the central ray at some point beyond the patient

transitional contour \trăn-zĭsh′an-al kŏn′tōōr**:** with respect to any restoration supported by a dental implant, the external form achieved between the abutment and the implant body

transitional denture \trăn-zĭsh′an-al dĕn′chur**:** a removable dental prosthesis serving as an interim prosthesis to which artificial teeth will be added as natural teeth are lost and that will be replaced after postextraction tissue changes have occurred. A transitional denture may become an interim complete dental prosthesis when all of the natural teeth have been removed from the dental arch—called also *complete denture*

transitional prosthesis: see INTERIM PROSTHESIS, TRANSITIONAL DENTURE

translating condyle: see NONWORKING SIDE CONDYLE

trans·la·tion \trăn-zĭsh′an, -sĭsh′-\ *n* (14c)**:** that motion of a rigid body in which a straight line passing through any two points always remains parallel to its initial position. The motion may be described as a sliding or gliding motion

translatory movement \trăns-lă′tōr-ē\ *obs***:** the motion of a body at any instant when all points within the body are moving at the same velocity and in the same direction (GPT-1)

trans·luc·en·cy \trănz′lōō′san-sē\ *n* (1611)**:** having the appearance between complete opacity and complete transparency; partially opaque

trans·mu·co·sal \trăns-myōō-kō′sal\ *adj***:** passing through the gingiva or oral mucosa

trans·os·teal \trăns-ŏs′tē-al\ *adj***:** the penetration of both the internal and external cortical plates of a bone

transosteal dental implant \trăns′ŏs-tē-al dĕn′tl ĭm-plănt′**: 1:** a dental implant that penetrates both cortical plates and passes through the full thickness of the alveolar bone **2:** a dental implant composed of a metal plate with retentive pins to hold it against the inferior border of the mandible that supports transosteal pins that penetrate through the full thickness of the mandible and pass into the mouth in the parasymphyseal region—called also *staple bone implant, mandibular staple implant, transmandibular implant*

transverse axis: see TRANSVERSE HORIZONTAL AXIS

transverse facial fracture: see LE FORTE III FRACTURE, MIDFACIAL FRACTURE

transverse horizontal axis \trănz-vûrs′, trănz-, trănz′vûrs′, trănz′-\: an imaginary line around which the mandible may rotate within the sagittal plane

trans·ver·sion \trănz-vûr′shun\ *n*: displacement of a tooth from its usual position or proper numerical position in the jaw

trau·ma \trou′ma, trô′-\ *n, pl* **trau·ma·ta** \trou′ma-ta\ or **trau·mas** \trou′mas\, **trau·mat·ic** \trou′măt-ĭk\ *adj*—**trau·mat·i·cal·ly** \trou′măt-ĭ-kă-lē\ *adv* (1693): an injury or wound, whether physical or psychic

trauma from occlusion: see OCCLUSAL TRAUMA

traumatic occlusion: see OCCLUSAL TRAUMA

trau·ma·to·gen·ic \trou′ma-ta-jĕn′ĭk\ *adj*: capable of producing a wound or injury

traumatogenic occlusion \trou′ma-ta-jĕn′ĭk a-klōō′zhun\ *obs*: an occluding of the teeth that is capable of producing injury to oral structures (GPT-4)

traveling condyle: see NONWORKING SIDE CONDYLE

treatment denture \trēt′mant dĕn′chur\: **1:** a dental prosthesis used for the purpose of treating or conditioning the tissues that is called on to support and retain it **2:** a dental prosthesis that is placed in preparation for future therapy—see INTERIM PROSTHESIS

treatment plan \trēt-mant plăn\: the sequence of procedures planned for the treatment of a patient after diagnosis

tre·phine *n*: a hollow rotary instrument (resembling a hole saw) used to make circular cuts. Used in dentistry to create a trough around pins or posts in a natural tooth prior to their removal or for removal of a dental implant from bone

trial base \trī′al bās\: a material or device representing the base of a removable dental prosthesis. It is used for making maxillomandibular relationship records and for the arrangement of teeth

