SIXTH EDITION

CONTEMPORARY FIXED PROSTHODONTICS

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ELSEVIER

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History Taking and Clinical Examination

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 while greatly enhancing esthetics (Fig. 1.1A and B). Treatment can range from fairly straightforward measures—such as restoration of a single tooth with a ceramic crown (see Fig. 1.1C), replacement of one or more missing teeth with a fixed dental prosthesis (see Fig. 1.1D), or an implant-supported restoration (see Fig. 1.1E)—to highly complex restorations involving all the teeth in an entire arch or the entire dentition (see Fig. 1.1F).

To achieve predictable success in this technically and intellectually challenging field, meticulous attention to every detail is crucial: the initial patient interview and diagnosis, the active treatment phases, and 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. The inexperienced dentist may plunge into the treatment phase before collecting sufficient diagnostic information that helps to predict likely pitfalls.

Making the correct diagnosis is prerequisite for formulating an appropriate treatment plan. All pertinent information must 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 is a review of the fundamentals of history taking and clinical examination, with special emphasis on obtaining the necessary information to make appropriate decisions about fixed prosthodontic treatment.

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 or only important problem. Therefore, when a comprehensive treatment plan is proposed, special attention must be given to how the chief complaint can be resolved. The inexperienced dentist who tries to prescribe an "ideal" treatment plan can easily lose sight of the patient's wishes. The patient may then become frustrated because the dentist does not appear to 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., pressure, hot, cold, or sweet things), any changes in its character, and whether it is localized or more diffuse in nature. It is often helpful for the patient to 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 mastication may result from a local problem such as a fractured cusp or missing teeth; they may also indicate a more generalized malocclusion or neuromuscular dysfunction.

Fig. 1.1 (A) Severely damaged maxillary dentition. (B) Restoration with metal-ceramic fixed prostheses. (C) Tooth supported zirconia three-unit fixed partial denture opposing implant-supported and tooth-supported zirconia crowns. (D) Three-unit fixed dental prosthesis that replaces missing mandibular premolar. (E) Congenitally missing maxillary lateral incisors replaced with implant supported crowns. (F) Extensive fixed prosthodontics involving restoration of multiple teeth. (D, Courtesy Dr. J. Nelson. E, Courtesy Dr. A. Hsieh.)

Social Aspects

A bad taste or smell often indicates compromised oral hygiene and periodontal disease. Social pressures prompt many affected patients 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. The teeth may be unattractively shaped, malpositioned, or discolored, or there may be a developmental defect. A single discolored tooth may indicate pulpal disease.

Personal Details

The patient's name, address, phone number, sex, occupation, work schedule, marital status, and budgetary flexibility 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 on which the patient can trust the dentist,

HEALTH QUESTIONNAIRE

REG. NO. ______________

Name ______________ Date ______________ Age ______________

Write Yes or No.

1. Have you been hospitalized or under the care of a physician within 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 or have been treated:

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.

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 medications the patient is taking and 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 such conditions are identified, treatment usually can be modified as part of the comprehensive treatment plan, although some conditions 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 affect the patient's response to dental treatment and may influence the prognosis. For instance, patients who have previously received radiation treatment in the area of a planned extraction require special measures to prevent serious complications.
3. Systemic conditions with oral manifestations. For example, periodontitis may be exacerbated by diabetes, menopause, pregnancy, or the use of anticonvulsant drugs (Fig. 1.4); in patients with gastroesophageal reflux disease, bulimia, or anorexia nervosa, teeth may be eroded by regurgitated stomach acid (Fig. 1.5)[1,2]; certain drugs may generate side effects that mimic temporomandibular disorders[3] or reduce salivary flow.[4,5]
4. Possible risks 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]

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 Dr. P.B. Robinson.)

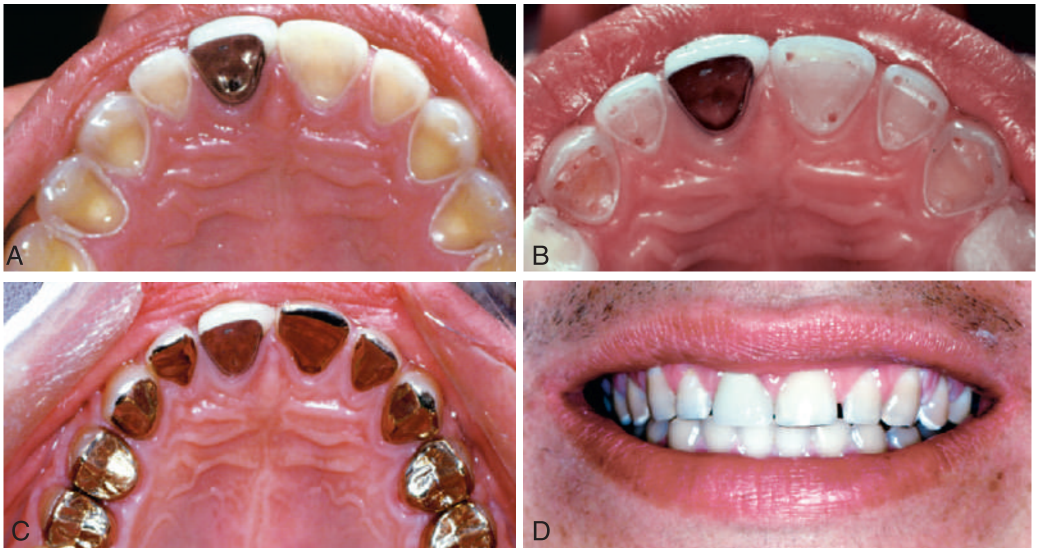


Fig. 1.5 (A) Extensive damage caused by self-induced acid regurgitation. Note that the lingual surfaces are bare of enamel except for a narrow band at the gingival margin. (B) Teeth prepared for partial-coverage restorations. (C and D) The completed restoration.

Dental History

Dentists should complete a thorough examination before establishing a diagnosis. With adequate experience, a dentist can often assess preliminary treatment needs during the initial appointment, but review and analysis of additional diagnostic information are frequently necessary (see Chapter 2). In addition, assessing the quality of a previously rendered treatment fairly 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 debridement 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 to 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).

Orthodontic History

Occlusal analysis should be an integral part of the assessment of dentition after orthodontic treatment. If restorative treatment needs are anticipated, the restorative dentist should perform the occlusal evaluation. Occlusal adjustment (reshaping of the occlusal surfaces of the teeth) may be needed to promote long-term positional stability of the teeth and to reduce or eliminate parafunctional activity (see Chapter 6). On occasion, root resorption (detected on radiographs) (Fig. 1.7) may be attributable to previous orthodontic treatment. Because this may affect the crown-to-root ratio, future prosthodontic treatment and its prognosis may also be affected. Restorative treatment can often be simplified by minor tooth movement. In 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 mention its existence. Careful questioning and examination usually elicit 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

The dentist must obtain information about missing teeth and any complications that may have occurred during tooth removal. 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 must be fully coordinated with the surgical component.

Radiographic History

Previously made radiographs may prove helpful in judging the progress of dental disease. They should be obtained if possible. 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.

Fig. 1.6 Defective endodontic treatment has led to recurrence of a periapical lesion. Re-treatment is required.

Fig. 1.7 Apical root resorption after orthodontic treatment.

Myofascial Pain and Temporomandibular Joint Dysfunction History

Myofascial pain, clicking in the temporomandibular joints (TMJs), or neuromuscular symptoms, such as abnormal muscle tone or tenderness to palpation, should be treated and resolved before fixed prosthodontic treatment begins. A screening questionnaire efficiently identifies patients with these symptoms who may be at higher risk for complications. Such patients should be questioned regarding any previous treatment for joint dysfunction (e.g., occlusal devices, medications, biofeedback, or physical therapy exercises).

EXAMINATION

In an examination, the dentist uses sight, touch, and hearing to detect abnormal conditions. 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 prospective patients who desire fixed prosthodontic treatment, and more detailed protocols 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, and vital signs, such as respiration, pulse, temperature, and blood pressure, are measured and recorded. Middle-aged and older patients can be at higher risk for cardiovascular disease. Relatively inexpensive cardiac monitoring units are available for in-office use (Fig. 1.8). Patients whose vital sign measurements are outside normal ranges should be referred for a comprehensive medical evaluation before definitive prosthodontic 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 dentist locates the TMJs by palpating bilaterally just anterior to the auricular tragi while the patient opens and closes the mouth. This enables a comparison between the relative timing of left and right condylar movements during the opening stroke. Asynchronous movement may indicate a disk displacement that prevents one of the condyles from making a normal translatory movement (see Chapter 4). Auricular palpation (Fig. 1.9) with

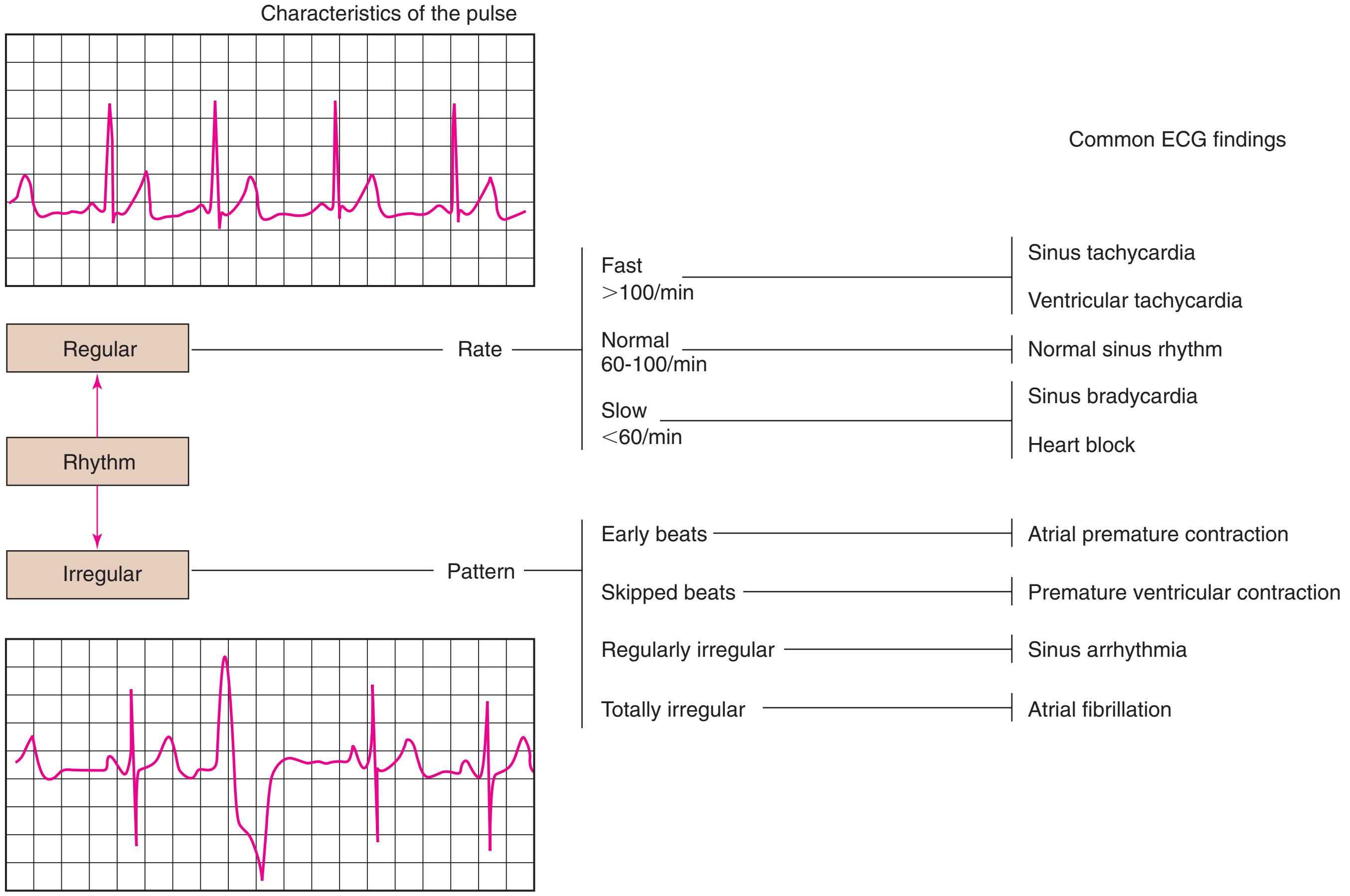


Fig. 1.8 Cardiac monitoring printout and representative electrocardiography findings. (Courtesy Dr. T. Quilitz.)

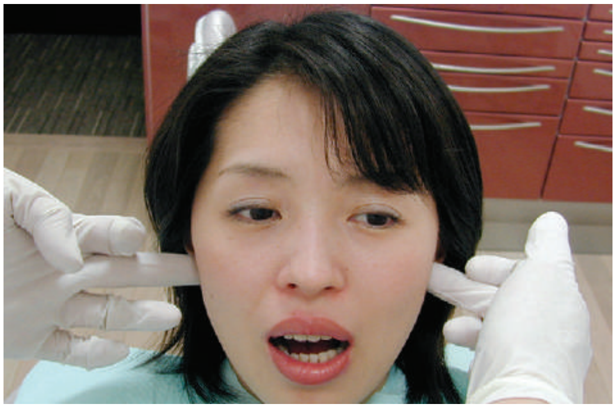


Fig. 1.9 Auricular palpation of the posterior aspects of the temporomandibular joints.

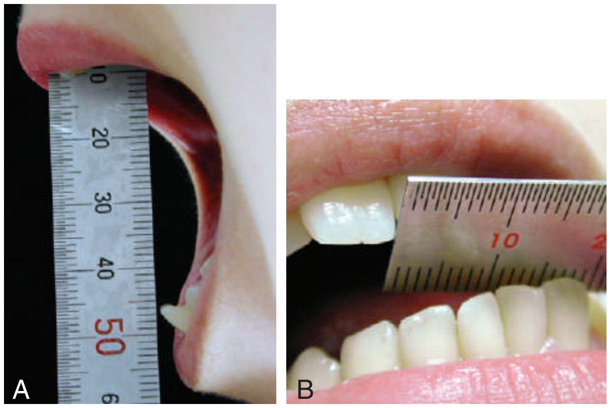


Fig. 1.10 Maximum opening of more than 50 mm (A) and lateral movement of approximately 12 mm (B) are normal.

light anterior pressure may help to 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 is difficult to detect by palpating directly over the lateral pole of the condylar process because the overlying tissues can muffle the click. Placing the fingertips on the angles of the patient's mandible permits identification of even a minimal click because very little soft tissue lies between the clinician's fingertips and the mandibular bone.

Joint abnormalities may also be identified by evaluating the patient's occlusal relationship in the fully seated condylar position (FSCP). This is done by hinging the patient's mandible with bimanual manipulation (see also Chapter 2), until the initial point of tooth contact, which is recorded. If in a growing child or adolescent a greater than 2-mm Angle class II relationship is observed and a 2-mm separation of the lower incisal edge is present (measured from where "normal" cingulum contact occurs), an internal derangement with disc dislocation (Piper IV—see Chapter 4) may be present on the deficient side. Although this is also true for adult patients, such may be more difficult to diagnose because adaptations may have occurred in the anterior region such as supraeruption of teeth. If the presence of any pathologies is suspected or uncertain, the following should be recorded: first molar and canine and Angle classification, open occlusal relationship, reverse articulation, magnitude, and direction of any midline deviations (see Chapter 4), and any gross arch discrepancies.

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 or closing is recorded. The maximum lateral movements of the patient can be measured (normal is approximately 12 mm) (Fig. 1.10).

Muscles of Mastication

Muscle palpation can provide helpful insight, although it provides information of only the status quo, at the time of examination. Following examination of the TMJs and the evaluation of range of motion, the masseter and temporal muscles and 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 that can be tolerated without discomfort on one's closed eyelid 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, the dentist should follow a systematic sequence for comprehensive muscle palpation as described by Solberg[9] and Krogh-Poulsen and Olsson.[11] Each palpation site is scored numerically on the basis of 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 the planning of fixed prosthodontic treatment,[12] especially when the need to fabricate crowns or fixed dental prostheses is anticipated in the esthetic zone. 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 (Fig. 1.13).[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 must be corrected (see Chapter 23).[15]

Screening for Sleep-Disordered Breathing

James E. Metz

Many signs and symptoms may be recognizable in dental patients.[16] The medical history may show presence of comorbid conditions such as hypertension or other cardiovascular disease, hyperlipidemia, or type 2 diabetes mellitus.[16–21] Dental and clinical examination may exhibit presence of a worn dentition;

Fig. 1.11 Muscle palpation of the masseter (A), the temporal muscle (B), the trapezius muscle (C), the sternocleidomastoid muscle (D), and the floor of the mouth (E).

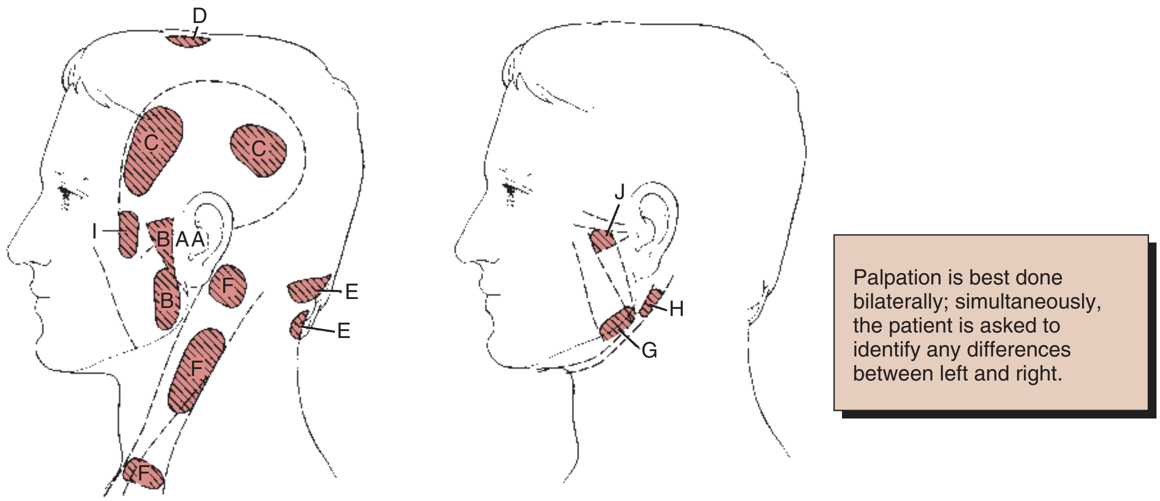


Fig. 1.12 Palpation sites for assessing muscle tenderness. *A*, Temporomandibular joint capsule: lateral and dorsal. *B*, Masseter: deep and superficial. *C*, Temporal muscle: anterior and posterior. *D*, Vertex. *E*, Neck: nape and base. *F*, Sternocleidomastoid muscle: insertion, body, and origin. *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*. 1966;10:627).

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. (C) This individual shows little tooth when smiling.

Fig. 1.14 The "negative space" between the maxillary and mandibular teeth is assessed during the examination.

missing teeth; tongue scalloping; enlarged palatine tonsils, tongue, or soft palate; and a high Mallampati or Friedman score.[16,22–28] Lateral cephalometric radiographs can also provide data indicative of an airway issue, including airway length; hyoid bone position; upper and lower face heights; and excessive soft tissues including tongue, velum, and lymphoid tissue.[29–31] Questionnaires can be used to screen dental patients for potential sleep-related breathing disorders (SRBDs). More than 100 surveys, questionnaires, and scales are available for use.[32] The STOP-Bang, Berlin Questionnaire, and Epworth Sleepiness Scale (ESS) can be useful to assess an individual's risk for sleep-disordered breathing in undiagnosed subjects, as well as to track improvement of symptoms through a course of treatment.[33–35]

These surveys should not be relied upon as the sole screening method; those with severe obstructive sleep apnea (up to 100 events per hour of sleep) may exhibit no daytime symptoms and score zero on the ESS.[36] Therefore it is critical to have an objective method for screening in combination with report of subject symptoms to discern which individuals warrant referral to a sleep medicine physician for definitive medical diagnosis. Dental professionals can use high-resolution pulse oximetry to screen for SRBDs. A wrist- and finger-worn device can be easily dispensed to the recall patient, eliminating wait time for an appointment in an overnight sleep laboratory. Such a device is inexpensive compared with a full-montage polysomnogram and can be run for multiple nights to rule out anomalous events. It can eliminate the "first night effect," by allowing for testing in the home sleep environment, and may overcome night-to-night variation in respiratory events.[37–44] High-resolution pulse oximetry data may indicate a high likelihood of an SRBD, and the findings are highly correlated to polysomnography, warranting referral for medical diagnosis and allowing for initiation of therapy.[45–47]

■ ■ ■

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

In a periodontal examination,[48] the clinician evaluates the status of bacterial accumulation, the response of the host tissues, and the degree of reversible and irreversible damage. Long-term periodontal health is prerequisite for successful fixed prosthodontics (see Chapter 5). Existing periodontal disease must be corrected before any definitive prosthodontic treatment is undertaken.

Gingiva

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

Healthy gingiva (Fig. 1.15A) is pink, stippled, and firmly bound to the underlying connective tissue. The free gingival margin is knife-edged, and sharply pointed papillae fill the interproximal spaces. Any deviation from these findings is noted. With the development of chronic marginal gingivitis (see Fig. 1.15B), the gingiva becomes enlarged and bulbous, stippling is lost, the margins and papillae are blunted, and bleeding and exudate are observed.

To assess the width of the band of attached keratinized gingiva around each tooth, the clinician measures the width of the surface band of keratinized tissue in an apicocoronal dimension with a periodontal probe and subtracts the measurement of the sulcus depth. Alternatively, the marginal gingiva can be gently depressed with the side of a periodontal probe or explorer.

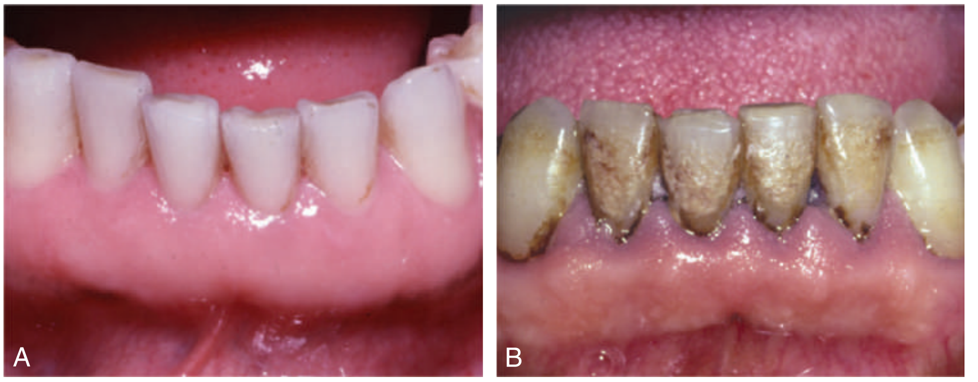


Fig. 1.15 (A) Healthy gingiva is pink, knife-edged, and firmly attached. (B) In gingivitis, plaque and calculus cause marginal inflammation, with changes in color, contour, and consistency of the free gingival margin. In this case, inflammation extends into the keratinized attached gingiva.

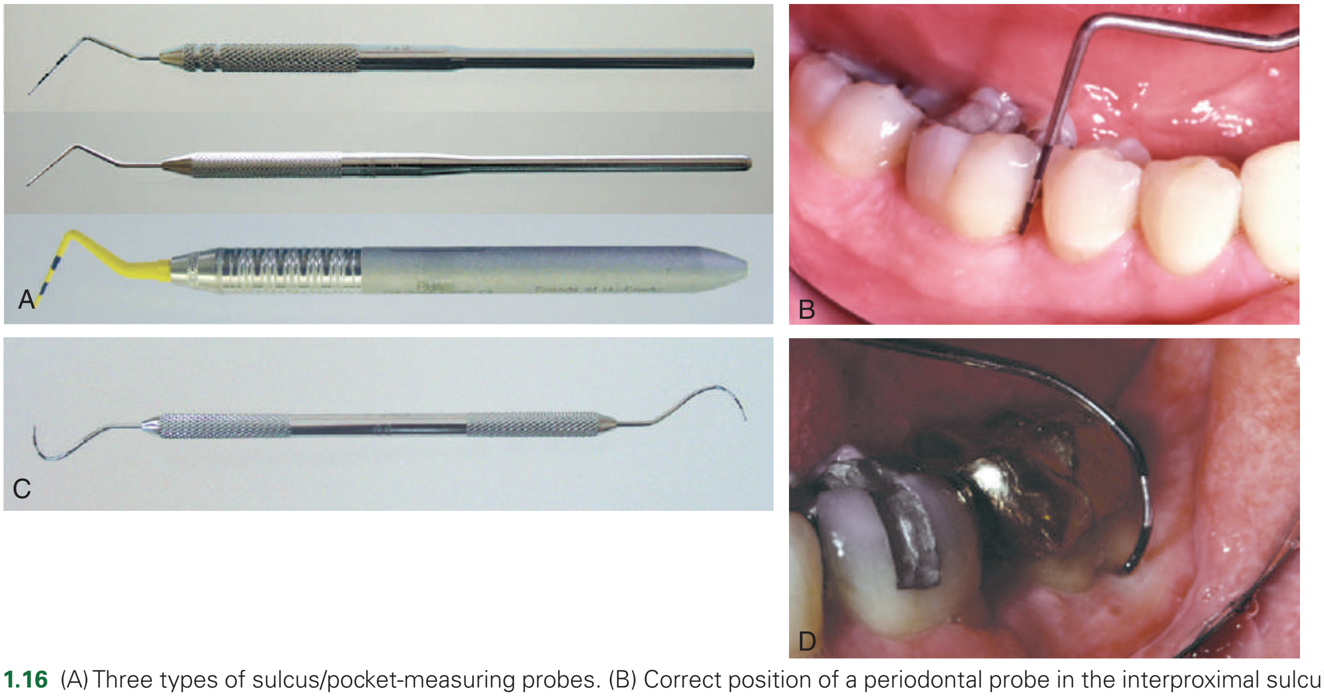


Fig. 1.16 (A) Three types of sulcus/pocket-measuring probes. (B) Correct position of a periodontal probe in the interproximal sulcular area, parallel to the root surface and in a vertical direction as far interproximally as possible. (C and D) Graduated furcation probe. (A and C, From Boyd LB. *Dental Instruments*. 5th ed. St. Louis: Saunders; 2015.)

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. A third technique is to inject anesthetic solution into the nonkeratinized mucosa close to the MGJ to make the mucosa balloon slightly.

Periodontium

The periodontal probe (Fig. 1.16A) provides a measurement (in millimeters) of the depth of periodontal pockets and healthy gingival sulci. 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 (see Fig. 1.16B). Thus any sudden change in the attachment level can be detected. The probe may also be angled slightly (5 to 10 degrees) interproximally 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 such as tooth mobility or malposition, open proximal 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 epithelial attachment helps the clinician to quantify periodontal destruction and is essential for rendering a diagnosis of periodontitis (loss of connective tissue attachment).[49,50] This measurement also provides objective information

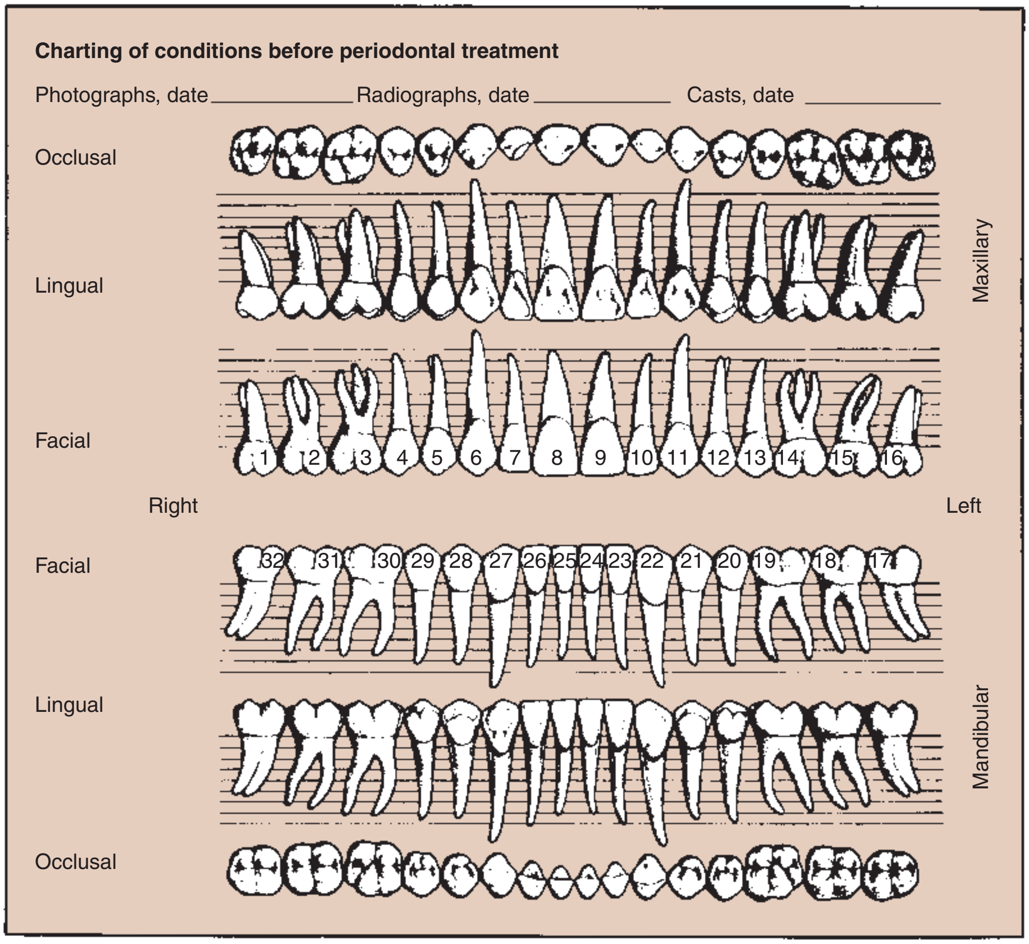


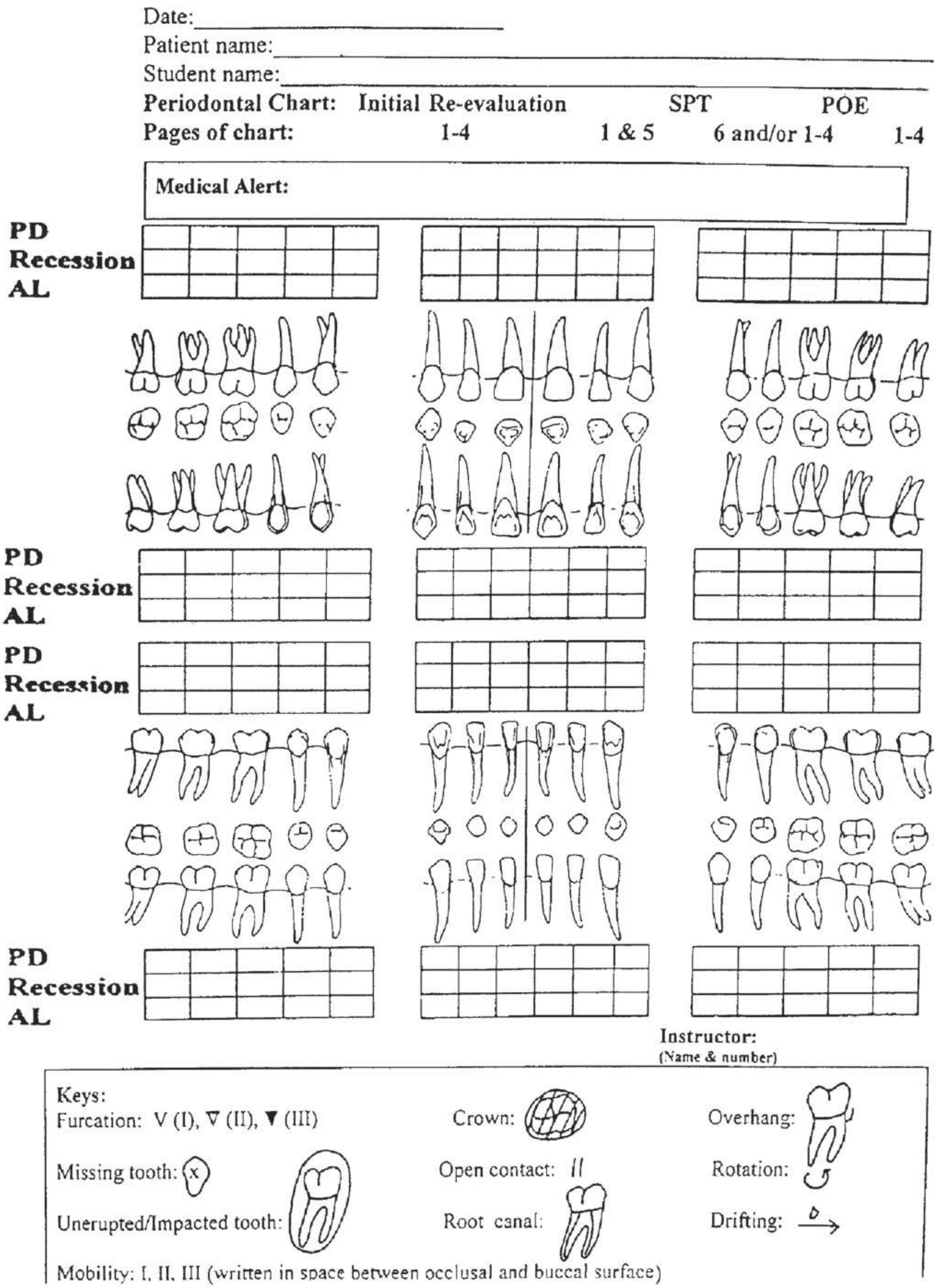
Fig. 1.17 Chart for recording pocket depths. The parallel lines are approximately 2 mm apart. The notations involved in using the chart are as follows: *1*, Block out any missing teeth. *2*, Draw a red × through the crown of any tooth that is to be extracted. *3*, Record the gingival level with a continuous *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 × 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.)

regarding the prognosis of individual teeth. 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 or the cementoenamel junction (CEJ). This is recorded on modified periodontal charts (Fig. 1.18). 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 attachment loss, and recession is noted as a negative number. When the attachment level is on root structure and the free gingival margin is at the CEJ, attachment loss equals the probing depth, and the recession is scored 0. When increased periodontal destruction and recession are present, attachment loss equals the probing depth plus the measurement of recession (see Fig. 1.18B and C).[51] Clinical attachment loss is a measure of periodontal destruction at a site, rather than of current disease activity; it may be considered the diagnostic standard for periodontitis[52] and should be documented in the initial periodontal examination.[53] It is an important consideration in the development of the overall diagnosis, treatment plan, and the prognosis of the dentition.

■ ■ ■

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) shows the presence or absence of teeth, dental caries, restorations, wear faceting and abrasions, fractures, malformations, and erosions. Tooth loss often affects the position of adjacent teeth (see Treatment of Tooth Loss section, Chapter 3). The presence of caries on one interproximal surface should prompt the examiner to carefully inspect the adjacent proximal surface, 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



A

Fig. 1.18 (A) Modified periodontal chart.

B C

Fig. 1.18 Cont'd (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 University of Detroit Mercy School of Dentistry, Department of Periodontology and Dental Hygiene, Detroit.)

are noted (e.g., amalgam, cast gold, composite resin, 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). However, wear facets are often easier to see on diagnostic casts (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 31). The location of fractures and any other abnormalities should be recorded.

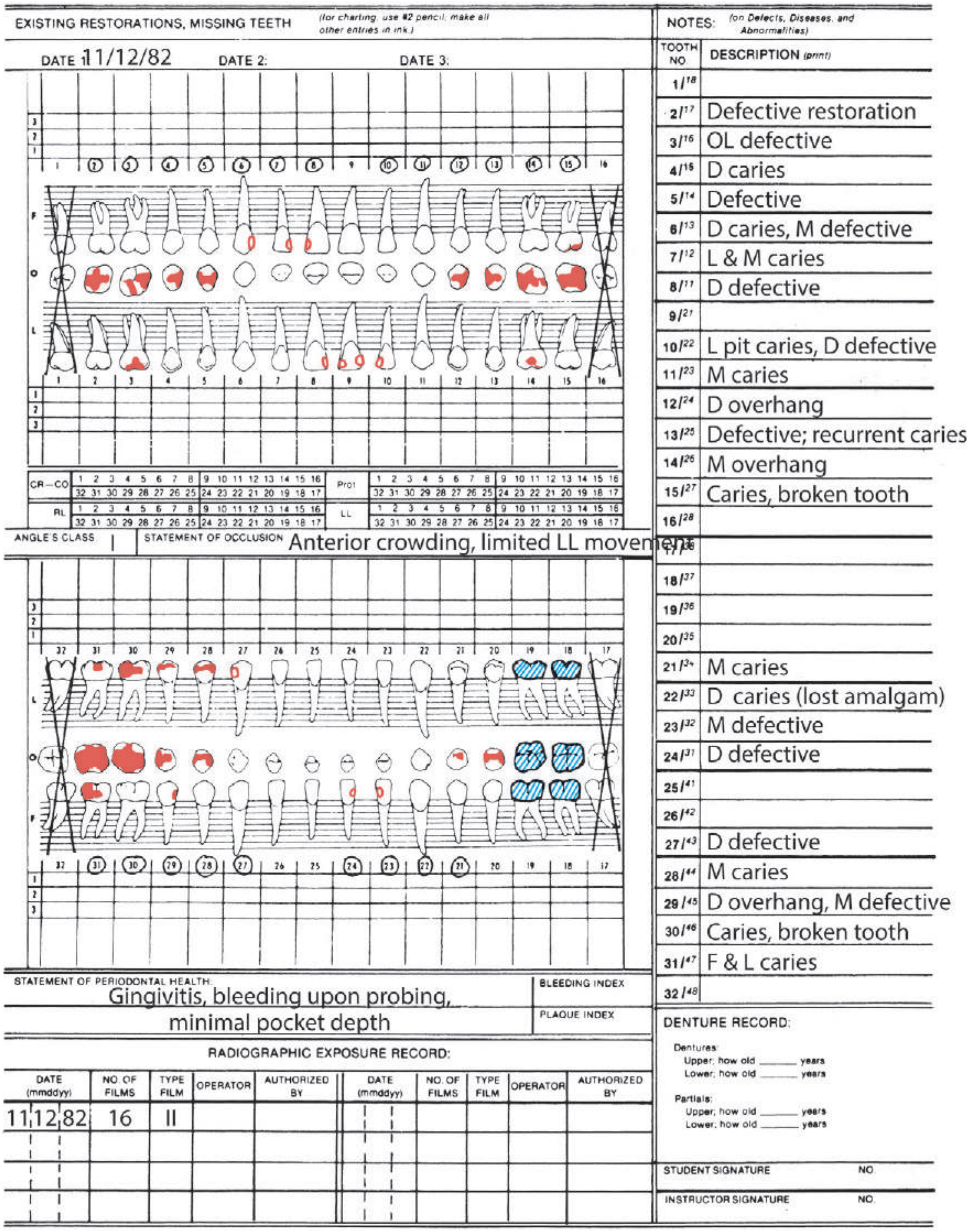
Occlusal Examination

The dentist starts the occlusal examination by asking the patient to make a few simple opening and closing movements, which the dentist carefully observes. 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 any difference that may exist. Special attention is given to initial contact, tooth alignment, eccentric occlusal contacts, and jaw maneuverability.

Initial tooth contact. The relationship of teeth in both centric relation (CR) (see Chapter 4) and the maximum intercuspation (MI) should be evaluated. If all teeth come together simultaneously at the end of terminal hinge closure, the CR position of the patient is said to coincide with the MI (see also Chapters 2 and 4). The patient is guided into a terminal hinge closure to detect where initial tooth contact occurs (see also the sections on bimanual manipulation and terminal hinge closure in Chapters 2 and 4). The dentist 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 length 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: for example, abnormal muscle tone previously observed during the extraoral examination, mobility (noted during the periodontal evaluation) on the teeth where initial contact occurs, and any wear facets on the teeth contacting during the slide.

General alignment. Any crowding, rotation, supraeruption, spacing, malocclusion, and vertical and horizontal overlap (Fig. 1.20) are recorded. In many cases, teeth adjacent to edentulous spaces have shifted slightly. Even minor tooth movement can significantly affect fixed prosthodontic treatment. Tipped teeth affect tooth preparation design or may necessitate minor tooth movement before restorative treatment. Supraerupted teeth are easily overlooked clinically but frequently complicate fixed dental prosthesis design and fabrication.

The relative relationship of adjacent teeth to planned fixed prostheses is important. A tooth may have drifted into the space previously occupied by the tooth in need of treatment because a large filling was lost for some time. Such changes in alignment can seriously complicate or preclude fabrication of a cast restoration for the damaged tooth and may even necessitate its extraction (see Fig. 1.20B).



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 patient's permanent record.

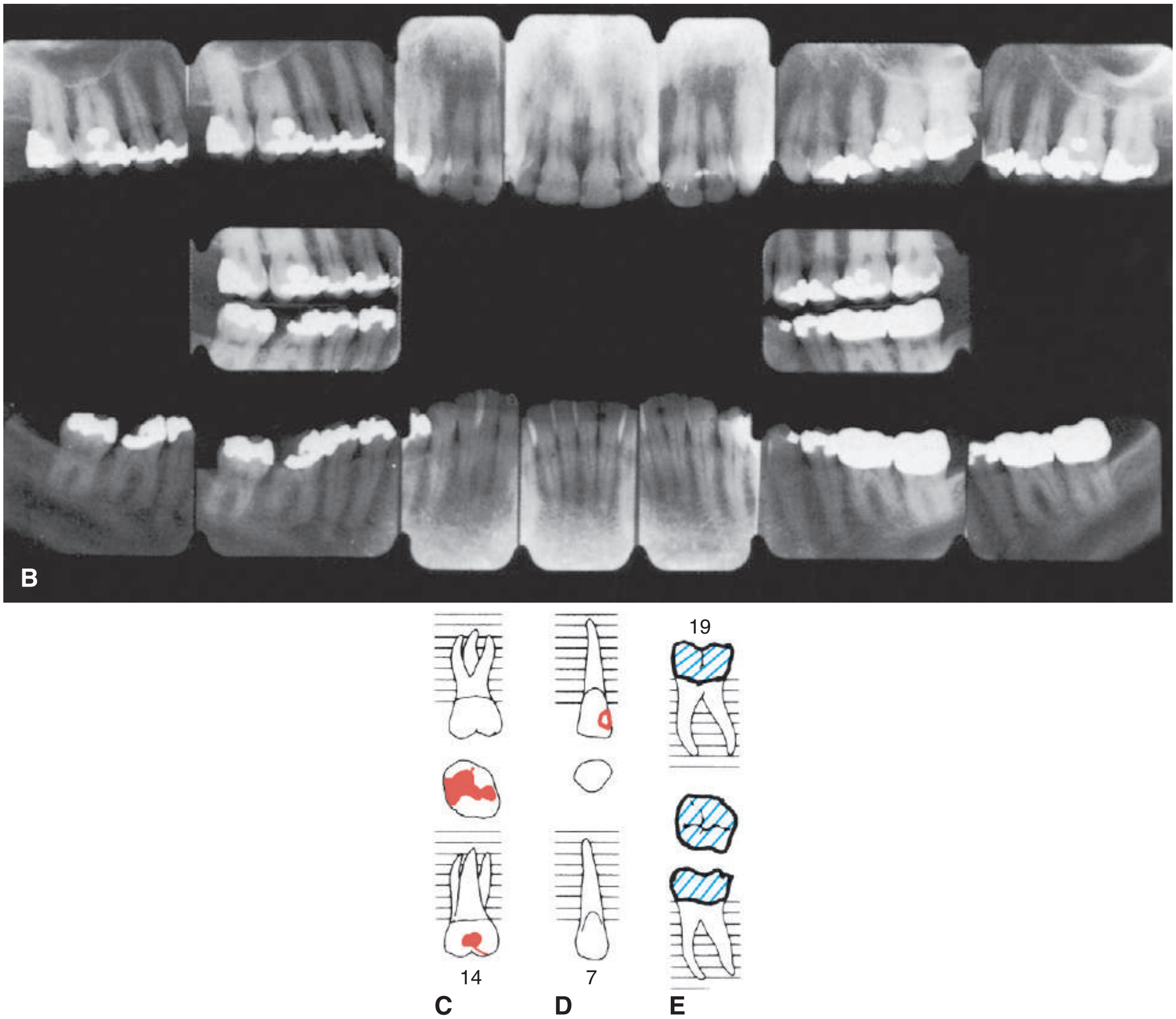


Fig. 1.19 Cont'd (B) Radiographic findings obtained from a full-mouth series are compared with the clinical findings and noted in the record. Charting is performed to provide a quick reference to conditions in the mouth. The following may be useful: (1) Amalgam restorations (C) are depicted by an outline 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 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.)

Lateral and Protrusive Contacts

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

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 subjected to excessive loading may develop varying degrees of mobility. Tooth movement (fremitus) should be confirmed by palpation (Fig. 1.22). If excessive occlusal 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.

Fig. 1.20 Alignment of the dentition can be assessed intraorally, although diagnostic casts allow a more detailed assessment. (A) This set of teeth is free of caries and in good alignment. (B) Poor vertical alignment: the mandibular molar is supraerupted, which has resulted in marginal ridge height discrepancy.

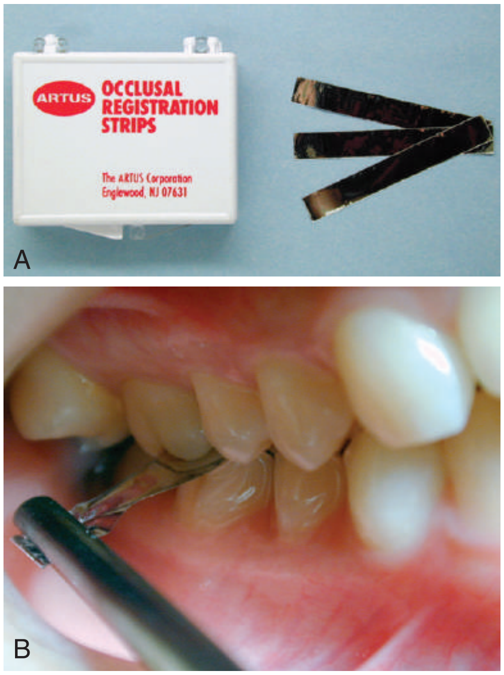


Fig. 1.21 Thin mylar shim stock (A) can be used to test eccentric tooth contact (B).

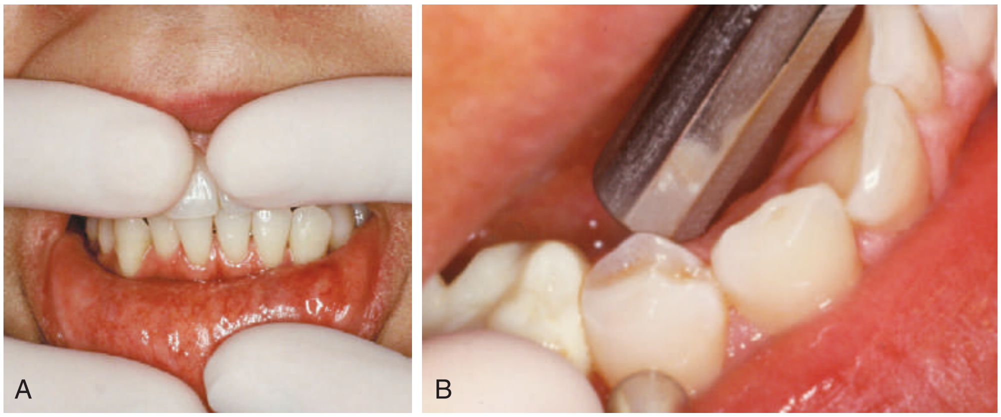


Fig. 1.22 (A) Fremitus (movement on palpation) indicates tooth contact during lateral excursions. (B) Mobility is tested by exerting horizontal force on the tooth between the handles of two instruments.