trial denture \trī′al dĕn′chur\: a preliminary arrangement of denture teeth that has been prepared for placement into the patient's mouth to evaluate esthetics and maxillomandibular relationships

trial fitting: see TRIAL PLACEMENT

trial flask closure \trī′al flăsk klō′zhar\: any preliminary closure made for the purpose of eliminating excess material and insuring that the mold is completely filled

trial placement \trī′al plās′mant\: the process of placing a trial denture in the patient's mouth for evaluation—see TRIAL DENTURE

trial plate *obs*: see TRIAL DENTURE

tricalcium phosphate \trī-kăl′sē-um fŏs′fāt\: an inorganic particulate or solid form of relatively biodegradable ceramic that is used as a scaffold for bone regeneration. It may be used as a matrix for new bone growth

trichromatic system \trī-krō-măt′ĭk sĭs′tam\: a system for specifying color stimuli in terms of the tri-stimulus value based on matching colors by additive mixtures of three primary colored lights

tri·chro·ma·tism \trī-krō′ma-tĭz′um\ *n*: a type of vision in which the colors seen require, in general, three independently adjustable primaries (such as red, green, and blue) for their duplication by mixture; trichromatism may be either anomalous trichromatism or normal vision

trigger area: see TRIGGER POINT

trigger point \trĭg′ur point\: a focus of hyperirritability in tissue which when palpated, is locally tender and gives rise to heterotopic pain

trigger spot: see TRIGGER POINT

trigger zone: see TRIGGER POINT

tripod marking \trĭg′ur măr′kĭng\: those marks or lines drawn on a cast in a single plane perpendicular to the survey rod to assist with repositioning the cast on a dental surveyor in a previously defined orientation

tri·pod·i·za·tion \trĭp′a-dī-zā′shun\ *n*: an occlusal scheme characterized by a cusp to fossa relationship in which there are three points of contact about the cusp and opposing fossa with no contact on the cusp tip

tris·mus *n* (ca. 1693): see MANDIBULAR T.

trismus appliance \trĭz′mus a-plī′ans\: a ancillary prosthesis that assists the patient in increasing the oral aperture width to eat and maintain oral hygiene—***syn*** DYNAMIC BITE OPENER, INTERARCH EXPANSION DEVICE, OCCLUSAL DEVICE FOR MANDIBULAR TRISMUS

tri-stimulus value \trī-stĭm′ya-lus văl′yōō\: (R, G, B: X, Y, Z, etc.) amounts of the three reference color stimuli, in a given trichromatic system, required to match the color of the stimulus considered

tri·ta·no·pia \trī-tă′nō-pē′a\ *n*: form of dichromatism in which reddish blue and greenish yellow stimuli are confused. Tritanopia is a common result of retinal disease but may be inherited—called also *blue blindness, hence tritanope*

try in: see TRIAL PLACEMENT

tube impression \tōōb, tyōōb ĭm-prĕsh′an\: **1:** a cylinder used as a tray to confine and direct impression material to make an impression of a single tooth **2:** the impression resulting from this procedure

tube teeth \tōōb tēth\ *obs*: artificial teeth with an internal, vertical, cylindrical aperture extending from the center of the base upward into the body of the tooth, into which a pin may be placed or cast for the attachment of the tooth to a fixed or removable denture base

tu·ber·cule \tōō-bûr′kyōōl\ *n* (1578): a small bony prominence or excrescence; a nodule

tu·ber·os·i·ty *n, pl* **-ties** (ca. 1611): see MAXILLARY T.

tunnel dissection \tŭn′ul\: a dissection of the periosteum from bone through a small incision, in a tunnel-like fashion

tur·gid \tûr′jĭd\ *adj* (1620): being on a state of distention; swollen

ty·po·dont \tī′pō-dĕnt\: a replica of the natural dentition and alveolar mucosa, set to average condylar motions, used in training students in dental care—*syn* TYPODENT

U

UCLA abutment *substand*: a colloquial term used to describe a dental crown that is attached directly to the implant body by means of a screw without an intervening abutment

ultimate strength \ŭl′ta-mĭt\: the greatest stress that may be induced in a material at the point of rupture—called also *ultimate tensile strength*

ul·tra·vi·o·let \ŭl′tra-vī′a-lĭt\: radiant energy of wavelengths shorter than extreme violet and lying beyond the ordinarily visible spectrum. Usually assigned to wavelengths shorter than 380 nm

[1]un·der·cut \ŭn′dur-kŭt\ *n* (1859): **1:** the portion of the surface of an object that is below the height of contour in relationship to the path of placement **2:** the

contour of a cross-sectional portion of a residual ridge or dental arch that prevents the insertion of a dental prosthesis **3:** any irregularity in the wall of a prepared tooth that prevents the withdrawal or seating of a wax pattern or casting

[2]un·der·cut \ŭn′dur-kŭt\ *v* (ca. 1598)**:** to create areas that provide mechanical retention for materials placement

uniform color space \yōō′na-fôrm kŭl′ar spās**:** color space in which equal distances are intended to represent threshold or above threshold perceived color differences of equal size

u·ni·lat·er·al \yōō′na-lăt′ur-al\ *adj* (1802)**:** relating to one side; one-sided

unilateral partial denture: see UNILATERAL REMOVABLE DENTAL PROSTHESIS

unilateral removable dental prosthesis \yōō′na-lăt′ur-al rĭ-mōōv′a-bal dĕn′tl prŏs-thē′sis**:** a removable dental prosthesis which restores lost or missing teeth on one side of the arch only

unilateral subperiosteal implant \yōō′na-lăt-ur-al sŭb-pĕr′ē-ŏs′tē-al ĭm-plănt′**:** an eposteal dental implant that provides abutments for support of a removable or fixed dental prosthesis in a partially edentulous arch

unstrained jaw relation \ŭn′rĭ-strānd′ jô rĭ-lā′shun\ *obs***: 1:** the relation of the mandible to the skull when a state of balanced tonus exists among all the muscles involved **2:** any jaw relation that is attained without undue or unnatural force and that causes no undue distortion of the tissues of the temporomandibular joints (GPT-4)

upper impression *slang***:** see MAXILLARY IMPRESSION

up·right \ŭp′rīt\ *adj***:** the movement of a tooth into an erect or normal position

V

vacuum casting \văk′yōō-um kăst′ĭng**:** the casting of a material (i.e., metal, plastic) in the presence of a partial vacuum

vacuum investing \văk′yōō-um ĭn-vĕst′ĭng**:** the process of investing a pattern within a partial vacuum

vacuum mixing \văk′yōō-um mĭks′ĭng**:** a method of mixing a material such as plaster of paris or casting investment below atmospheric pressure

val·ue \văl′yōō\ *n* (14c)**:** the quality by which a light color is distinguished from a dark color, the dimension of a color that denotes relative blackness or whiteness (grayness, brightness). Value is the only dimension of color that may exist alone—see MUNSELL VALUE

Munsell, AH. A color notation. Baltimore: Munsell Color Co., 1975:14-7.

van der Walls' bond [Johannes D. van der Walls, Dutch physicist] (ca 1926)**:** *eponym* for a bond that involves weak inter-atomic attractions such as variation in physical mass or location of electrical charge; e.g., molecular polarization, electrical dipoles and dispersion effects—hydrogen bridges—called also *secondary bond*

vascular pain \văs′kya-lur pān**:** a type of deep somatic pain of visceral origin that emanates from the afferent nerves that innervate blood vessels

ve·lum \vĕl′um\ *n* (1771)**:** a covering; a general term for a veil or veil like structure—see SOFT PALATE

veneer \va-nîr′\ *n* (1702)**: 1:** a thin sheet of material usually used as a finish **2:** a protective or ornamental facing **3:** a superficial or attractive display in multiple layers, frequently termed a *laminate veneer*

[1]vent *n***: 1:** a small auxiliary sprue to aid and improve casting procedures **2:** a small perforation placed in a cast restoration to facilitate complete cementation by minimizing hydraulic pressure