Jaw Maneuverability

The ease with which the patient moves the jaw and the way the mandible can be guided through hinge closure and excursive movements should be evaluated because this information is useful for assessing neuromuscular and masticatory function. If the patient has developed a pattern of protective reflexes, manipulating the jaw in a reproducible hinge movement can be difficult or impossible. Any restriction in maneuverability is recorded. A patient may move relatively freely in one lateral excursion but have difficulty moving to the contralateral side. Such limitation in maneuverability should be considered in the context of comprehensive occlusal and neuromuscular analysis (see Chapters 4 and 6).

Radiographic Examination

Digital 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 critical for establishing a comprehensive fixed prosthodontic treatment plan. According to radiation exposure guidelines, the number of radiographs should be limited to only those that will result in potential changes in treatment decisions; however, a full periapical series (Fig. 1.23) is normally required for new patients so that a comprehensive fixed prosthodontic treatment plan can be developed.

Panoramic films (Fig. 1.24) provide useful information about the presence or absence of teeth. They are especially

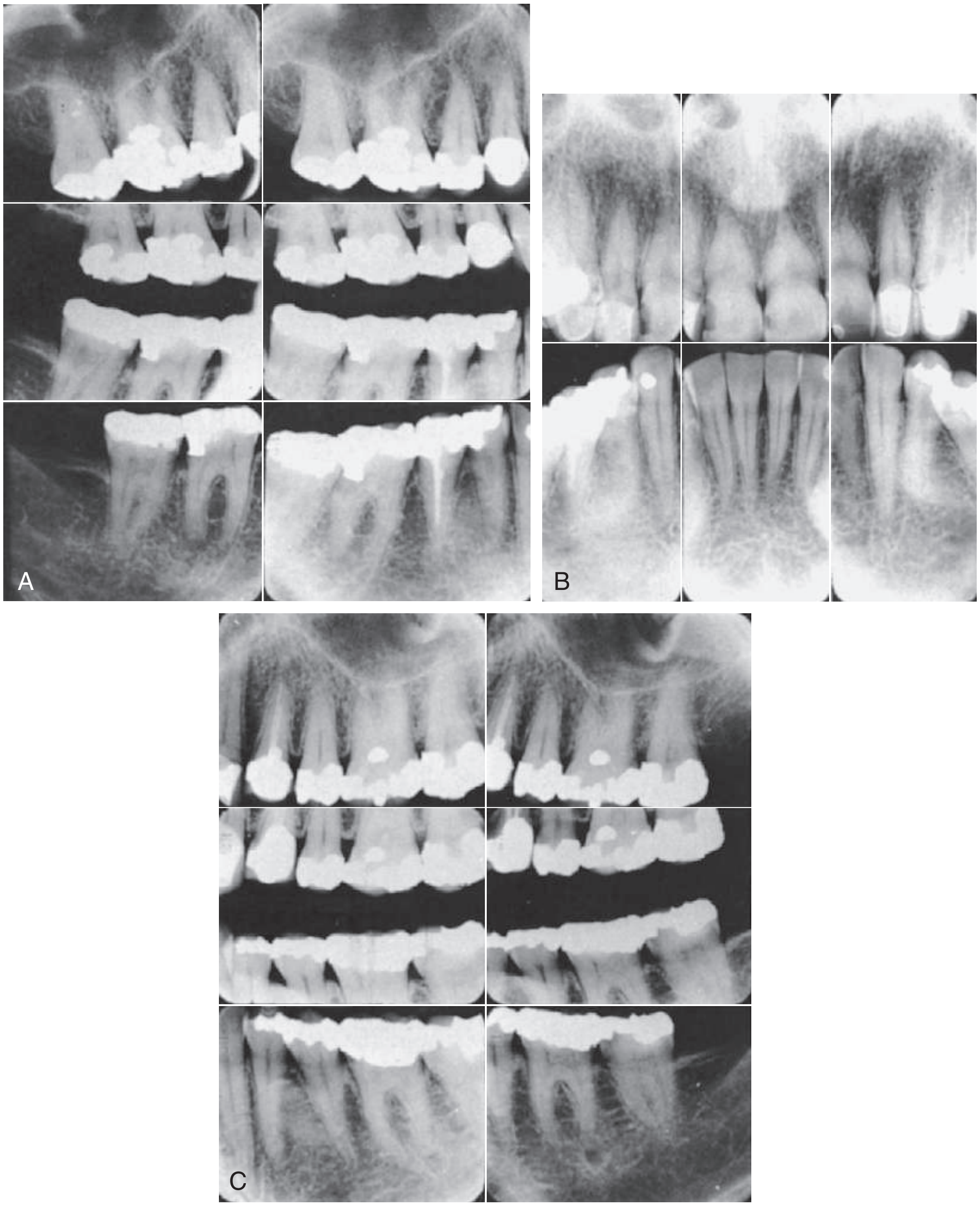


Fig. 1.23 (A–C) A full-mouth radiographic survey should enable the dentist to make a detailed assessment of the structure of each tooth and its bone support.

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.

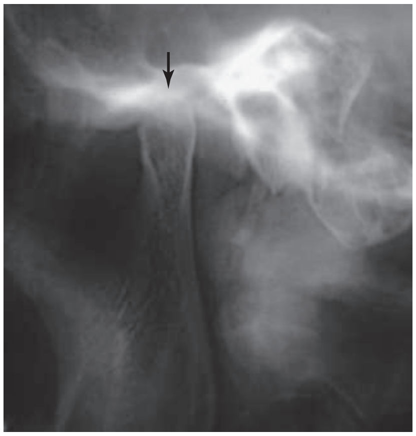


Fig. 1.25 A transcranial radiograph shows the lateral pole of the mandibular condyle *(arrow)*.

helpful in assessing third molars and impactions, screening the vertical amount of bone before making a cone-beam computed tomography (CBCT) scan for implant placement (see Chapter 13), and evaluating edentulous arches for buried root tips. However, they do not provide a detailed view sufficient 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 pathologic conditions ranging from bone and mineral disorders to metabolic disorders, genetic abnormalities, and soft tissue calcifications, such as carotid artery calcification.[53] 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 some structural and positional changes. However, interpretation may be difficult,[54] and more information may be obtained from other images (Fig. 1.26).[55] Cone-beam imaging is considered prerequisite to most dental implant placements. In this form of imaging, osseous contours and bone volume are visualized, which improves decision making about the size of implant fixtures that realistically can be accommodated (Fig. 1.27).

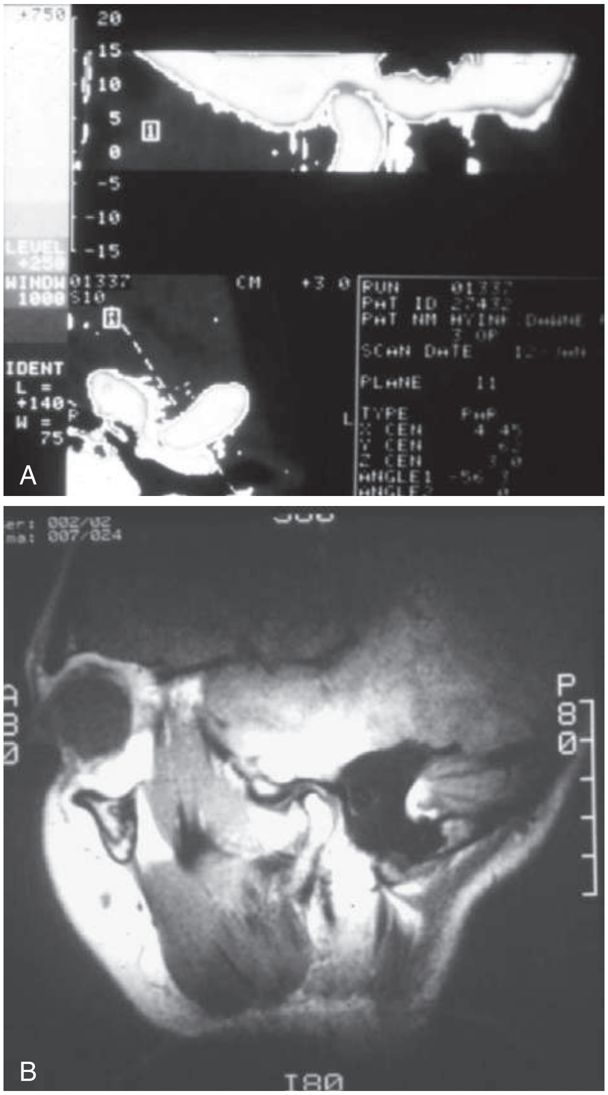


Fig. 1.26 More sophisticated techniques enable the generation of computer-assisted images of clinician-determined cross-sections. (A) A computed tomographic (CT) scan. (B) A magnetic resonance image showing the soft tissue in greater detail. (Courtesy Dr. J. Petrie.)

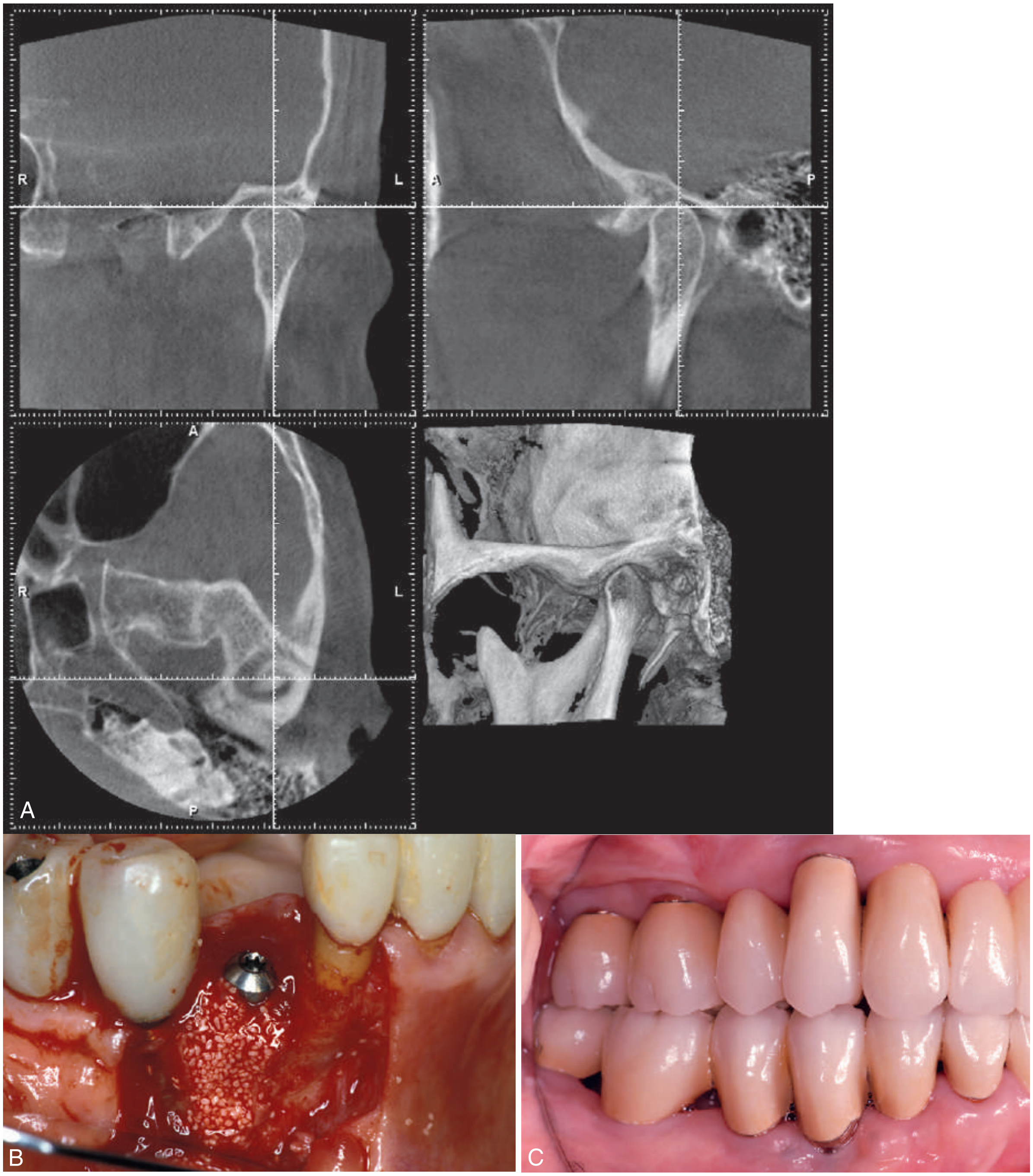


Fig. 1.27 (A) Cone beam technology is useful for definitive evaluation of pathologic conditions of the temporomandibular joint because it enables viewing of any desired cross section. (B) Ridge augmentation surgery. (C) Completed restoration.

Vitality Testing

Before any restorative treatment is begun, pulpal health must be confirmed, usually by assessing the response to thermal stimulation. However, in vitality tests, only the afferent nerve supply is assessed. 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 of symptoms of occlusal dysfunction. Treatment may be needed to eliminate obvious potential sources of the complaint, such as dental caries or a fractured tooth. A logical and systematic approach to diagnosis helps to avoid mistakes.

Differential Diagnosis

When the history and examination are complete, a differential diagnosis is made. The most likely causes of the observed conditions are identified and recorded 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 man, 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 in four posterior quadrants, with recession noted on teeth #23, #24, and #25; 5-mm pockets on teeth #18, #30, and #31. Radiographic evidence of periradicular 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 probably has existed longer than the symptoms that caused the patient 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 setting: In the moist oral environment, the teeth are subject to constant changes in temperature and acidity and to considerable load fluctuation. A comprehensive clinical examination helps to establish 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. Analysis of systemic problems in the context of the patient's age and overall health provides important information. For example, the incidence of periodontal disease is higher in diabetic patients than in the general population, and special precautionary measures may be indicated in those patients before treatment begins. Such conditions also affect the overall prognosis.

Some patients are capable of exerting an extremely high occlusal force (see Fig. 7.45), whereas others are not. If muscle tone of hypertrophied elevator muscles is identified as abnormal 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 patient who fatigues 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. Minimal vertical overlap is generally less favorable because higher load on posterior teeth results (see Chapter 4). 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 patient, in whom additional growth can be anticipated, but may be of lesser concern in an older patient.

Individual tooth mobility, root angulation, root structure, crown-to-root ratios, and many other variables all have an effect on the overall prognosis for fixed prosthodontic devices. They are addressed later in this book (see also Chapter 3).

Prosthodontic Diagnostic Index for Partially Edentulous and Completely Dentate Patients

The American College of Prosthodontists (ACP) has developed diagnostic indices for partial edentulism[56] and for completely dentate patients[57] 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 to 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 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 partially edentulous patients):

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

For completely dentate patients, 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 conditions is present:

- 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 tooth is missing.

The substantially compromised edentulous area includes the following conditions:

- 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 the following condition:

- 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)

In cases of ideal or minimally compromised abutment teeth,

- No preprosthetic therapy is indicated.

In cases of moderately compromised abutment teeth,

- Tooth structure is insufficient to retain or support intracoronal restorations, in one or two sextants.
- Localized adjunctive therapy (i.e., periodontal, endodontic, or orthodontic procedures, in one or two sextants) is required for abutments.

In cases of substantially compromised abutment teeth,

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

In cases of severely compromised abutment teeth,

- Abutments have a guarded prognosis.

Occlusal Scheme

Ideal or minimally compromised occlusal schemes are characterized by the following conditions:

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

Moderately compromised occlusal schemes are characterized by the following conditions:

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

Substantially compromised occlusal schemes are characterized by the following conditions:

- Necessity for reestablishment of entire occlusal scheme but without any change in the occlusal vertical dimension
- Class II molar and jaw relationships

Severely compromised occlusal schemes are characterized by the following conditions:

- Necessity for reestablishment of entire occlusal scheme, with changes in the occlusal vertical dimension
- Class II, division 2, and class III molar and jaw relationships

Residual Ridge

The Classification System for Complete Edentulism[58] is used to categorize any edentulous span present in a partially edentulous patient. The residual ridge can be classified by the method devised by Seibert (see Chapter 3).

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. 1.28 and 1.29) is characterized by ideal or minimal compromise in the location and extent of an 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 structure conforms to the class I complete edentulism description.

Class II

This class (Figs. 1.30 and 1.31) is characterized by moderately compromised location and extent of edentulous areas in both

Fig. 1.28 Class I. 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 movement. (H) Left lateral view, left working movement. (I) Full-mouth radiographic series. (From McGarry TJ, Nimmo A, Skiba JF, et al: Classification system for partial edentulism, *J Prosthodont*. 2002;11:181.)

arches, abutment conditions that necessitate localized adjunctive therapy, occlusal characteristics that necessitate 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 necessitate localized adjunctive therapy.

Fig. 1.29 Class I. This patient is categorized as class I because an ideal or minimally compromising tooth condition and occlusal scheme are 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, Nimmo A, Skiba JF, et al: Classification system for the completely dentate patient, *J Prosthodont*. 2004;13:73.)

3. Occlusion is moderately compromised:
   - Occlusal correction necessitates localized adjunctive therapy.
   - Maxillomandibular relationship is characterized as class I molar and jaw relationships.
4. Residual ridge structure conforms to the class II description of complete edentulism.

Class III

This class (Figs. 1.32 and 1.33) is characterized by substantially compromised location and extent of edentulous areas in both arches, abutment condition that necessitates substantial localized adjunctive therapy, occlusal characteristics that necessitate reestablishment 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.
   - 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 necessitate more substantial localized adjunctive therapy (i.e., periodontal, endodontic, or orthodontic procedures).
   - Abutments have a fair prognosis.
3. Occlusion is substantially compromised:
   - The entire occlusal scheme must be reestablished without an accompanying change in the occlusal vertical dimension.
   - Maxillomandibular relationship is characterized as class II molar and jaw relationships.
4. Residual ridge structure conforms to the class III complete edentulism description.

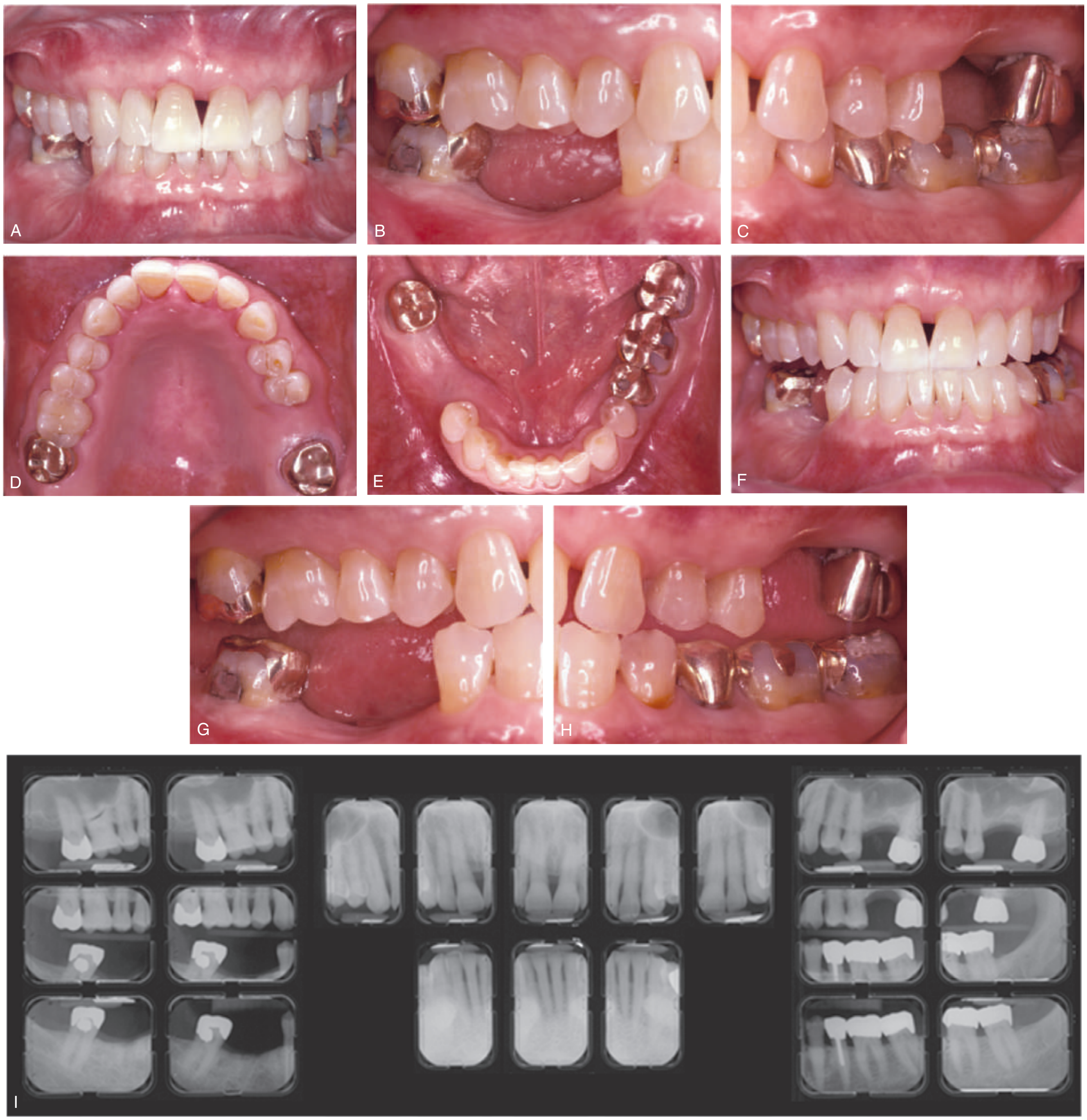


Fig. 1.30 Class II. This patient is categorized as class II because edentulous areas are present in two sextants in different arches. (A) Frontal view, maximum intercuspation. (B) Right lateral view, maximum intercuspation. (C) Left lateral view, maximum intercuspation. (D) Occlusal view, maxillary arch. (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, Nimmo A, Skiba JF, et al. Classification system for partial edentulism. *J Prosthodont.* 2002;11:181.)

Fig. 1.31 Class II. This 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, Nimmo A, Skiba JF, et al. Classification system for the completely dentate patient. *J Prosthodont*, 2004;13:73.)

Fig. 1.32 Class III. 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, Nimmo A, Skiba JF, et al. Classification system for partial edentulism, *J Prosthodont*. 2002;11:181.)

Fig. 1.33 Class III. This patient is categorized as class III because large defective amalgam and composite resin restorations are present in four sextants. The remaining tooth structure is substantially compromised in most posterior teeth. The occlusion is substantially compromised, which necessitates 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, Nimmo A, Skiba JF, et al. Classification system for the completely dentate patient, *J Prosthodont.* 2004;13:73.)

Class IV

This class (Figs. 1.34 and 1.35) is characterized by severely compromised location and extent of edentulous areas with guarded prognosis, abutment conditions that necessitate extensive therapy, occlusion characteristics that necessitate 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 be present 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.
   - Abutment conditions in four or more sextants necessitate 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 is characterized as 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 or ataxia, and refractoriness (a patient's presenting with chronic complaints after appropriate therapy).

Guidelines for the Use of Prosthodontic Diagnostic Index Classification System for Partial Edentulism and Complete Dentition

The analysis of diagnostic factors is facilitated with the use of a worksheet (Fig. 1.36 and Table 1.1). Each criterion is evaluated, and a checkmark is placed in the appropriate box. In instances in which a patient's diagnostic criteria overlap two or more classes, the more complex class is the selected diagnosis.

Fig. 1.34 Class IV. This patient is categorized as class IV because 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, which necessitate extracoronal restorations and adjunctive therapy. The occlusion is severely compromised, which necessitates 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, Nimmo A, Skiba JF, et al. Classification system for partial edentulism, *J Prosthodont.* 2002;11:181.)

Fig. 1.35 Class IV. This 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, which necessitates reestablishment of 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, Nimmo A, Skiba JF, et al. Classification system for the completely dentate patient, *J Prosthodont*. 2004;13:73.)

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 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 cases of class I and class II dentition.
4. The presence of symptoms of temporomandibular disorder raises the classification by one or more levels in patients with class I and class II dentition.
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 is the case of 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.

Description	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: more than three teeth				
Severely compromised: guarded prognosis				
Congenital or acquired maxillofacial defect				
Abutment Condition				
Ideal or minimally compromised				
Moderately compromised: one to two sextants				
Substantially compromised: three sextants				
Severely compromised: four 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				

Fig. 1.36 Worksheet used to determine prosthodontic diagnostic index classification. 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 1.1 Worksheet Used to Determine Prosthodontic Diagnostic Index Classification of Completely Dentate Patients

Description	Class I	Class II	Class III	Class IV
Teeth Condition				
Ideal or minimally compromised: three or fewer teeth in one sextant	X			
Moderately compromised: one or more teeth in one to two sextants		X		
Substantially compromised: one or more teeth in three to five sextants			X	
Severely compromised: four 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 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 this worksheet:
1. Consideration of future treatment procedures must not influence the diagnostic level.
2. Initial preprosthetic treatment 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 temporomandibular joint 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. Situations that fail to conform to the definition of completely dentate should be classified according to the classification system for partial edentulism.

OVD, Occlusal vertical dimension.

The classification system for partial edentulism is based on the most objective criteria available to facilitate uniform use of the system. Such standardization may help to improve 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 treatment, this partial edentulism classification system, coupled with the complete edentulism classification system, helps dental school faculty to 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.

SUMMARY

A comprehensive history and a thorough clinical examination 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. In addition, the overall outcome and prognosis may be adversely affected. In particular, it is crucial to develop a thorough understanding of each patient's special concerns relating to previous care and his or her 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 causes. The patient's overall prognosis is influenced by general and local factors.

STUDY QUESTIONS

1. Discuss the importance of the chief complaint and its management during examination and presentation of the treatment plan.
2. What is the classification of conditions observed as part of the medical history?
3. Describe the various areas included in the documentation of a comprehensive dental history.
4. What systemic conditions may cause oral manifestations that can affect a plan for fixed prosthodontic treatment?

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 in the evaluation for fixed prosthodontic treatment?
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.

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2

Diagnostic Procedures

At data collections appointments, the care provider is a scientist. As the scientist, the main goal is to collect all information relevant to the needs of the patient so that individualized treatment plan options can be offered. This chapter provides a resource of information that can be considered for collection to address specific patient needs. Instructions and armamentarium for clinical photography are given, and the analysis of the data within the clinical photographs and correlation with dentofacial analysis and diagnostic casts is discussed. Methods to record centric relation (CR) and its relevance in digital and traditional fixed prosthodontics are detailed. Excellent patient communication is based on the collection, processing, and presentation of the correct data relevant to the needs of the individual patient. Digital smile designs and diagnostic templates are helpful aids in patient communication so that patients better understand the dentists' scientific endeavors.

CLINICAL PHOTOGRAPHY

Dental photography has many uses in fixed prosthodontics. First, photographs record the patient's initial presentation to aid in the diagnostic process, communicate needs to other specialists, and to help communicate to the patient the clinical findings and the objectives of their treatment. Second, photographs are used throughout treatment to record critical steps, to track progression of healing for periodic reevaluations, and to determine if treatment is progressing without complications or if adjustments are warranted in the treatment plan. Third, photographs are used to communicate with laboratory technicians and master ceramists to facilitate one's vision on color, shade, contours, proportions, and positions of the future restorations before, during, and even after their fabrication. Fourth, dental photography is valuable in showing patients how their new restorations look before they give consent to cementation. It is of great value to leave the dental operatory and sit down with patients to critically review their own images to confirm their satisfaction with the esthetic appearance that has been achieved. Such an extra step has proven to be one key to success. Fifth, photographs are important to record the post-cementation of the definitive restorations once the treatment plan is finalized. Not only does such document the completed treatment, but more importantly it is useful at later reevaluation appointment throughout the continuation of the patient's dental maintenance. Last, dental photography permits thorough documentation of treatment rendered, which may prove helpful if a legal situation evolves.

Armamentarium

- SLR digital camera
- True macro lens; the focal length of the lens will depend upon the image size of the camera. Typically, it is a 100-mm or a 105-mm macro lens.
- Ring flash or twin flash
- Camera case
- Camera neck strap
- 2 yards of black velvet
- Four sets of transparent plastic cheek retractors
- Dental mirrors
  - Large occlusal
  - Medium occlusal
  - Small occlusal
  - Large buccal
  - Medium buccal
  - Small buccal
- Intraoral contraster (black paddle)
- Mixing bowl
- Warm water
- 4 × 4 cotton gauze

A high-quality digital camera is one of the most important investments one can make for a dental practice. However, cameras used in a clinical setting are at high risk of getting dropped and damaged. To minimize the high risk of damage, the photographer should always follow two simple rules.

Rule #1: When the camera is not in use, store it in a professional camera case. A case will protect the camera from a blunt impact like a fall. In addition, a camera case will protect the camera from dust. Over time if a camera is left out in the elements, dust and debris will migrate into the camera and lens and contaminate the camera's digital sensor. When debris migrates into the camera, the quality of pictures will be negatively affected. Many times, debris will result in unwanted black spots in the pictures.

Rule #2: When in use, it is highly recommended for the photographer to always wear the camera's neck strap. A neck strap frees up the photographer's hands for when cheek retractors and mirrors are being inserted into the patient's mouth. With the camera hanging around the photographer's neck, fewer hand transfers are required of the camera between the

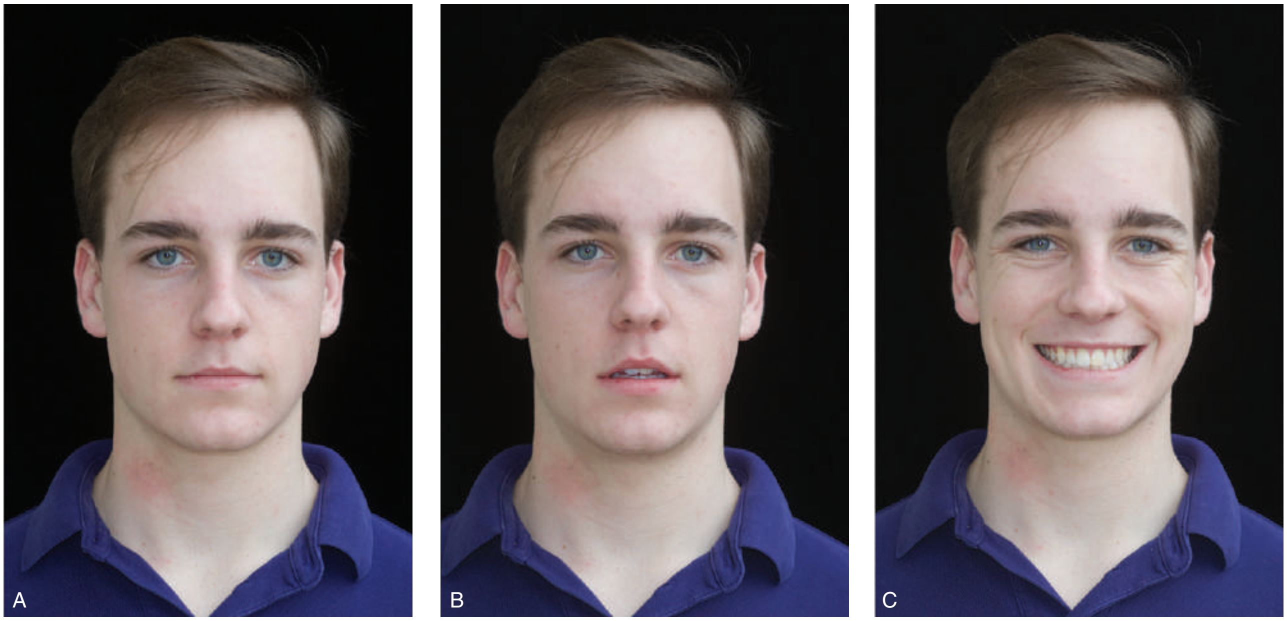

Fig. 2.1 Frontal portrait. (A) Lips together. (B) Repose. (C) Smile.

photographer and assistant. It takes only one drop to render a digital camera inoperable.

Extraoral photographs should be made before the intraoral photographs and diagnostic impressions. The logic is simple: photographs of blushed faces resulting from pulling on the lips and cheeks with retractors and mirrors are of lesser value. Similarly, one would not want images that show smeared impression material on the face or pieces of impression material between the teeth. As a result, the recommended sequence is first extraoral photographs, followed by intraoral photographs, and then diagnostic impressions and occlusal records.

Extraoral Photographs

The concept in photography for fixed prosthodontics is to start with a global view and then progress down to a microscopic view. Following this logic, a frontal view of the full face is the starting point. Mount on a wall the 2 yards of black velvet purchased at a fabric store. The black velvet will eliminate shadows cast on the wall from the camera's flash. Position the patient in a swivel chair 2 feet away from the wall in front of the black background. Frame the picture to include the top of the patient's head down to the collar bone. Both right and left ears need to be in the frame. If long hair is covering the ears, have the patient bring the hair behind his or her ears. Exposure of the ears helps to correlate lateral cephalometric analysis if one is needed (see Fig. 2.2D). The working distance (i.e., the distance between the patient and the front of the camera lens) is approximately 150 to 200 cm (60 to 80 inches), but there is variability between camera brands. The aperture should be set between f/5.6 and f/8. The shutter speed may be set automatically with some brands of cameras. With a Canon camera, the shutter speed is set to $\frac{1}{125}$ second. The focal length will vary with the brand of macro lens, but typically it is approximately 6 feet or 2 m. Focus on the patient's eyes. Make a few pictures with the patient's lips together and the teeth in maximal intercuspation. Once you have confirmed the camera settings, have the patient wet and slightly separate the lips. Instruct the patient with the lips separated to completely relax all facial muscles. The relaxed or reposed facial expression is the starting point for all facial expressions. After the repose photograph has been made, instruct the patient to smile (Fig. 2.1).

Once the three ideal frontal photographs have been obtained, have the patient turn 90 degrees in the swivel chair for three profile photographs: lips together with teeth in maximum intercuspation (MI), repose, and smile (Fig. 2.2). Make sure that long hair is still brushed behind the ears.

With the completion of the profile view, have the patient turn back to face the photographer. The photographer will now shorten the working distance to 25 to 40 cm (10 to 15 inches) to photograph the lips in repose and smiling. To do this, dial the aperture down to f/32 and set the shutter speed at $\frac{1}{125}$ of a second. The lens position will range from 0.45 to 0.50 m (dependent on the manufacturer) because macro lenses will have a small variation dependent upon their focal length. One helpful hint for the smile line is the effect of the angle of the camera to the occlusal plane. A camera positioned a few degrees above the occlusal plane gives the appearance of a curvature in the maxillary incisal edge that follows a similar curve of the lower lip.[1] During the data collection phase, this optical illusion is generally not wanted. To calibrate photographs, the camera is parallel to the occlusal plane. Once the repose and smile frontal photographs are captured, the subject can turn in the swivel chair face the photographer and produce the close-up photographs of repose and smile with the same camera settings (Fig. 2.3).

Intraoral Photographs

For best visual acuity, composition, and exposure, maximal retraction of the lips and buccal mucosa are essential when taking intraoral photographs. Transparent plastic cheek retractors are preferred over metal ones because they are less distracting if captured in the picture. Adult-sized clear plastic cheek

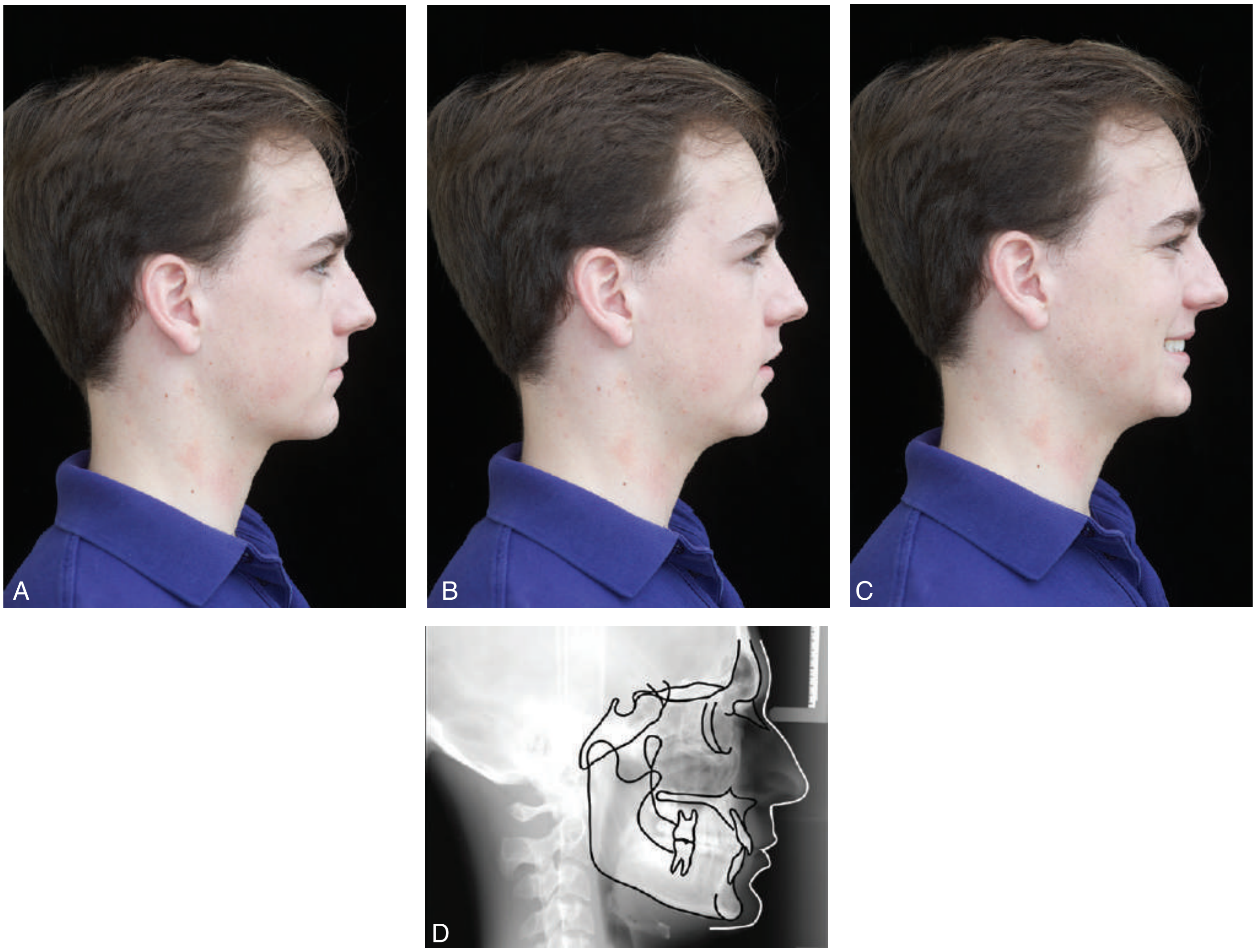

Fig. 2.2 Profile portrait. (A) Lips together. (B) Repose. (C) Smile. (D) An analysis can be done on a lateral cephalogram to evaluate facial proportions, incisor positions, and maxilla and mandible positions.

retractors can be modified with conventional dental slow speed separating discs and denture acrylic polishing equipment. Removal of three quarters of an inch from the apex of each wing of the retractors produces a medium-size retractor. Likewise, the removal of 1.0 inch from all retractor wings creates an essential size for the small mouth. Sectioning away most of one wing from a set of plastic retractors makes for easy occlusal retraction. However, before modifying the retractors, it is highly recommended to mark the location of the intended cuts with a marker. Modifications differ, respectively, for a right and left retractor (Fig. 2.4).

First (or front) surface mirrors (FSMs) produce fine image resolution without ghosting and double imaging as created with second (back) surface mirrors. Available scratch-resistant coatings deliver a durable mirror that, with a little care, will provide a long period of service. Dental mirrors and plastic cheek retractors are autoclave safe. After intraoral use, never place the mirrors in an ultrasonic cleaner. Instead, wash with soap and water and then individually wrap the mirrors in 4 × 4 cotton gauze and bag to be autoclaved.

Dental patients should be seated in the dental chair for all of the following intraoral photographs. The dental chair can be reclined so the patient is supine while the photographer stands next to him or her.

The retracted frontal view picture should be framed to include the maxillary and mandibular teeth in occlusion. No mirror is used. Both dental arches, including the buccal surfaces of all posterior teeth, should fill the frame. The occlusal plane and the dental midline should form an imaginary cross in the center of the frame with the same working distance as the close-up photographs of the lips, approximately 25 to 40 cm (10 to 15 inches). With some practice, many patients can hold their own retractors. The lips need to be retracted laterally and anteriorly to expose the buccal surfaces of the posterior teeth and to capture maximal light from the camera's flash. The aperture should be down to f/32 or as small as the camera will allow. One may let the camera automatically set the shutter speed, or, if a manual setting is preferred, $\frac{1}{125}$ of a second is recommended. The lens position will range from 0.45 to 0.50, depending on the brand of macro lens. Once the camera is set and the patient is in position, focus by bodily moving the camera back and forward to focus on the canines and first premolars. A helpful hint is when the subject is practicing with the retractors, use a slow speed saliva ejector to remove the excess saliva between the teeth and

Fig. 2.3 Extraoral frontal views. (A) Repose. (B) Smile. (C) Profile in repose. (D) Smile in profile.

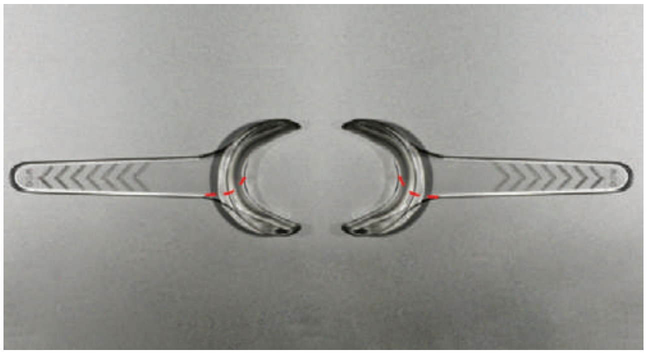

Fig. 2.4 Planning the modification of cheek retractors to make space for an occlusal mirror.

Fig. 2.5 Example of framing the photograph before looking through the camera for the frontal retracted view.

cheeks. When copious amounts of saliva persist, place cotton rolls in the lingual border of the mandible, under the tongue. However, if many teeth are missing, the cotton roll will be visible and negatively affect the photographs. An additional hint is to frame the picture with your eyes before bringing the camera up and viewing through the viewfinder. It is much more difficult to orient oneself and frame the ideal photograph when the first attempt is through the camera's viewfinder (Fig. 2.5).

The right and left buccal view pictures use the same aperture, shutter speed, and working distance as the retracted frontal view picture. Keeping the same working distance will calibrate tooth size across all intraoral photographs. With the teeth in occlusion, the canines and most posterior teeth all should be within the frame. Centered in the frame, the occlusal plane should divide the photograph in half. No direct imaging of the teeth should occur. To achieve an ideal buccal view, place the buccal mirror in hot water. A warm mirror will not fog when used intraorally. Have the patient insert both retractors while the photographer is drying and removing all smudge marks from the warm mirror with sterile 4 × 4 cotton. With the retractors deflecting the lips and cheeks and the patient's jaws

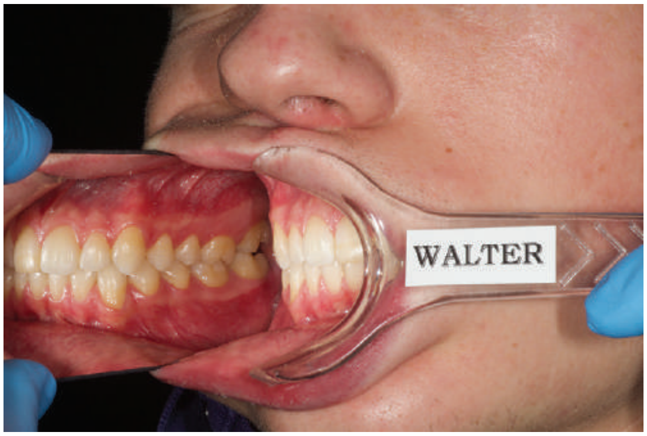

Fig. 2.6 Example of how to frame the photograph before framing through the viewfinder for the retracted buccal view.

Fig. 2.7 Retracted maxillary occlusal view. Note the modified cheek retractors to accommodate space for the large occlusal mirror.

separated, place the buccal mirror between the cheek and teeth. Once in place, remove the retractor that is on the same side as the buccal mirror and have the patient close into maximal intercuspation. Without touching the last molar or the surrounding posterior soft tissues with the mirrors end, rotate the mirror to a 45-degree angle from the buccal surfaces of the teeth. The buccal mirror can now be used as a substitute for a cheek retractor and is pressed against the corner of the mouth. The mirror is made of double-strength glass so it will not break during intraoral use, but for patient comfort, care is needed not to apply too much pressure. To achieve the 45-degree mirror position, the patient needs to bring the contralateral cheek retractor toward their midline to allow the lips to move toward the side with the mirror. Before the photographer sights through the viewfinder, they should frame the picture first with a naked eye (Fig. 2.6). It may be quite awkward to attempt to frame the picture through the viewfinder first while reflecting the image off of a mirror. In addition, framing the picture first without the camera will decrease patient discomfort and reduce the risk that the delicate soft tissues are pinched with the edge of the mirror. Once the picture is framed, the photographer brings the camera up and views the frame through the viewfinder while focusing on the premolar area. After completion of one buccal view picture, the steps are repeated to capture the contralateral buccal view with the positions of the retractor and mirror reversed.

The maxillary occlusal view photograph should include the entire maxillary arch from the central incisor to the most posterior tooth or tuberosity. The labial surfaces of the central incisors need to be parallel with the top of the frame and the midline centered in the frame. Many times, the midpalatal suture and palatal rugae are handy aids in centering the picture (Fig. 2.7). While the aperture and shutter speed are the same as the frontal and buccal view settings, the working distance may increase to 0.50 to 0.60 m if needed to simplify the framing of the occlusal photograph. During the postprocessing stage, the picture can be cropped to eliminate the unwanted parts. To capture the maxillary occlusal view, keep the patient in the supine position in the dental chair. Use the modified cheek retractors with the one wing completely removed, and have the patient gently deflect the upper lip anteriorly and superiorly. Dry the occlusal surfaces of the teeth with compressed air. Place the dry warm occlusal mirror on top of the tongue in the area where the retractor wings were removed. The largest side of the occlusal mirror that fits in the patient's mouth should be selected. A large mirror will aid in retracting the buccal mucosa near the last molar teeth. The photographer takes a position behind the supine patient and shoots over the patient's head into the mirror while the patient retracts and opens as wide as possible. To keep fingers out of the frame, the mirror is grasped from underneath and held at a 45-degree angle to the occlusal arch without contacting the teeth or pinching soft tissues in the posterior. Likewise, the camera is aimed at a 45-degree angle to the mirror.

The mandibular occlusal view includes the complete mandibular arch, from central incisor to last molar. Ideally, the dorsal surface of the tongue is not in the photograph. The labial surface of mandibular central incisor parallels the bottom of the frame and the patient's midline is centered. As with the maxillary occlusal view photograph, the mandibular occlusal working length will range from 0.45 to 0.60 m, and the patient is left in the supine position in the dental chair. Depending on the brand of camera, the aperture and shutter speed are left the same as the previous intraoral views, f/32 and $\frac{1}{125}$ second. While the largest occlusal mirror that will fit in the patient's mouth is warming in the water, have the subject switch the retractors with the missing wings in their hands to retract the lower lip. Dry and polish clean the mirror with sterile 4 × 4 cotton gauze, instruct the patient to lift up their tongue, and use the mirror to retract the tongue posteriorly, out of the frame. The patient's tongue is retracted out of the frame because the dental arch is the subject of the photograph and a tongue would be distracting if it is not intended to be the subject of the image. With the patient's tongue retracted out of the frame, the lingual frenum of the tongue is a helpful aid for centering the photograph. Tilt the mirror to a 45-degree angle to the mandibular occlusal plane without contacting the mandibular arch. Position the camera approximately 45-degree angle to the warm, clean mirror. Ask the patient to open wide, and make sure the retractors are keeping the lower lip away from the mandibular anterior teeth (Fig. 2.8). Once again, after framing with the naked eye,

Fig. 2.8 Example of how the occlusal view would appear before it is framed through the camera's viewfinder. Note how the mirror is used to retract the tongue.

Fig. 2.9 Modified half cheek retractions deflect the upper lip to reveal the maxillary incisors and gingiva. A black photographic paddle placed behind the dentition creates contrast against the color of the teeth and highlights the contours of the incisal edges.

the photographer will confirm the final composition through the view finder before making the picture.

With the same modified cheek retractors as the occlusal view photographs, the ones with one wing completely removed (see Fig. 2.4), close-up photographs can be made from a frontal view of anterior teeth. To accent tooth incisal edge contours, a black contraster or modified autoclavable kitchen spatula[2] can be inserted in the mouth behind the teeth (Fig. 2.9).

DENTOFACIAL ANALYSIS

Facially generated tooth positions have found great esthetic and functional success in dentistry.[3–5] Historically, tooth positions were solely analyzed and determined from stone casts mounted on an articulator in CR. Reconstructions were governed with objectives to achieve a class 1 occlusion and have maximal intercuspation equal to centric occlusion to achieve optimal function. Known as functional reconstructions, mechanically, this proved very successful. However, in some situations, patients who were reconstructed with only a functional philosophy might have looked a little strange when an observer stepped back and viewed their entire face. Esthetic failures sometimes resulted simply because the lips were never considered during the analysis of the articulated diagnostic casts.[4] To address the relation of the face and the teeth, it is recommended to start the analysis with the esthetics of tooth position and then proceed to function, structure, and biology of the teeth.[6,7] Function is not ignored; it is still just as important, but in the work flow of planning the restorations, it follows after the esthetic considerations. Interestingly, when the esthetics are considered first in planning, function seems to naturally follow. Facial norms will be discussed next; however, it is important to recognize that the presented values do not govern patient treatment in an absolute manner. The numbers generated by research merely offer suggested guidelines that may prove quite helpful.

TABLE 2.1 Effect of Age on Amount of Anterior Tooth Display

Age	Maxillary Central Incisor (mm)	Mandibular Central Incisor (mm)
Up to 29	3.4	0.5
30–39	1.6	0.8
40–49	1.0	2.0
50–59	0.5	2.4
60+	−0.04	3.0

From Vig RG, Brundo GC. The kinetics of anterior tooth display. *J Prosthet Dent*. 1978;39:502–504.

Repose: The Starting Point

In an interdisciplinary team, the role of the restorative dentist is to identify where the teeth should be positioned to optimize esthetics, phonetics, and function. With a facially generated tooth position, the arrangement of teeth starts with the evaluation of the maxillary incisal edge to the resting upper lip, also known as the repose facial expression.[4] Vig and Brundo showed in a classic article that, as a person ages, the facial soft tissues tend to lose their elasticity which succumbs in a downward migration of the face on the skull. As a result of aging, less maxillary incisal is displayed when the lips were slightly separated in a resting position.[8] Conversely, as the maxillary anterior teeth become less visible in repose, the mandibular anterior teeth become more visible (Table 2.1). The resting facial expression is the optimal facial expression to determine the incisal edge position because of its static nature.[8–12]

Lip Form

An online survey was created to classify and define lip form and to evaluate the influence of lip form on dentists' and laypersons' preferences for the amount of incisal display with lips at rest. Three distinct lip forms were used. When evaluated between the commissures of the resting maxillary lip, lip form can follow a straight path or have a moderate or high vertical elevation.[13] Conclusions were drawn for when the lip form changed from straight to moderate to high, an increase of maxillary incisal display was preferred. Respondents' preference for male and female amounts of incisal display were the same except more incisal display was favored for the females with a high lip form.[13] Although restorative dentists do not have control over lip form, clinicians do control the maxillary incisal edge position. It is important to understand that, as the maxillary lip gets shorter through a vertically curved arch pattern, it is natural to show more maxillary incisor.

Lips in Smile

Although a smile is a universal facial expression,[14] it is difficult to show high levels of evidence for objective measures for attractive or unattractive smiles because of subjective bias. At the treatment planning phase, one must recognize that smiles are dynamic facial expressions and have great variability within an individual that is closely linked to emotions.[14,15] Research has shown the importance of dental alignment[16,17] but not symmetry of the face because there are conflicting objective evaluations to qualify the summation of all the parts.[18] Furthermore, differences in opinions within dental professionals and patients exist on what is considered an acceptable amount of gingival display.[19–23] Consequently, smiles are open to subjective interpretation with cultural and individualized perceptions of beauty.[24,25]

Tjan et al developed a classic smile classification system of high, average, and low smiles. The high smile was defined as exhibiting the total cervicoincisal length of the maxillary anterior teeth and a contiguous band of gingiva.[26] Average smile revealed 75% to 100% of the maxillary anteriors plus the interproximal papillae. Smiles with less than 75% dental display were classified as low smile. It was also found that women tended to have a higher smile line than men.[26] Since then, other investigators have drawn the same conclusion about women having larger smiles than men.[27–29] In a multicenter interracial study, Owen et al reported that when smiling (African American, White, Chinese, Hispanic, Japanese, and Korean) women displayed significantly more gingival tissues in four of the six ethnic groups,[30] and African Americans displayed significantly more gingival tissues than any other ethnic group.[30]

More recent evaluation of papillae display in a smile found that the interdental soft tissue was visible in 91% of all individuals,[31] demonstrating the important role of the periodontal tissues in achieving excellent facial esthetics. Those who were classified as having a low gingival smile line displayed papillae 87% of the time.[31] Other researchers agree that gingival esthetics is far more important than previously realized. The aforementioned results are drastically different than the results of Tjan's high, average, and low smile line classification,[26] whose low smile line classification did not show gingival tissue and did show that the majority of patients' gingiva is a factor in facial esthetics that should be part of the dentofacial analysis.[31]

Smile Types

Guillaum-Benjamin Amand Duchenne, a 19th century French neurologist, is considered the first researcher to describe a difference between a sociable smile and a maximal or joyous smile through electrical stimulation of facial muscles of expression.[32] Later Charles Darwin agreed with Duchenne in that the joyous smile involved the contraction of both the zygomatic major muscles and the orbicularis oculi muscles.[33] Out of respect to the French neuroscientist, the true joyous smile has become to be known as the Duchenne smile.[14]

Ekman et al described three distinctly different smiles tied to independent emotions.[34] They described the Duchenne smile as a felt smile that was linked to positive emotions. A false smile is a facial expression that can be generated to deliberately attempt to appear positive; however, it is used to mask feelings of contempt or deceit. A miserable smile can be displayed when a person experiences pain, fear, or anxiety and an attempt to smile will show a will for survival. When the total face is evaluated and not just the smile, up to 50 different types of smiles have been identified.[35] This leaves a clinician with one question: When you ask your patient to smile, what type of smile is your patients giving you?

Dentists need to evaluate the morphologic and dynamic characteristics of a smile. Examples of morphologic keys with a Duchenne smile or maximal smile are an open mouth, raising of the cheeks, and wrinkling of the corners of the eyes.[36] Dynamics in smiles refers to the rate of temporal unfolding or velocity with which a smile begins and terminates. Duchenne smiles have larger amplitude, longer duration, and more abrupt onset and offset than do polite or embarrassed smile types.[37]

Because smiles can vary in both morphologic and dynamic qualities within one individual, it is important to note what type of smile the patient is producing so that a patient who can generate a high smile is not incorrectly classified as a medium or low smile type because they just happened to not produce their maximal smile. To minimize errors in categorizing patient smile types, it is important to remember to evaluate the eyes and confirm that there is contraction of the orbicularis oculi, which results in wrinkling at the corners of the eyes along with elevation of the middle third facial soft tissues.[36]

Esthetics in Speech

Some suggest that clinicians should view the dynamics of the anterior dentition with video recordings as a continuum delineated by time points of repose, speech, social smile, and Duchenne smile.[22–24]

With a spontaneous smile, the height of the upper lip is generally increased when compared with the lip height during speech.[38] Contrary to the maxilla, the mandibular anterior teeth are more visible during speech than during a smile.[39,40] In one study, 93% of the participants had their mandibular anteriors form part of an esthetic zone during speech.[39]

CEPHALOMETRIC ANALYSIS

Valuable craniomaxillofacial information can be gleaned from cephalometric data. A lateral cephalometric radiograph is a two-dimensional image of the head that captures the bones and soft tissue profile in the sagittal view. Traditionally, the image is made with a cephalostat, but this analysis can also be done with cone-beam computed tomography (CBCT) or magnetic resonance imaging (MRI).[41,42] If a dental patient's reconstruction needs a skeletal/soft-tissue analysis, care should be taken in ordering the image to minimize radiation exposure.[43] Anatomic landmarks

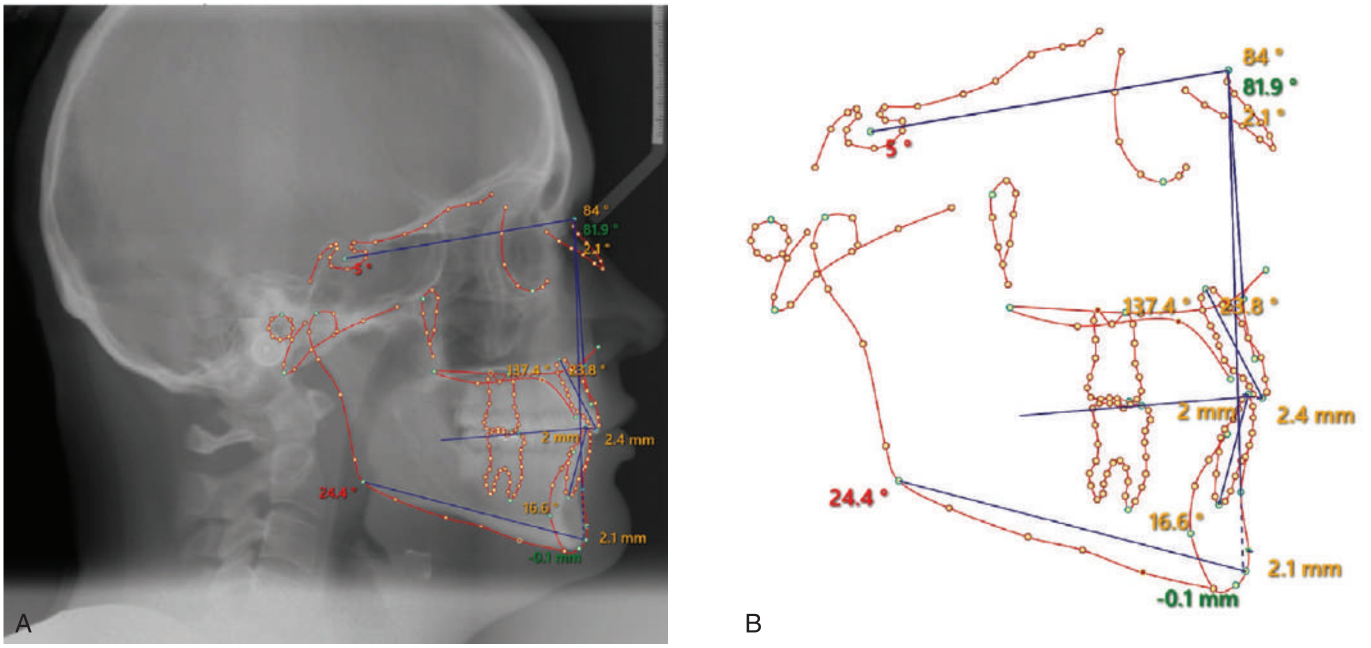

Fig. 2.10 (A) Cephalometric analysis. (Courtesy Todd Ehrler DDS, MS.) (B) Example of how measurements were obtained for the Steiner analysis in Table 2.2.

TABLE 2.2 Cephalometric Analysis[a]

Name	Value	Range
Skeletal Analysis		
SNA	84°	81.8 ± 3.7°
SNB	81.9°	79.2 ± 2.3°
ANB	2.1°	2.6 ± 2.4°
Dental Analysis		
Upper incisor to NA distance	2.4 mm	3.8 ± 2.7 mm
Upper incisor to NA angle	23.8°	21.4 ± 6.9°
Lower incisor to NB distance	2 mm	3.4 ± 3.6 mm
Lower incisor to NB angle	16.6°	22.4 ± 9.6°
Upper incisor to lower incisor angle	137.4°	133.6 ± 13°
Pogonion to NB distance	1.1 mm	2.1 ± 1.6 mm
Pogonion and lower incisor to NB difference	0.9 mm	2.6 ± 1.7 mm
Occlusal plane to SN angle	5°	14.4 ± 2.5°
Gonion-Gnathion to SN angle	24.4°	31.3 ± 3.1°

[a]Age: 37 years, 5 months; Timepoint: Initial 2019-12-10; Gender: F; Analysis: Steiner

Example of a cephalometric analysis. The red font indicates measurements that were outside of the established ranges.

ANB, A point–nasion–B point angle; *NA*, nasion-A point (subspinale); *NB*, nasion-B point (supramentale); *SN*, sella–nasion line; *SNA*, sella–nasion–A point angle; *SNB*, sella–nasion–B point angle.

have been defined and traced so that measurements and angles between the cranial base, maxilla, mandible, dentition, and facial soft tissue profile can be made (Fig. 2.10). The lateral cephalometric radiograph is a standardized image. Accordingly, population norms have been established so comparisons among individuals can be made (Table 2.2). Interpretation of a lateral cephalogram explains a patient's dentofacial proportions and helps to clarify if there is a skeletal discrepancy and/or a dental malocclusion. Many times, malocclusions that are caused with an underlying skeletal issue cannot be corrected with restorative dentistry alone. Hence, if during the planning phase a skeletal malocclusion is diagnosed, interdisciplinary treatment combining orthodontics and/or surgery may be indicated. Numerous cephalometric analyses exist to evaluate the craniofacial complex; however, one is not better than another. The data presented here are provided to quickly aid in the diagnostic process to help determine if a more in-depth comprehensive analysis may be necessary (Fig. 2.11).

DIGITAL SMILE DESIGN AND ESTHETIC TEMPLATES

In comprehensive dental care, one challenge has always been the communication of the vision of the treatment plan between the care provider(s) and patient.[6] Computer imaging offers the patient a virtual vision of what a proposed treatment plan has to offer and provides excellent communication between the patient and doctor (Fig. 2.12).[44–47]

A digital smile design or diagnostic tooth waxing can be converted to an esthetic template that fits over patients existing dentition.[48] In fixed prosthodontics, an esthetic template is equivalent to a denture wax clinical evaluation in removable prosthodontics. It can be designed and milled or three-dimensional (3D) printed with computer-aided design and computer-aided manufacturing (CAD-CAM) technologies or with traditional articulated casts and a diagnostic waxing. Traditionally, a silicone impression or a thermoplastic mold from a duplicated cast of the diagnostic waxing was used to transfer the new tooth forms intraorally with interim restorative resins. The esthetic template fits over the patient's unprepared

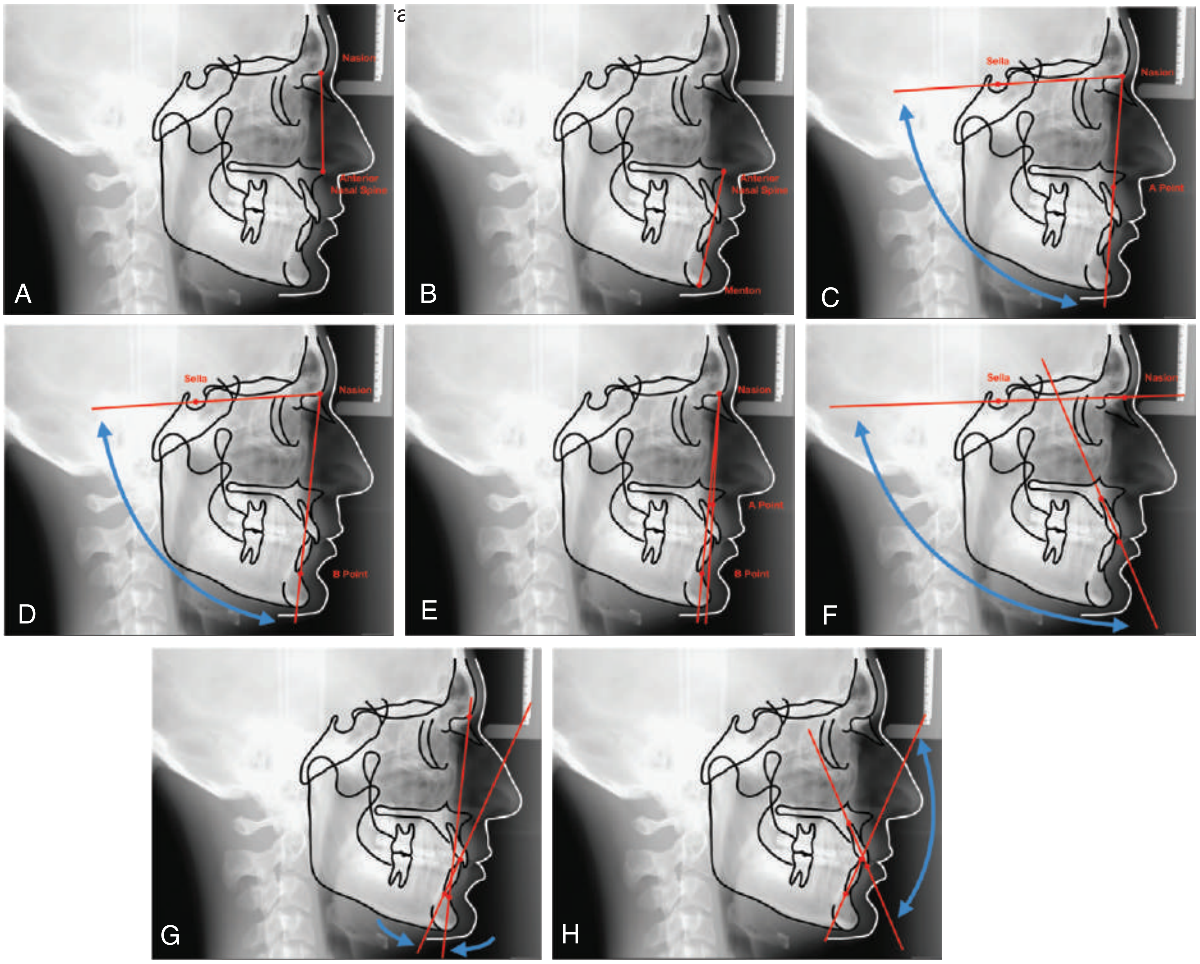

Fig. 2.11 (A and B) Anterior facial height is divided into an upper and lower face. The upper anterior face height (UAFH) (A) is a linear measurement between nasion and anterior nasal spine (N-ANS). The lower anterior face height (LAFH) (B) is a linear measurement between anterior nasal spine and menton (ANS-ME). The ratio between the upper and lower facial height (the UAFH/LAFH ratio**)** gives guidance on whether the lower face is long or short. The ration between the two facial heights is more relevant than the solitary individual measurements.

- UAFH/LAFH ratio <0.8 indicates a longer lower anterior facial height (LSFH)
- UAFH/LAFH ratio >0.8 portrays a shorter lower anterior facial height (LSFH)

(C) Sella-nasion-A point (SNA) is an angle that shows the horizontal position of the maxilla (A point) relative to the cranial base (sella-nasion).

- 82° ± 3° Average
- >85° indicates a prognathic maxilla
- <79° indicates a retrognathic maxilla

(D) Sella-nasion-B point (SNB) is an angle used to explain the anteroposterior position of the mandible relative to the cranial base. B point is marked at the most apical part of the alveolus and concave part of the mandibular symphysis.

- 80° ± 3° Average
- >83° indicates a prognathic mandible
- <77° indicates a retrognathic mandible

(E) ANB gives an angle for the relationship of the maxilla to the position to the mandible. (SNA) − (SNB) = ANB

- Average ranges between 1° and 5° indicate a skeletal Class I
- Positive value >5° for ANB is indicative of a Class II skeletal jaw relationship (i.e., maxilla anterior to mandible).
- Negative values or <1° ANB value means a Class III skeletal jaw relationship (i.e., maxilla posterior to mandible)

(F) Maxillary incisor (U1) to sella-nasion (SN) is the angle between the anterior cranial base and inclination of the central incisor.

- Average value = 103° ± 6°
- >109° indicates a proclined incisor (Class II division 1)
- <97° indicates a retroclined incisor (Class II division 2)

(G) Mandibular incisor (L1) to nasion-B point (NB) is used to communicate the mandibular incisor position to the mandibular alveolar base.

- Average angle 25° ± 7°
- >32° indicates a more proclined incisor (Class II division 1)
- <18° indicates an upright or retroclined incisor (Class II division 2)

(H) Maxillary incisor (U1) to mandibular incisor (L1) is an angle developed between the long axis of the maxillary and mandibular central incisors.

- Average angle 135° ± 11°
- >146° indicates that the incisors are more proclined (Class II division 2)
- <124° indicates that the incisors are more retroclined (Class II division 1)

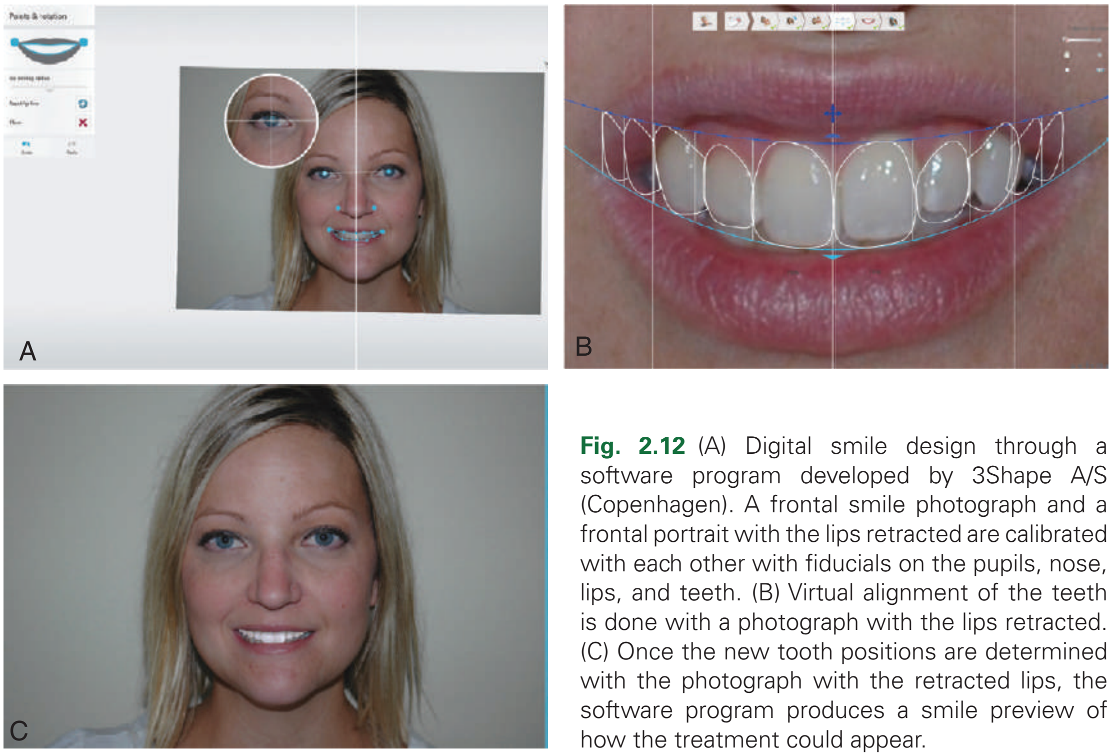

Fig. 2.12 (A) Digital smile design through a software program developed by 3Shape A/S (Copenhagen). A frontal smile photograph and a frontal portrait with the lips retracted are calibrated with each other with fiducials on the pupils, nose, lips, and teeth. (B) Virtual alignment of the teeth is done with a photograph with the lips retracted. (C) Once the new tooth positions are determined with the photograph with the retracted lips, the software program produces a smile preview of how the treatment could appear.

teeth so the dentist can evaluate the proposed treatment in real time with the patient's face (Fig. 2.13). As a reversible procedure, the function of the lips can be assessed before treatment is started. Once the accuracy of the proposed treatment is confirmed, the patient can evaluate the esthetic template and take it home for further evaluation with friends and family. Video recordings can also be helpful to assess the facial functional effect with different facial expressions and phonetics while wearing an esthetic template.

DIAGNOSTIC CASTS AND RELATED PROCEDURES

Accurate diagnostic casts, whether in a digital format or transferred to a traditional analog semiadjustable articulator (Figs. 2.14 and 2.15), are essential in planning fixed prosthodontic treatment. This enables examination of static and dynamic relationships of the teeth 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 CR interocclusal record has been used for articulation of the mandibular cast, and the condylar elements have been appropriately set (as with protrusive and excursive interocclusal records), reproducing the patient's movements with reasonable accuracy is possible. If the casts have been articulated in CR, both the CR and the MI position can be assessed 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 enable 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 the proposed treatment.

IMPRESSION MAKING FOR DIAGNOSTIC CASTS

Accurate digital scans or traditional impressions of both dental arches are required. Saliva or foreign debris on the occlusal surfaces of optical scans are interpreted as hard contours of the teeth and result in errors in articulation. Flaws in the traditional impressions result in inaccuracies in the casts that easily multiply. 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 optical scan or traditional impression extends several millimeters beyond the cervical line of the teeth, the borders of diagnostic impressions are usually not of great concern

Fig. 2.13 (A) Retracted frontal view of teeth with severe attrition. (B) A periodontal probe can be used to measure the relationship of the maxillary incisal edge to the resting lip in a repose facial expression. (C) Maximal smile shows 100% of the worn anterior teeth and a continuous band of gingiva in the maxillary and mandibular arches. (D) A tray was fabricated from a diagnostic waxing and will be used as a shell for an esthetic template. The proposed tooth proportions were increased both apically and incisally. (E) The esthetic templates, trays filled with white colored impression material, are placed over the nonprepared teeth for an esthetic evaluation. Both the dentist and patient can approve of the treatment plan through a reversible technique before irreversible procedures of crown lengthening and tooth preparations are performed.

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, unlike the optical scan, the material does require pouring within 2 hours to avoid dimensional change[49] and does not reproduce sufficient surface detail for suitable definitive casts and dies on which actual fixed prostheses are fabricated (see Chapter 17). Materials with a composition similar to that of polyvinyl siloxane materials (see Chapter 14) have been marketed as an alternative to traditional irreversible hydrocolloids.[50] These materials should be considered if a delay in pouring is necessary and an optical scan is not available.[51]

Digital scanning techniques are reviewed in Chapter 14.

Irreversible Hydrocolloid

The irreversible hydrocolloids, or alginates, are essentially sodium or potassium salts of alginic acid and are therefore water

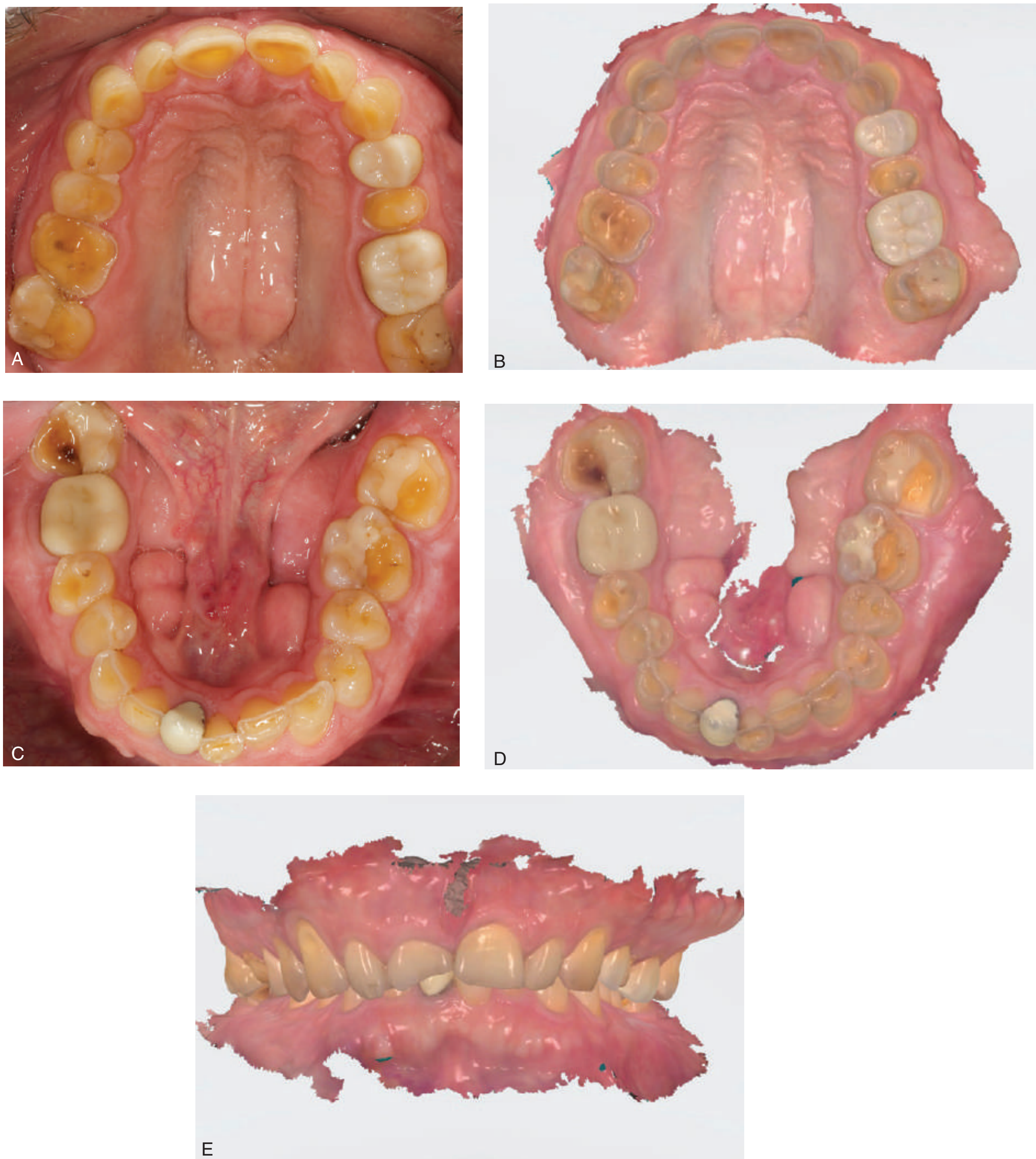

Fig. 2.14 (A) Occlusal view of a maxillary arch at the data collection appointment. (B) Digital scan of maxilla for a diagnostic cast. (C) Mandibular occlusal view at the data collection appointment. (D) Mandibular digital representation. (E) Digital diagnostic casts.

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 plastic impression compound
- Mixing bowl
- Mixing spatula
- Gauze squares

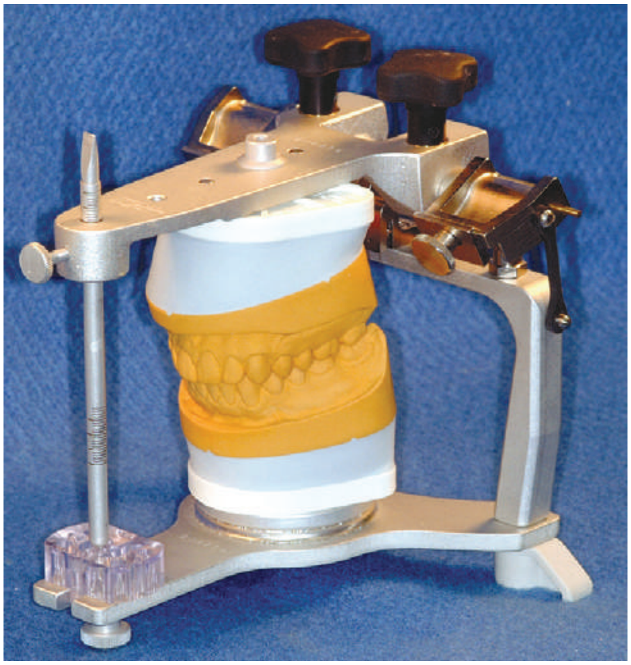

Fig. 2.15 Diagnostic casts mounted on a semiadjustable articulator. (Courtesy Whip Mix Corporation, Louisville, KY.)

Fig. 2.16 Stock impression trays can be readily modified with modeling plastic impression 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.

- Irreversible hydrocolloid
- American Dental Association (ADA) type IV or V stone
- Vacuum mixer
- Humidor
- Disinfectant

Tray Selection

All impression materials must be retained in the impression tray. This can be accomplished for irreversible hydrocolloid with an adhesive or by means of perforations or undercuts around the rim of the tray. All types of trays are capable of producing impressions with clinically acceptable accuracy,[52] although casts may be produced more accurately by rigid plastic trays than by perforated metal trays.[53] 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 ratio of surface area to volume 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 plastic impression compound (Fig. 2.16).

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.[54] Concurrently, a small amount of material is wiped into the crevices of the occlusal surfaces (Fig. 2.17A and B) before the tray is seated (see Fig. 2.17C). In addition, 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 instructed to "close gently" on the tray. If the patient continues to stretch the mouth 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. Excessive opening greater than 20 mm or protrusion of the mandible may also lead to inaccuracies in a mandibular impression because of mandibular flexture.[55]

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. In addition, certain irreversible hydrocolloid materials become distorted if held in the mouth more than 2 or 3 minutes after gelation.[56] After removal (see Fig. 2.17D), 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

Fig. 2.17 Making an alginate impression for diagnostic casts. (A) and (B) A small amount of alginate being wiped into the crevices of the occlusal surfaces. (C) Seating of the tray. (D) The completed impression.

and protecting laboratory personnel (see Chapter 14); irreversible hydrocolloid impressions carry significantly higher numbers of bacteria than do elastomeric materials.[57] No significant loss of accuracy or surface detail is caused by the disinfection procedure.[58,59] 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.[60]

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 to minimize bubble formation (see the section on pouring stone dies in Chapter 17). If air is trapped, a small instrument (e.g., a periodontal probe or a wax spatula) can be used to poke the bubbles and eliminate them. While they are 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.[61] 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 from the impression 1 hour after being poured.

Evaluation

Although it is apparently a simple procedure, diagnostic cast fabrication is often mishandled. Seemingly minor inaccuracies can lead to serious diagnostic errors. Questionable impressions and casts should be discarded and the process repeated (Fig. 2.18). 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.

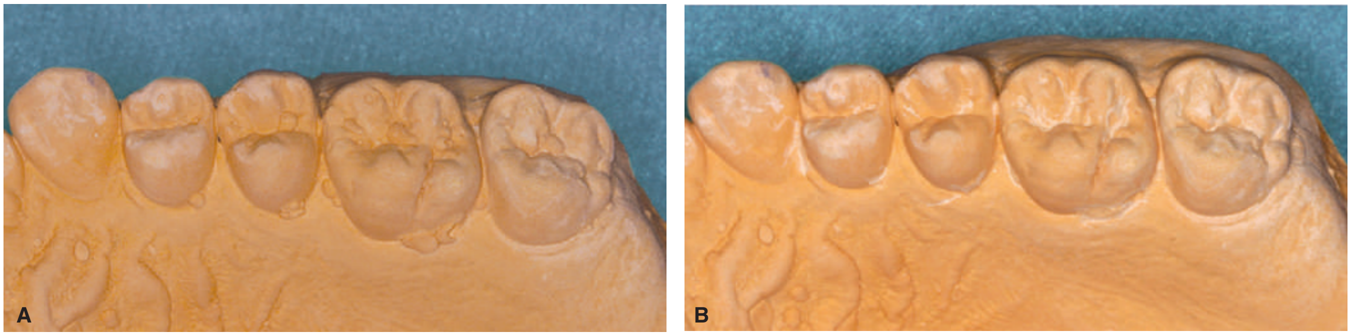

Fig. 2.18 Diagnostic casts must be accurate if they are to articulate properly. (A) Occlusal nodules may make proper occlusal analysis impossible. (B) Proper technique ensures a satisfactory cast.

Articulator Selection

Virtual articulators. With the advances in CAD-CAM, optical scanning of entire arches has become a fairly straightforward procedure (see Fig. 2.20) (see also the section Optical Impressions, Chapter 14). Because of recent software developments, it is again time to reassess the mandibular transverse horizontal axis theory. As defined, the transverse horizontal axis is an imaginary line around which the mandible may rotate within the sagittal plane. The imaginary line is also known as the condylar axis—a hypothetical line through the mandibular condyles around which the mandible may rotate. To quote Preston, "Past experiments have been useful, but none have provided or disproved the presence of collinear or non-collinear condyle arcs. Only the arc of the rigid clutch and its associated mechanism is located. Such an apparent arc may result from the resolution of compound condylar movements."[61a] CAD-CAM technologies can not only scan the dental arches but can also scan mandibular movements in real time without any interferences from an operator or rigid clutches and kinematic facebows (Fig. 2.19). Currently, the one limitation is that the video recording of the mandibular movements is a large file size. As a result, only a portion of the occluding dental arches can be viewed at one time (Fig. 2.20).

Traditional articulators. Traditional handheld casts can provide information concerning alignment of the individual arches but do not enable analysis of functional relationships. For such 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 technician 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 another 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 parts that are more easily handled. Use 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. 2.21). 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; thus restorations may have 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. 2.22).

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 premature contacts are likely to occur on the nonworking side (see Chapters 4 and 6).

Semiadjustable articulators. For most routine fixed prostheses, the use of a semiadjustable articulator (Fig. 2.23) is a practical approach to obtaining 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

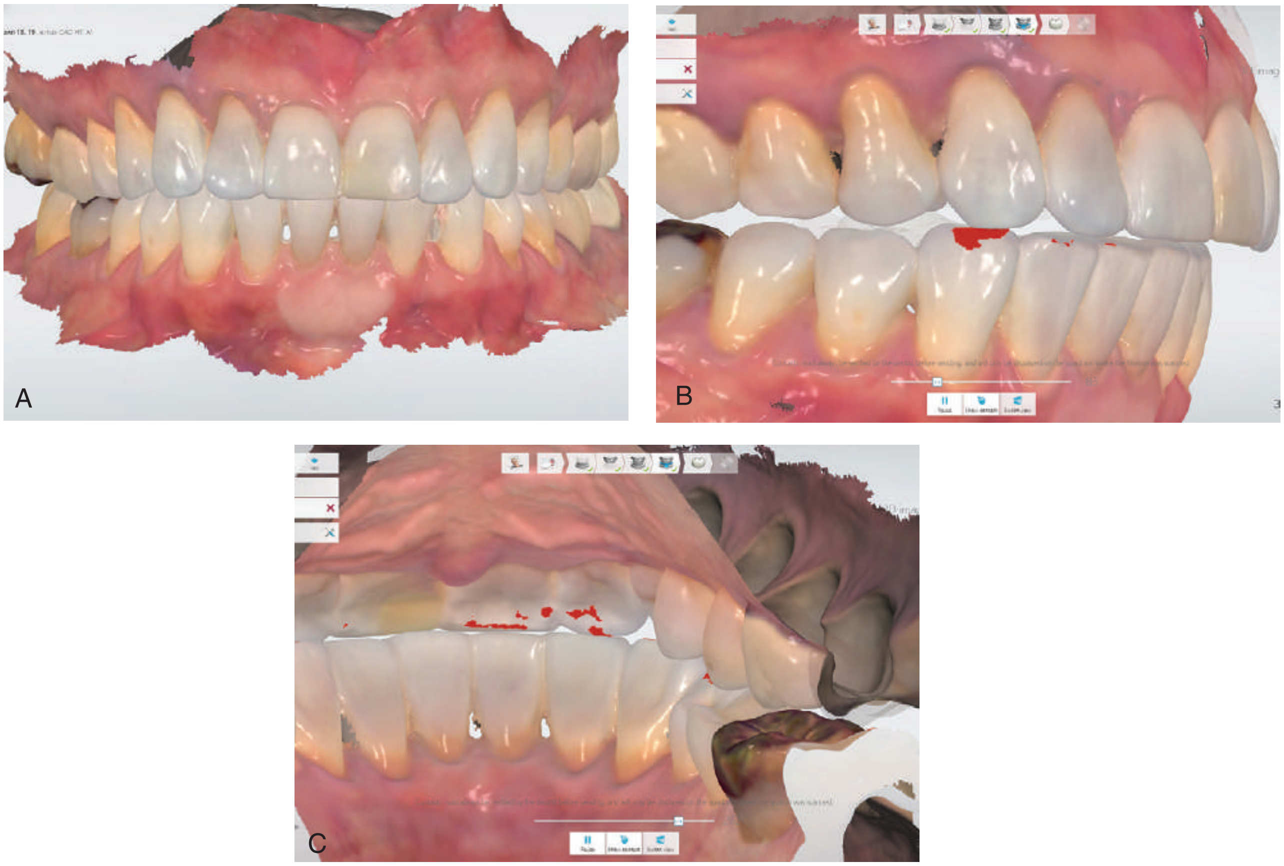

Fig. 2.19 (A) Digital diagnostic casts not only record the teeth and free gingival margins but color and pathosis as well. Note the mandibular anterior free gingival graft around tooth numbers 24 and 25, the mandibular central incisors. (B) A digital video can record all mandibular movements. The *red color* marks on the mandibular canine shows the occlusal pathway of the canines in a working mandibular movement. (C) To further understand the patient's mandibular movements, the same digital diagnostic casts can be viewed from the lingual.

Fig. 2.20 Example of how a digital video aids in identifying tooth contacts in lateral and protrusive mandibular movements. The *red color* marks indicate tooth contacts and the timing of the contacts. One limitation is the limited view one gets of the dental arches.

Fig. 2.21 A small nonadjustable articulator.

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 articulator and condyle) (Fig. 2.24A and C) and the nonarcon (see Fig. 2.24B and 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

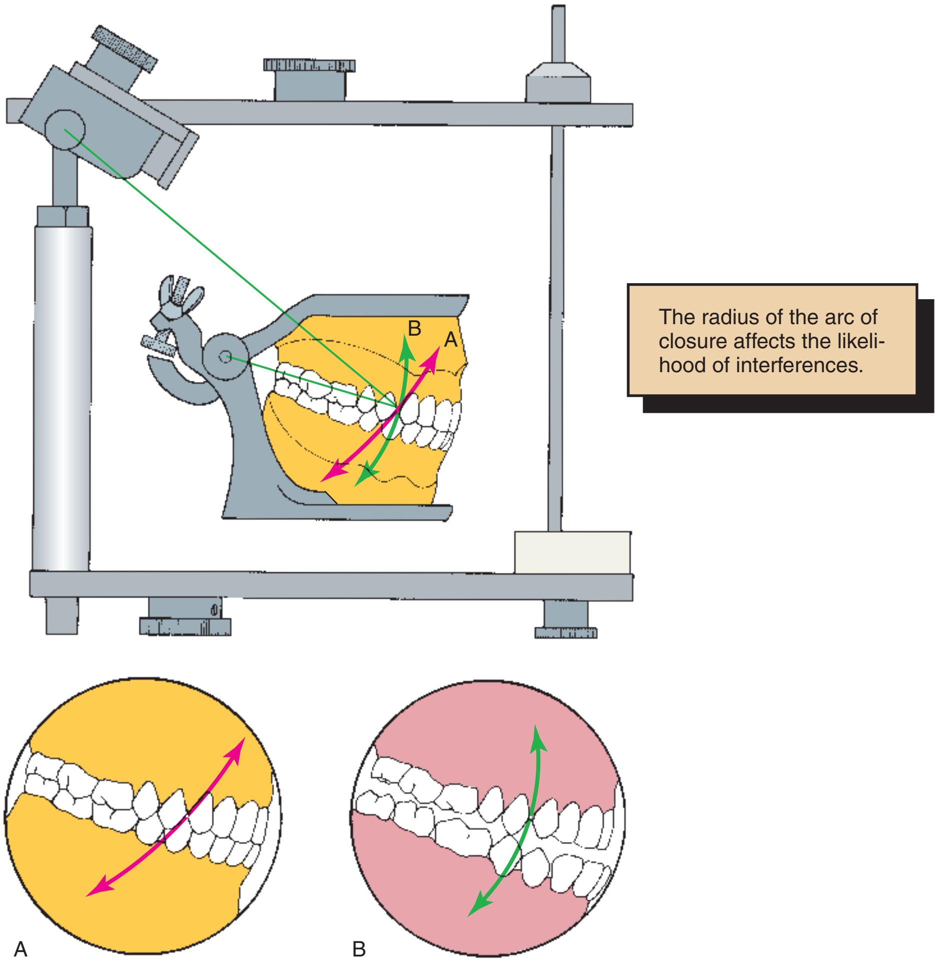

Fig. 2.22 Discrepancies in the path of closure when a small nonadjustable articulator is used can cause restorations to have premature occlusal contacts. (A) An anatomically accurate articulator shows an accurate path of closure. (B) With the small nonadjustable instrument, the radius of the path of closure is smaller, which results in premature contact at the clinical evaluation appointment between the premolars during hinge closure.

positioned. However, as a consequence of their design, certain inaccuracies occur in cast restorations, 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 "backward"). 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 allow adjustments to the condylar inclination and progressive or immediate side shift. Some have straight condylar inclined paths, although newer 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 into which the patient has bitten. These records can be several millimeters thick, and so 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 causes reduction in cuspal heights in subsequently fabricated prostheses (see Table 4.3).

Fully adjustable articulators. A fully (or highly) adjustable articulator (Fig. 2.25) 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, a series of special pantographic tracings are used to record the patient's border movements. The armamentarium used to

Fig. 2.23 Semiadjustable arcon articulators. (A) The Denar Mark 330 articulator. (B) The Whip Mix model 2240 articulator. (C) The Hanau Wide-Vue articulator. (A–C, Courtesy Whip Mix Corporation, Louisville, KY.)