[2]vent *v***: venting** *ppr***: 1:** to place an auxiliary sprue **2:** to place a perforation

verti-centric \vûr′tē-sĕn′trĭk\ [Earl Pound, U.S. prosthodontist, 1901-1986]**:** a record used in complete removable dental prosthesis fabrication. It involves the simultaneous recording of the vertical dimension of occlusion with the jaws in centric relation

vertical axis: see VERTICAL AXIS OF THE MANDIBLE

vertical axis of the mandible \vûr′tĭ-kul ăk′sĭs ŭv tha măn′dĭ-bal**:** an imaginary line around which the mandible may rotate through the horizontal plane

vertical dimension \vûr′tĭ-kal dĭ-mĕn′shun**:** the distance between two selected anatomic or marked points (usually one on the tip of the nose and the other upon the chin), one on a fixed and one on a movable member—see OCCLUSAL V.D., REST V.D., V.D. OF SPEECH

vertical dimension decrease \vûr′tĭ-kal dĭ-mĕn′shun dĭ-krēs\ *obs***:** decreasing the vertical distance between the mandible and the maxillae by modifications of teeth, the positions of teeth or occlusion rims, or through alveolar or residual ridge resorption (GPT-1)

vertical dimension increase \vûr′tĭ-kal dĭ-mĕn′shun\ *obs***:** increasing the vertical distance between the mandible and the maxillae by modifications of teeth, the positions of teeth, or occlusion rims (GPT-1)—see OCCLUSAL VERTICAL DIMENSION

vertical dimension of occlusion: see OCCLUSAL VERTICAL DIMENSION

vertical dimension of rest position: see PHYSIOLOGIC REST POSITION

vertical dimension of speech \vûr′tĭ-kal dĭ-mĕn′shun ŭv spēch**:** that distance measured between two selected points when the occluding members are in their closest proximity during speech

vertical opening: see VERTICAL DIMENSION

vertical overlap \vûr′tĭ-kal ō′var-lăp**: 1:** the distance teeth lap over their antagonists as measured vertically; especially the distance the maxillary incisal edges extend below those of the mandibular teeth. It may also be used to describe the vertical relations of opposing cusps **2:** the vertical relationship of the incisal edges of the maxillary incisors to the mandibular incisors when the teeth are in maximum intercuspation

ves·ti·bule \vĕs′ta-byōōl\ *n* (ca. 1728)**: 1:** any of various bony cavities, especially when serving as or resembling an entrance to another **2:** the portion of the oral cavity that is bounded on the medial side by the teeth, gingiva, and alveolar ridge or the residual ridge, and on the lateral side by the lips and cheeks—see BUCCAL V., LABIAL V.

ves·tib·u·lo·plas·ty \vĕ-stĭb′ū-lō-plăs-tē\ *n***:** a surgical procedure designed to restore alveolar ridge height by lowering muscles attaching to the buccal, labial, and lingual aspects of the jaws

vibrating line \vī′brā-tĭng līn**:** an imaginary line across the posterior part of the palate marking the division between the movable and immovable tissues of the soft palate. This can be identified when the movable tissues are functioning

Vickers hardness number: (VHN) a measure of hardness obtained with a diamond pyramidal indenter with a square base and an angle of 136°. VHN is proportional to the ratio of the applied load to the area of the indentation. Devised in the 1920's by engi-

neers at Vickers, Ltd. in the United Kingdom

videofluoroscopy \vĭd′ē-ō′flōō′a-rŏs′ka-pē, flōō-rŏs′-\ *n*: dynamic x-rays recorded on videotape

viewing conditions \vyōō′ĭng kun-dĭsh′unz\: various conditions under which visual observation is made including the size of the stimulus, characteristics of the surrounding area, nature of the illuminant, angle of viewing, area of the retina, etc.

vinyl poly·siloxane \vī nal pŏl′ē sī-lŏks′ān′\ *n*: an addition reaction silicone elastomeric impression material of silicoen polymers having terminal vinyl groups that cross-link with silanes on activation by a platinum or palladium salt catalyst