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 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 by the dentist and the technician. However, once this skill has been acquired, 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 a patient's 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 the 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 (Fig. 2.26). 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

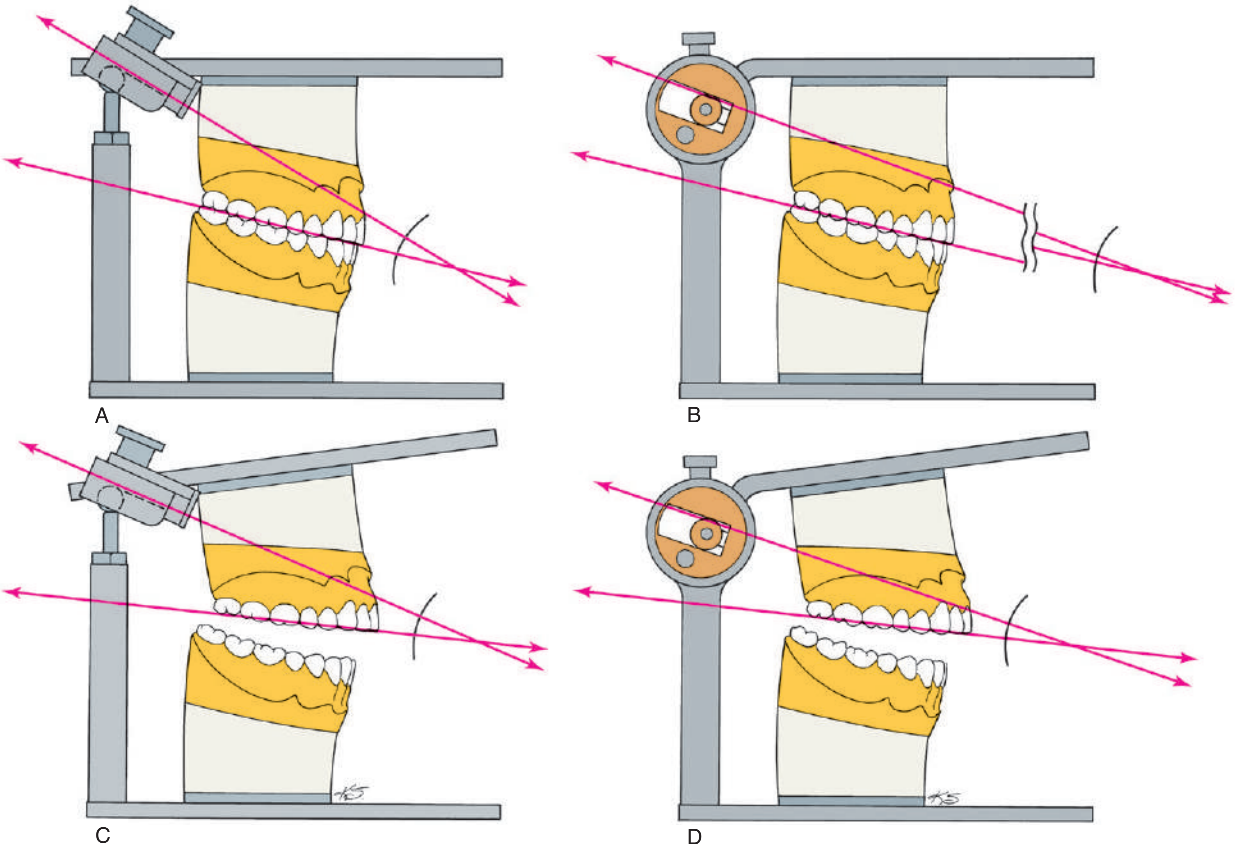

Fig. 2.24 Articulators. (A) and (C) An arcon articulator; (B) and (D) a nonarcon articulator. An advantage of the arcon design is that the condylar inclination of the mechanical fossae is at a fixed angle to the maxillary occlusal plane. With the nonarcon design, the angle changes as the articulator 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.)

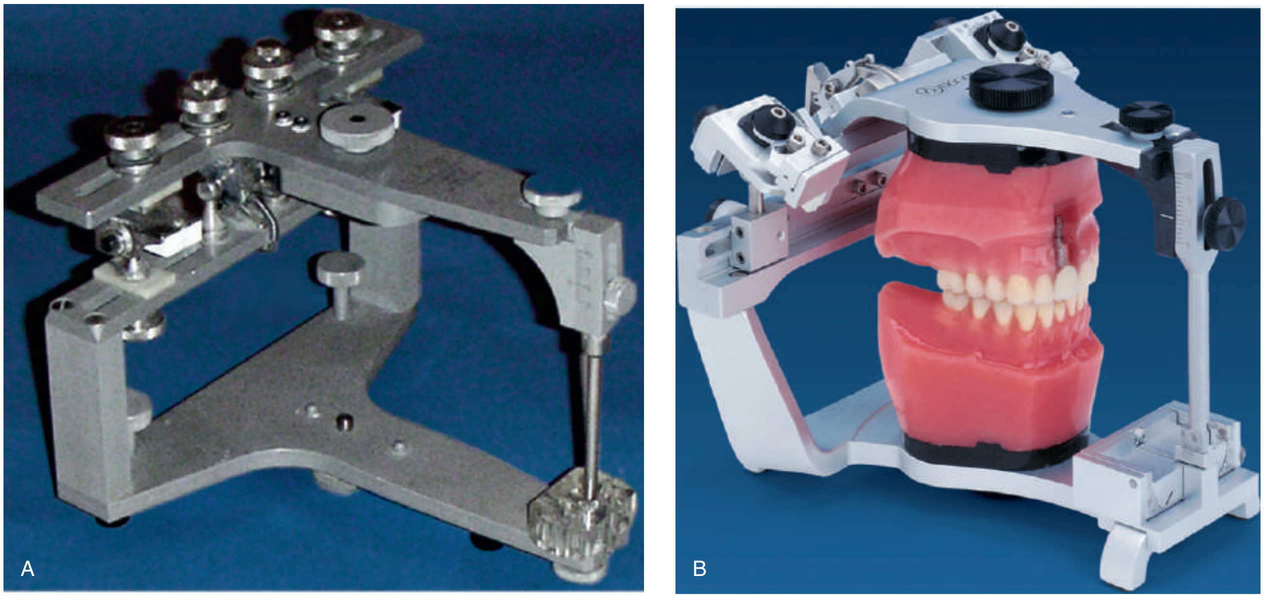

Fig. 2.25 Fully adjustable articulators. (A) The Stuart articulator. (B) The Denar D5A articulator. (Courtesy Whip Mix Corporation, Louisville, KY.)

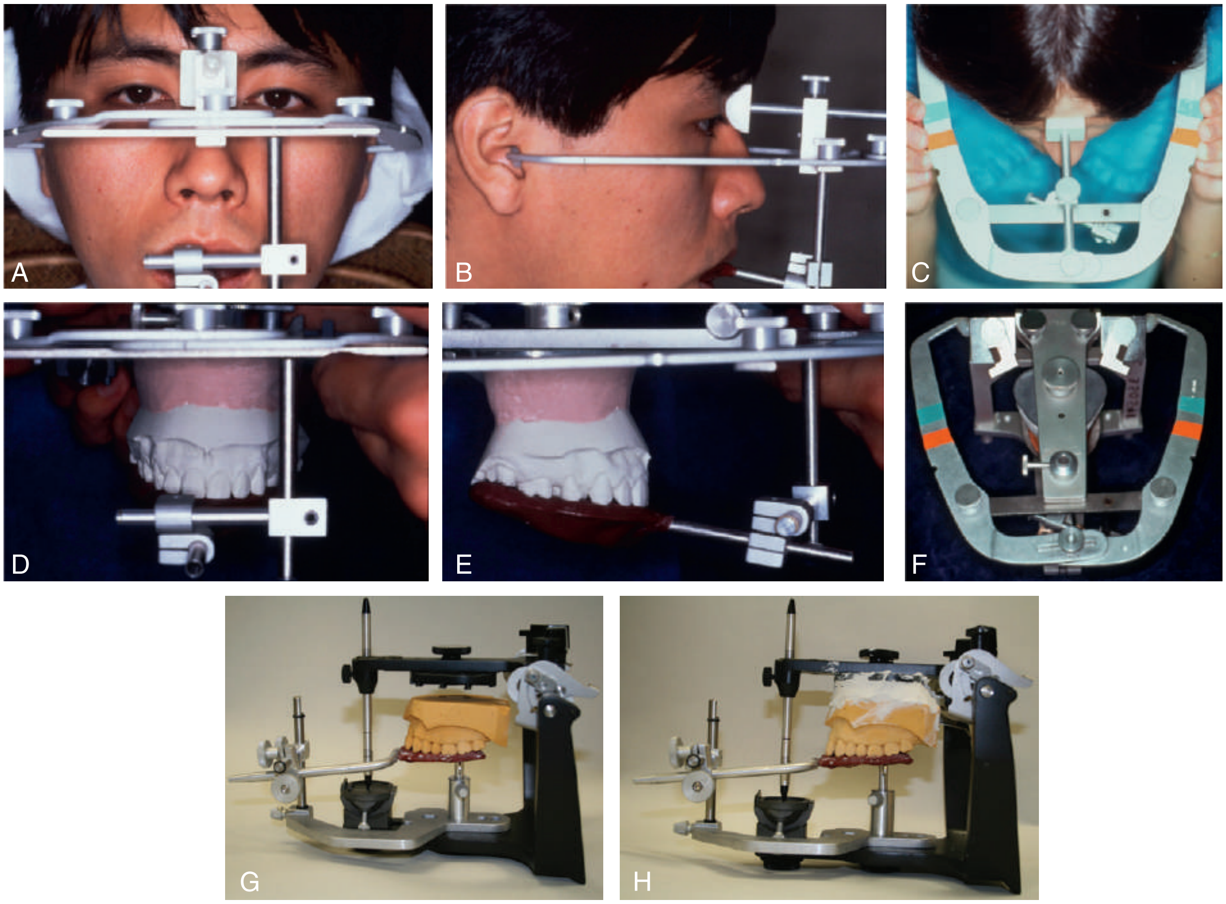

Fig. 2.26 Semiadjustable facebow transfer orients the relationship of the maxillary cast to the hinge axis. (A) Frontal view of facebow assembled on patient. (B) Lateral view, in which the nasion is used as third reference point. (C) Superior view. (D–F) Same views demonstrating the relationship to the axis of the articulator. Alternatively, a special transfer jig may be used to transfer the relationship to the instrument (G and H).

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: average axis and kinematic. Average axis 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 clinician can determine the hinge axis of the mandible 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 tray–like device, is attached to the mandibular teeth with a suitable rigid material such as polyvinyl siloxane putty or 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. 2.27). 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. 2.28). 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. To prevent skin movement from introducing any inaccuracy, the patient must be in the same position that was used when the axis was marked. A pointer

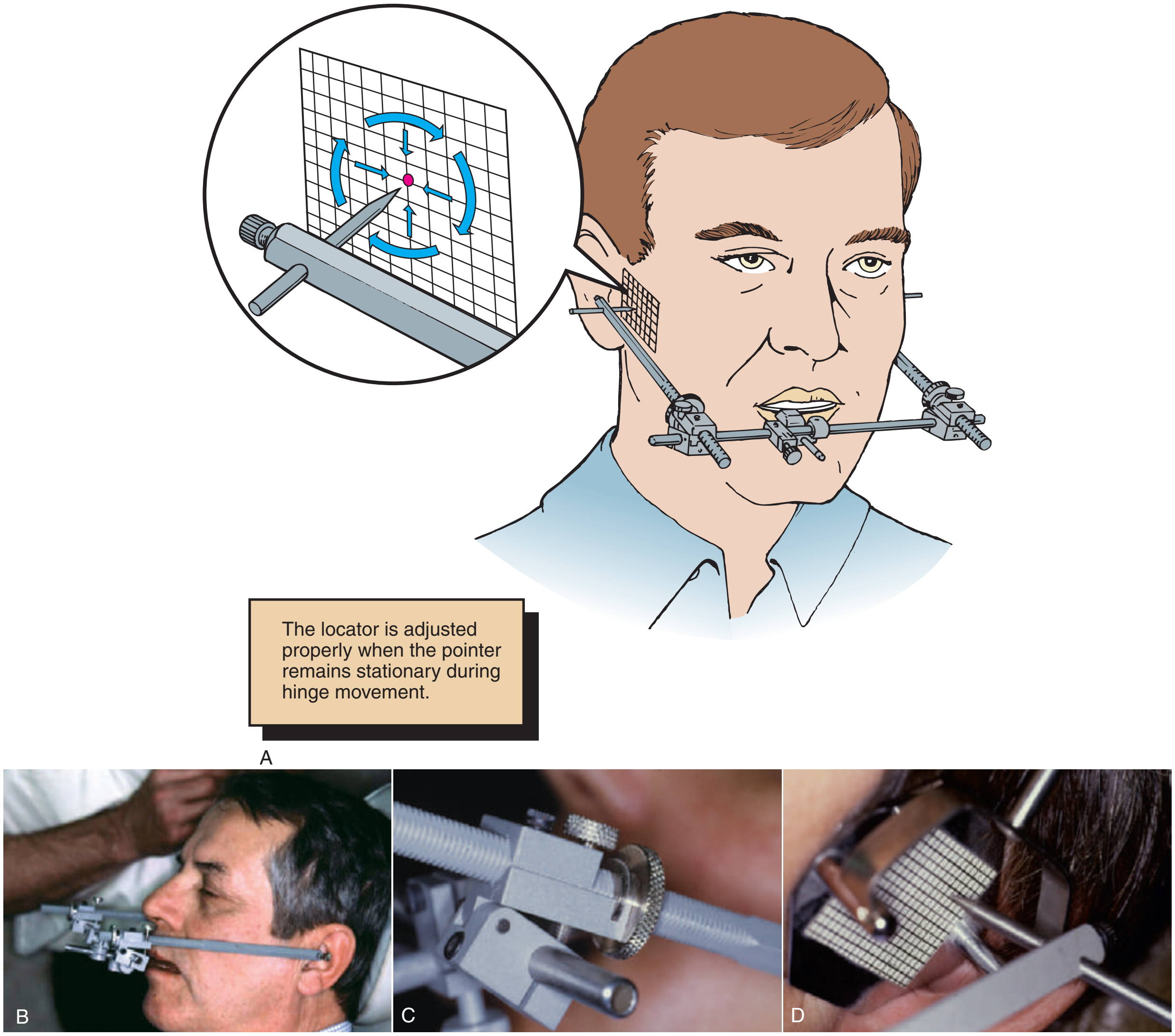

Fig. 2.27 Hinge axis recording. (A) Left and right styli are attached via a facebow to a clutch affixed to the mandibular teeth. When the mandible makes a strictly rotational movement, the stylus remains stationary if aligned with the actual axis of rotation. If the stylus is positioned forward or backward, 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 is positioned. (C) Set screws allow side arm adjustment. (D) Adjustment continues until no arcing of the pointer is seen.

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, and so its use 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 compromise the result.

Average Axis Facebow

Arbitrary hinge axis facebows (Fig. 2.29) approximate the horizontal transverse axis and rely on anatomic average values. Manufacturers design these facebows so that 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 stethoscope. Such facebows can be used single-handedly because they are self-centering and assembly is not complicated. They depict 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,[62] as can errors in the steepness of the occlusal plane.[63] 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. 2.30) 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

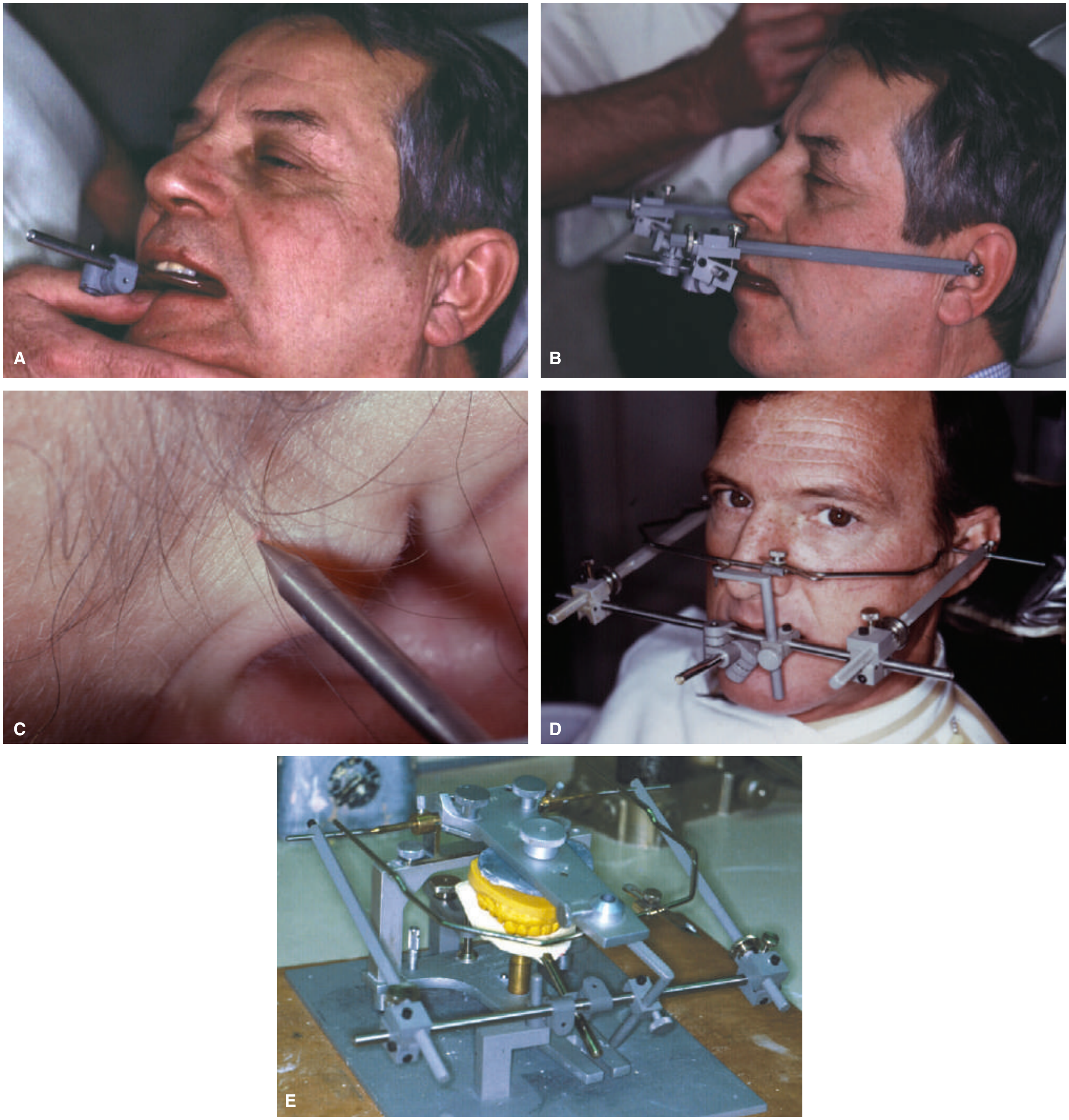

Fig. 2.28 Kinematic hinge axis facebow. (A) Clutch seated on the mandibular teeth. To separate the clutch for removal into two components, the screws on left and right sides are loosened. (B) Kinematic hinge axis facebow assembly positioned. (C) Pointers aligned with the previously marked hinge axis location. (D) Assembled kinematic hinge axis facebow. (E) Kinematic hinge axis facebow aligned on the articulator.

reference point, such as the inner canthus of the eye or a freckle or mole on the skin, is selected. After this point 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 the need to repeat the facebow determinations and 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 the need to readjust the instrument on the basis of eccentric records.
- When the articulator has been adjusted, the resulting numeric 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.

Fig. 2.29 Average axis facebows. (A) The Denar Slidematic facebow. (B) The Whip Mix QuickMount facebow. Note the nasion relator as the anterior reference point. (Courtesy Whip Mix Corporation, Louisville, KY.)

Fig. 2.30 Anterior reference point. With the Denar Slidematic facebow, a mark 43-mm superior to the incisal edge of the maxillary central incisor serves as an anterior reference point. With other systems, the infraorbital foramen or nasion is used to determine the anterior reference point. The mark serves as a reference to average anatomic values. It also allows subsequent casts to be mounted without repeated recording. (Courtesy Whip Mix Corporation, Louisville, KY.)

Facebow Transfer

Armamentarium

- Average axis facebow
- Modeling plastic impression compound
- Cotton rolls

Step-by-step procedure

1. Add modeling plastic impression compound to the facebow fork (Fig. 2.31A).
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 allow 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, repositioning of the cast can become inaccurate 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 occurred (see Fig. 2.31B). 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 occluding 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 (see Fig. 2.31C).
6. Tighten the screws securely in the correct sequence to complete the transfer (see Fig. 2.31D).
7. If the articulator has an adjustable intercondylar width, record this measurement (see Fig. 2.31E). Remove the facebow from the mouth.

The technique is slightly different with other arbitrary facebows (see Fig. 2.31F–K).

Kois Dento-Facial Analyzer. The Kois Dento-Facial Analyzer offers an esthetic solution for articulation of a maxillary cast on a semiadjustable articulator. Instead of using anatomic averages to reference the maxilla to the skull, as does an average axis

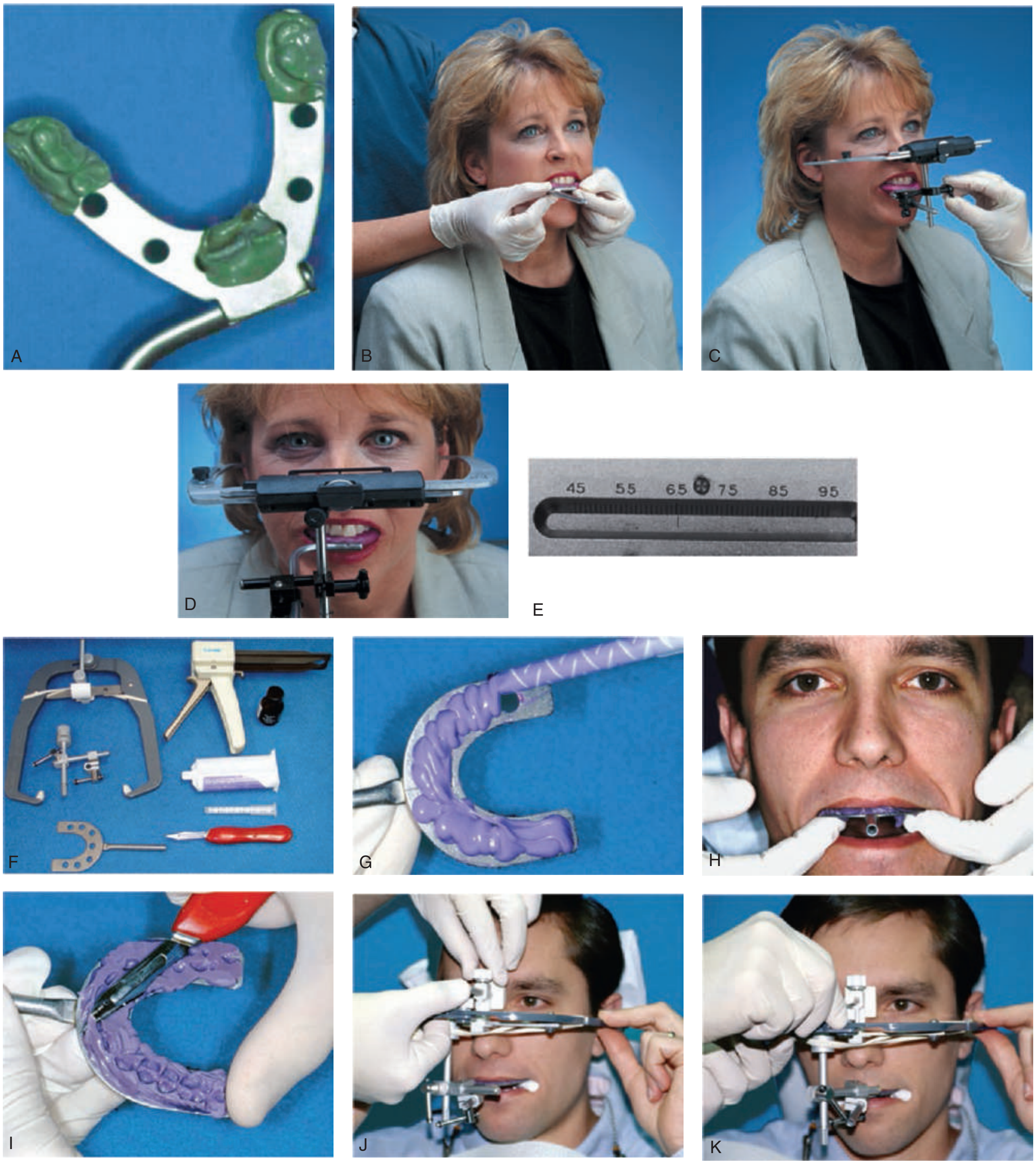

Fig. 2.31 Facebow technique. (A–E) Denar Slidematic facebow technique: (A) Indentations are obtained in modeling plastic impression compound. (B) Facebow fork is positioned. (C) Facebow is attached to facebow fork, and toggles are tightened. (D) Transfer is complete. (E) Width measurement is read from the top of the facebow. (F–K) Whip Mix QuickMount facebow technique: (F) Armamentarium. (G) Automixed elastomer is applied to the transfer fork. (H) The facebow fork is adapted to the maxillary teeth. (I) The obtained record is trimmed with a sharp blade to facilitate seating. (J) The nasion relator is positioned. (K) Knobs and toggles are tightened. (Courtesy Whip Mix Corporation, Louisville, KY.)

facebow, it relates the maxillary incisal edge position, maxillary occlusal plane, dental midline, and patient's facial midline to the horizon (Fig. 2.32). Once the record has been made, a patient's maxillary cast can be mounted to the Panadent articulator using a mounting platform (Fig. 2.33). The mounting platform is used as a horizontal reference to communicate to a dental laboratory technician for maxillary incisal edge position, dental midline, and occlusal plane location (Fig. 2.34). If a digital format is wanted, the casts can be digitized and/or printed casts can be used (Fig. 2.35).

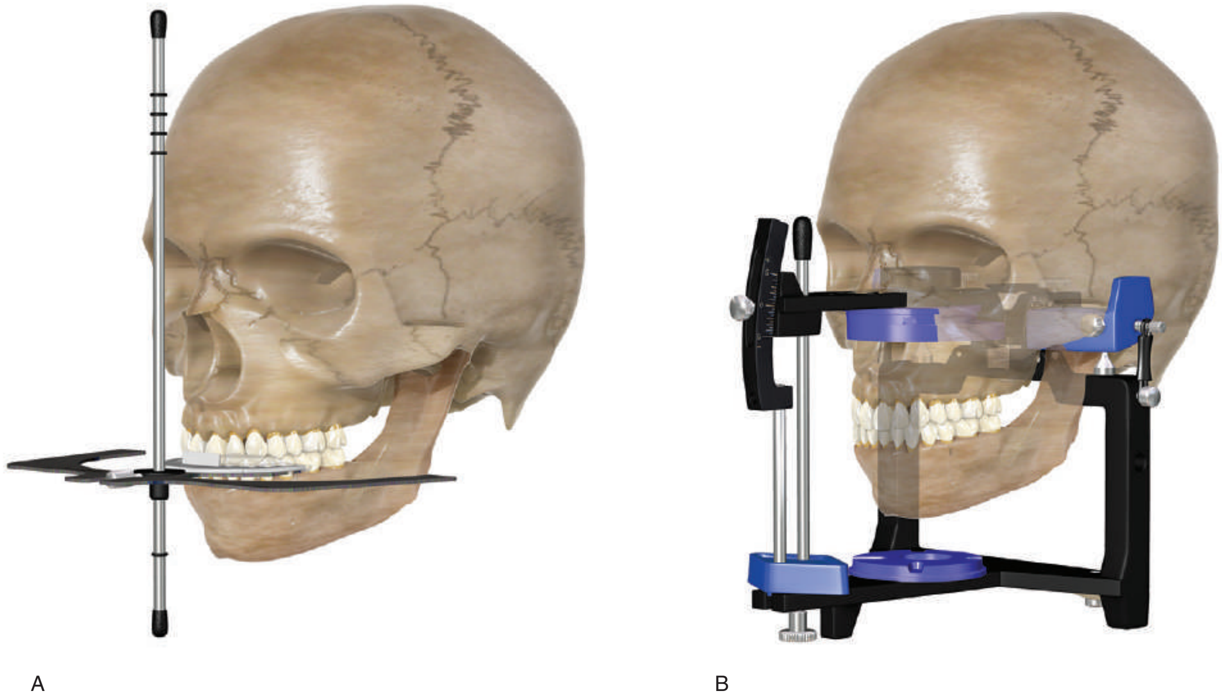

Fig. 2.32 (A) Kois Dento-Facial Analyzer relates the maxillary occlusal plane to the horizontal plane. The vertical analyzing rod is used to record the facial midline. (B) With the Kois Dento-Facial Analyzer record, the patient's dentition is able to be transferred to the dental articulator so that the casts are esthetically positioned just as the dentist sees the patient. The dental laboratory technician and the dentist are able to see the patient from the same view to communicate tooth position. (A and B Courtesy Thomas Lee, President of Panadent Corp.)

Fig. 2.33 The maxillary cast is mounted on the dental articulator with the Kois mounting device. The cast is position into the center of the articulator (100 mm from the terminal hinge axis). (Courtesy Thomas Lee, President of Panadent Corp.)

Fig. 2.34 Clinical treatment of a patient with an irregular occlusal plane and how it is referenced to the horizontal plane. Note how the horizontal plane contacts only the one tooth that has the most inferior location (here the left first molar). An esthetic mounting of the maxillary cast helps to communicate to the dental laboratory technician how to position a straight maxillary dental midline without a cant.

Centric Relation Record

A CR record (Fig. 2.36) 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

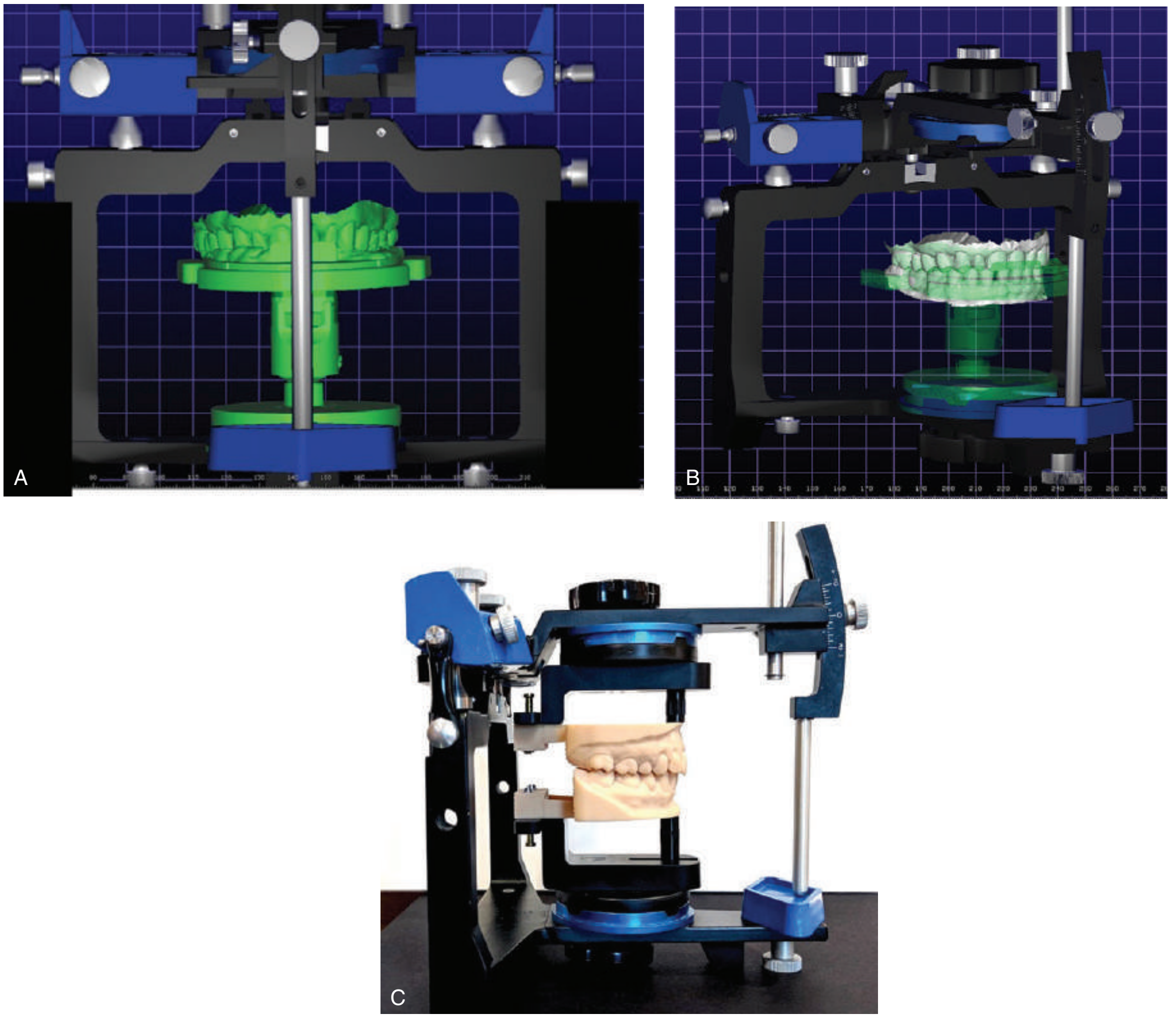

Fig. 2.35 (A and B) Examples of digital casts on a virtual Panadent articulator. (C) Example of the Panadent mounting system for printed casts. (A–C Courtesy Thomas Lee, President of Panadent Corp.)

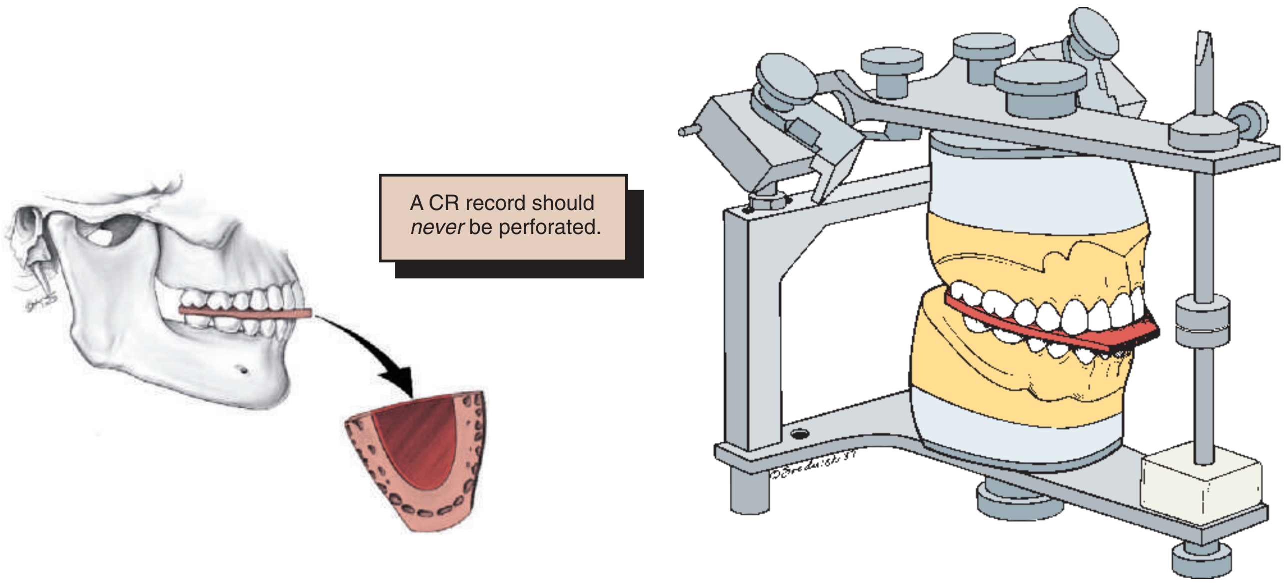

Fig. 2.36 A centric relation (CR) record transfers the tooth relationships at CR from the patient to the articulator.

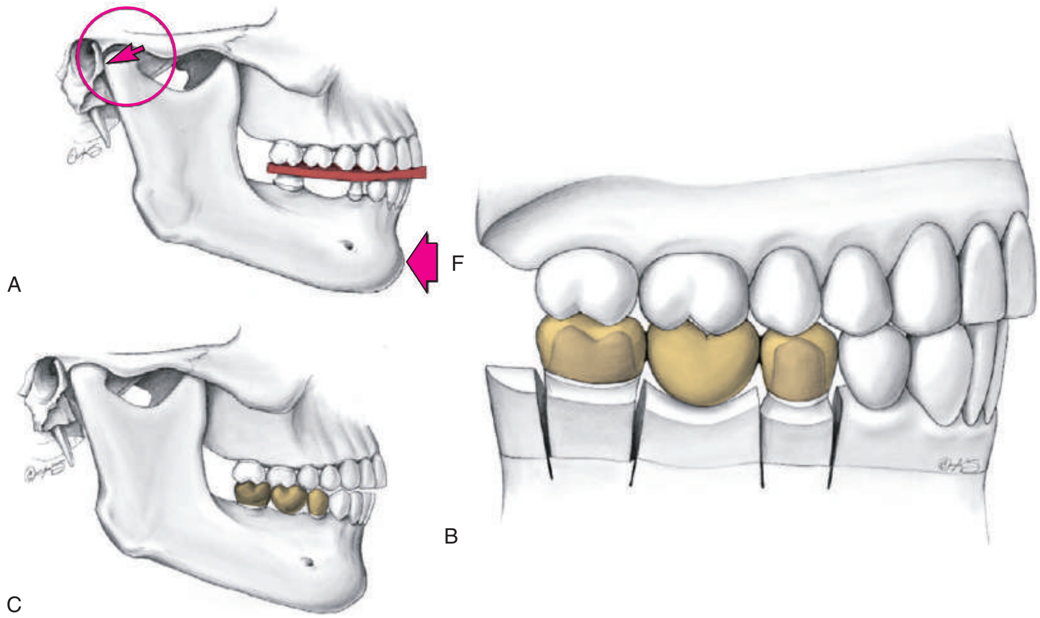

Fig. 2.37 Incorrect centric relation recording. (A) If the mandible is forced backward *(F)*, the condyles are not in their most superior position but are moved backward and downward *(small arrow)*. (B) Any restorations made on casts related with this centric relation record are in supraclusion when evaluated in the mouth. (C) Note the relationship of the anterior teeth.

which the condyles articulate with the thinnest avascular portion of their respective discs, with the condyle-disc 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. 2.27). 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 the clinician can determine 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 average axis facebow is used, any arcing movement results in some degree of inaccuracy. The use of either type of facebow is subject to small errors, which can be minimized by keeping the record thin.[64,65] However, it is essential that the teeth not perforate the record. Any tooth contact during record fabrication can cause mandibular translation (because of neuromuscular protective reflexes governed by mechanoreceptors in the periodontium) and thereby render the resulting articulation useless.

Jaw Manipulation

Accurate mounting of casts depends on the dentist's precise manipulation of the patient's mandible. The condyles should remain in the same place throughout the opening-closing arc. Trying to force the mandible backward leads to downward translation of the condyles, and restorations made to such a mandibular position are in supraclusion at the evaluation stage (Fig. 2.37).

The load-bearing surfaces of the condylar processes, which face anteriorly, should be manipulated into apposition with the mandibular fossae of the temporal bones; the disc should be 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 (1973)[66] is recommended as a reproducible technique[67] that can be reliably learned.[68] In this technique, the dental chair is reclined, and the patient's head is cradled by the dentist. With both thumbs on the patient's chin and the fingers resting firmly on the inferior border of the patient's mandible (Fig. 2.38A), the dentist exerts gentle downward pressure on the thumbs and upward pressure on the fingers, manipulating the condyle-disc assemblies into their fully seated positions in the mandibular fossae. Next, the mandible is carefully hinged along the arc of terminal hinge closure. In the single-handed approach (see Fig. 2.38B), the fingers exert upward pressure. In this way, it is more difficult to ensure that the condyles are properly located, although this technique does allow the other hand to hold the record.

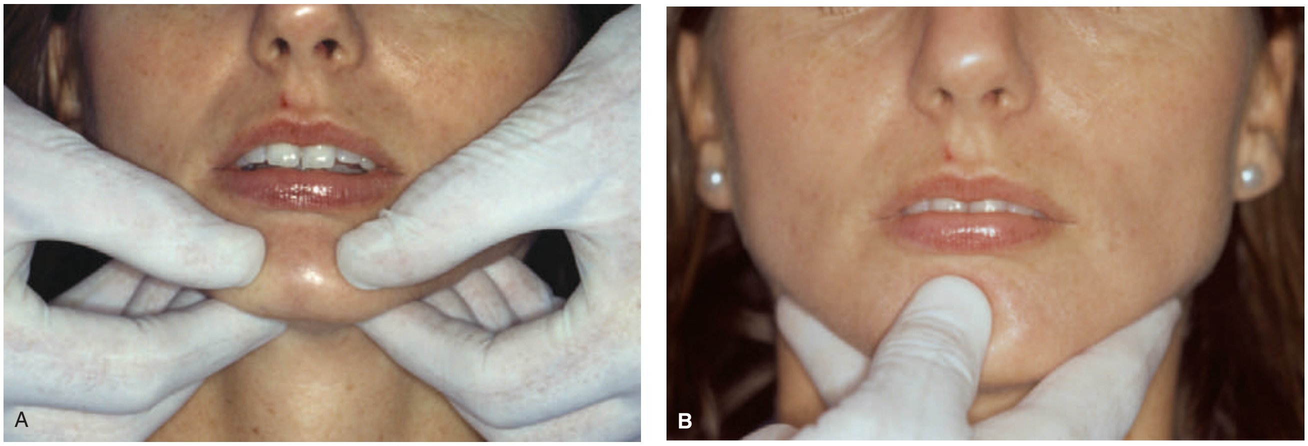

Fig. 2.38 Manipulating a patient's mandible into centric relation: the bimanual technique (A) and the single-handed technique (B). Note the position of the dentist's thumbs and fingers on the mandibular border.

Anterior Deprogramming Device

In some patients in whom CR does not coincide with MI, resistance may be encountered when the mandible is hinged. 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, these reflexes disappear, and manipulation becomes easier. The teeth can be kept apart with cotton rolls, a plastic leaf gauge (Fig. 2.39), or a small anterior programming device made of autopolymerizing acrylic resin (also known as a *Lucia jig*).[69]

If the mandible cannot be manipulated satisfactorily after an anterior programming device has been in place for 30 minutes, the patient is likely to have marked neuromuscular dysfunction. Normally, this is relieved by 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 malleable material, such as interocclusal wax, provided the record is properly reinforced. Most studies have shown considerable variability among various registration materials and techniques,[70] and so particular care is needed with this procedure.

Reinforced Aluwax Record

Reinforced Aluwax is a malleable material for recording the CR position (Fig. 2.40A). This type of record, originally described by Wirth (1971)[71] and Wirth and Aplin (1971),[72] is reliable and the technique has provided consistent results.[73,74]

Armamentarium

- Heat-retaining wax sheet (i.e., Aluwax)
- Soft metal sheet (No. 7 Ash's soft metal)
- Hard pink wax
- 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 (see Fig. 2.40B). Allow the patient to close lightly, and make cuspal indentations of the mandibular teeth. 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 hard pink baseplate wax to the mandibular anterior region of the record (see Fig. 2.40C), add soft metal sheet to reinforce the palatal area, and seal along the periphery with sticky wax (see Fig. 2.40D).
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 another layer of baseplate wax (see Fig. 2.40E and 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 of 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 (see Fig. 2.40G), repeating several times to ensure reproducibility. Remove the wax record, and rechill it in ice water until the anterior indentations are hard.
8. Add a small amount of heat-retaining wax in the mandibular posterior region (see Fig. 2.40H), and reseat the record (see Fig. 2.40I). 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

Fig. 2.39 An anterior deprogramming 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. (C) The completed device 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. (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 view through the device is illustrated. (I) and (J) A plastic leaf gauge may be used to prevent habitual closure into maximal intercuspation.

close lightly. The baseplate wax prevents excessive closure. Excessive force may distort the record or flex the mandible.[75] 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.

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 becomes distorted easily. Therefore, if the patient's mouth is not guided into exactly the same position, this problem becomes readily apparent (see Fig. 2.40J).

Fig. 2.40 Centric relation recording technique. The reproducibility of the centric relation (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 No. 7 Ash's soft metal 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) Additional wax is added to the area of the first molars. (I) Hinge closure is repeated. (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 CR record is completed. (Courtesy Dr. J.N. Nelson.)

Once the completed record has been obtained with adequate but fairly shallow indentations for all cusps (see Fig. 2.40K and L), the same arcing motion has been reproduced four times, confirming that the CR position has been accurately captured.

CR records can be generated with different techniques and materials. Hard pink baseplate wax and preformed blue wax wafers with a slight taper from front to back are especially popular choices for these records (Figs. 2.41 and 2.42).

Fig. 2.41 Centric relation recording technique with hard pink baseplate wax. (A) Armamentarium. (B) After being softened and folded into a double layer, the record is trimmed to the appropriate shape. (C) Hinge movement is practiced with the patient. (D) The record is adapted to the maxillary arch. (E) The adaptation ensures shallow indents of the cusp tips from the canine posteriorly. (F) The record is trimmed through the buccal cusp tips of the premolars and molars. (G) The trimmed record has this appearance. (H) The wax is bent over the facial aspect of the canine teeth. The patient stabilizes the record while the hinge movement is reproduced. (I) The frontal view of the completed record has this appearance. (J) Note the shallow indentations, which allow accurate seating of the cast.

Fig. 2.42 Centric relation recording technique with preformed wax wafer and leaf gauge. (A) Preformed wax and a leaf gauge are used for occlusal registration. (B) The leaf gauge is positioned to achieve separation of the posterior teeth. (C) Lateral aspects of the wax are softened in a water bath. (D) The wax record is adapted to the maxillary teeth. (E) The record is trimmed through the buccal cusp tips. (F) The wax is resoftened. (G) The patient's mandible is guided into centric relation, and indents of the mandibular cusp tips are obtained. (H) The record is chilled with cold water. (I) Excess wax can be removed with a sharp blade until only indents of the cusp tips remain. (J) After clinical verification, the record is stored in cold water for subsequent use in the laboratory.

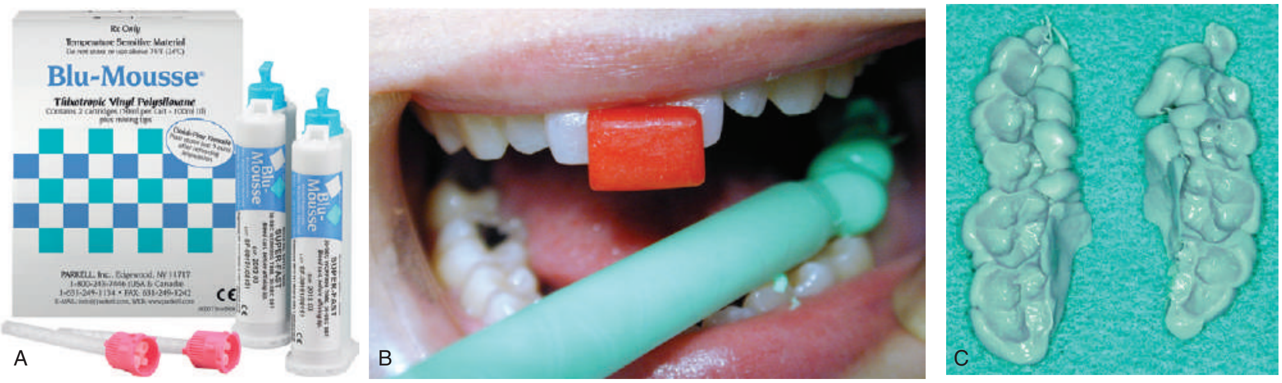

Fig. 2.43 Centric relation recording. (A) Elastomeric material is used for centric relation recording. (B) Once mandibular quadrants are coated, the dentist uses an anterior resin jig (see Fig. 2.26) to ensure that a reproducible recording position is obtained. The patient remains occluded until the material has set. (C) This is the appearance of the record before trimming. (A, Courtesy Parkell, Inc., Edgewood, NY.)

Anterior Deprogramming Device With Elastomeric or Zinc Oxide–Eugenol Record

Armamentarium

- Autopolymerizing resin
- Petroleum jelly
- Elastomeric material
- Syringe
- Scalpel blade

Step-by-step procedure

1. Fabricate an anterior programming device from autopolymerizing 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 deprogramming device should follow the lingual contours of the teeth. After trimming, it should result in separation of the posterior teeth (see Fig. 2.39H). 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 allow 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. 2.43A). (The Automix materials are convenient.)
6. Dry the occlusal surfaces of the teeth with an air compressor, and, using a syringe, apply the material onto the occlusal surface of the mandibular arch (see Fig. 2.43B).
7. Guide the patient's mandible into hinge movement until the mandible comes to rest on the anterior deprogramming device. Have the patient maintain this position until the material has set.

Fig. 2.44 Gauze mesh cloth forms with plastic holders, and zinc oxide–eugenol paste can be used instead of elastomeric paste.

8. Remove the record from the mouth (see Fig. 2.43C), 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 (ZOE) occlusal registration paste can be used (Fig. 2.44). The step-by-step procedure is the same as that for the elastomeric material, but 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. However, care must be taken to position the frame that holds the cloth form so that it does not interfere with the closure movement.

Alternative materials for the recording medium include impression plaster or autopolymerizing resin. With all these

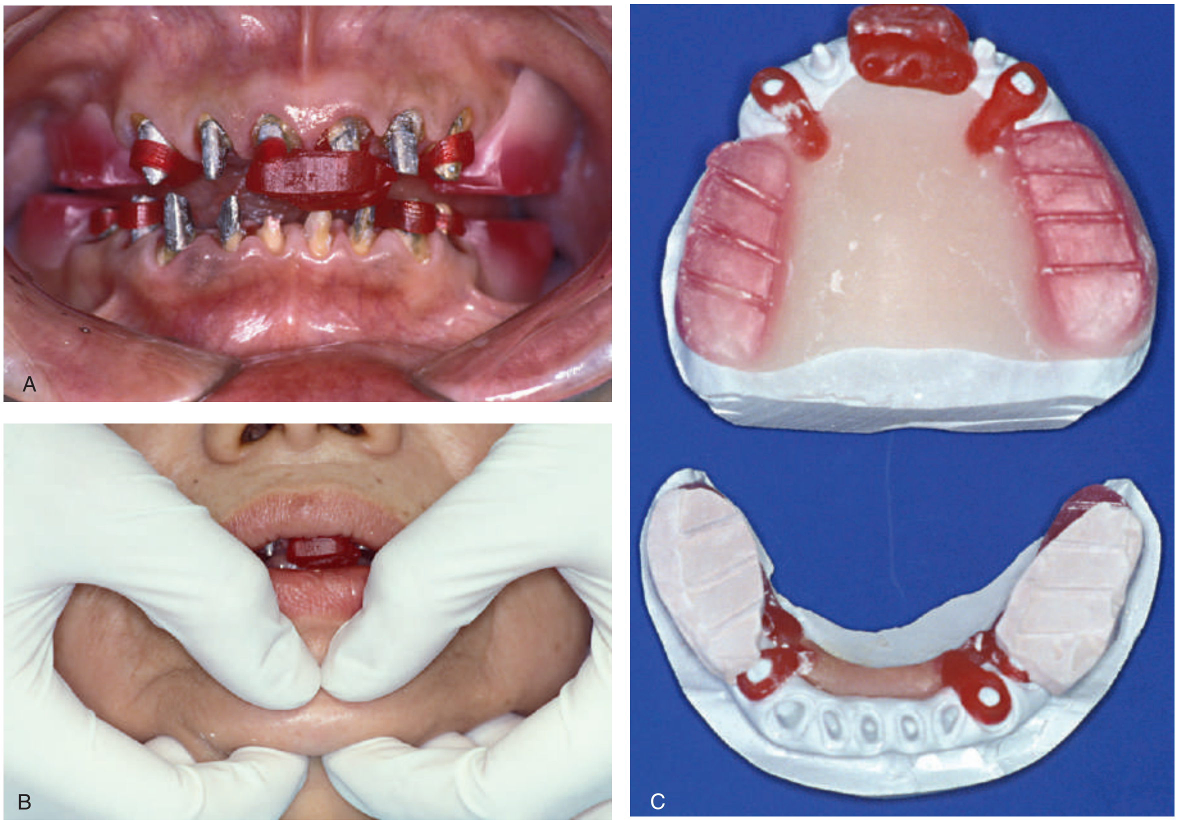

Fig. 2.45 (A–C) Acrylic resin record bases used to mount partially edentulous casts.

materials, accuracy depends on complete seating of the casts into the recording medium. Seating is often prevented by 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. 2.45). 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 Optical Scans and Casts

Virtual articulation. Currently, digital scans can be mounted in either maximal intercuspation, centric occlusion, or CR. The selection of mounting method is dependent on the treatment position for the future restoration: CR or maximal intercuspation. To mount digital scans in CR, a leaf gauge or other anterior jig may be used to find CR at the vertical dimension of which the case will be restored (Fig. 2.46). Once CR at the desired vertical dimension has been obtained, an occlusion or "bite" scan made from the most posterior tooth to the canine is captured bilaterally. The right and left side scan will mount the scan of the maxillary arch to the mandibular digital scan at the given vertical dimension and CR. The leaf gauge itself should not be scanned during the occlusion scans. If a new vertical dimension is unknown or the planned restorative work will be accomplished in maximal intercuspation, the occlusion scan should be done while the teeth are in maximal intercuspation. After the applicable interarch scan has been captured, a digital mandibular movement video can be created. The following technique is recommended for either maximal intercuspation or CR mountings.

Step by step process for digital mandibular movement video

1. Place leaves from a leaf gauge or preferred anterior jig between central incisors until centric occlusion is determined at the desired vertical dimension. If the patient will be restored in maximal intercuspation, the leaf gauge is not used.
2. Before capturing a video, working, nonworking, and protrusive mandibular movements are rehearsed with the patient.
3. Once the patient is well rehearsed, place the scanner head between the buccal surfaces of the posterior teeth and the cheek. Frame the computer image so that both dental arches are centered in the screen.
4. Start video recording. Remove the leaf gauge and instruct the patient to close into maximal intercuspation to record any horizontal or vertical slides between centric occlusion and maximal intercuspation.

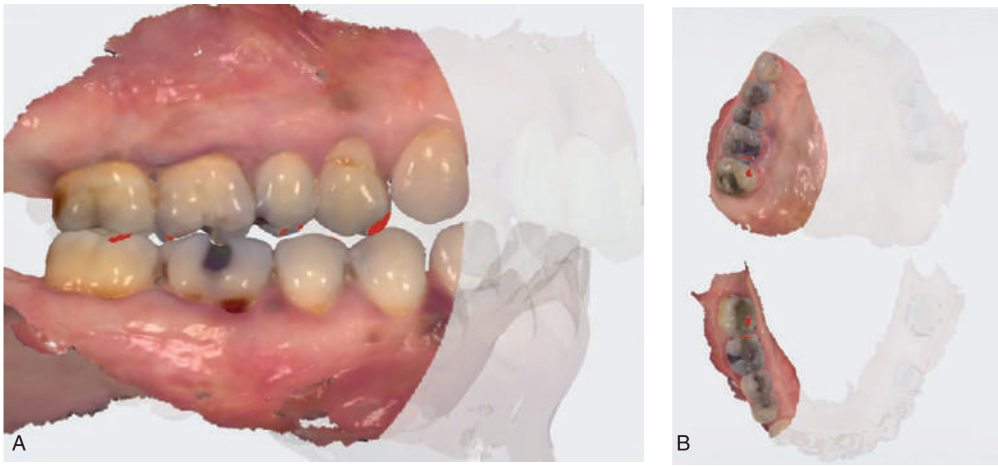

Fig. 2.46 The digital scans can also be articulated in centric relation. (A) The red marks highlight the centric occlusion marks during a digital video. (B) The digital models can be opened for further analysis of the red marks indicating the centric occlusal contacts.

5. Do not turn the recording off, and keep the head of the scanner very still. From maximal intercuspation, have patient protrude his or her mandible until the mandibular incisal edges meet the maxillary incisal edges. Once the mandible is in protrusion, instruct the patient to return to maximal intercuspation.
6. With the scanner head still in the same position, instruct the patient to go into a mandibular right and left working movement. With each mandibular movement, instruct the patient to return to maximal intercuspation.
7. Once all mandibular movements are recorded, stop the video.
8. Watch the video to confirm that the tooth contacts are identical in all mandibular movements to those of the patient.

Traditional maxillary cast. The maxillary cast (Fig. 2.47) 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.

Traditional 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. 2.48) is then carefully seated in the record, and each cast is checked for stability. The maxillary and mandibular casts can be luted together with sticky wax and either metal rods or pieces of wooden tongue blade. 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 should be made to smooth the stone until it has fully set.

Evaluation. Accuracy is crucial in both CR and MI. Before the articulator controls are adjusted, the dentist must confirm the accuracy of CR by comparing the tooth contacts on the casts with those in the patient's mouth (Fig. 2.49). 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. To transfer their exact location, the patient should 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, MI of the articulated casts should be examined. MI 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 (Whip Mix Corporation, Louisville, Ky.) (Fig. 2.50).

Traditional analog posterior articulator controls. The advantages and disadvantages of the different articulators are summarized in Table 2.3. 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 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.[76]

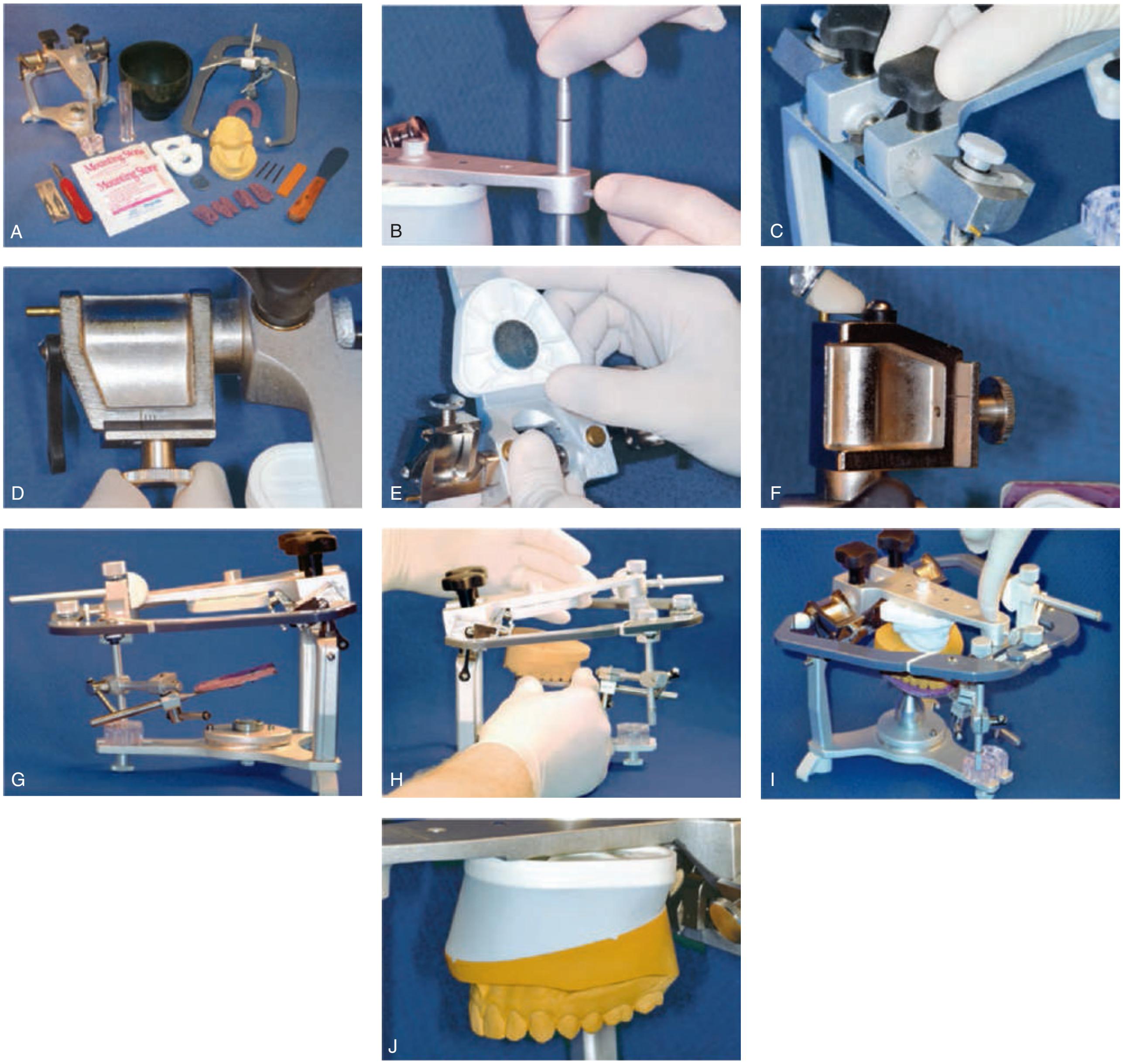

Fig. 2.47 Mounting the maxillary cast on a Whip Mix articulator. (A) Armamentarium. (B) The incisal pin is removed. (C) The condylar inclination is adjusted to the facebow setting. (D) The side shift is set to zero. (E) A mounting plate is attached. (F) The facebow earpieces are attached to the condylar elements. (G) The facebow is attached to the articulator. (H) The scored maxillary cast is positioned on the facebow fork, and the cast is prewetted. (I) The 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 Whip Mix Corporation, Louisville, KY.)

Average (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 in relation to the Frankfort horizontal plane (FHP) and the midsagittal plane. For instance, an average value of 1.0 mm has been reported[77] for immediate side shift.

When average 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, the use of 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).

Traditional eccentric interocclusal recordings. Eccentric interocclusal records (check bites) have been recommended[78] for setting the posterior controls of a semiadjustable articulator. These consist of 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

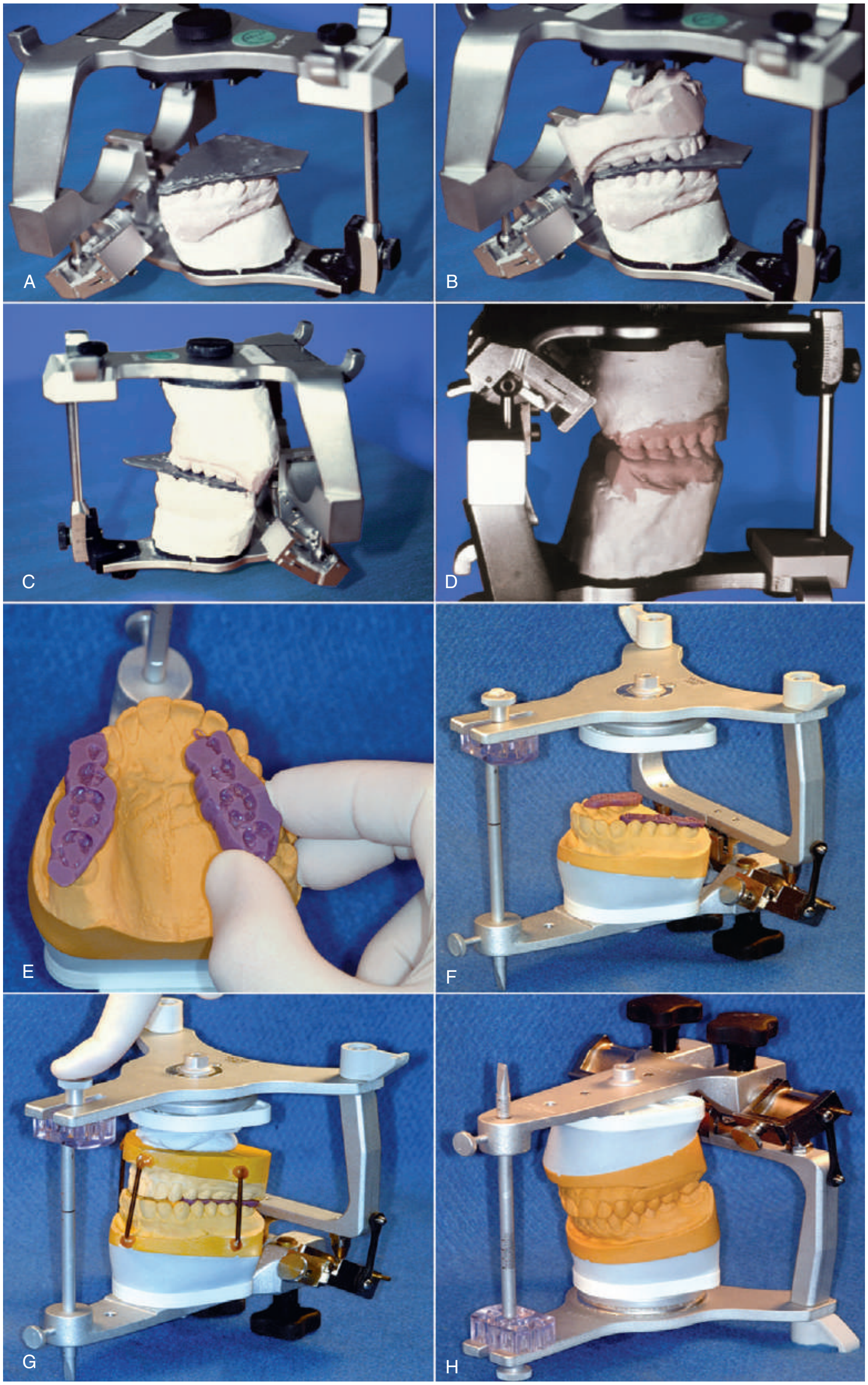

Fig. 2.48 Mounting the mandibular cast. (A–D) Denar articulator: (A) The centric relation (CR) record is positioned on the inverted maxillary cast. (B) The incisal guide pin is adjusted, and the mandibular cast is oriented in the record. (C) The cast is attached with mounting stone. (D) When the pin is raised, the casts contact in CR closure. (E–H) Whip Mix articulator: (E) Elastomeric CR records are trimmed. (F) CR records are 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) Mounting is completed. (E–H, Courtesy Whip Mix Corporation, Louisville, KY.)

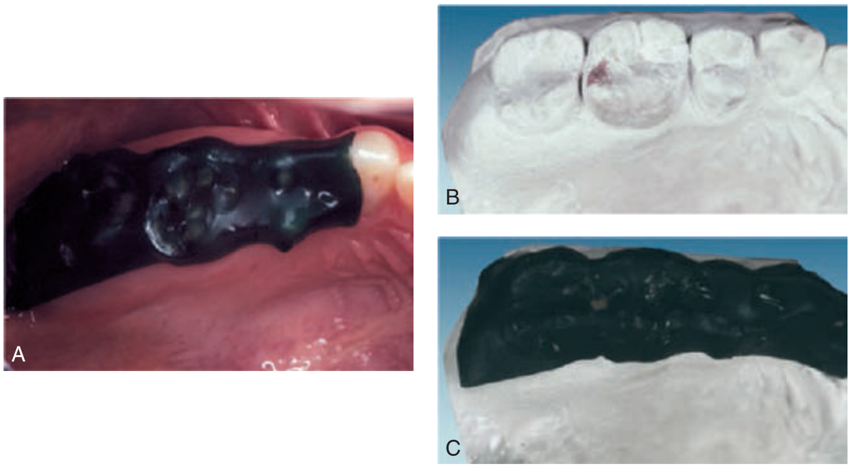

Fig. 2.49 Verifying mounting accuracy. (A) Occlusal indicator wax is adapted to the maxillary teeth, and the patient's mouth is guided into centric relation closure. (B) The cast contacts are marked with thin articulating film. (C) If the mounting is accurate, the markings correspond to perforations in the wax.

Fig. 2.50 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. By examining these marks, the dentist can compare successive centric relation records. (Courtesy Whip Mix Corporation, Louisville, KY.)

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. 2.51). 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 path 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 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. The author and colleagues have found guiding the patient helpful in obtaining the records easily, although unguided records have been equally accurate.[79]
2. Adapt a wax record to the maxillary arch (Fig. 2.52A), and guide the patient's mouth into a protrusive position. Have the patient close to form indentations in the recording medium (see Fig. 2.52B). 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 (see Fig. 2.52C and D).
5. Repeat this step for the other lateral excursion.
6. Mark each record to facilitate its identification when it is used to adjust the posterior articulator controls (see Fig. 2.52E).

Simplified pantographs. A simplified pantograph (Fig. 2.53) 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 assembled quickly. Numeric 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 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

TABLE 2.3 Articulator Selection for Fixed Prosthodontics

FULLY ADJUSTABLE	SEMIADJUSTABLE		NONADJUSTABLE		UNMOUNTED CASTS	
Denar D5-A	**Arcon**	**Nonarcon**	**Large**	**Small**	**Arch**	**Quadrant**
Stuart	Denar Mark II	Hanau 96H20				
TMJ	Whip Mix	Dentatus				
	Hanau 183-2					
More	←	Diagnostic information provided			← Less	
More	←	Occlusal information conveyed to laboratory			← Less	
More	←	Time and skill needed at initial appointment			← Less	
Less	→	Chair time needed before cementation			→ More	
Multiple opposing restorations	Diagnostic assessment and treatment of most patients requiring fixed prosthodontics		Large articulators for single restorations; some adjustment necessary		Only when occlusal influence minimal	
No anterior guidance			Small hinge articulator only when occlusal influence minimal			
Extensive occlusal pathology						

TMJ, Temporomandibular joint.
Modified from Rosenstiel SF. Occlusal relationships, registration, and articulation. In: Rayne J, ed. *General Dental Treatment*. London: Kluwer; 1983.

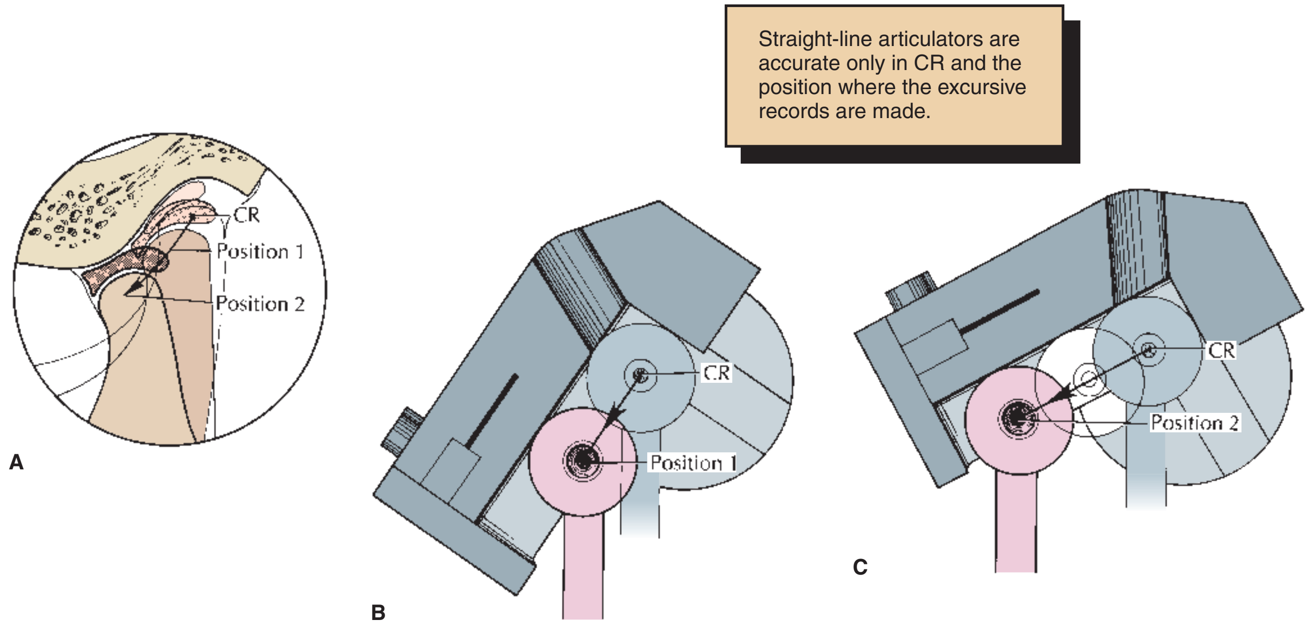

Fig. 2.51 (A) The typical condylar path is curved, with its steepest inclination near centric relation. If a semiadjustable articulator with a straight condylar path is programmed from an eccentric record, very different values will be obtained (depending on where the record is made) from what is actually performed by the mandible. (B) Record made at position 1. (C) Record made at position 2.

depends on the measurements obtained with a simplified pantograph (Fig. 2.54).

Pantographic recordings. Fully adjustable articulators are usually programmed on the basis of a pantographic recording (Fig. 2.55). 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 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. 2.56). A simpler, although less accurate, procedure is to measure the tracings directly and adjust the condylar controls without transferring the recordings.

Electronic pantograph. The electronic pantograph (the Cadiax Compact 2 System) is designed to record and measure functional and border movements (Fig. 2.57). It consists

Fig. 2.52 Eccentric interocclusal records. (A) Adaptation of wax to the maxillary arch. (B) Protrusive record. (C and D) Guiding the patient's mandible into left and right lateral excursive movements. Records are made in the left and right canine edge-to-edge positions. (E) The completed records.

Fig. 2.53 (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–C, Courtesy Panadent Corporation, Colton, CA.)

of upper and lower bows that record and measure mandibular movements and has been shown to provide valid and reliable measures of condylar determinants.[80]

Stereograms. Another approach to reproducing posterior condylar controls is to cut or mold a 3D recording of the jaw movements. This "stereogram" 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. 2.58). 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 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 the dentist is 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 (Fig. 2.59A). The technique

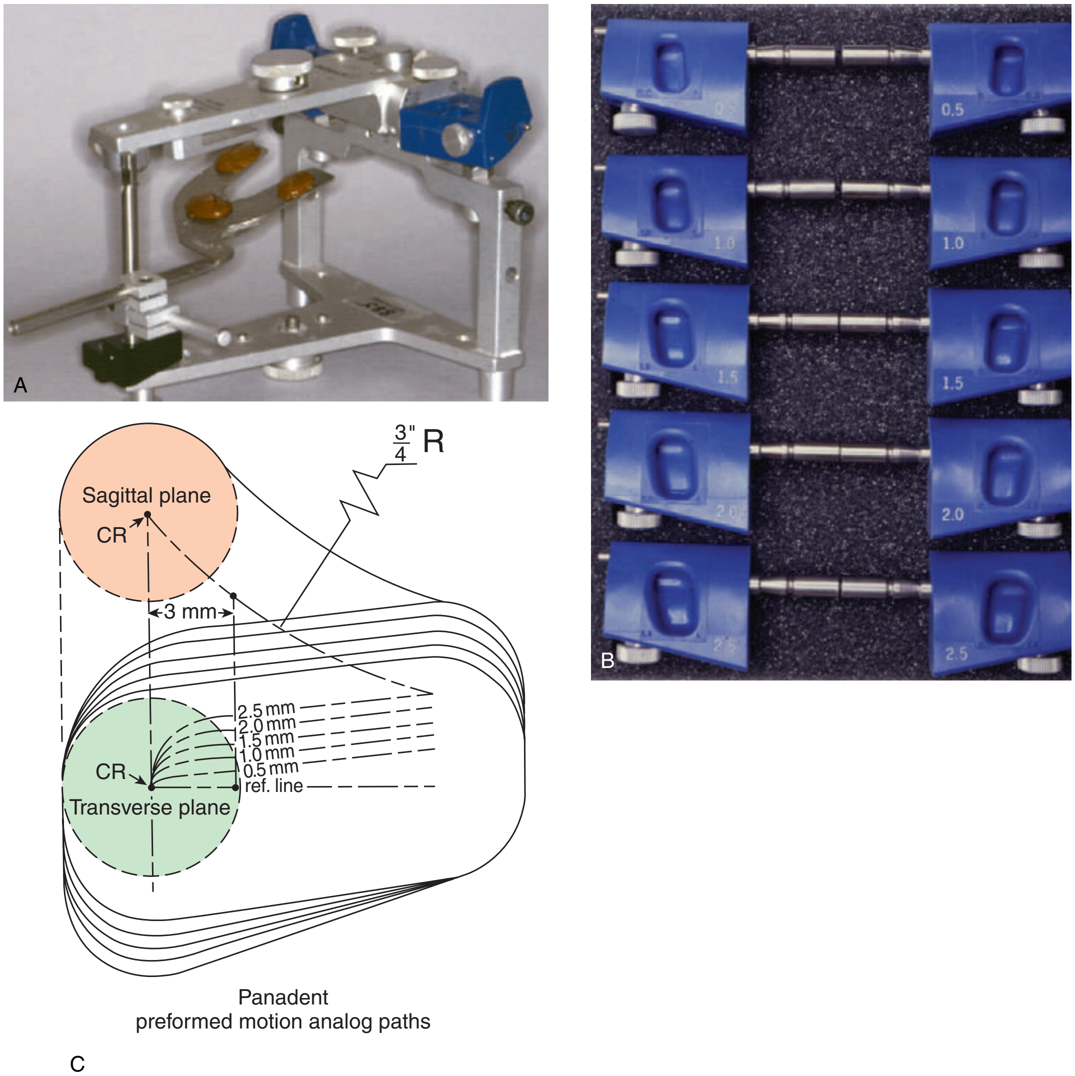

Fig. 2.54 (A) The Panadent PCH Articulator with support legs. (B) Fossa blocks (motion analogs) with different amounts of Bennett movement are selected from the simplified recorder or lateral interocclusal records. The blocks are rotated to the correct condylar inclination. (C) Schematic showing the sagittal and transverse planes of the available motion analog blocks. *CR*, Centric relation; *3/4-inch R*, 3/4-inch radius of fossa curvature. (A–C, Courtesy Panadent Corporation, Colton, CA.)

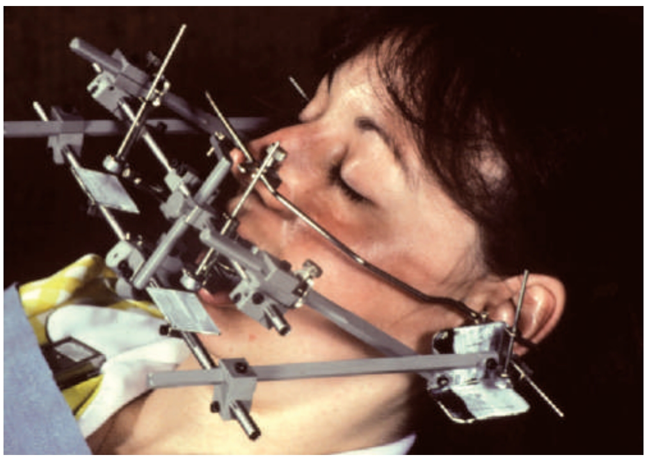

Fig. 2.55 The Stuart instrument, used to make pantographic recordings. (Courtesy Drs. R. Giering and J. Petrie.)

is similar to that for stereographic recording used in setting the posterior controls of some articulators.

Custom Guide Table Fabrication

Armamentarium

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

Step-by-step procedure

1. After the pin is raised and lubricated, moisten the plastic incisal table with acrylic resin monomer to ensure a good bond (see Fig. 2.59B–D).
2. Mix a small quantity of resin and mold it to the table (see Fig. 2.59E).
3. Raise the incisal pin approximately 2 mm from the table, cover its tip with petrolatum, and close it into the soft resin (see Fig. 2.59F and G).

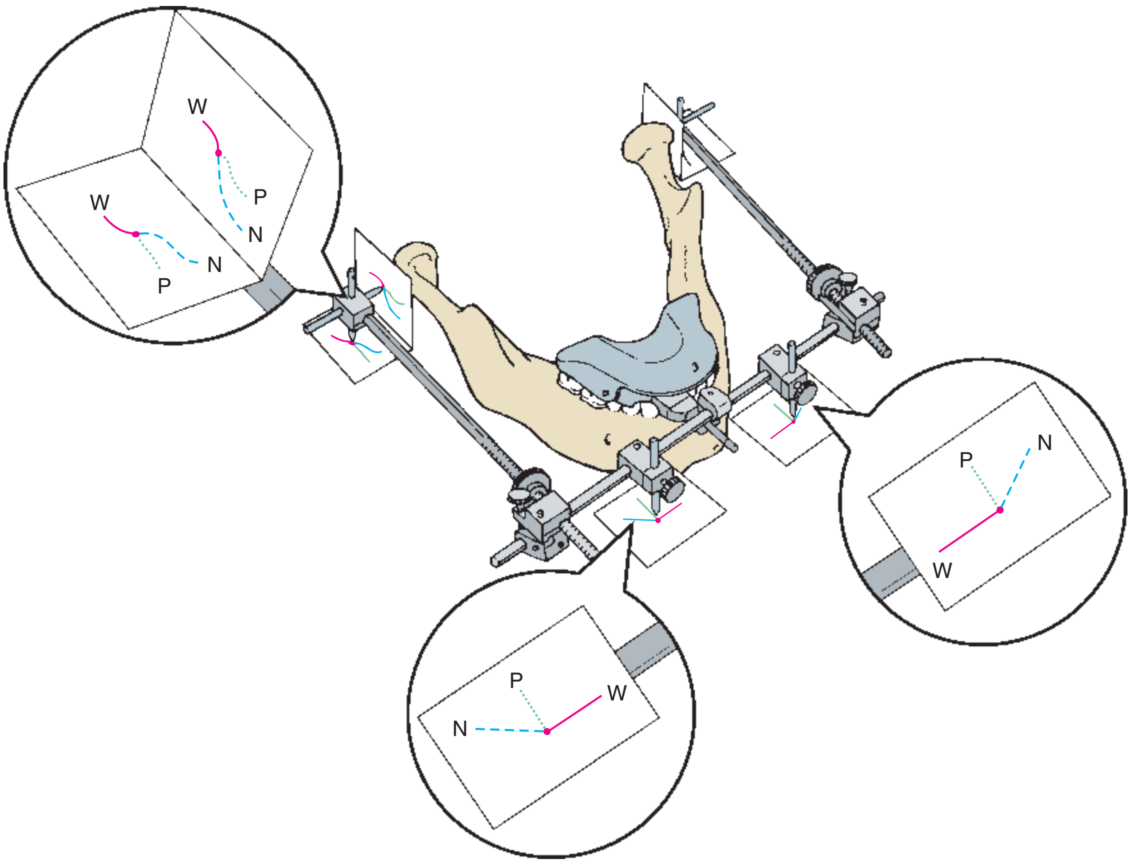

Fig. 2.56 Pantographic tracings represent information that could be obtained only with an infinite number of excursive records. This simplified schematic shows the relative orientation of six recording plates (attached to the maxillary bow, omitted for clarity) to the scribing styli, attached to the 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. 2.57 (A and B) Electronic jaw recording system. The Cadiax Compact 2 System is an electronic recording system that automatically calculates articulator adjustment. (Courtesy Whip Mix Corporation, Louisville, KY.)

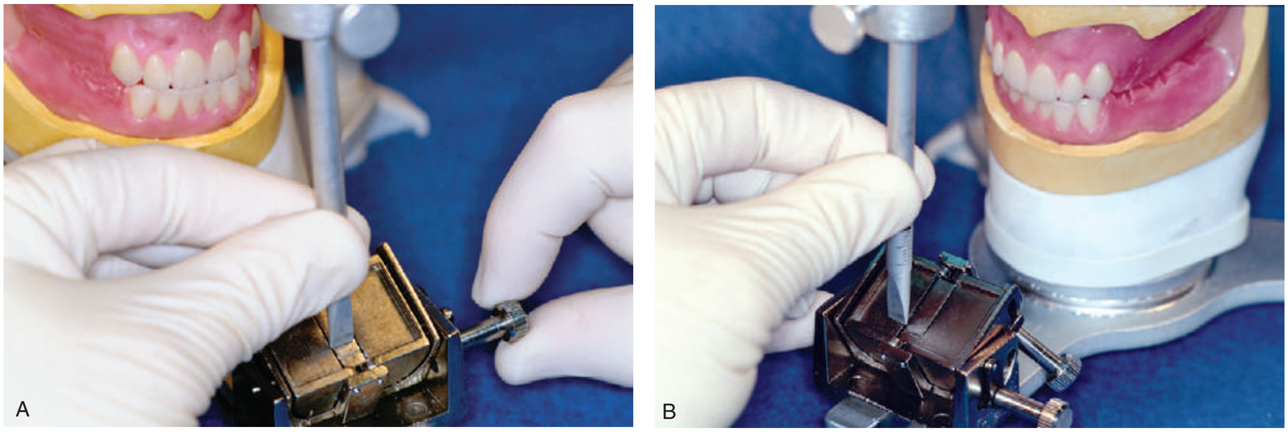

Fig. 2.58 Mechanical anterior guide table. (A) The protrusive path has been adjusted. The side screw adjusts the lateral flange. (B) Lateral flange adjusted to the right working movement.

4. Manipulate the articulator in hinge, lateral, and protrusive movements while the resin is in the doughy stage of polymerization (see Fig. 2.59H and I). 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 3D record of the mandibular movements and their lateral and protrusive limits through the functional range (see Fig. 2.59K and 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 to 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 shim stock (Mylar strips). 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. 2.60). Excess can be easily trimmed away.

Patient-Specific Anatomical Articulator

Shereen S. Azer

The process of simulating mandibular movements to fabricate complex restorations involves technique sensitive procedures for optimal mounting of patient casts. Currently available dental articulators have limitations for reproducing mandibular movements. The patient-specific custom anatomic articulator[81] is an innovative device which accurately simulates patient anatomy and eliminates technique-sensitive mounting procedures, thus substantially diminishing potential errors in mounting and articulator settings. Using 3D printing technology, CBCT patient data (Fig. 2.61A) is used to print 3D replicas of the condylar fossae as well as the actual condyles at the correct intercondylar distance. The maxilla (maxillary teeth/edentulous ridge) is printed with the correct spatial relationship (Fig. 2.61B) to the condylar complexes and the FHP. Those printed structures are then premounted onto a modified articulator frame (Fig. 2.61C) to render it "anatomic." The custom anatomic articulator accurately mimics the patient's anatomic movements rather than rely on average values, representing the first truly fully adjustable articulator that is more precise than a pantographic tracing can generate (Figs. 2.61–2.62). It saves time and effort, eliminating facebow transfers and mounting errors to help accurate fabrication of complex prosthodontic treatments.

The anatomic articulator provides the following accurate features to simulate the patient-specific mandibular movements: The patient's condyles and respective fossae and the maxilla (whether dentulous or edentulous), which are all anatomically related to each other, are printed in the exact relationship (see Fig. 2.61C). In addition, they are oriented to the FHP, eliminating potential mounting errors compared with conventional methods. This feature eliminates the need for a facebow transfer (see Fig. 2.61E). Depending on the patient's anatomy, the intercondylar distance is precisely reproduced eliminating the need for measuring it or using average values (see Fig. 2.61D). The shapes of the condyles and bony slopes (superior, backward, and medial) are obtained directly and precisely from the patient and are not based on average values. The standard procedures for setting the dental articulator for optimal function is to use intraoral protrusive and lateral records to set the horizontal and lateral condylar inclinations, respectively. This practice is eliminated because the exact movement is reproduced and simulated based on the printed fossa contours for each condyle and its respective fossa. The patient-specific inclinations are reproduced into the printed condylar parts (see Fig. 2.61E and F). By virtue of the printed anatomic features, the built-in immediate mandibular lateral translation movement, whether it truly exists or not, would be determined by the patient's anatomy. The printed maxillary reference model serves as the "facebow" record for cross-mounting when needed. It is related accurately to the FHP and to the condylar hinge axis (see Figs. 2.61B–F). The new articulator also has the potential to study and diagnose anatomic relationships and pathways of difficult treatments as well as evaluate and diagnose temporomandibular disorders.

■ ■ ■

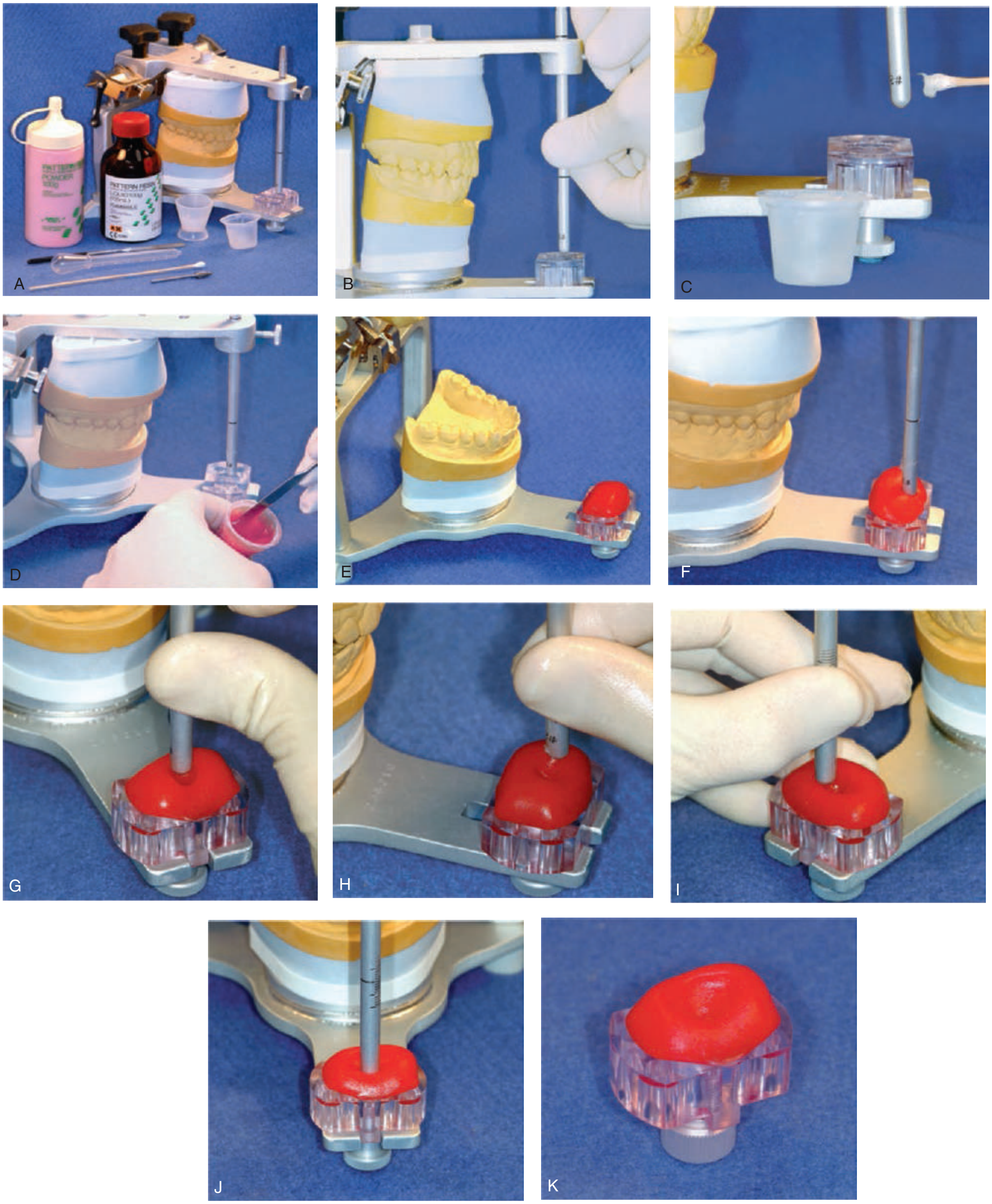

Fig. 2.59 Fabrication of a custom anterior guide table. (A) Armamentarium. (B) Incisal pin is raised 1 or 2 mm. (C) The tip of the pin is lubricated. (D) Resin is dispensed and mixed. (E) Resin is applied to acrylic table. (F) Pin is inserted when resin is at the doughy stage. (G) The protrusive path 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 Whip Mix Corporation, Louisville, KY.)

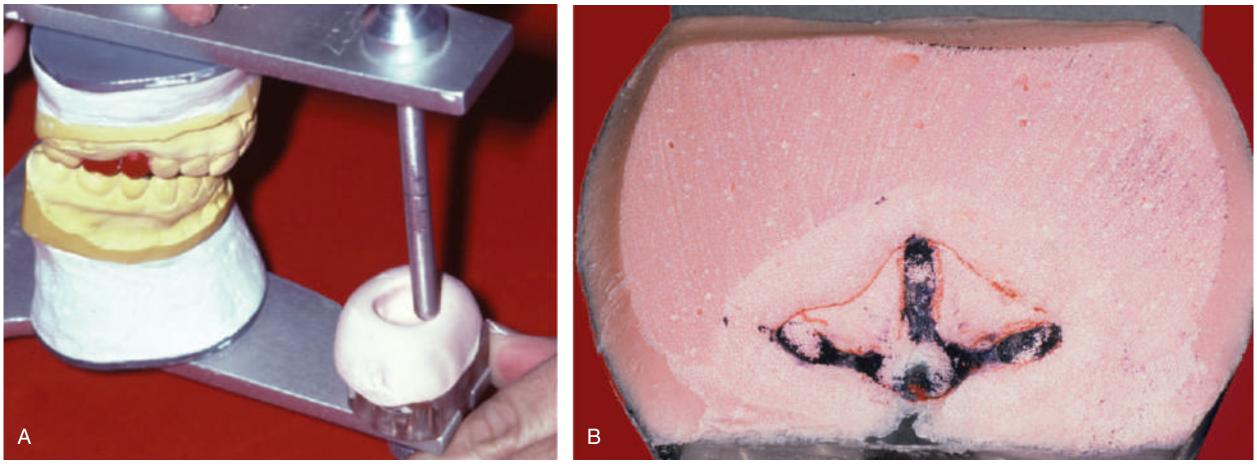

Fig. 2.60 (A) A custom anterior guidance table made with excess resin. This must be trimmed if it interferes with the path of closure of the incisal pin. (B) The completed table with excess resin ground away. Note the lateral and protrusive paths.