Virginia bridge: see RESIN-BONDED PROSTHESIS

visceral pain \vĭs′ur-al pān\: deep somatic pain originating in visceral structures such as mucosal linings, walls of hollow viscera, parenchyma of organs, glands, dental pulps, and vascular structures

visible spectrum \vĭz′a-bal spĕk′trum\: the section of the electromagnetic spectrum that is visible to the human eye. It ranges from 380 nm to 760 nm

visual adaptation \vĭzh′ōō-al ăd′ăp-tā′shun\: adjustive change in visual sensitivity due to continued visual stimulation or lack of stimulation. Three recognized types are: 1) *scotopic* or dark adaptation 2) *photopic* or light adaptation 3) *chromatic* or color adaptation

visual photometry \vĭzh′ōō-al fō-tŏm′ĭ-trē\: the measurement of luminous radiation based on its effect on the visual receptors

vul·can·ite \vŭl′ka-nīt\ *n*: an obsolete denture base material that is a combination of caoutchouc and sulfur. These harden in the presence of suitable heat and application of pressure

vul·can·ize \vŭl′ka-nīz′\ *vb* **-nized**; **-niz·ing** *vt* (1846): to produce flexible or hard rubber, as desired, by subjecting caoutchouc, in the presence of sulfur, to heat and high steam pressure in a processing unit, termed a *vulcanizer*, made for that purpose

W

warp \wôrp\ *vt* (13c): torsional change of shape or outline; to turn or twist out of shape

wash impression *slang*: see FINAL IMPRESSION

wave length \wāv lĕngkth\: the distance at any instant between two adjacent crests (or identical phases) of two series of waves that are advancing through a uniform medium. The wavelength varies inversely with the vibration rate or number of waves passing any given point per unit period of time

wax \wăks\ *n* (bef. 12c): one of several esters of fatty acids with higher alcohols, usually monohydric alcohols. Dental waxes are combinations of various types of waxes compounded to provide desired physical properties—see BASEPLATE W., BOXING W., CASTING W., DENTAL IMPRESSION W., MODELING W

wax addition technique: the process used to develop a wax pattern through organized sequential addition of wax to shape the individual components of the desired anatomic form

wax elimination \wăks ĭ-lĭm′a-nā′shun\: the removal of wax from a mold, usually by heat

wax expansion \wăks ĭk-spăn′shun\: a method of expanding a wax pattern to compensate for the shrinkage of gold during the casting process

wax model denture: see TRIAL DENTURE

wax pattern \wăks păt′urn\: a wax form that is the positive likeness of an object to be fabricated

wax try in: see TRIAL PLACEMENT

wax·ing \wăks′ĭng\ *v obs*: the contouring of a wax pattern or the wax base of a trial denture into the desired form (GPT-1)

waxing up \wăks′ĭng ŭp\ *obs*: **1:** the contouring of a pattern in wax generally applied to the shaping in wax of the contours of a trial denture (GPT-1) **2:** the process of waxing and carving of the wax to the shape and contour desired (GPT-1)

wear facet \wâr făs′ĭt\: any wear line or plane on a tooth surface caused by attrition

Weber-Fergusson incision [Sir E.S. Fergusson, Scottish surgeon, dates vary: 1808-1877 or 1871-1944]: *eponym* for a facial incision used in exposing the maxillary bone in a maxillectomy procedure

Zange J. Operationen im Bereich der nase und ibver nebenholen. In: Theil R. Opthalmologische, Operationslehre. Leipzig: Vebthieme, 1950.

[1]weld \wĕld\ *n* (1831): a welded joint; the state or condition of being welded

[2]weld \wĕld\ *vb*: to unite or fuse two pieces by hammering, compression, or by rendering soft by heat with the addition of a fusible material

whit·ing \hwī′tĭng, wī′-\ *n*: pure white chalk (calcium carbonate) that has been ground and washed; it is used for polishing dental materials

wire splint \wīr splĭnt\: a device used to stabilize teeth in the maxillae or mandible loosened by an accident or by a compromised periodontium; a device to reduce and stabilize maxillary or mandibular fractures by application to both arches and connection with intermaxillary wires or elastic bands