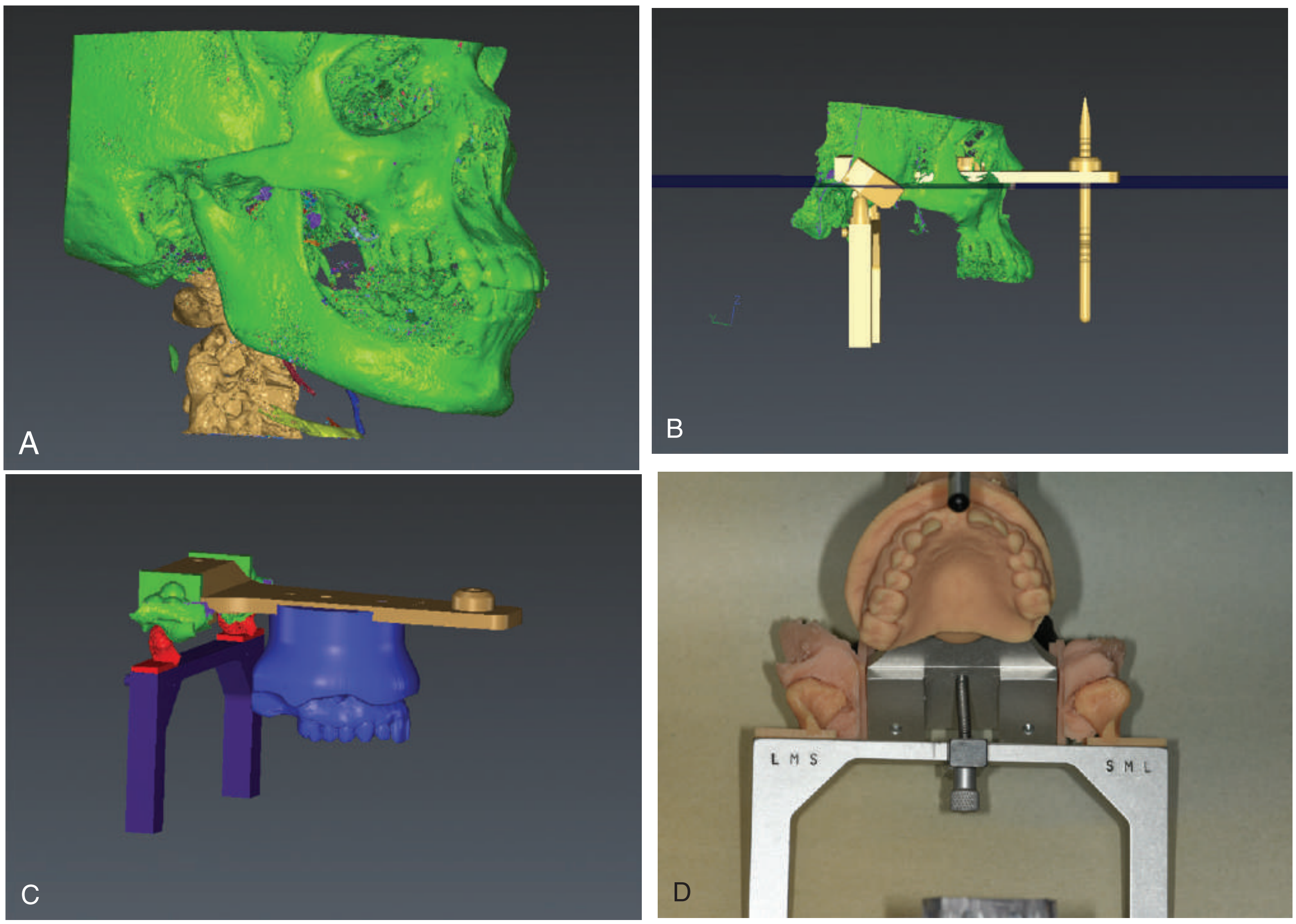

Fig. 2.61 The Patient Specific Anatomical Articulator. (A) Patient cone-beam computed tomography data are converted to STL file. (B) The articulator upper member aligned to the Frankfurt horizontal plane. (C) Patient anatomic landmarks exactly related to the articulator as they are in reality. (D) True anatomic relationship of condyles, fossae, and maxilla maintained in exact relationship as the patient, eliminating the need for a facebow transfer.

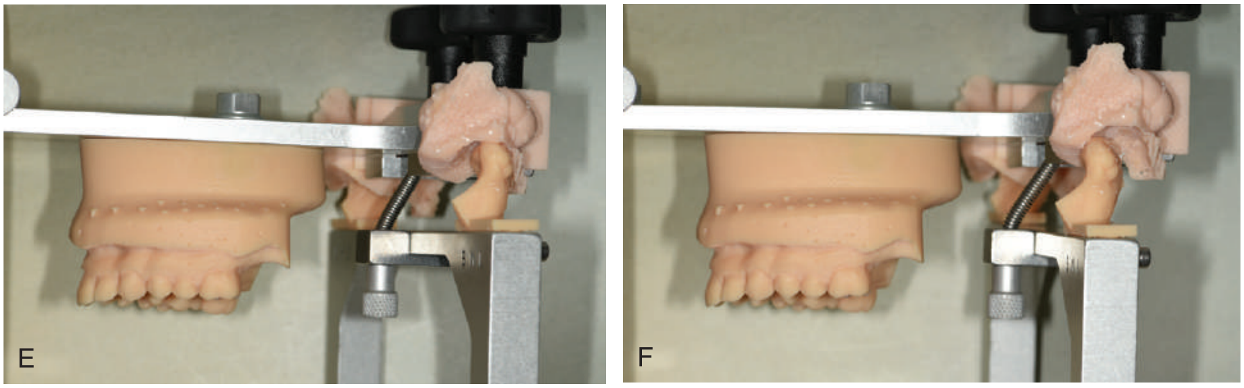

Fig. 2.61 cont'd (E) Centric relation condylar position. (F) Protrusive condylar inclination based on patient anatomy. (Courtesy Dr. Shereen S. Azer).

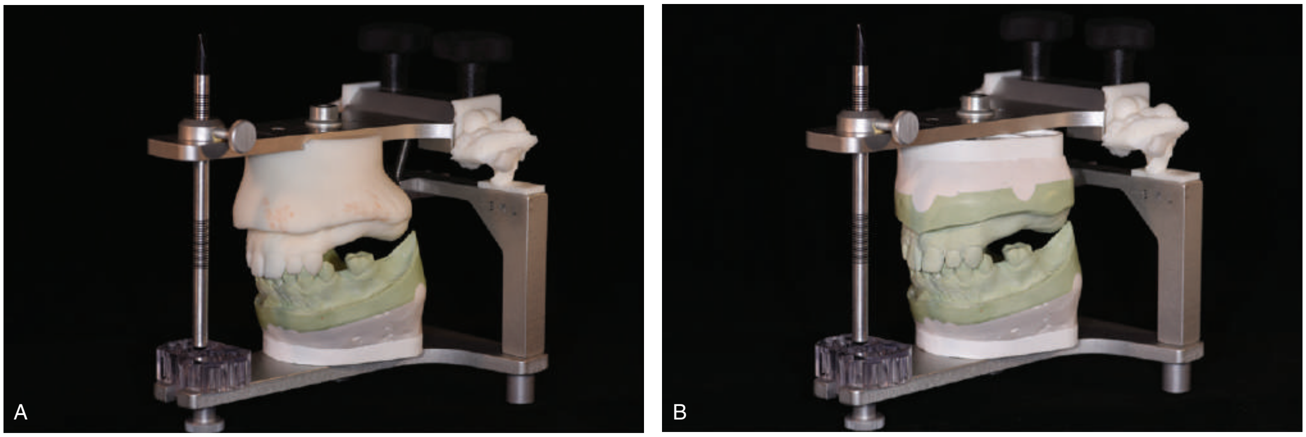

Fig. 2.62 Full assembly of the custom-printed anatomic structures representing the condylar elements, and maxilla related to each other and to the Frankfort horizontal plane from the patient cone-beam computed tomography onto the Whip Mix 8500 series frame. (A) Mandibular cast mounted to the printed maxillary index using traditional centric relation (CR) record, and (B) the maxillary cast is cross-mounted using the same CR record. This patient-specific articulator requires no settings or adjustments. (Courtesy Dr. Shereen S. Azer).

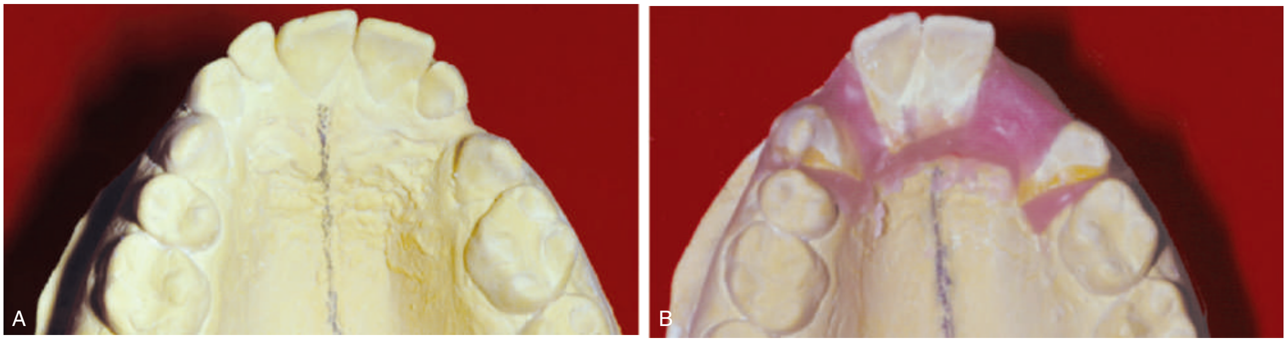

Fig. 2.63 (A and B) Diagnostic cast modifications in advance of orthodontic treatment.

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. 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 skeletal jaw discrepancy is to be corrected surgically.
2. Changing the tooth position before orthodontic procedures (Fig. 2.63).

Fig. 2.64 Diagnostic waxing procedure. Diagnostic tooth preparation and waxing help to 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–H) Diagnostic waxing, performed in conjunction with diagnostic denture tooth arrangement. (Courtesy Dr. J. Bailey.)

3. Modifying the occlusal scheme before any selective occlusal adjustment is attempted.
4. Trial tooth preparation and waxing (Fig. 2.64) 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, dentists can simplify 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) by adhering to these diagnostic techniques.

SUMMARY

Clinical photography is an important mode of documenting any or all phases of therapy. With the proper equipment and techniques, a photographic narrative can be created of what needs to be done and what has been completed for a dental patient.

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 intraoral scans or with irreversible hydrocolloid impressions that should be transferred to a semi-adjustable articulator with the use of a facebow transfer and interocclusal record. For most routine fixed prosthodontic diagnostic purposes, the use of optical scans or a traditional arbitrary hinge axis facebow is sufficient. If special concerns apply, such as a change in vertical dimension, a kinematic facebow transfer or an optical occlusal scan with the condyles seated in CR is needed. Two types of analog articulators are recognized: arcon and nonarcon. For highly complex treatment needs, a fully adjustable articulator may be indicated. Such articulators are adjusted by means of a pantographic tracing. However, many comprehensive reconstructions are successfully done with virtual articulation or an analog arcon articulator.

Diagnostic casts should be articulated in CR to enable observation of deflective tooth contact and to 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 discs with the complex in the anterosuperior position against the shapes of the articular eminences. This position is independent of tooth contact. To record it, the dentist uses a suitable medium interposed between the maxillary and mandibular teeth and guides 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. This can be used to help minimize "muscle memory," which would result 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.

The development of virtual articulators is exciting. In its current form, it is time again to reassess the concepts of collinear and noncollinear mandibular movements. The software used for such virtual instrumentation is quite capable of recording unobstructed mandibular movements. At the present time, one limitation is the large size of the files and not being able to virtually view both complete arches bilaterally simultaneously.

Diagnostic procedures such as dentofacial analysis, cephalometric analysis, digital smile design, diagnostic waxing, and diagnostic cast modification can greatly enhance diagnosis, treatment planning, and patient communication. Many times, the definitive answers about tooth position are answered after a digital smile design or diagnostic setup and are transferred to the patients mouth through an esthetic template.

STUDY QUESTIONS

1. Discuss how to frame each of the extraoral and intraoral photographs.
2. Explain the objectives of a dentofacial analysis.
3. In a multidisciplinary team, what role does the restorative dentist have?
4. What facial cues would a dentist look for to determine if a dental patient was producing a maximal or Duchenne smile?
5. List methods to evaluate dental malocclusions.
6. What angles are evaluated to guide a diagnosis for a skeletal versus a dental malocclusion?
7. Discuss the uses and limitations of irreversible hydrocolloid, and include an overview of its material properties.
8. Why are diagnostic casts articulated in centric relation? Why are they not articulated in maximum intercuspation?
9. What needs to be done to mount digital scans in centric relation?
10. List five items that are determined more easily on diagnostic casts than intraorally.
11. What is accomplished with a facebow transfer? How do average axis facebows differ from kinematic facebows? When would one be selected over the other?
12. 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?
13. What is the role of excursive records in adjusting the articulator?
14. What does a simplified pantograph record? What does a pantograph record? When would either be indicated?
15. For what purpose is a custom acrylic guide table fabricated, and when is its use necessary?
16. Give two examples of situations in which a diagnostic waxing procedure is indicated.

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3

Treatment Planning

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Benjamin Franklin famously said, "failing to plan is planning to fail." In medicine, a treatment plan has been defined as "a detailed plan with information about a patient's disease, the goal of treatment, the treatment options for the disease and possible side effects, and the expected length of treatment. A treatment plan may also include information about likely treatment cost and anticipated follow-up care after treatment completion."[1] The Glossary of Prosthodontic Terms defines a treatment plan as "the sequence of procedures planned for the treatment of a patient after diagnosis."[2] Essentially, the process of treatment planning in prosthodontics consists of comprehensively addressing four objectives: (1) patient's chief concern, (2) correction of any existing dental disease; (3) improvement of function, occlusion and esthetics, and (4) prevention of future disease by instilling a lifelong professional and at-home maintenance regimen. Because of the elective and expensive nature of many prosthodontic procedures, it is of utmost importance for the dentist to appropriately educate the patient and explain the advantages, disadvantages, alternatives, risks, costs, sequence, and timeline of the planned treatment. The importance of explaining alternative treatment procedures, including the option of no treatment, cannot be overemphasized. Treatment planning must incorporate the best available scientific evidence while considering the clinician's expertise and the patient's needs. Because of issues encountered during the course of treatment, patients should be educated that the planned course of treatment on occasion may need to be changed. Once the patient agrees, the detailed plan is presented in an easily understood written format for the patient's approval. The signed and dated document should then be stored as part of the patient's (electronic) chart records. This systematic approach can aid in delivering consistently high-quality dental treatment and may aid in clarity should medical-legal conflicts arise.

This chapter outlines some of the systemic and local factors pertaining to treatment planning in prosthodontics, the choices of contemporary biomaterials, along with a discussion of various restoration types, biomechanical considerations, and introduces considerations in the development of a logical treatment sequence.

PATIENT CONSIDERATIONS IN TREATMENT PLANNING

Patient's Personality

A popular axiom in prosthodontics is "meet the patient's mind before you meet the mouth." Successful treatment planning is based on the identification of patient needs, desires, and a thorough understanding of patient expectations. Understandably, most patients prefer that missing teeth are replaced permanently, inexpensively, and quickly. Biologic and material limitations often make this impossible. Most fixed prosthodontic treatment is elective and expensive (compared with no treatment or alternative removable prosthodontic treatment). Therefore, it is imperative that the dentist fully understands the patient's motivation and his or her dedication, understanding, and willingness to devote the necessary time to accomplish the treatment objectives. Also, the patient's personality and financial commitment, as it relates to their dental treatment, are critical to arrive at the optimal treatment recommendation. In complete denture therapy, a method of classification of a patient's personality proposed by House includes four categories: philosophical, indifferent, hysterical, and exacting.[3] This approach can be applied to treatment planning in fixed prosthodontics as well, in order to recognize the patient's expectations with respect to the treatment plan and treatment sequence. The classification is made after evaluation with a questionnaire and has been updated with contemporary terminology and considering the role of the dentist as well as the patient.[4]

Patient's Systemic Health

Incorporating the patient's systemic/medical health history and current status is a fundamental consideration in treatment planning. Several medical conditions are treated by drugs that are known to cause xerostomia, which can significantly increase caries risk status and jeopardize fixed prosthodontic treatment (Fig. 3.1A and B).[5,6] Patients with a history of radiation therapy in the head and neck region may suffer from xerostomia as well. Certain medical conditions can preclude patients from enduring long appointments, which are typically necessary when complex prosthodontic treatment is performed. Allergies to specific materials or reactions to commonly used drugs are also important factors to consider when developing a comprehensive treatment plan.

Mouth Opening and Temporomandibular Joint Health

Most fixed prosthodontic procedures require the patient to open their mouth wide enough to accomplish the planned treatment. It is prudent to consider this before deciding on a definitive treatment plan. The average mouth opening ranges from 40 to 60 mm, while the medical definition of trismus is a mouth opening that is restricted to 35 mm.[7] Patients who

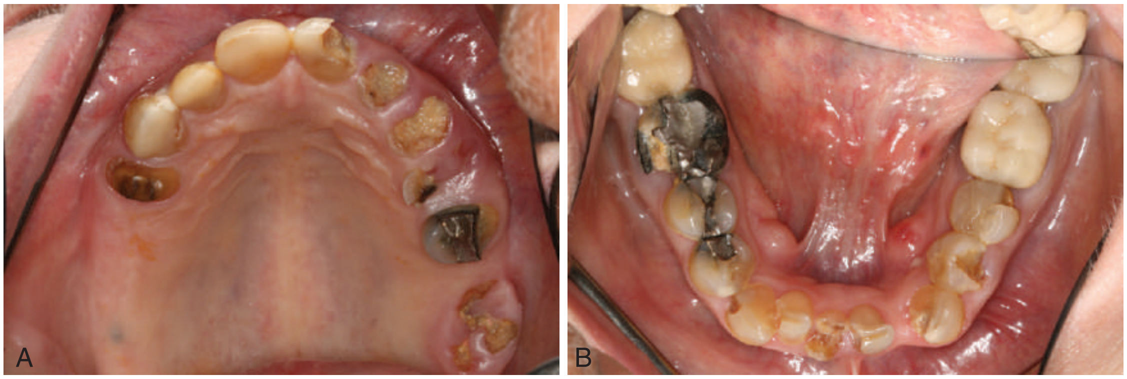


Fig. 3.1 (A) Generalized caries due to xerostomia in the maxillary arch. (B) Significant caries due to xerostomia in the mandibular arch. Such patients are a contraindication to fixed prosthodontics.

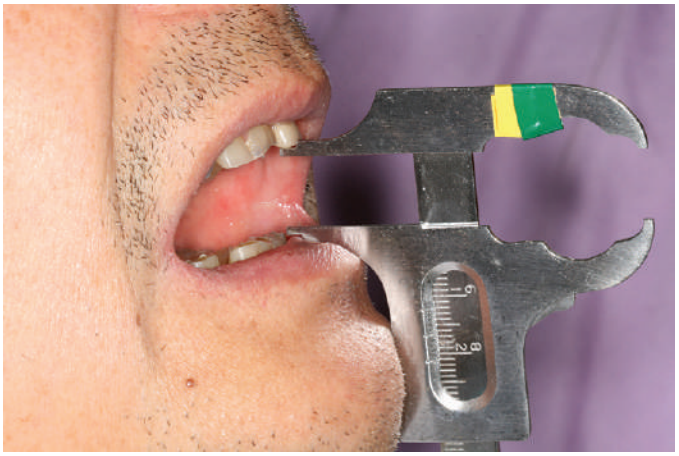


Fig. 3.2 Patients with limited mouth opening such as trismus pose a significant challenge for fixed prosthodontics and need therapy before commencing any treatment.

Fig. 3.3 Classical features of bruxism noticed in this patient. Notice the shortened anterior crown height and reduced vertical overlap due to significant wear of teeth.

are on the lower end of this range may present a tremendous challenge for the dentist to accomplish optimal prosthodontic procedures in the posterior regions of the mouth (Fig. 3.2). This is specifically true for procedures such as tooth preparation, definitive impressions or scans, and guided surgery for implant placement. Such patients need to be educated about their condition. Some patients may benefit from being prescribed anxiolytics which may facilitate the procedures while causing reduced discomfort. Although one of the goals of treatment is to preserve the dentition, reduced access may necessitate the decision to electively extract a second or third molar if adequate access for sound prosthodontic procedures is not possible. An example of this is when on opening, the coronoid process effectively makes access to the buccal surface of the second molar next to impossible.

Temporomandibular joint (TMJ) health assessment is also an important consideration during treatment planning, as it affects the treatment sequence, pace, and success[8,9] (see also Chapter 4). Dentists should record any pre-existing TMJ conditions. Any such issues should be resolved before commencing complex fixed prosthodontic treatment.[8,9] Failure to do so may exacerbate the condition.

Bruxism

Bruxism has been defined as "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."[2] Patients with bruxism tend to have a higher prevalence of prosthodontic complications, including a higher incidence of fracture of restorations, fracture of teeth and higher implant failures (Fig. 3.3).[10–12] Understanding a patient's bruxism status before treatment may lead to a different choice of restoration or treatment and will drive the decision to provide the patient with an occlusal device on completion of prosthodontic treatment.[10–12] Additionally, bruxism patients may need to have their treatment sequence modified to prevent excessive fractures of interim restorations during treatment. All of this can significantly increase treatment time and cost. Patient education about bruxism is paramount to the success of treatment.

Oral Hygiene

Good oral hygiene is a prerequisite to the success of any prosthodontic treatment. Patients with poor oral hygiene should be given comprehensive oral debridement followed by scaling

Fig. 3.4 Extremely poor oral hygiene in a patient seeking fixed prosthodontic treatment. Non-compliant patients are not good candidates for fixed prosthodontic treatment.

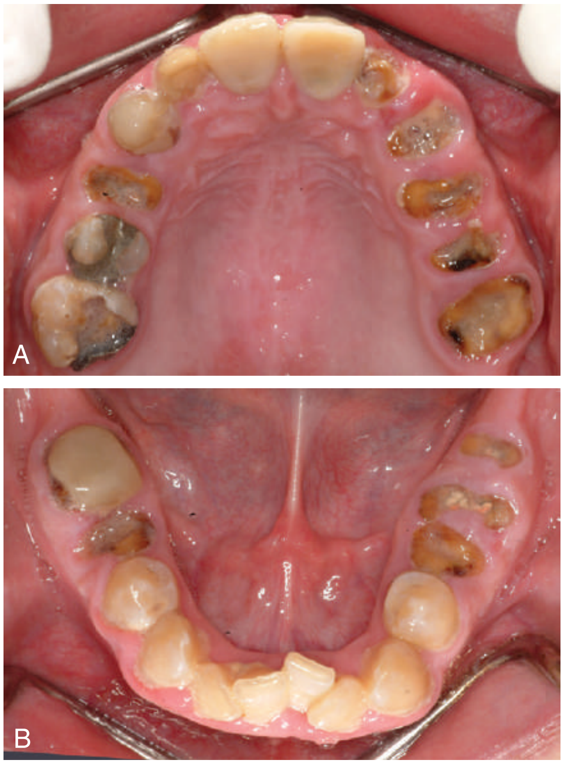


Fig. 3.5 (A) Generalized dental caries in the maxillary arch. (B) Dental caries in the mandibular arch except six anterior teeth, which are frequently spared. Such patients are a contraindication to fixed prosthodontics. Compare this patient to the one presented in Fig. 3.1, who had xerostomia.

and root planning. They should also be given detailed oral hygiene instructions, which must be reinforced periodically during the course of treatment. Proper oral hygiene instructions can lead to a reduced risk for loss of teeth.[13] Fixed prosthodontic treatment should not be initiated until the patient is able to demonstrate that they can comply with oral hygiene instructions (Fig. 3.4). Non-compliant patients may be better served with interim removable prostheses or no treatment until their oral hygiene practices are adequate.

Smoking

The smoking status of a patient should be assessed with respect to specific types of smoking (tobacco, vaping, marijuana), frequency per day per week, and the number of years of smoking. Habits such as the use of chewing tobacco should be considered. Smokers have a proven risk of periodontal disease and poor bone quality and may have medical co-morbid factors that can affect fixed prosthodontic treatment, including dental implant failures.[14] Smokers also tend to develop nicotine stains which can compromise esthetics. Patients should be educated about the benefits of smoking cessation, associated risks for oral cancer and systemic conditions, and be forewarned about possible premature failures of prosthodontic treatment.

Dental Caries Status

Severe dental caries is a contraindication to fixed prosthodontic treatment, and a caries risk assessment during the diagnostic stage is beneficial (Fig. 3.5A and B).[15] The scientific literature shows that the primary complication of fixed prosthodontic treatment is dental caries.[16] Therefore, the patient's caries status and risk for future caries should be incorporated during the planning phase. Patients with primary caries or secondary caries around existing restorations should have all existing restorations removed, caries excavated, and then have a restorability assessment performed. At this stage, the decision should be made whether (1) the tooth can be restored with a new restoration; (2) the tooth requires additional pre-prosthetic procedures such as endodontics or periodontics before a new restoration is placed; or (3) the tooth needs to be extracted and replaced with an implant or fixed partial denture (FPD). Patients should be educated about these options and should be forewarned about the potential associated costs and additional treatment needs before proceeding with the restorability assessment. In patients with caries, additional oral, topical agents such as 1.1% NaF (sodium fluoride) toothpaste and 0.12% chlorhexidine gluconate rinses should be prescribed at the commencement of prosthodontic treatment, and patients should continue to use these agents throughout treatment.[17] Additionally, dentists may consider prescribing 1.1% NaF toothpaste as a lifelong regimen in patients after complex fixed prosthodontic treatment.[18]

Periodontal Status

The patient's periodontal status is an important treatment planning consideration. In the absence of poor oral hygiene or mobility of teeth, patients often perceive their periodontal status as "healthy" or "workable," and even dentists may be tempted to use such teeth as abutments for FPDs (Fig. 3.6A–C). Clinical attachment loss, periodontal probing depths, radiographic bone levels, root length, and the presence and quality of attached gingiva are all important contributory factors in the assessment of periodontally involved teeth. Often, patients with periodontal disease may not necessarily have poor oral hygiene but will still require periodontal therapy to eliminate periodontal pockets. Dentists should educate patients about

Fig. 3.6 (A) Severe periodontal disease in a patient without poor oral hygiene. (B) Maxillary view shows an intact dentition, and patient only desired replacement of her maxillary incisor tooth. (C) Mandible shows missing molars and drifted teeth with mobility. Such teeth are poor abutments for fixed prosthodontic treatment.

Fig. 3.7 (A) Patient with a high smile line with an infected right central incisor and a failing restoration on left central incisor. Such patients are challenging to manage because of their high smiles. (B) Patient was treated by extraction and implant-supported zirconia crown at right central incisor and a new zirconia crown on the left central incisor.

lifelong periodontal therapy and maintenance if periodontally involved teeth are to be used as abutments for fixed prosthodontic treatment.[18–20] Patients unwilling to commit to such rigorous maintenance schedules should be offered alternative treatment options. Generally, teeth with severe mobility should not be used as abutments for fixed prostheses. A detailed description of periodontal considerations can be found in Chapter 5.

Smile Line

The patient's smile line is an important consideration because esthetic outcomes of prosthodontic treatment are visible, judgeable (by patients and others), and tangible. Additionally, dentists have no control over a patient's smile line and must work to create restorations in harmony with the patient's smile line. Human smiles have been classified in prosthodontics as low smiles, average smiles, high smiles, and gummy smiles.[21,22] Understandably, fixed prosthodontic treatment in patients with low smiles is easier to manage, but most patients, irrespective of their age, have either an average or high smile, meaning that they display at least up to the maxillary first molar. High smile and gummy smile patients are the most challenging to manage due to the visibility of the entire dentogingival complex, including any crown margins (Fig. 3.7A and B). Dentists should be cognizant of this when making restoration selections and performing margin placement during tooth preparation. Assessing and recording a patient's smile line during treatment planning can help the dentist educate patients about the importance of specific treatment choices to enhance the esthetic result. Making a series of intraoral and full-face photographs during the planning phase can be helpful to educate patients while simultaneously maintaining proper treatment records.

PRE-PROSTHETIC CONSIDERATIONS IN TREATMENT PLANNING

Oral Radiology

Baseline full-mouth radiographs and panoramic radiographs are necessary before the commencement of all comprehensive fixed prosthodontics treatment. When patients have multiple partially edentulous spaces planned for dental implants, a cone-beam computed tomography (CBCT) is also essential. Limiting radiographs to only bitewings is not recommended before the commencement of fixed prosthodontic treatment, even for relatively straightforward treatment, because it precludes assessment of any chronic apical pathology. For all comprehensive fixed prosthodontics treatment, dentists should also make post-treatment radiographs to confirm restoration adaptation and establish a baseline for future recall and maintenance.

Dental Anesthesia

Some patients have dental phobias and may have specific fears related to "fear of the needle" or "fear of the drilling sound." Fear is one of the primary reasons some patients in need may not seek treatment.[23] Fixed prosthodontics treatment requires lengthy appointments, and it is beneficial to assess any such concerns during treatment planning. If local anesthesia is deemed insufficient to manage the patient's needs, a variety of options ranging from nitrous oxide, oral anxiolytic medications, or conscious (intravenous) sedation may be considered. The latter may permit accomplishing a multitude of procedures (e.g., preparation of an entire arch or both arches in a single visit). However, patients should fully understand the additional costs and precautions necessary before engaging in such approaches to treatment.

Restorative/Operative Dentistry

A patient's caries status may require all restorative/operative dentistry to have been completed before the commencement of fixed prosthodontic treatment. It is important that restorative dentistry is accomplished at the earliest to prevent further deterioration of tooth structure and to assess the restorability of individual teeth as any tooth loss may alter the treatment plan. Restorative material selection during this stabilization phase is important as it should anticipate subsequent treatment. For example, if ceramic restorations are planned in the esthetic zone, it may be prudent to restore such teeth with tooth-colored materials rather than amalgam since such could impact the ability to achieve an esthetic result.

Patients may elect to have existing restorations replaced for esthetic purposes, and the specific choice of restorative material should be discussed and should anticipate the planned material for crowns or FPDs that are to be made subsequently. An unrestored, caries-free tooth is an ideal abutment for FPD. It can be prepared conservatively for a strong restoration with excellent resistance and retention form, resulting in optimal esthetics. Preparation margins can be placed without the modifications often needed to accommodate existing restorations or caries.

Endodontics

Endodontic procedures are an important adjunct to fixed prosthodontics. Oftentimes, endodontic procedures are necessary even before the start of treatment due to existing chronic periapical lesions or because a dentist determines that extracoronal preparation of a malpositioned or supra-erupted tooth might encroach on the pulp. In the presence of caries or existing restorations, excavation is necessary to determine restorability before proceeding with endodontic treatment. Survival of posterior teeth that have been endodontically treated is significantly better when a complete crown is placed.[24] The principles for the restoration of endodontically treated teeth are described in detail in Chapter 12.

Orthodontics

Pre-prosthetic orthodontics may be an important adjunct procedure sometimes under-utilized in fixed prosthodontics (Fig. 3.8A–G).[25,26] If extreme arch discrepancies exist, orthognathic surgery may be considered before the initiation of fixed prosthodontics.

More commonly, single tooth extrusion to gain crown length or to facilitate future implant placement, aided by orthodontics, is a practical approach to improve the long-term prognosis. Mesially tipped molars are sometimes managed without pre-prosthetic orthodontics by careful tooth preparation and incorporating buccal grooves and minimal preparation on the distal aspect just to create a margin (Fig. 3.9A–F). As preparation complexity increases performing diagnostic preparations on diagnostic casts are extremely useful to visualize final preparation design and feasibility. It should be noted that when pre-prosthetic orthodontics is not considered or is declined by the patient, the alternative is often excessive tooth preparation, a need for elective endodontics, and even extraction.[25,26] When teeth are malpositioned, there are limits to what can be accomplished by fixed prosthodontic treatment alone. Inevitably, compromises ensue. Understandably, many adult patients, for a variety of reasons, do not want to commit to pre-prosthetic orthodontics: "social stigma," additional time, and cost. In such situations, before proceeding with treatment, the applicable limitations should be discussed in detail with the patient.

Exodontia

Exodontia is frequently necessary before or during fixed prosthodontic treatment. Teeth may need to be extracted for the following reasons, not limited to non-restorable teeth, teeth with periodontal disease, hard and soft tissue impactions, root fractures and periapical infections, orthodontic treatment, and finally, third molars causing occlusal interferences in a comprehensive treatment plan design. Occasionally, asymptomatic and healthy natural teeth may also need to be extracted to serve as sites for implant placement around failed bone graft sites or to facilitate prosthodontic treatment in patients refusing prosthetic orthodontic treatment (Fig. 3.10A and B).[27] With the success of complete arch fixed implant-supported prostheses (CAFIPs),[28] another treatment planning consideration is to determine if six or more teeth in an arch will need to be extracted and indicated for implant restorations. In such situations, instead of restoring six individual spaces with implants, in addition to restoring any remaining natural teeth, a predictable alternative solution would be to extract the remaining teeth (if they are compromised or require substantial intervention, including endodontics or periodontics) and place the same six implants with broader distribution and provide the patient with a one-piece CAFIP. This will help optimize esthetics and the occlusal plane. This may also allow placement of implants without additional bone grafting procedures and take advantage of existing alveolar bone. Further discussions of CAFIPs are presented in Chapter 13.

Periodontics

Periodontal procedures to be factored during treatment planning include routine maintenance procedures like debridement, scaling, root planning which are important, especially in patients with periodontal disease.[18–20]Adjunctive therapeutic procedures include gingivectomy and crown lengthening procedures for esthetics or to enhance the clinical length of

Fig. 3.8 (A) Adult patient with severe wear, malocclusion, and missing teeth. (B) Notice the supra-eruption of the maxillary and mandibular premolars with minimal restorative space and occlusal plane. (C) Notice the mesial-distal migration of teeth compromising esthetics and restorative space. (D) Pre-prosthetic orthodontics is particularly helpful in management of such patients. (E) An interim anchorage device was used in the right mandibular molar region to accelerate movement of teeth. (F) After 33 months of orthodontic treatment, pre-prosthetic orthodontics was completed, and patient was ready for fixed prosthodontic treatment. (G) Frontal view after completion of fixed prosthodontic treatment using a combination of crowns, fixed partial dentures, and an implant-supported crown. (From Bidra AS, Uribe F. Preprosthetic orthodontic intervention for management of a partially edentulous patient with generalized wear and malocclusion. *J Esthet Restor Dent*. 2012;24[2]:88–100.)

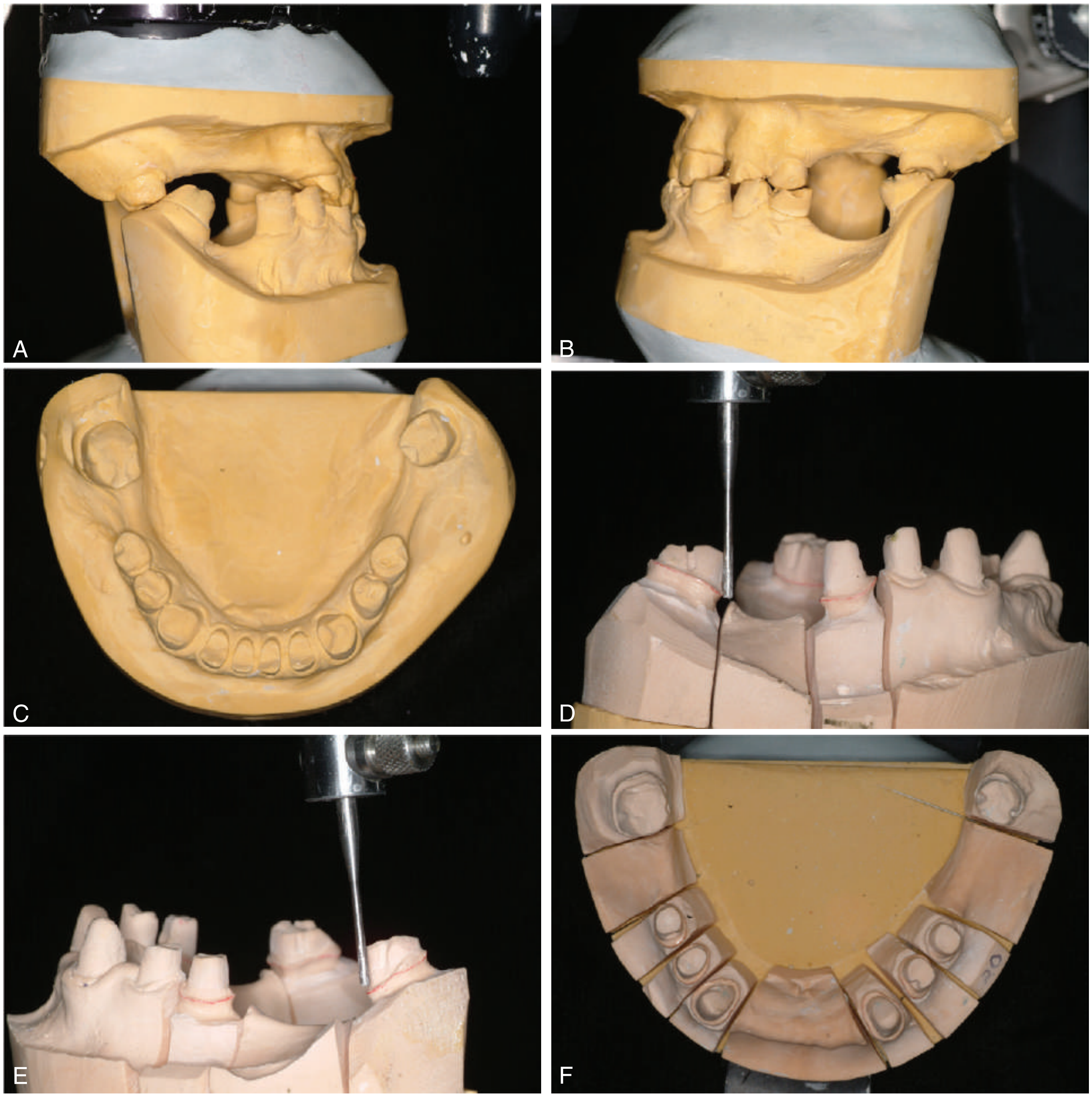


Fig. 3.9 (A) Significant mesial tipping of mandibular distal right molar planned for use as an abutment for a fixed partial denture (FPD). (B) Significant mesial tipping of mandibular distal left molar planned for use as an abutment for an FPD. (C) Occlusal view of diagnostic cast showing lingual rotations of molars and buccal rotations of premolars. Trial (mock) teeth preparations on patient's diagnostic casts will be helpful in such situations before actual teeth preparations in the mouth. (D) Mesially tipped right molar was prepared carefully by incorporating a buccal groove, and parallelism is confirmed with mesial abutment using a dental surveyor. (E) Mesially tipped left molar was prepared carefully by incorporating a buccal groove, and parallelism was confirmed with mesial abutment using a dental surveyor. (F) Definitive teeth preparations on cast showing all teeth preparations in this patient.

abutment teeth and improve resistance and retention form of tooth preparations (Fig. 3.11A–D).[26] Only evidence-based periodontal procedures should be provided to save natural teeth, and experimental or elaborative treatment should be avoided in the era of successful implant dentistry. For example, an endodontic treatment failure could be managed by retreatment, crown lengthening, or a post and core restoration to be followed by a single crown instead of extraction and replacement by an implant-supported crown.

In planning comprehensive fixed prosthodontic treatment, it is important for dentists to determine whether damaged or worn teeth need to be increased in length coronally or apically. If abutment length needs to be improved coronally, then adjunctive endodontics and post and core restorations may be needed (Fig. 3.12A–D). However, if the abutment length needs to be improved apically, crown lengthening procedures may be indicated (see Fig. 3.11).[26] A detailed description of periodontal considerations can be found in Chapter 5.

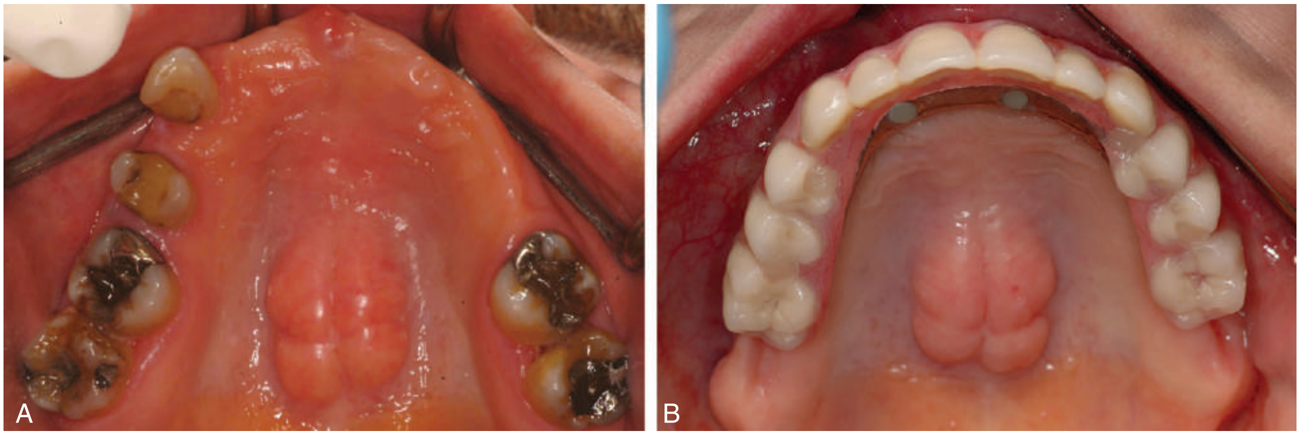


Fig. 3.10 (A) Sometimes, symptomatic but malpositioned natural teeth may also need to be extracted to serve as sites for implant placement to facilitate comprehensive prosthodontic treatment. (B) Patient restored with complete arch fixed implant-supported prosthesis in the maxilla.

Fig. 3.11 (A) Patient with short clinical crowns due to altered passive eruption and wear is an ideal candidate for pre-prosthetic gingivectomy and crown lengthening procedures. (B) Gingivectomy and crown lengthening procedures were performed in the maxilla and posterior mandible using diagnostic waxing as a guide. (C) Healing after crown lengthening in maxilla and posterior mandible. (D) Patient's clinical crown height and occlusal plane were restored along with closure of anterior maxillary diastemas. (From Bidra AS. Fixed prosthodontic rehabilitation in a wear patient with Fabry's disease. *J Prosthodont*. 2011;20[Suppl 2]:S2–S8.)

BIOMATERIAL CONSIDERATIONS IN TREATMENT PLANNING

All existing restorative materials and techniques have limitations, and none exactly match the properties of natural tooth structure. Dentists must understand these limitations in detail before they can select the appropriate restorative material.

Complete-Metal

Metal single crowns or FPDs are infrequently used today in part because of esthetic concerns but also cost. However, they have the longest track record of all biomaterials.[29] Historically, cast gold was the only material available. Despite their higher costs due to the price of alloy and labor, gold crowns and FPDs are straightforward monolithic restorations that permit conservative tooth

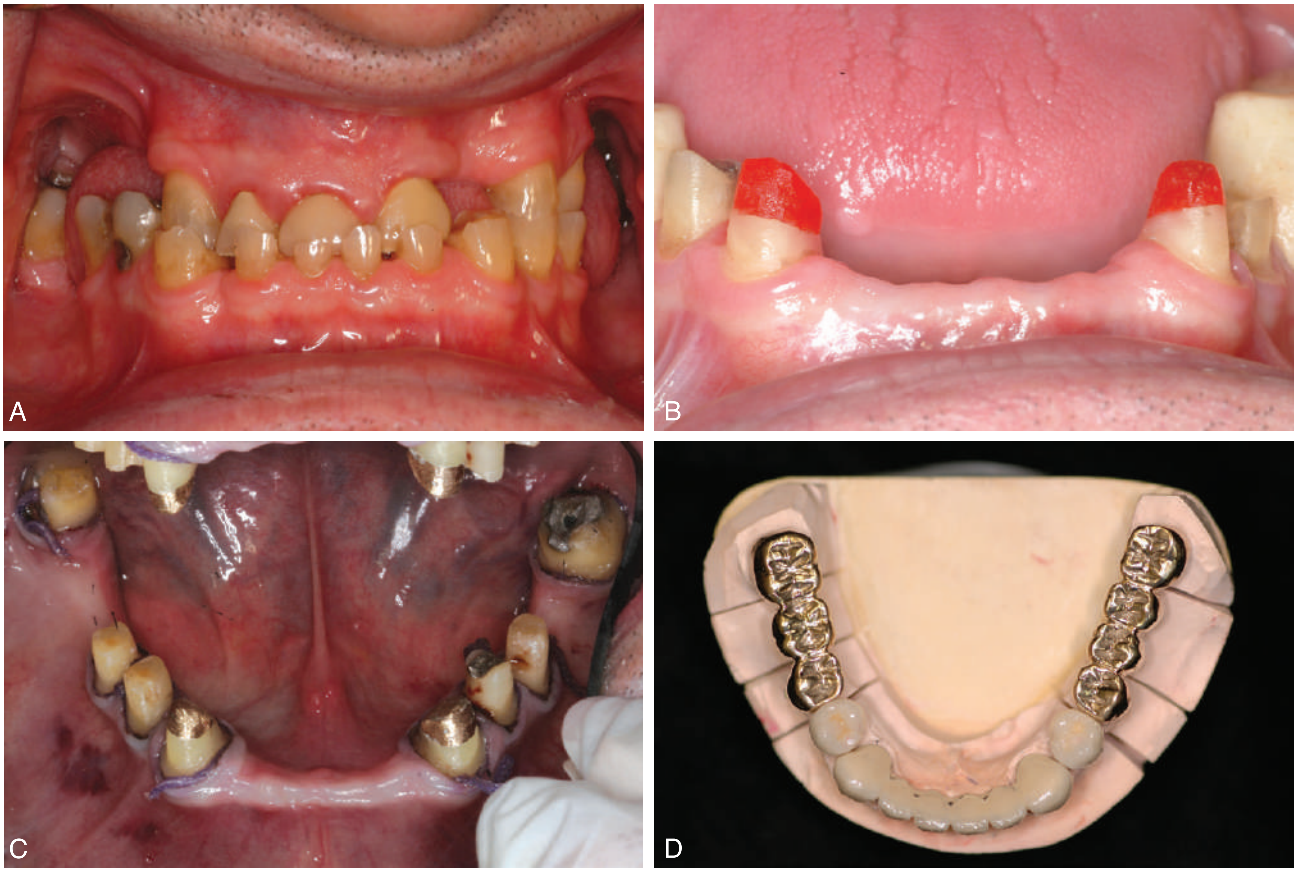


Fig. 3.12 (A) Frontal view of same patient from Fig. 3.9 showing significant wear of teeth due to bruxism, requiring improvement of abutment height in coronal direction. (B) Mandibular incisors were extracted, and mandibular canines were prepared for abutments for a fixed partial denture (FPD). After elective endodontics, pattern resin was used to fabricate custom post and core from cast gold. (C) Occlusal view of teeth preparations before final impression. Notice the custom post and core in cast gold have significantly improved the abutment height coronally. (D) Definitive restorations showing a combination of gold FPDs, metal-ceramic crowns on premolars, and metal-ceramic FPD in the anterior mandible. These restorations were opposing a complete denture in this patient.

preparations.[29] They have minimal chances of fracture, making them an ideal choice of restoration in high load positions, such as for patients with bruxism (see Fig. 3.12D).[25,29] Contemporary metal restorations can be fabricated by computer-aided design and computer-aided manufacturing (CAD-CAM) and can be milled from gold, cobalt-chromium, or titanium. Further discussion on these restorations can be found in Chapters 9 and 22.

Metal-Ceramic

Metal-ceramic restorations ameliorate metal restorations by providing a porcelain tooth-colored facing that is either fused or pressed to the metal.[30] Metal-ceramic restorations have a long track record and provide esthetic and functional restorations (Fig. 3.13A–F).[31–33] They can be fabricated conventionally (manual waxing and casting of metal and applying porcelain) or by CAD-CAM technology where the metal coping is either fabricated by selective laser melting[34] or milled from a block of metal,[35] and the wax pattern for pressing is designed by CAD-CAM split file technology.[36] The porcelain is then pressed to the metal.

A commonly reported complication with metal-ceramic restoration is chipping or fracture of the veneered porcelain, especially in patients with bruxism.[31–33] Alternative designs such as metal-ceramic restorations with metal occlusal surfaces can obviate these challenges. Further discussion on these restorations can be found in Chapters 10 and 24.

Ceramic

With significant advancements in the development of ceramic materials, ceramic restorations are currently the most popular restorative material in fixed prosthodontics. Several ceramic materials have emerged over the years, and zirconia and lithium disilicate have substantive scientific evidence for clinical usage.[37,38] Both materials possess the advantages of excellent esthetics, high strength, biocompatibility, favorable soft tissue response, CAD-CAM fabrication, usable in monolithic form, and reasonable cost.[39] Some of their disadvantages include the need to reduce substantial tooth structure to provide material strength, the need to bond in some situations, and difficulty in sectioning and removal of these restorations if needed. Lithium disilicate has excellent translucency compared with zirconia and can be used in esthetically challenging situations, especially to optimize shade matching with adjacent teeth, a particularly challenging situation (Fig. 3.14A and B).[40] However, it has lower tensile and flexural

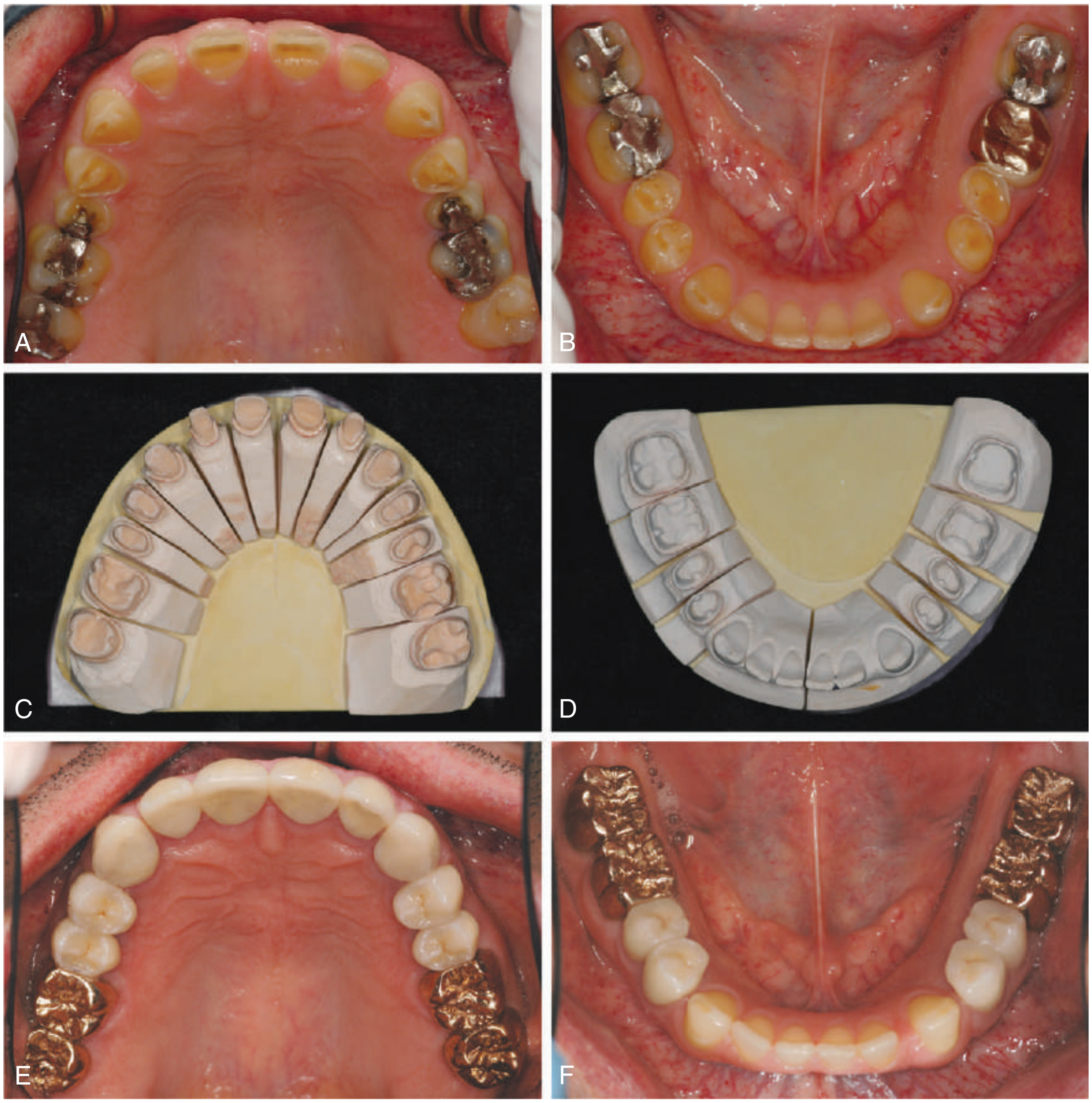


Fig. 3.13 (A) Same patient from Fig. 3.11 showing significant maxillary occlusal wear due to mechanical and chemical wear of teeth. (B) Mechanical and chemical wear on all mandibular teeth except the incisors. (C) Definitive maxillary teeth preparations. Notice that previous preparations for amalgam restorations have been removed and not replaced but simply incorporated into the crown preparations to improve resistance form. (D) Definitive mandibular teeth preparations. Notice that previous preparations for amalgam restorations have been removed and not replaced but simply incorporated into the crown preparations to improve resistance form. (E) Definitive restorations with gold crowns on molars and metal-ceramic crowns on remaining teeth. (F) Definitive mandibular restorations with gold crowns on molars and metal-ceramic crowns on premolars. Mandibular incisors did not require any treatment. (From Bidra AS. Fixed prosthodontic rehabilitation in a wear patient with Fabry's disease. *J Prosthodont*. 2011;20[Suppl 2]:S2–S8.)

strength than zirconia and is contraindicated for long-span FPDs.[37] Zirconia needs to be veneered with a more translucent feldspathic porcelain when excellent esthetics are desired, which can be critical in the anterior region.[38] High-strength zirconia ceramics are especially helpful when used in monolithic form in patients with bruxism (Fig. 3.15A–E).[39] These restorations are described further in Chapters 8, 11, and 25.

Other Materials

Several additional restorative materials have emerged, although data are limited as to their long-term performance: fiber-reinforced composite resin (FRC),[41] nanocomposite resin materials,[42] polyetheretherketone (PEEK),[43] polyetherketoneketone (PEKK),[44] graphene, and other advanced polymers.[45] The dentist should use evidenced-based principles in planning their application, and preference should be given to materials with documented clinical performance.

TYPES OF RESTORATIONS IN TREATMENT PLANNING

A dental restoration has been defined as "a broad term applied to any material or prosthesis that restores or replaces lost tooth structure, teeth, or oral tissues."[2] Fixed restorations on natural

Fig. 3.14 (A) Matching the shade of a single central incisor to the contralateral incisor is one of the most challenging procedures in fixed prosthodontics. (B) Using complete-ceramic material like lithium disilicate offers esthetic advantages over other materials.

Fig. 3.15 (A) Same patient from Fig. 3.3 showing signs of maxillary wear from bruxism. (B) Significant wear in all mandibular teeth is also evident due to bruxism. (C) All maxillary teeth were prepared and restored with monolithic zirconia because of its increased strength and good esthetics. (D) Mandibular teeth also restored with monolithic zirconia material. (E) Frontal view showing good esthetics. Minimal veneering of porcelain was present only on maxillary and mandibular incisor restorations. Compare to Fig. 3.3.

teeth can be classified as intracoronal restorations (direct fillings and inlays) and extra-coronal restorations (onlays, veneers, crowns, FPDs). Additionally, there are implant-supported removable and fixed prostheses that are used to replace a missing tooth or teeth.

Inlays

Direct fillings (composite resin or amalgam) are by far the most popular type of restoration in dentistry. They are quick, relatively inexpensive, and easy to perform. However, their mechanical properties are inferior to those of complete metal, metal-ceramic, or ceramic restorations. Their longevity depends on the strength and integrity of the remaining tooth structure. When the tooth structure needs reinforcement or when the planned direct restoration is large, the direct approach is challenging, and defective contours and poor occlusion often result. Therefore, inlays are an excellent restoration for such situations. These are restorations made extraorally to correspond to the form of the prepared cavity; they are retained by mechanical or adhesive means and have better marginal fit and strength.[2] Gold inlays have the longest track record in dentistry,[29] but because of esthetic reasons, ceramic inlays are currently the most popular type of inlay restorations (Fig. 3.16A and B).[46]

Onlays

Onlays or partial coverage restorations are extracoronal restorations that restore one or more cusps and the adjoining occlusal surfaces or the entire occlusal surface, which are then cemented or bonded into the tooth. Onlays have excellent strength after bonding and offer a conservative solution when complete coverage restorations (crowns) are not desired. Preparation design is similar to that of inlays with divergent walls for the path of insertion, and gold onlays have the longest track record in dentistry, but again, because of esthetic reasons, ceramic onlays enjoy excellent patient acceptance (Fig. 3.17A–C). Onlays have gained increased popularity in recent years because of material improvements and improved bonding.[47,48] Dentists should make careful judgments on when an onlay may sufficiently restore a tooth as compared with a crown. Although onlay preparations can exhibit outstanding retention and resistance, when an onlay relies primarily on bonding for retention, it should be recognized that a crown has the advantage of encircling all of the remaining tooth structure, and assuming good preparation geometry, often will possess superior resistance and retention.

Veneer Restorations

When discussing veneer restorations, it is important to clarify the terminology. A simple definition of the term "veneer" signifies a thin sheet of material usually used as a finish.[2] This term is applicable when a restorative material such as porcelain is bonded to a framework (e.g., metal-ceramics–see Chapters 19 and 24). Laminate veneer restorations are defined as thin, bonded restorations that restore the facial, incisal, and part of the proximal surfaces of teeth requiring esthetic restoration.[2] Veneers rely exclusively on bonding for retention. The most common veneer materials in dentistry are composite resin and ceramic. Composite resin veneer restorations are typically fabricated as a direct restoration in the mouth. They are less popular because composite resin material is limited when trying to achieve natural esthetics and is subject to staining. However, ceramic veneers are always fabricated extraorally and have superior natural esthetics and better durability and longevity when the restorations are bonded properly (Fig. 3.18A–C).[49] Veneer restorations are indicated when the patient has reasonably aligned teeth and desires an esthetic improvement in color or when a patient is not satisfied with the outcome of bleaching. An additional indication is for mandibular anterior teeth to improve occlusal contacts, where the mandibular lingual surfaces can be spared. Veneer restorations can only be bonded to enamel, and clinical data related to dentin bonding is scarce. Dentists should not use veneer restorations as a quick fix "cosmetic treatment" for orthodontic correction and should also educate patients that in the absence of adequate enamel, a veneer preparation may need to be converted into a complete crown to provide better retention, resistance, and longevity. These restorations are described further in Chapter 10.

Fig. 3.16 (A) Inlay preparations were chosen to restore these carious teeth instead of direct composite resin or amalgam restorations due to patient's esthetic requirements. (Courtesy Dr. G. Giglio.) (B) Bonded ceramic inlay restorations made of lithium disilicate material. (Courtesy Dr. G. Giglio.)

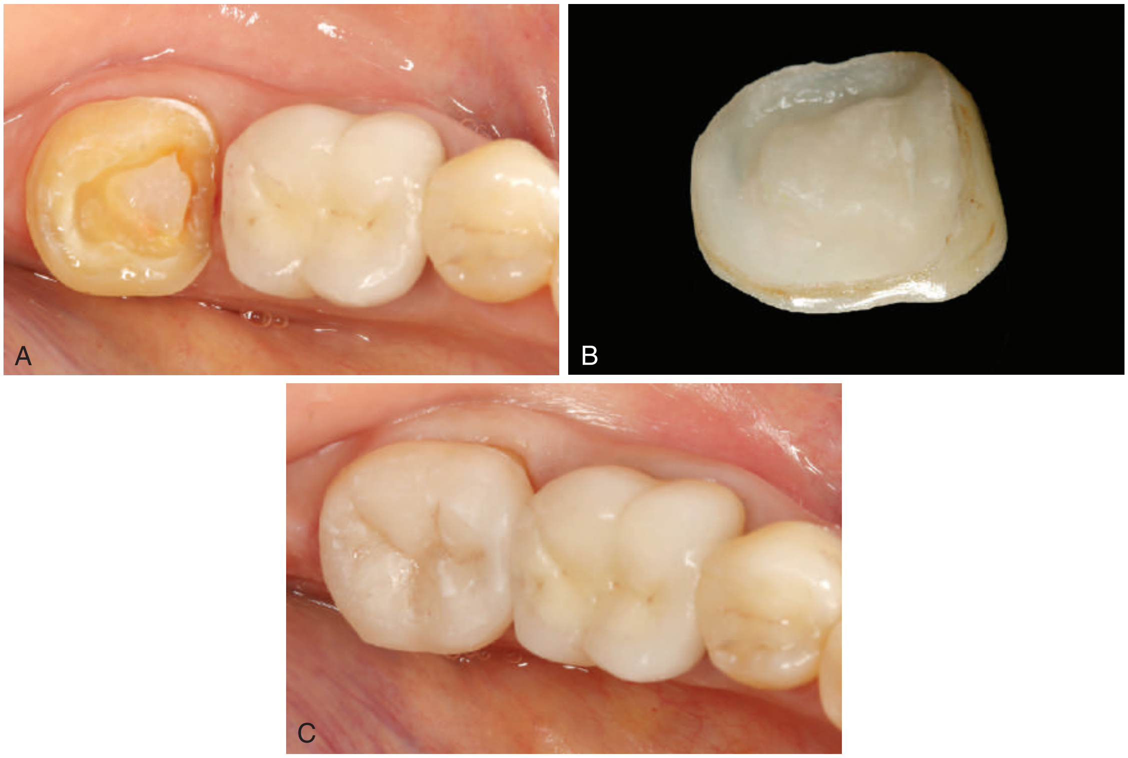


Fig. 3.17 (A) This second molar was prepared conservatively for a ceramic onlay instead of a crown. (B) Ceramic onlay restoration made of lithium disilicate material. (C) Bonded ceramic onlay restorations. When chosen carefully, they offer an excellent conservative alternative to crowns. (A–C, Courtesy Dr. G. Giglio.)

Fig. 3.18 (A) The four maxillary incisors in this patient have discolorations and previous failing restorations in the cervical region. (B) Veneer preparations were restricted to enamel and were conservative. (C) Bonded ceramic veneer restorations offered a long-term durable and esthetic result and left the palatal surfaces intact.

Crowns

Single crowns are some of the most fundamental and popular restorations in fixed prosthodontics.[39] Crowns restore missing tooth structure by encircling part or all of the remaining structure with either a complete metal, metal-ceramic, or ceramic material (see Figs. 3.13, 3.15, and 3.19). The decision to restore a diseased or damaged tooth with a crown versus onlay is dependent on the amount of lost tooth structure, the residual tooth structure available for bonding, the ability to locate preparation margins in enamel, and the need to alter the occlusion. Contemporary treatment planning in fixed prosthodontics centers on the anticipation of future needs. Therefore, in complex treatments, whenever feasible, teeth should be restored as single crowns rather than splinting teeth as was practiced historically and may still be popular in some countries.[25,26] When teeth are missing in an arch, single-unit implants could be considered if there is favorable hard and soft tissue. This allows the teeth to be restored individually, facilitating plaque control measures and reducing the risk of future biological or mechanical problems. Further discussion on tooth preparations for various types of single crowns can be found in Chapters 8 to 11.

Fixed Partial Dentures

An FPD is indicated when there is a missing tooth or teeth in an arch and when adjacent teeth are deemed as endodontically, restoratively, and periodontally healthy and biomechanically sound (Fig. 3.20A–D).[31–33] The tooth or teeth being replaced are called pontics, and the adjacent teeth that provide support are called abutments. The FPD retainers unite the prosthesis to the abutments. The retainers are joined to the pontics by means of connectors on either side. FPDs are typically supported by abutments on either side. However, resin-bonded FPDs may be retained on one side only, in which case the pontic is considered to be a cantilever. Abutments for resin bonded FPDs may be intact teeth or only minimally prepared, retention being provided by bonding (Fig. 3.21A and B). They can be made of base metal, which allows etching, or from zirconia (see Chapter 26).

Fig. 3.19 Single crown restorations made of gold, metal-ceramic, or complete-ceramic material are the fundamental and the most popular restoration in fixed prosthodontics.

While implants are usually the first choice for the replacement of missing teeth, FPDs are valuable in a number of situations. For example, when a patient declines surgery, there is a history of failed implants, the patient has limited finances, teeth on either side of the edentulous space already require complete coverage restorations, and when a patient desires that treatment is completed quickly, because implants require additional treatment time.[25] However, dentists should avoid indiscriminate preparation of healthy unrestored teeth to replace missing teeth because FPDs can increase the risk of future complications and, when poorly planned or executed, may even contribute to accelerated tooth loss. Long-term FPD survival is hampered by biological issues related to caries, the possible need for endodontic treatment, and periodontal disease. Similarly, mechanical complications can arise, such as fracture of a brittle ceramic veneer or even the FPD itself (see Chapters 19, 20, and 27).[16]

Implant-Supported Restorations

In general, implant-supported restorations are the first choice for replacing single or multiple missing teeth. In the absence of contraindications, dentists should offer this option rather than proceed with far more invasive irreversible treatments such as FPDs (Fig. 3.22A–D). Implants can be used to replace a single missing tooth, multiple teeth, or even an entire arch. They can be also be used to retain and support removable prostheses. Not every tooth to be replaced requires an implant, and all teeth in an arch can be replaced with a minimum of four implants (see also Chapter 13).

Removable Partial Dentures

A removable partial denture (RPD) is a removable prosthesis that replaces some teeth in a partially edentulous arch and can be readily inserted and removed from the mouth by the patient.[2] A well-fabricated FPD improves health and has better function than an RPD[50] and is preferred by most patients. RPDs can be made of metal-resin, flexible polyamide,[51] or completely in acrylic resin; the latter are predominantly used for interim purposes. It may appear paradoxical to discuss RPDs in a chapter on treatment planning for fixed prosthodontics, but certain long-span partially edentulous situations may require RPDs (when implants are not an option) in conjunction with fixed prostheses (Fig. 3.23). A common example is when anterior maxillary or mandibular teeth are restored with crowns or FPDs, and the posterior dentition is replaced with RPDs since no posterior abutment is present or because of anatomic or financial limitations. Any fixed restorations that support an RPD should be carefully designed to provide a proper path of insertion for the RPD (through guide planes), proper support (through rest seats), and adequate retention (by carefully planned heights of contour) (see Chapter 21).

Complete Dentures

Well-known difficulties encountered with complete dentures are lack of stability and gradual loss of supporting bone with time. Patients tend to tolerate a well fabricated maxillary complete denture better than a well-fabricated mandibular complete denture because of differences in jaw shape, surface

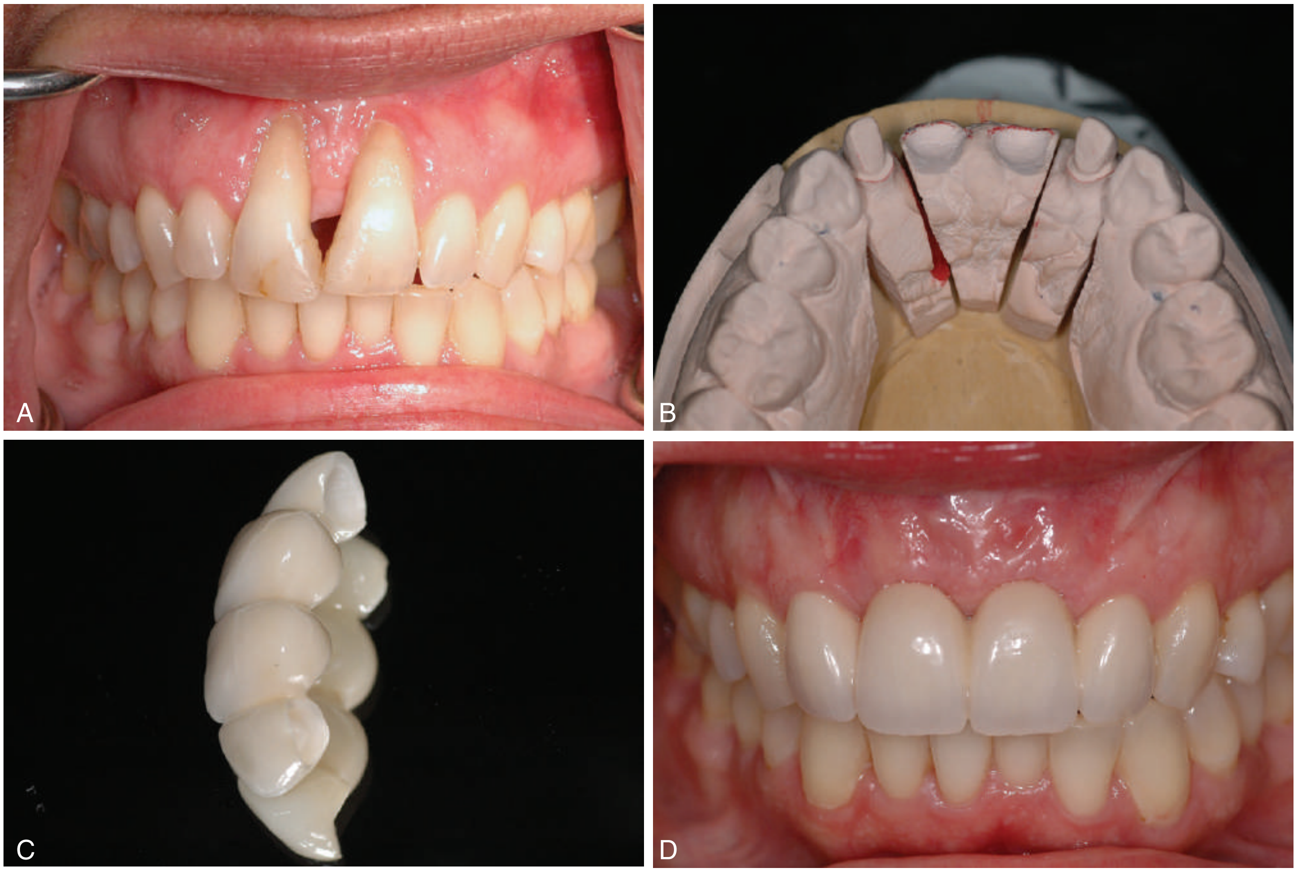


Fig. 3.20 (A) Patient with failing maxillary central incisors with loss of hard and soft tissues. A fixed partial denture (FPD) was chosen by the patient over implants to avoid the significant pre-prosthetic reconstruction that would be necessary before implant placement. (B) Definitive cast showing teeth preparations on lateral incisors and pontic site development. (C) The 4-unit FPD was made of zirconia with veneered facial ceramic. Notice the smooth and convex shape of the pontics. (D) The zirconia FPD restored the esthetics and function effectively in this patient. (From Bidra AS, Chapokas AR. Treatment planning challenges in the maxillary anterior region consequent to severe loss of buccal bone. *J Esthet Restor Dent*. 2011;23[6]:354–60.)

Fig. 3.21 (A) Left mandibular central incisor being replaced by resin-bonded, single-winged zirconia cantilevered fixed partial denture. (B) Frontal view showing excellent esthetics from the resin-bonded prosthesis (see Chapter 26). (A and B, From Kern M, Chaar S, Passia N. Frugale Methoden in der prothetischen Zahnmedizin. zm 2019;109:52–58.)

area, influence of the tongue, and the difference in peripheral seal. Therefore, as an adjunct in treatment planning complex scenarios, a common scenario favored by many patients to reduce treatment cost is to extract all remaining teeth in the maxilla and restore the opposing mandibular dentition with fixed restorations (Fig. 3.24). This permits optimization of esthetics, occlusion, and function and may extend the prognosis of compromised mandibular teeth. Such an approach can retain the option of future treatment of the maxillary arch with a CAFIPs. Nevertheless, any treatment plan that

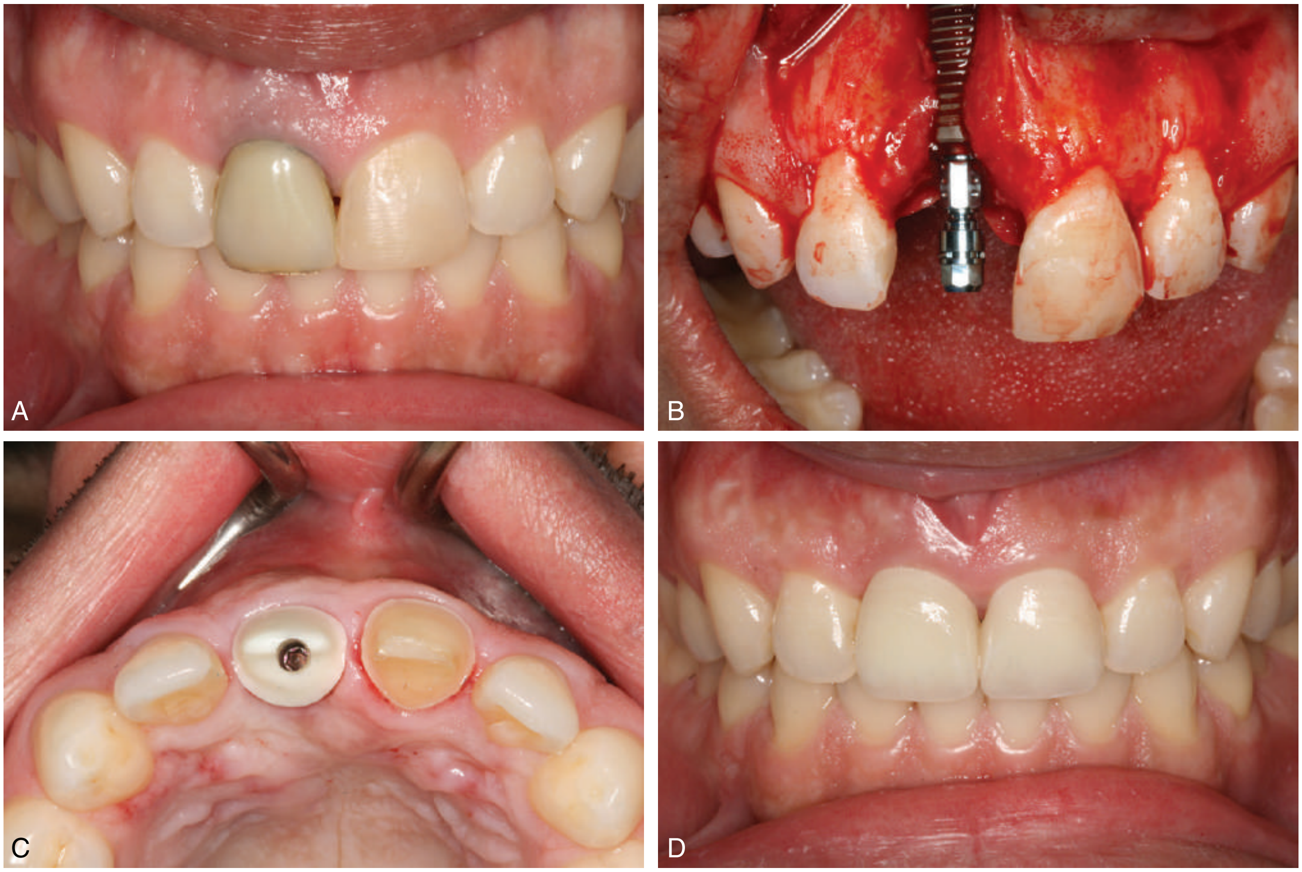


Fig. 3.22 (A) Same patient from Fig. 3.7 showing infected right central incisor and a failing restoration on left central incisor. (B) Despite the left central incisor requiring a crown, the treatment plan was to place a single implant at the right incisor instead of preparing the lateral incisor for a 3-unit fixed partial denture. (C) Occlusal view showing the zirconia abutment over the implant and crown preparation on the left incisor. (D) Single crown zirconia restorations with veneered porcelain cemented over both incisors. Notice the excellent soft tissue contour and esthetics.

Fig. 3.23 When implants are not an option in long-span edentulous regions, a removable partial denture is necessary and is often fabricated in conjunction with fixed prosthodontics treatment.

Fig. 3.24 Same patient from Figs. 3.9 and 3.12 showing maxillary complete denture opposing mandibular fixed restorations. This is a common form of treatment when implants are not an option in the maxilla and allows optimization of esthetics, vertical dimension, and occlusal plane and provides a cost-effective solution.

involves a complete denture opposing fixed restorations requires careful planning of the occlusion and choosing appropriate biomaterials.[52]

BIOMECHANICAL CONSIDERATIONS IN TREATMENT PLANNING

Biomechanical considerations in fixed prosthodontics include the following: role of the abutment tooth with respect to the design of the restoration (i.e., onlay, single crown, FPD), root angulation, root surface area, edentulous span/number of teeth to be replaced, need for cantilevers, periodontal health, nature of occlusion and the opposing dentition. Additional biomechanical considerations include the condition of the proposed abutment and the physical properties of the prosthetic materials.

Root Angulation and Root Surface Area

When periodontal support is compromised, the root shape, angulation, and length should be carefully evaluated. A molar with long and divergent roots provides better support than one with short conical roots and little or no interradicular bone. A single-rooted tooth with an elliptic cross-section offers better support than does a tooth with a similar root surface area but with a circular cross-section.

The root surface area of potential abutment teeth must be evaluated when fixed prosthodontic treatment is planned. Ante[53] suggested in 1926 that it was unwise to provide an FPD when the root surface area of the abutments was less than the root surface area of the teeth being replaced; this suggestion has been adopted and reinforced by other authors as Ante's law.[54–56] Average values for the root surface area of adult teeth are given in Table 3.1.[57] As an example of Ante's law, consider the patient who has lost a first molar and a second premolar. In this situation, a four-unit FPD 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 FPD is not considered a good risk because the total root surface area of the teeth being replaced is greater than that of the potential abutments.

Nyman and Ericsson,[20] however, cast doubt on the validity of Ante's law by demonstrating that teeth with considerably reduced bone support can be successfully used as FPD abutments. In the majority of the treatments that they discussed, 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. Nyman and Ericsson attributed this success to meticulous root planning during the active phase of treatment, proper plaque control during the observed period, and meticulous occlusal design of the prostheses. Other authors have confirmed that abutment teeth with limited periodontal bone can successfully support FPDs.[58,59] However, with the advent of predictable implant prosthodontics, long-span FPDs should ideally be reserved for select cases after thoughtful consideration of all alternative treatment options.

TABLE 3.1 Root Surface Area of Abutment

Area in Quadrant	Root Surface Area (nm²)	Percentage of Root Surface
Maxillary		
Central incisor	204	10
Lateral incisor	179	9
Canine tooth	273	14
First premolar	234	12
Second premolar	220	11
First molar	433	22
Second molar	431	22
Mandibular		
Central incisor	154	8
Lateral incisor	168	9
Canine tooth	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*. 1963;21:35.

Replacement of a Single Missing Tooth

When an implant is not an option, and an FPD is chosen to replace a single missing tooth, a three-unit FPD that includes one mesial and one distal abutment tooth is a straightforward solution. Two exceptions include when the FPD is replacing either a maxillary or mandibular canine tooth. Under these circumstances, the small lateral incisor may be splinted to the central incisor to prevent lateral drift of the FPD. This use of two adjacent abutment teeth is referred to as double-abutting. Another exception is when replacing a maxillary lateral incisor, which occasionally can be replaced by cantilevering it from a single distal retainer on the canine as long the latter is in sound periodontal health, and the occlusal load on the cantilever can be kept to a minimum.

Replacement of Multiple Missing Teeth

Fixed prosthodontic treatment becomes more difficult when several teeth need to be replaced. Problems are encountered in restoring a single long, uninterrupted edentulous area or multiple edentulous areas with an intermediate abutment tooth ("pier abutment"), even more so when anterior and posterior teeth are to be replaced with a single FPD (Fig. 3.25A–C).

Underestimating the challenges involved in extensive prosthodontic treatment often leads to failure. It is prudent and helpful to design the prostheses by diagnostically waxing the planned restorations on articulated diagnostic casts. This is essential for complex fixed prosthodontic treatments, particularly when an uneven occlusal plane is to be corrected, the occlusal vertical dimension is to be altered, an implant-supported prosthesis is recommended, or a combination of FPDs and RPDs is planned.

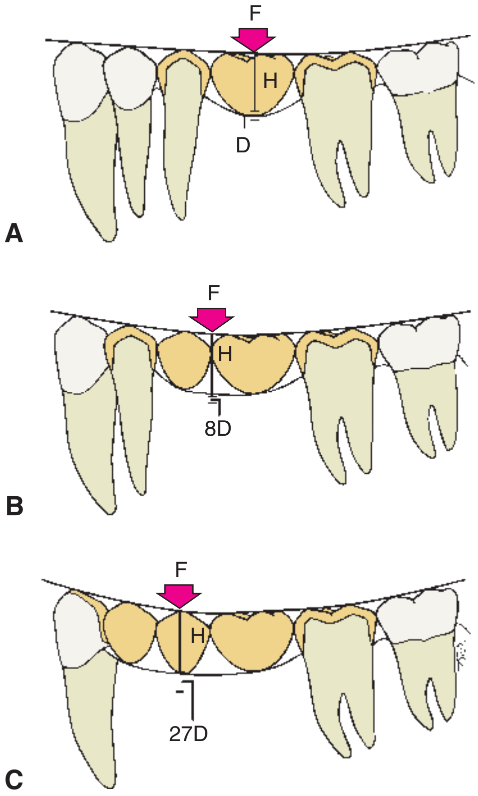
Fig. 3.25 (A) Same patient from Fig. 3.8. Long span partially edentulous sites seen on maxillary right side where a fixed partial denture (FPD) was planned. Such long-span FPDs require careful planning and meticulous fabrication technique. (B) To improve accuracy in fabrication and to relieve stress on the 6-unit FPD, the FPD metal framework was fabricated as two separate castings with a key and keyway. Image shows the method of seating of the posterior component. (C) The definitive restorations cemented in the mouth show accurate fit and seating of all components. Metal occlusal surfaces were used because of patient's bruxism habits. (From Bidra AS, Uribe F. Preprosthetic orthodontic intervention for management of a partially edentulous patient with generalized wear and malocclusion. *J Esthet Restor Dent*. 2012;24(2):88–100.)

Span Length

Because of biological, material, and technical limitations, span length is an important consideration when using FPDs to replace missing teeth. Long-span FPDs are challenging to make, and clinical procedures such as impression making are more complex. FPD design must anticipate that excessive flexing under occlusal loads can cause premature failure, leading to fracture of the porcelain veneer, connector fracture, loosening of a retainer, tooth mobility, or an unfavorable soft tissue response, rendering the prosthesis useless. All FPDs can flex slightly when subjected to a load—the longer the span, the greater the flexure. The relationship between deflection and length of the 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 eight times as much, and a span of three will move 27 times as much (Fig. 3.26A and B).[60]

One method that can mitigate some of the challenges associated with long-span FPDs is to segment them into smaller components. Often nonrigid connectors can be used for this purpose when metal-ceramic has been selected as the material of choice.[25,61] In this scenario, two separate well-fitting metal castings are fabricated, one with a matrix and another with a patrix. The interface will then provide some relief and separation to accommodate the flexure of the long-span FPDs (see Fig. 3.25B). This design is restricted to metal and cannot be used with ceramic materials like zirconia or lithium disilicate. Additionally, dentists should anticipate the likelihood of complications as a prosthesis has served for many years, and sectioning off a long-span FPD of any material is significantly more difficult than the relatively straightforward removal of a small-span FPD.

An FPD with one pontic has the most favorable prognosis in any part of the mouth. This is followed by an FPD with two pontics in the anterior region. Thereafter, any FPD with two or more pontics in the posterior regions have a lesser prognosis which should be carefully weighed against alternative treatment options such as an implant-supported prosthesis or an RPD. Exceptions to these scenarios include when the FPD is opposing a complete denture where the occlusal loads tend to be lower. Another successful FPD in the mandibular anterior



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

Fig. 3.26 (A) The deflection of a fixed dental prosthesis is proportional to the cube of the length of its span. A single pontic deflects a small amount (D) when subjected to a certain force (F). (B) Two pontics deflect 2^3 times as much (8D) to the same force. (C) Three pontics deflect 3^3 times as much (27D).

region includes a six-unit FPD from canine to canine. In the maxillary arch, it is prudent to use two abutment teeth for an FPD replacing the four incisors on at least one side of the arch by incorporating the first premolar.

Overloading of Abutment Teeth

The ability of the abutment teeth to accept applied forces without drifting or becoming mobile should be estimated and has a direct influence on the prosthodontic treatment plan. Such forces can be particularly severe if a patient engages in parafunctional activities such as bruxism or clenching, and it is desirable to eliminate or reduce such detrimental activities prior to initiating the comprehensive restoration of a severely compromised dentition. Although ideally, a well-redesigned occlusion will reduce the incidence, duration, and load associated with parafunctional activity, there is little scientific evidence to support this. It is unwise to initiate extensive prosthodontics treatment on the assumption that the new restorations will reduce parafunctional activity unless this has been tested and confirmed prior to restorative treatment with occlusal device treatment over a significant period.[62]

Cantilever Fixed Partial Dentures

FPDs in which only one side of the pontic is attached to one or multiple retainers are referred to as cantilevered. A classic popular example is a lateral incisor pontic attached only to the adjacent canine retainer.[63] Cantilever FPDs can be made of metal-ceramic or ceramic materials such as zirconia. Cantilevered FPDs remain popular because they are obviously more conservative of tooth structure, and some of the difficulties encountered in making a three-unit FPD are lessened. Especially thin central incisors with pronounced inciso-cervical lingual curvature can be very challenging. 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 in most other situations is poor.[64] Forces are best tolerated by the periodontal supporting structures when directed along the long axes of the teeth.[65] This is the case when a simple three-unit FPD 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. Laboratory analysis[66,67] has confirmed the potentially harmful nature of such FPDs. However, clinical experience with resin-retained FPDs has suggested that they are more successful when cantilever designs are used compared with being bonded on both sides, with tooth movement causing bonding failure (see Chapter 26).[68,69] Cantilevers can also successfully be used with implant-supported prostheses (see Chapter 13).

Nature of Occlusion and Opposing Dentition

Ultimately, every type of fixed prosthodontic restoration is subject to occlusal loads. Therefore, occlusal design, consideration of the type of opposing dentition, and compatibility between the types of materials used should be considered. In general, incorporating a mutually protected articulation with canine guidance should be the first choice for any complex treatment where one entire arch or both arches are being restored. In other scenarios, in the absence of pathologies that are obviously related to the occlusion, the patient's existing occlusal arrangement may be retained, but all undue mediotrusive (non-working) or protrusive interferences in the new restorations should be eliminated. Dentists may perform occlusal adjustments and reshaping when opposing dentition has shown supra-eruption or tipping of teeth in an effort to improve the long-term prognosis. Also, such occlusal treatment is helpful to enable a reproducible mandibular position during the course of comprehensive prosthodontic treatment. However, there is no scientific evidence for generalized occlusal reshaping of a patient's remaining natural dentition to improve comfort or TMJ health.[70]

The nature of opposing the dentition plays an important role in the success of fixed restorations. Prostheses opposing complete dentures may have better longevity because of reduced loading, but the removable prosthesis itself may need to be replaced more frequently if severe wear occurs due to differences in wear properties between plastic denture teeth and opposing porcelain restorations (see Fig. 3.24). Complications can also be expected when periodontally involved abutment teeth supporting fixed restorations are opposing implant-supported fixed restorations. Dentists should pay careful attention to the opposing dentition when selecting materials and making treatment planning decisions.

TREATMENT SEQUENCE

Because of the diverse nature of each patient's clinical situation and the diverse scenarios encountered with individual teeth, a detailed specific treatment sequence may be difficult to develop. However, a general treatment sequence encompassing (1) patient's chief concern, (2) correction of any existing dental disease; (3) improvement of esthetics, occlusion, and function; and (4) prevention of future disease by instilling a lifelong professional and at-home maintenance regimen is described below in points as a potential logical sequence. The importance of proper sequencing is emphasized because mistakes can lead to compromised outcomes and/or unnecessary and expensive remakes.[71,72]

1. Treatment of patient symptoms (e.g., pain, sensitivity, abscess, mobile tooth)
2. Urgent treatment of nonacute problems (e.g., lost anterior crown, a cracked or broken porcelain veneer, or a fractured RPD).
3. Comprehensive diagnostics and evaluation, including caries risk analysis, periodontal evaluation, endodontic evaluation (vitality testing), TMJ, and occlusal evaluation (see Chapters 2, 4, and 6). A signed treatment plan including financial obligations should be written and signed at this stage.
4. Periodontal treatment, including scaling and root planning or oral prophylaxis.
5. Restorability assessment of all planned teeth by removing all questionable old restorations and determining which teeth can be restored and which ones are indicated for extraction. Interim restorations can be made to mimic the existing situation before the commencement of definitive prosthodontic treatment.
6. Extraction of non-restorable teeth, periodontally compromised teeth, teeth with interferences, and elective extractions.
7. Diagnostic waxing (manual or digital) to establish ideal esthetics, tooth proportions, and occlusal plane. When pre-prosthetic orthodontics is planned, this step can be accomplished after orthodontic treatment is completed.
8. Pre-prosthetic treatment including orthodontics, elective endodontics, periodontal surgery, subcrestal prosthodontics (implant surgery, ridge augmentation).
9. Definitive prosthodontic treatment including teeth preparations, interim restorations, soft tissue health management, final impressions of teeth and/or implants, maxillomandibular relationship (jaw relation) records, trial insertion, and definitive insertion of all restorations.
10. Insertion of an occlusal device in patients with complex fixed prosthodontic treatment (to protect the restorations) and in patients with a diagnosis of bruxism.
11. Lifelong professional maintenance and at-home maintenance.

FOLLOW-UP AND MAINTENANCE

It is important for dentists and patients to understand that fixed prosthodontics does not in any way imply "permanence." All restorations have a finite lifespan, but with good recall and maintenance, their longevity can be significantly enhanced. The American College of Prosthodontists clinical practice guidelines[18] recommends a regular professional recall of patients with any type of fixed dental restorations at least every 6 months as a lifelong regimen. The guidelines also recommend various protocols for professional and at-home maintenance depending on the specific types of restorations and emphasize the importance of dentists providing repeated oral hygiene instructions to patients (see Chapter 31).[18]

COMPLEX PROSTHODONTICS

Carefully planned treatment sequencing is critically important in the planning of complex prosthodontic treatments involving alteration of the vertical dimension or a combination of FPDs and partial RPDs. One recommended approach is the use of cross-mounted diagnostic casts, illustrated in Fig. 3.27. 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 endpoint of treatment, with denture teeth inserted where partial RDPs 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

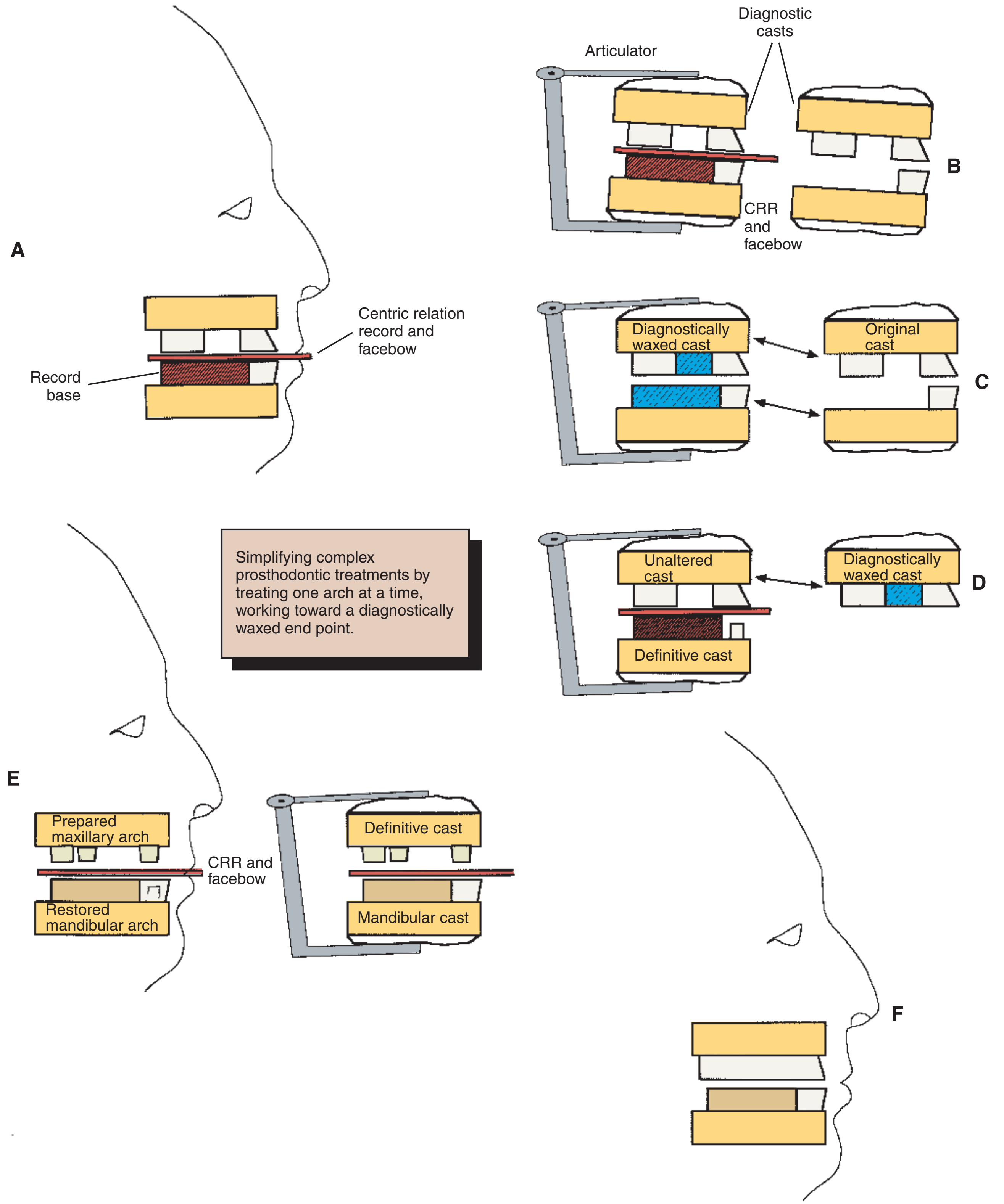


Fig. 3.27 Complex prosthodontic treatment sequence with the use of cross-mounted diagnostic casts. (A) Diagnostic impressions, facebow, and centric relation records (CRRs) are made for a patient requiring complex prosthodontic treatment. In this schematic, a record base is needed for mounting the mandibular 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 CRR. (C) One pair of diagnostic casts is waxed to the proposed endpoint of treatment. If a partial removable dental 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. In this example, the mandibular arch has been prepared for crowns. The definitive cast is mounted on the articulator with a CRR 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. (F) The completed restoration conforms to the diagnostic waxing.

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

SUMMARY

The basis of treatment planning consists of addressing the four primary objectives of a patient's chief complaint: correction of any existing dental disease, improvement of esthetics, occlusion and function, and an effort to prevent future disease by instilling a lifelong professional and at-home maintenance regimen. Treatment planning should also encompass pre-prosthetic considerations from various disciplines, material considerations and biomechanical considerations.

Importantly, treatment planning should incorporate the best available scientific evidence along with the clinician's expertise and the patient's needs.

STUDY QUESTIONS

1. Discuss 12 considerations that affect the design of a fixed dental prosthesis (FDP) and their general effect on the design of such prostheses.
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 dental 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 the span length and design of the FDP 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 problems. Briefly explain the importance of the treatment sequence.