Wolff's Law [Julius Wolff, German anatomist, 1836-1902]: *eponym* for the principle that a bone, either normal or abnormal, will develop the structure most suited to resist those forces acting on it

work \work\ *n* (bef. 12c): the product of a force acting on a body and the distance through which the point of application of the force moves

work authorization: a signed written order provided by the dentist to the dental laboratory detailing the work to be performed and specifying the materials to be used

working articulation \wûr′kĭng ăr-tĭk′ya-lā′shun\: the occlusal contacts of teeth on the side toward which the mandible is moved

working bite: see WORKING ARTICULATION

working bite relation: see WORKING ARTICULATION

working cast: —see FINAL CAST

working condyle: see WORKING SIDE CONDYLE

working contacts \wûr′kĭng kŏn′tăkts\ *obs*: contacts of teeth made on the side of the occlusion toward which the mandible has been moved (GPT-1)

working model: see CAST

working occlusal surface \wûr′kĭng a-klōō′zal sûr′făs\ *obs*: the surface or surfaces of teeth on which mastication can occur (GPT-1)

working occlusion \wûr′kĭng a-klōō′zhun\ *obs*: the occlusal contacts of teeth on the side to which the mandible is moved (GPT-1)

working side \wûr′kĭng sīd\: the side toward which the mandible moves in a lateral excursion

working side contacts \wûr′kĭng sīd kŏn′tăkts**:** contacts of teeth made on the side of the articulation toward which the mandible is moved during working movements

working side condyle \wûr′kĭng sīd kŏn′dīl**:** the condyle on the working side

working side condyle path \wûr′kĭng sīd kŏn′dīl păth**:** the path the condyle travels on the working side when the mandible moves in a lateral excursion

wrought \rôt\ *adj* (13c)**: 1:** worked into shape; formed **2:** worked into shape by tools; hammered

X

[1]X-ray \ĕks′rā\ *vt* (1896)**:** the process of exposing objects to roentgen rays and projecting their shadow on sensitized surfaces

[2]X-ray \ĕks′rā\ *n* (1900)**:** see ROENTGEN RAY

X-ray picture: see ROENTGENOGRAM

xenogenic graft \zĕn′a-jĕn′ĭk**:** a graft from one species to another species—called also *heterologous graft*

xer·o·stomia \zîr′a-stō′mē-a\ *n***:** dryness of the mouth from lack of normal secretions

Y

yield strength \yēld strĕngkth**:** the strength at which a small amount of permanent (plastic) strain occurs, usually 0.1% or 0.2%, and most frequently measured in MPa or psi

Young's modulus: [Thomas Young (1773-1829) English physician and physicist] *eponym* for the constant of proportionality expressed in the stress-strain plot as the slope in the elastic region where elastic recovery occurs upon release of the stress inducing the strain; usually given the symbol E. A higher modulus (GPa, psi) denotes a greater stiffness or material rigidity. *Also termed* MODULUS OF ELASTICITY

Z

zero-degree teeth \zĭr′ō-dĭ-grē′, zē′rō′-tēth**:** posterior denture teeth having 0-degree cuspal angles in relation to the plane established by the horizontal occlusal surface of the tooth—called also *zero-degree nonanatomic teeth*—see NONANATOMIC TEETH

zinc oxide eugenol cement: a cement or luting agent resulting from mixing zinc oxide with eugenol (oil of cloves), typically dispensed in the form of a powder and liquid or sometimes two pastes. ANSI/ADA Type I or Type II zinc oxide and eugenol cements are respectively designated for provisional or permanent cementation of restorations fabricated outside of the mouth—see EBA CEMENT

zinc phosphate cement: a cement or luting agent resulting from mixing zinc oxide (powder component) with phosphoric acid, water, aluminum phosphate and zinc phosphate (liquid component). Magnesium oxide is often used as the principal modifier

zinc polycarboxylate cement: a cement or luting agent resulting from mixing zinc oxide, magnesium oxide and sometimes stannous oxide (powder component) with an aqueous solution of polyacrylic acid and copolymers

zirconia ceramic post: a ceramic post used in the restoration of endodontically treated teeth, especially when a metal post may compromise esthetics. Typically used with composite resin or compression ceramics to form the core

zygoma \zī-gō′ma\ *n* (ca. 1684)**:** the area formed by the union of the zygomatic bone with the zygomatic processes of the temporal and maxillary bones

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