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Principles of Occlusion

Most restorative procedures affect the shape of the occlusal surfaces. Proper dental care ensures that functional occlusal contact relationships are restored in harmony with both dynamic and static conditions. Maxillary and mandibular teeth should contact uniformly on closing to allow optimal function, minimize trauma to the supporting structures, and allow for uniform load distribution throughout the dentition. Positional stability of well-aligned teeth is crucial if arch integrity and proper function are to be maintained over time.

Most dentitions deviate from optimal alignment and occlusion. Many patients adapt well to less than optimal occlusion, but malocclusion may be associated with undesirable changes to the teeth, the musculature, the temporomandibular joints (TMJs), or the periodontium. 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 concepts of what is "ideal," "acceptable," and "harmful" continue to evolve.

This chapter reviews the anatomic structures important to the study of occlusion and includes a discussion of mandibular (lower jaw) movement. The concept of ideal versus pathologic occlusion is introduced, as is the history of occlusal theory. The chapter concludes with general guidelines for the initial phase of occlusal treatment.

ANATOMY

Temporomandibular Joints

The major components of the TMJs are the cranial base, the mandible, and the muscles of mastication with their innervation and vascular supply. The TMJs are ginglymoarthrodial, meaning that they are capable of both a hinging and a gliding articulation. An articular disc separates the mandibular fossa and the 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 disc 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 (called *bilaminar* because it consists of two layers: an elastic superior layer and a collagenous inelastic inferior layer). The retrodiscal pad connects to the posterior wall of the articular capsule surrounding the joint (Fig. 4.1). Medially and laterally, the articular disc 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 disc 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 articular disc follows condylar movement during both hinging and translation, which is made possible by the loose attachment of the posterior connective tissues.

Ligaments

The body of the mandible is attached to the base of the skull by muscles and three paired ligaments: the temporomandibular (also called the *lateral*), the sphenomandibular, and the stylomandibular ligaments (Table 4.1). Ligaments cannot be stretched significantly and thus joint movement is limited. The temporomandibular ligaments restrict rotation of the mandible, limit border movements, and protect the structures of the joint.[1] The sphenomandibular and stylomandibular ligaments (Fig. 4.2) limit separation between the condylar process and the articular disc; the stylomandibular ligaments also limit forward *(protrusive)* movement of the mandible.

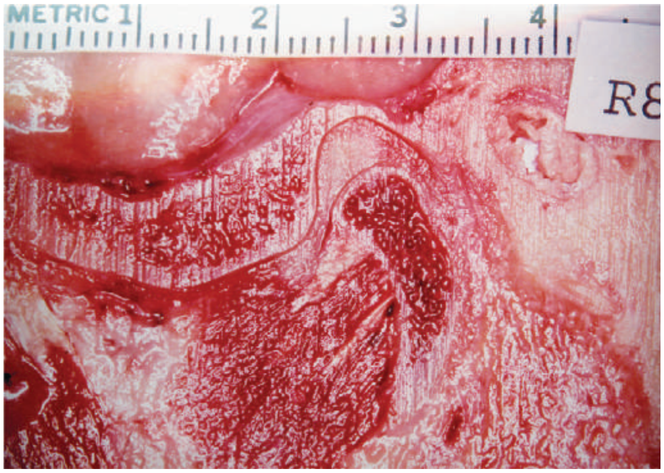
Musculature

Several muscles are responsible for mandibular movements. These can be grouped as the muscles of mastication and the suprahyoid muscles (Fig. 4.3). The former include the temporal, masseter, and medial and lateral pterygoid muscles; the latter are the geniohyoid, mylohyoid, and digastric muscles. Their respective origins, insertions, innervation, and vascular supply are summarized in Table 4.2.

Muscular Function

The functions of the mandibular muscles are well coordinated and complex. Three paired muscles of mastication provide elevation and lateral movement of the mandible: the temporal, masseter, and medial pterygoid muscles. The lateral pterygoid muscles each have two bellies that function as two separate

A



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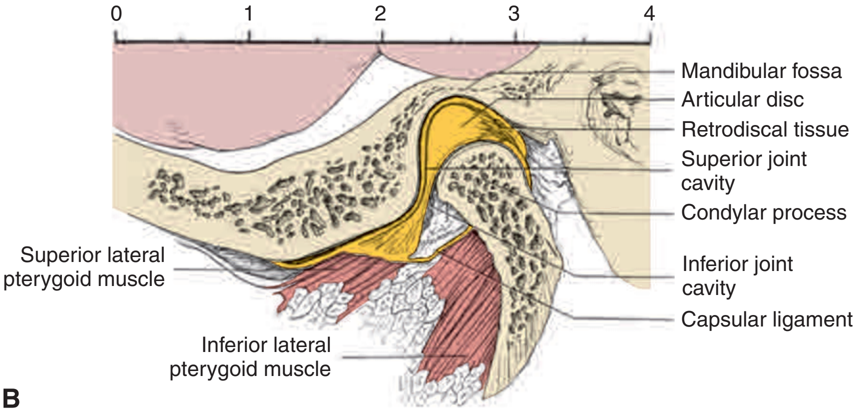


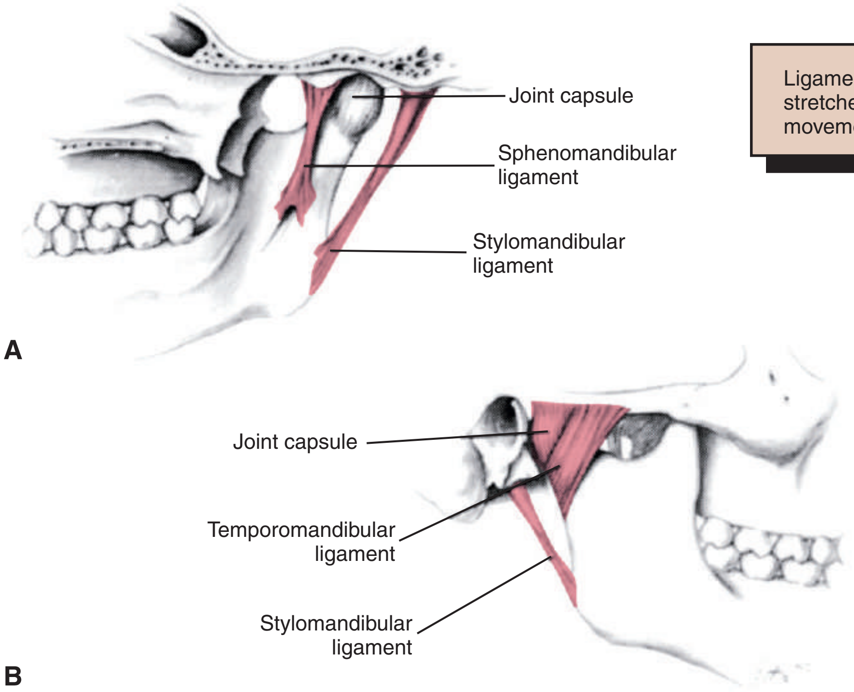
Fig. 4.1 Temporomandibular joint (lateral section). (A) The mandible is open. (B) Schematic representation of the dissected components in A. (A, Dissection courtesy of Dr. K.A. Laurell.)

TABLE 4.1 Mandibular Ligaments

Ligament	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

muscles, which contract in the horizontal plane during opening and closing; the inferior belly (inferior lateral pterygoid muscle) is active during protrusion, depression, and lateral movement of the mandible; the superior belly (superior lateral pterygoid muscle) is active during closure. Because the superior belly has been shown to attach to the articular disc and the neck of the condyle, it is thought to assist in maintaining the integrity of the condyle–articular disc assembly by pulling the condylar process firmly against the articular disc.

The suprahyoid muscles 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 mandibular 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 muscles 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.



Ligaments cannot be stretched, which limits movement.

Fig. 4.2 Ligaments of the temporomandibular joint. (A) Medial view. (B) Lateral view.

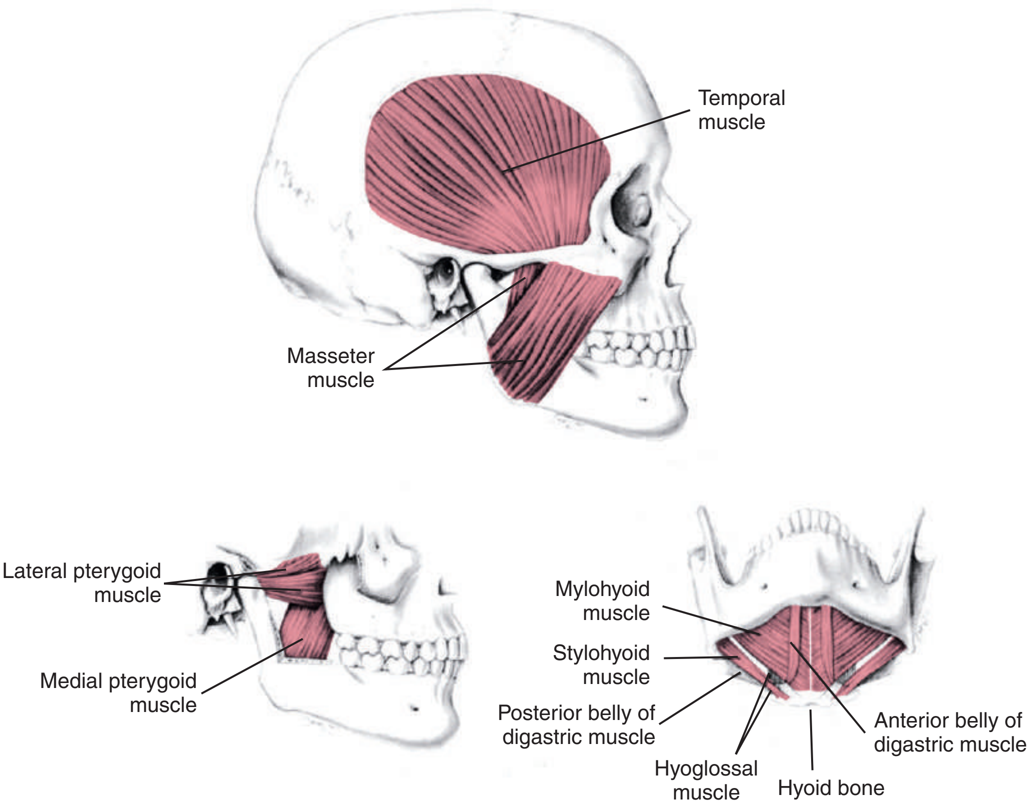


Fig. 4.3 The muscles of mastication and the suprahyoid muscles.

TABLE 4.2 Muscles of Mastication

Muscle	Origin	Insertion	Innervation	Vascular Supply	Function
Temporal	Lateral surface of skull	Coronoid process and anterior border of ramus	Temporal nerve (branch of mandibular nerve)	Middle and deep temporal arteries (branches of superficial temporal and maxillary arteries)	Elevates and retracts mandible, assists in rotation; active in clenching
Masseter	Zygomatic arch	Angle of mandible	Masseteric nerve (division of trigeminal nerve)	Masseteric artery (branch of maxillary artery)	Elevates and protracts mandible, 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 nerve)	Branch of maxillary artery	Elevates mandible, enables lateral movement and protrusion
Superior lateral pterygoid	Infratemporal surface of greater wing of sphenoid	Articular capsule and disc, neck of condyle	Branch of masseteric or buccal nerve	Branch of maxillary artery	Positions articular disc 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 mandible, enables lateral movement
Mylohyoid	Inner surface of mandible	Hyoid and mylohyoid raphae	Branches of mylohyoid nerve (division of trigeminal nerve)	Submental artery	Elevates and stabilizes hyoid bone
Geniohyoid	Genial tubercle	Hyoid bone	First cervical nerve via hypoglossal nerve	Branch of lingual artery	Elevates and draws hyoid bone forward
Anterior belly of digastric nerve	Tendon linked to hyoid bone by fascia	Digastric fossa (lower border of mandible)	Branch of mylohyoid nerve (division of trigeminal nerve)	Branch of facial artery	Elevates hyoid bone, depresses mandible

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 the harmonious movement of the mandible during function. Ideally, in the fully bilateral seated position of the condyle–articular disc 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 closure without excessively loading any one tooth, while left and right TMJs concurrently are 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; this is sometimes considered the best fit of the teeth regardless of condylar position.

If the mesiobuccal cusp of the maxillary first molar is aligned with the buccal groove of the mandibular first molar, the orthodontic relationship is considered Angle class I (Fig. 4.4); this is considered normal occlusion. In such a relationship, the anterior teeth overlap both horizontally and vertically. This position is defined as the dental relationship in which the anteroposterior relationship of the jaws is normal, as indicated by correct intercuspation of maxillary and mandibular molars, Orthodontic textbooks[3] have traditionally described an arbitrary 2-mm horizontal overlap and 2-mm vertical overlap as being ideal. For most patients, however, greater vertical overlap of the anterior teeth is desirable for preventing undesirable posterior tooth contact. Mandibular flexing during mastication also may contribute to such undesirable contact. 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.

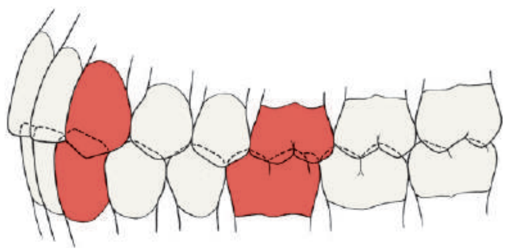


Fig. 4.4 The Angle class I occlusal relationship.

CENTRIC RELATION

Centric relation is defined as the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective articular discs 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 anterior and is restricted to a purely rotary movement about the transverse horizontal axis.

Centric relation is considered a reliable and reproducible reference (and treatment) 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 is initiated.

MANDIBULAR MOVEMENT

As any other movement in space, complex three-dimensional mandibular movement can be divided into two basic components: *translation*, in which all points within a body have identical motion, and *rotation*, in which 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 hinging motion occurs between the condylar process and the articular disc. During translation, the inferior lateral pterygoid muscle contracts and moves the condyle–articular disc 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

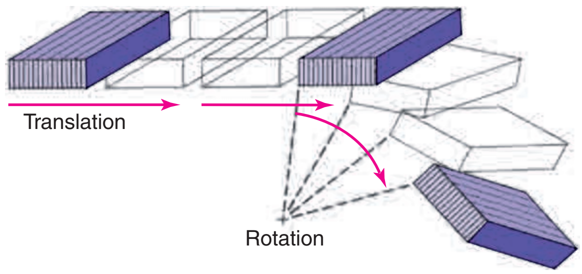


Fig. 4.5 Three-dimensional movement of a body can be defined by a combination of translation (all points within the body having identical movement) and rotation (all points turning around an axis).

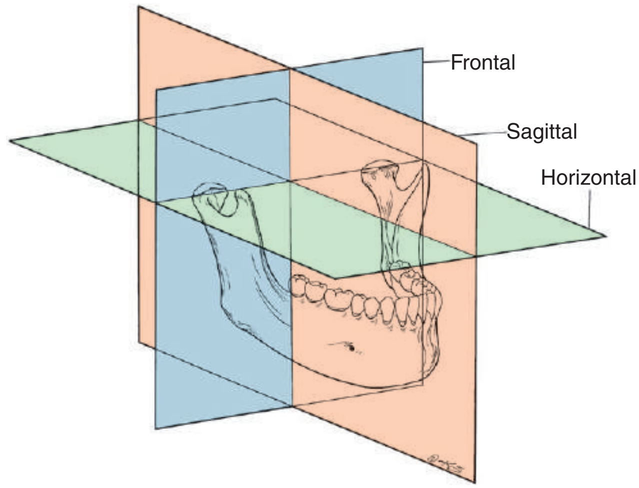


Fig. 4.6 Reference planes.

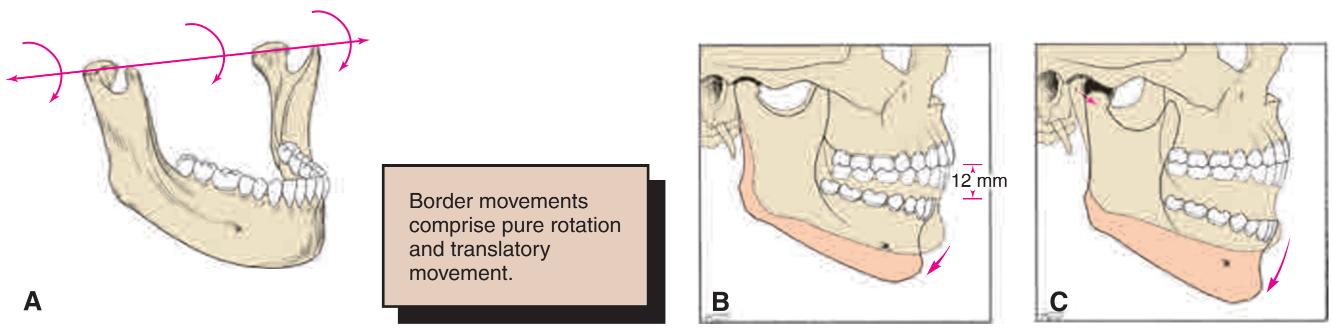


Fig. 4.7 (A) In a sagittal plane, the mandible can rotate around the terminal hinge axis. (B) After about 12 mm of incisal opening, the mandible is forced to translate. (C) Maximum opening; the condyles have translated forward.

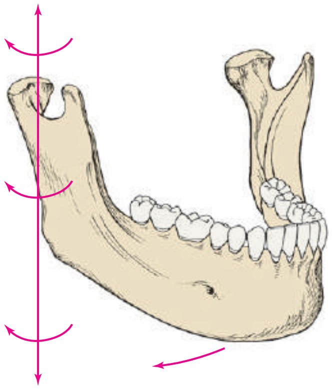


Fig. 4.8 Rotation in the horizontal plane occurs during lateral movement of the mandible. (The vertical axis is situated in the condylar process.) Normally, there is relatively little translation (side shift).

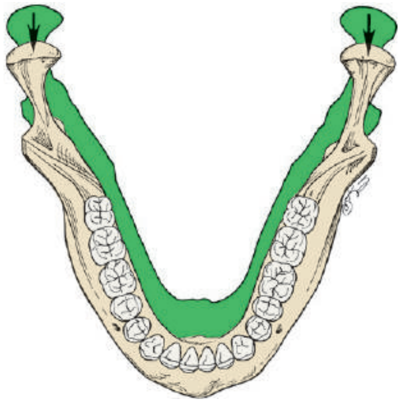


Fig. 4.10 Protrusive mandibular movement in the horizontal plane.

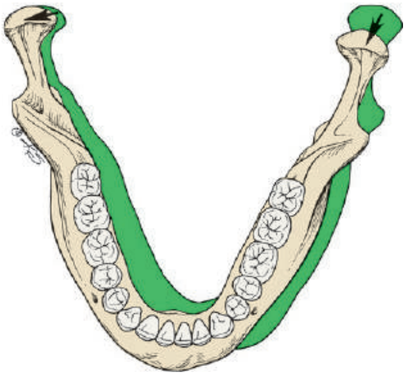


Fig. 4.9 Right lateral mandibular movement in the horizontal plane.

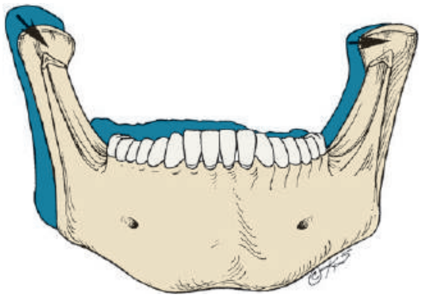


Fig. 4.11 Lateral movement in the frontal plane.

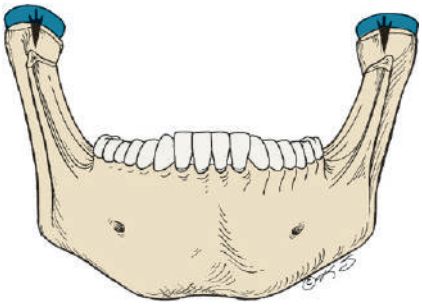


Fig. 4.12 Protrusive movement in the frontal plane.

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 in a slightly forward direction *(lateroprotrusion)* or slightly backward direction *(lateroretrusion)*. The orbiting (nonworking) condyle travels forward and medially as limited by the medial aspect of the mandibular fossa and the temporomandibular ligament. In addition, the mandible can make a straight protrusive (anterior) movement (Fig. 4.10).

Frontal Plane

In a lateral movement in the frontal plane, the nonworking *(mediotrusive)* condyle moves down and medially, whereas the working *(laterotrusive)* 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 movement may be lateral and upward *(laterosurtrusion)* or lateral and downward *(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 Fig. 4.12.

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 to help understand how the determinants control the extent to which movement can occur.

Posselt used a three-dimensional representation of the extreme movements of which the mandible is capable (see Fig. 4.13B). 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. 4.13B).

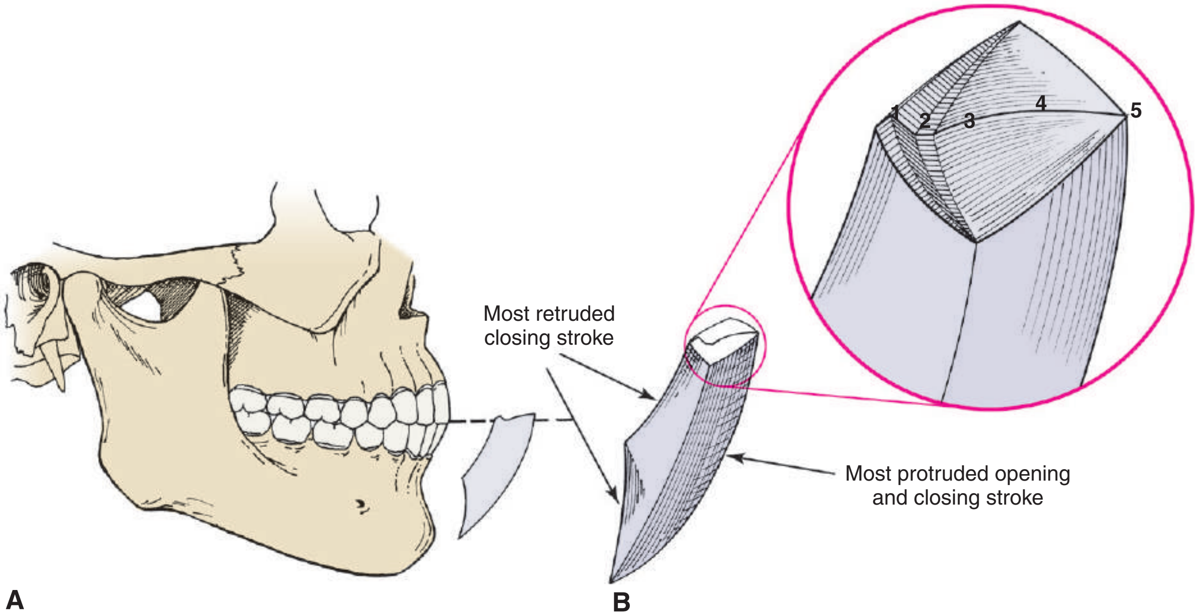


Fig. 4.13 (A) Mandibular border movement in the sagittal plane. (B) Posselt's three-dimensional representation of the total envelope of mandibular movement. *1*, Mandibular incisors track along the lingual concavity of the maxillary anterior teeth. *2*, Edge-to-edge position. *3*, Incisors move superiorly until posterior tooth contact recurs. *4*, Protrusive path. *5*, Most protrusive mandibular position.

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. As a result, posterior tooth contact is gradually lost 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 that represents 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.

The border farthest to the right of Posselt's solid in Fig. 4.13B 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 articulation of the teeth. The posterior determinants of mandibular movement are the temporomandibular controls and their associated 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 altered by the dentist, and the neuromuscular responses of the patient can be influenced only indirectly (e.g., through changes in the shape of the contacting teeth or with an occlusal device). If a patient has steeply sloped eminences, the large downward component of condylar movement during lateral and protrusive excursions results in early separation of the posterior teeth. Similarly, variations in the anatomy of the medial wall of each fossa, which normally allows the condyle to move slightly medially as it travels forward (mandibular side shift, or *transtrusion*), affect the extent of medial movement. The side shift becomes greater as the extent of medial movement increases. The anatomy of the joint dictates the actual path and timing of condylar movement. Laterotrusive movement of the working condylar process is influenced predominantly by the anatomy of the lateral wall of the mandibular fossa. The amount of the side shift is a function of the mediotrusive condyle; on the working side, however, the anatomy of the lateral aspect of the fossa is what 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 of the anterior teeth and the form of the lingual concavities of the maxillary anterior teeth. These can sometimes be altered by restorative and orthodontic treatment. More vertical overlap causes increased downward mandibular incisor movement during the early phase of protrusive movement and a more vertical pathway at the end of the chewing stroke. Increased horizontal overlap allows a more horizontal mandibular movement.

Although the posterior and anterior determinants combine to affect mandibular movement, no correlation has been

TABLE 4.3 Effect of Selected Variables on Occlusal Form of Restorations

Determinants	Variation	Effect on Restoration
Posterior		
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		
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

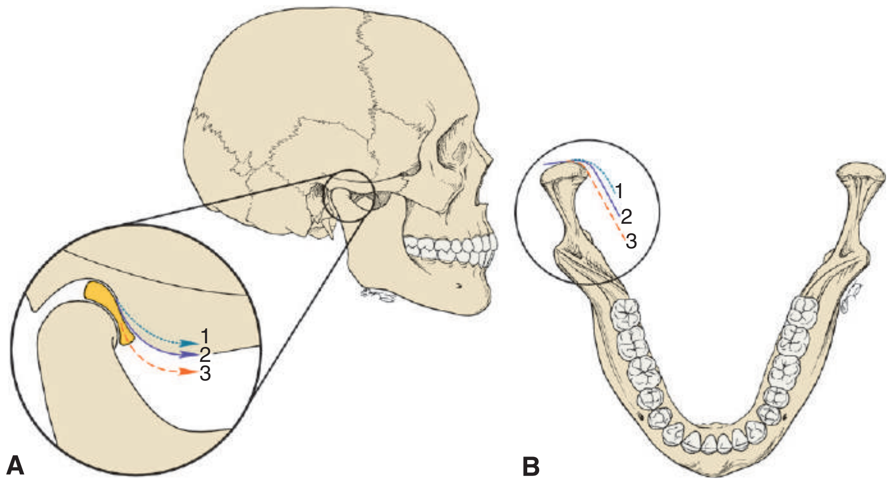


Fig. 4.14 Posterior determinants of occlusion. (A) Angle of the articular eminence (condylar guidance angle). *1*, Flat; *2*, average; *3*, steep. (B) Anatomy of the medial walls of the mandibular fossae. *1*, Greater than average; *2*, average; *3*, minimal side shift.

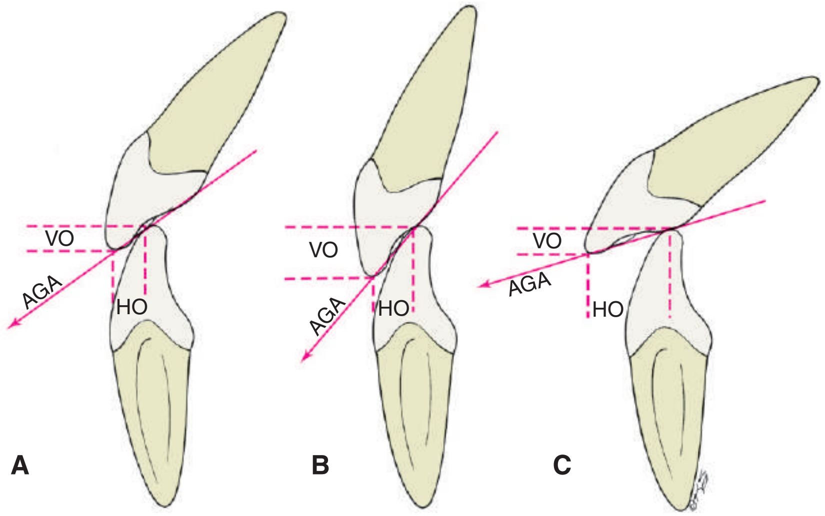
established;[7] that is, patients with a steep anterior guidance angle do not necessarily have a steep posterior disclusion, and those with a steep posterior disclusion do not necessarily have a steep guidance angle.

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 activities. 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.

Mastication

Mastication is a learned process. At birth, no occlusal plane exists, and only after the first teeth have erupted far enough to



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 overlap *(HO)* and vertical overlap *(VO)* produce different anterior guidance angles *(AGA)*. (A) Angle class I. (B) Angle class II, division 2 (increased VO; steep AGA). (C) Angle class II, division 1 (increased HO; flat AGA).

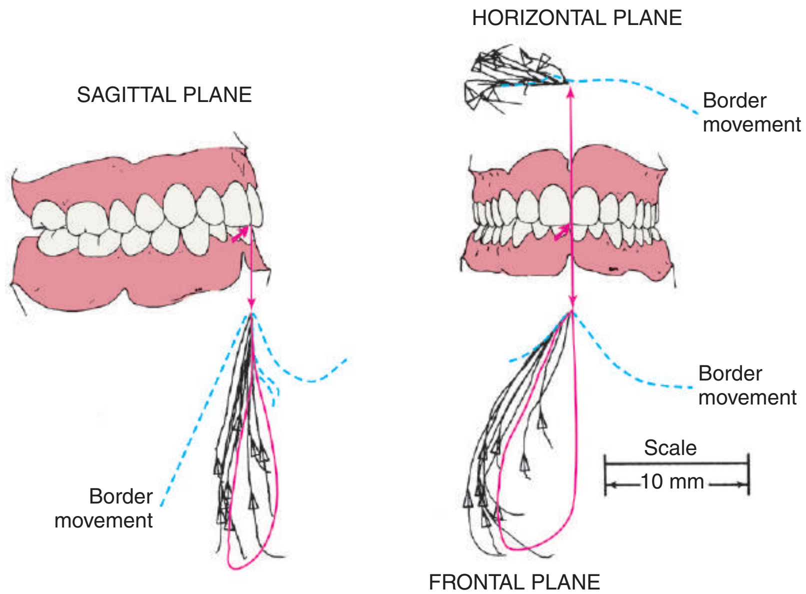


Fig. 4.16 Comparison of border and chewing movements for soft food at the central incisor: sagittal, frontal, and horizontal views in an orthographic projection. (From Gibbs CH, Lundeen HC, Mahan PE, et al. Chewing movements in relation to border movements at the first molar. *J Prosthet Dent*. 1981;46:308.)

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.

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 table, and, after moving sideways, the mandible closes into the food until

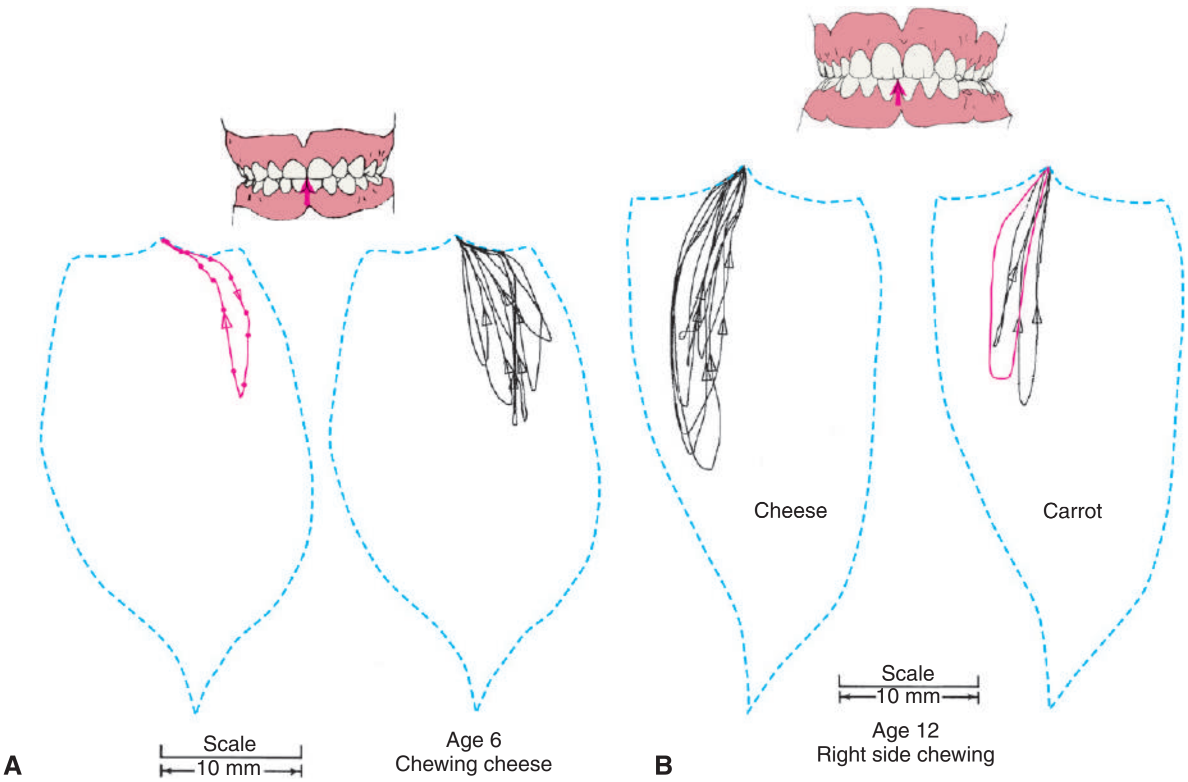


Fig. 4.17 Frontal views of chewing. The *dashed lines* represent border movements. (A) Chewing in a young person, characterized by a wide lateral movement on opening and decreased lateral movement on closing. (B) In an older child, the chewing pattern resembles that of an adult. (From Wickwire NA, Gibbs CH, Jacobson AP, et al. Chewing patterns in normal children. *Angle Orthod*. 1981;51:48.)

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 mandible approaches maximum intercuspation.[10]

The mastication 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 masticate increasingly like adults, with a more vertical stroke (Fig. 4.17).[11] Stimuli from the pressoreceptors play an important role in the development of functional mastication cycles.[12]

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 a person pronounces 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 speech. There are many forms of parafunctional activities, including bruxism, clenching, nail biting, and pencil chewing. Parafunction is typically 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, parafunction can result in excessive wear; widening of the periodontal ligament; and mobility, migration, or fracture of the teeth. Muscle dysfunction such as elevated muscle tone, myospasm, myositis, myalgia, and referred pain (headaches) from trigger point tenderness may occur as well. The degree of symptoms varies considerably among individuals. The two most common forms of parafunctional activities are bruxism and clenching. Radiographic bone density of the alveolar process is often increased in patients with a history of sustained parafunctional activity.

Bruxism

Involuntary rhythmic or spasmodic nonfunctional gnashing, grinding, or clenching of teeth, in other than chewing movements of the mandible, may lead to occlusal trauma; such oral

Fig. 4.18 Extensive abrasion (tooth wear) that resulted from parafunctional grinding. (A) Frontal view in the occluded position. (B) Occlusal view of severely abraded mandibular teeth. (Courtesy of Dr. M. Padilla.)

habits are collectively 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 during sleep. 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 causes of bruxism are 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 people who smoke.[22] Altered mastication has been observed in subjects with bruxism[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.

Fig. 4.19 Prominent masseter muscles at the angle of the mandible.

However, the chewing patterns of normal people can be quite varied, and the relationship, if any, between altered mastication and occlusal dysfunction is not clear.[25]

According to one theory,[26] bruxism is performed on a subconscious reflex-controlled level in relation 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, muscle tone may increase, 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 with bruxism 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 in association 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 causes 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; affected patients may have noticeably prominent masseter muscles at the angle of the mandible (Fig. 4.19). 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 control voluntarily.

Fig. 4.20 (A) Mutually protected (canine-guided) articulation. During lateral excursions, there are no contacts on the mediotrusive (nonworking side) teeth; all contacts are between the laterotrusive (working side) canines. (B) Unilaterally balanced (group function) occlusion. During lateral excursions, there are no contacts between teeth on the mediotrusive (nonworking) side, but there are uniform excursive contacts on the laterotrusive (working) side.

Fig. 4.21 Unilaterally balanced (group function) occlusion. During lateral excursions, there are no contacts between teeth on the mediotrusive (nonworking) side (A), but even excursive contacts occur on the laterotrusive (working) side (B).

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. 4.20). 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 this 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.

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, rates of failure were high. The rate of occlusal wear was increased, periodontal breakdown was increased or accelerated, and neuromuscular disturbances occurred. 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 (Fig. 4.21).[31]

Unilaterally Balanced Articulation (Group Function)

In a unilaterally balanced articulation, excursive contact occurs between all opposing posterior teeth on only the laterotrusive side. This occlusal arrangement is also referred to as *group function*. On the mediotrusive side, no contact occurs until the mandible has reached centric relation. Thus, 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. On the working side, the occlusal load during functional movement is then distributed over the periodontal surface area of all teeth in the quadrant while the posterior teeth on the nonworking side do not contact. In the protrusive movement, no posterior tooth contact occurs.

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. Other authors[33] have advocated long centric because in healthy natural dentitions, centric relation only rarely coincides with the maximum intercuspation position. However, its length is arbitrary. At given vertical dimensions, long centric lengths ranging from 0.5 to 1.5 mm have been advocated. This occlusal theory presupposes that the condyles can translate horizontally in the fossae over a commensurate trajectory before beginning to translate downward. It also necessitates a greater horizontal space between the maxillary and mandibular anterior teeth (deeper lingual concavity) that would allow horizontal movement before posterior disocclusion (separation of opposing teeth during eccentric movements of the mandible).

Mutually Protected Articulation

In 1963, Stuart and Stallard[34] advocated an occlusal scheme called *mutually protected articulation*, which was 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 all 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 for the success of this occlusal scheme. In a mutually protected articulation, the posterior teeth come into contact only at the very end of each mastication 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. To maximize occlusal function, posterior cusps should be sharp and should pass each other closely without contacting. 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. Bakke and colleagues[37] showed that occlusal contact influences 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 parallel predominantly 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 McDevitt and Warreth[38] suggested that occlusal treatment objectives include maintenance or improvement of the number of such contacts.

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. Contact of stable posterior teeth 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. Harmonizing of anterior tooth contacts with functional mandibular movements

To achieve 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 class III lever (Fig. 4.22), which is the least efficient of lever systems. An example of another class III lever is 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 resulting load to which the teeth are subjected. 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 a unilaterally balanced (group function) occlusal arrangement are subjected to greater horizontal and potentially more pathologic force than the same teeth would be in a mutually protected articulation.

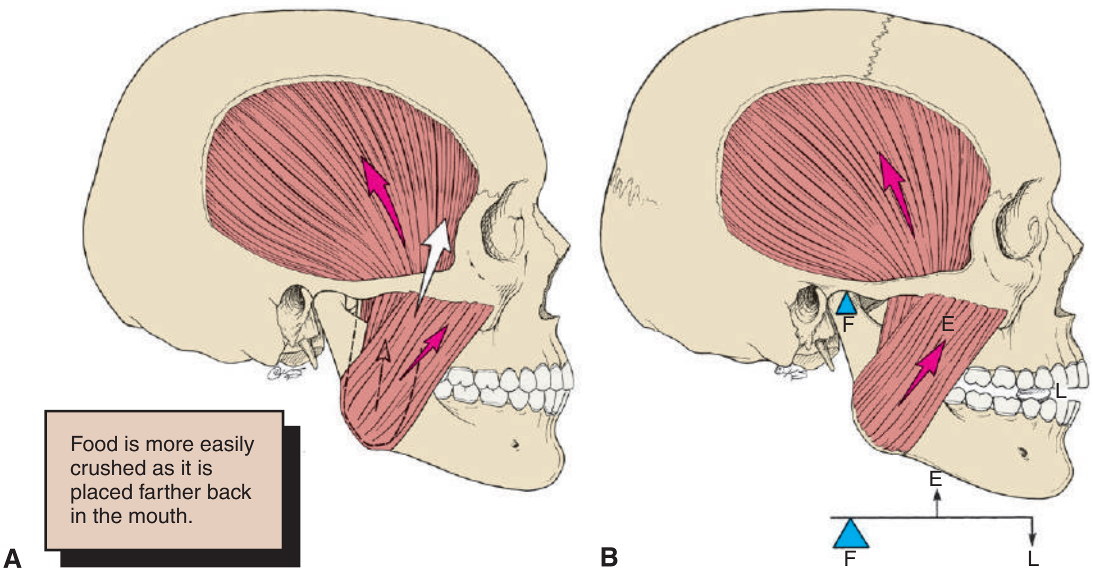


Fig. 4.22 Lever system of the mandible. (A) The elevator muscles of the mandible insert anterior to the temporomandibular joints (TMJs) and posterior to the teeth, forming a class III lever system. (B) The fulcrum *(F)* is the TMJ, the force or effort *(E)* is applied by the muscles of mastication, and 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.

PATIENT ADAPTABILITY

The adaptive response of individual patients to occlusal abnormalities differs significantly. Some are unable to tolerate seemingly trivial occlusal deficiencies, whereas others are able to tolerate distinct malocclusions without developing obvious symptoms (Fig. 4.23). Most patients seem able to adapt to small occlusal deficiencies without exhibiting acute symptoms.

Lowered Threshold

In patients with a low pain threshold, diagnosis is generally not difficult. 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 will vary: It is lower at times of emotional stress and general malaise, and clinical symptoms such as severe headaches, muscle spasm, and pain may surface at such times.

Raised Threshold

Individuals who have adapted to existing malocclusions may report being quite comfortable with their dentition, although a number of signs of existing pathologic processes are evident. However, even in the absence of pain or patient complaints, occlusal treatment may be advised to prevent or minimize additional wear on the teeth and further damage to the musculature or TMJs.

PATHOGENIC OCCLUSION

A pathogenic occlusion is an occlusal relationship capable of producing pathologic changes in the stomatognathic system. In such occlusions, disharmony between the teeth and the TMJs is sufficient to result in symptoms that necessitate intervention.

Signs and Symptoms

The presence of a pathogenic occlusion has many indications. 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. To detect such contacts, the dentist can place the tip of an index finger on the crown portion of the mobile tooth and ask 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. 4.24). Diagnostic casts made during previous treatment help the dentist 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 patients, 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

Fig. 4.23 Patient adaptability: None of the four patients described here expressed any functional 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.

Fig. 4.24 Unstable occlusion. Removal of a tooth without replacement has led to tilting and drifting.

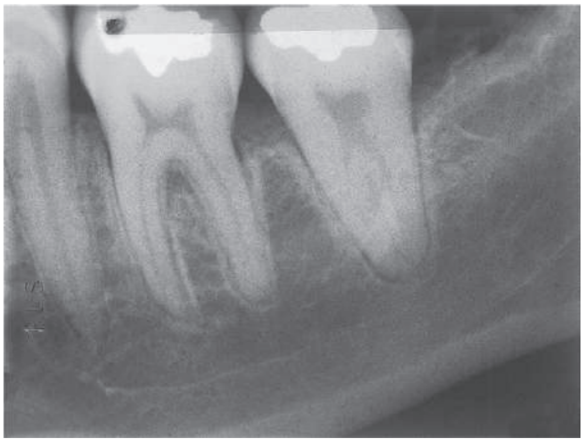


Fig. 4.25 Widened periodontal ligament space and increased mobility of mandibular molars. Occlusal premature contacts were noted in lateral and protrusive movements.

widened periodontal ligament space (detected radiographically) may indicate premature occlusal contact and is often associated with tooth mobility (Fig. 4.25). 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 more 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-to-root ratio than in those with better periodontal support (see Chapter 5 and 31).

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. 4.26).[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 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 during opening and closing (reciprocal click) in conjunction with a midline deviation may have a displaced articular disc. The midline deviation typically occurs toward the side of the affected joint because the displaced articular disc can prevent (or slow down) the normal anterior translatory movement of the condyle. For detecting a clicking joint, palpation at the angle of the mandible is generally more effective than palpation over the lateral pole because less tissue is interposed between the clinician's finger and the underlying osseous tissues.

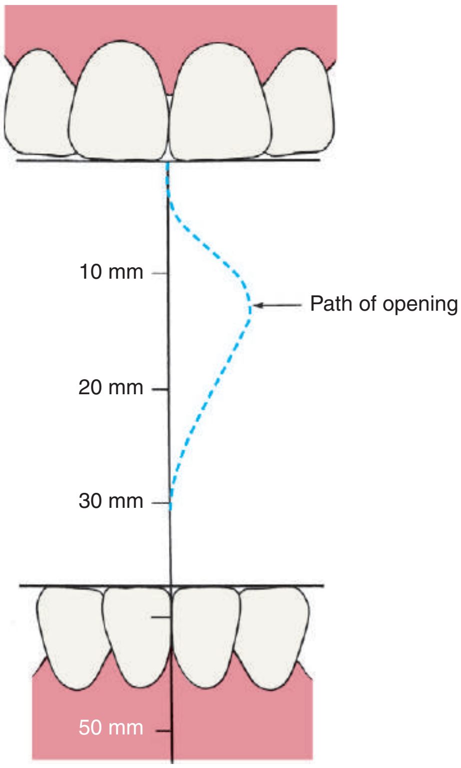


Fig. 4.26 Midline deviation during opening and closing movements can be indicative of asymmetric muscle activity or joint derangement. In this illustration, during opening, translation is less than optimal on the patient's left side.

Temporomandibular Joint Disorders

Jack M. Marincel

Myofascial pain dysfunction (MPD) syndrome has been labeled a syndrome due to a lack of diagnostic information available to categorize specific conditions.[50] Most patients with symptoms of temporomandibular joint disorders (TMDs) were assumed to have masticatory muscle–related problems. It was thought that an intra-articular disc dislocation was primarily a micro-traumatic process caused by sustained lateral pterygoid contraction due to a posterior occlusal interference creating parafunction and overloaded occlusal forces.[51] Today, it is believed that these forces may be a contributing factor causing further progression of the disc dislocation but that macrotrauma is usually found to be the initiating cause of the disc dislocation.[52] With the advent of 3D diagnostic imaging, detailed information is now accessible regarding the structures within the joint capsule. Cone beam computed tomography (CBCT) and magnetic resonance imaging (MRI) studies of symptomatic and suspected derangements have confirmed a higher incidence of internal derangements of TMJs than previously thought.[53,54] With these improved diagnostic tools, a segment of what was once considered a high percentage of muscle incoordination and spasm can now be properly diagnosed and categorized as internal derangements of the joint itself.

Pain symptoms are typically the driving force for a patient to seek treatment; however, diagnosis and prognosis of internal derangements, even when pain is absent and only clinical signs are present, will prevent many restorative treatments from failing. If the patient's chief complaint involves TMDs, the examination must begin with a thorough history of when the symptoms began, if the symptoms were preceded by a traumatic event to the face or head, and the extent of the quality and quantity of pain the patient is experiencing. Such a traumatic event might have occurred years previously and initiated loosening or tearing of the tethering ligaments of the articular disc (Fig. 4.27). The examination continues with a methodical digital palpation of the muscles of the head and neck and includes the joint itself (Fig. 4.28) (see Chapter 1). Range of motion is measured and

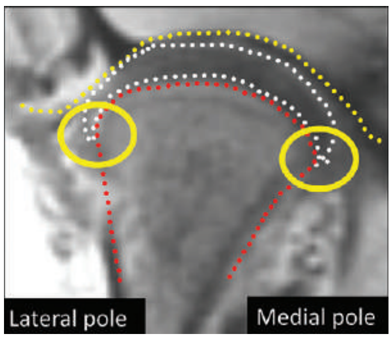


Fig. 4.27 Location of medial and lateral collateral ligaments. (Illustration: Jim McKee, D.D.S.)

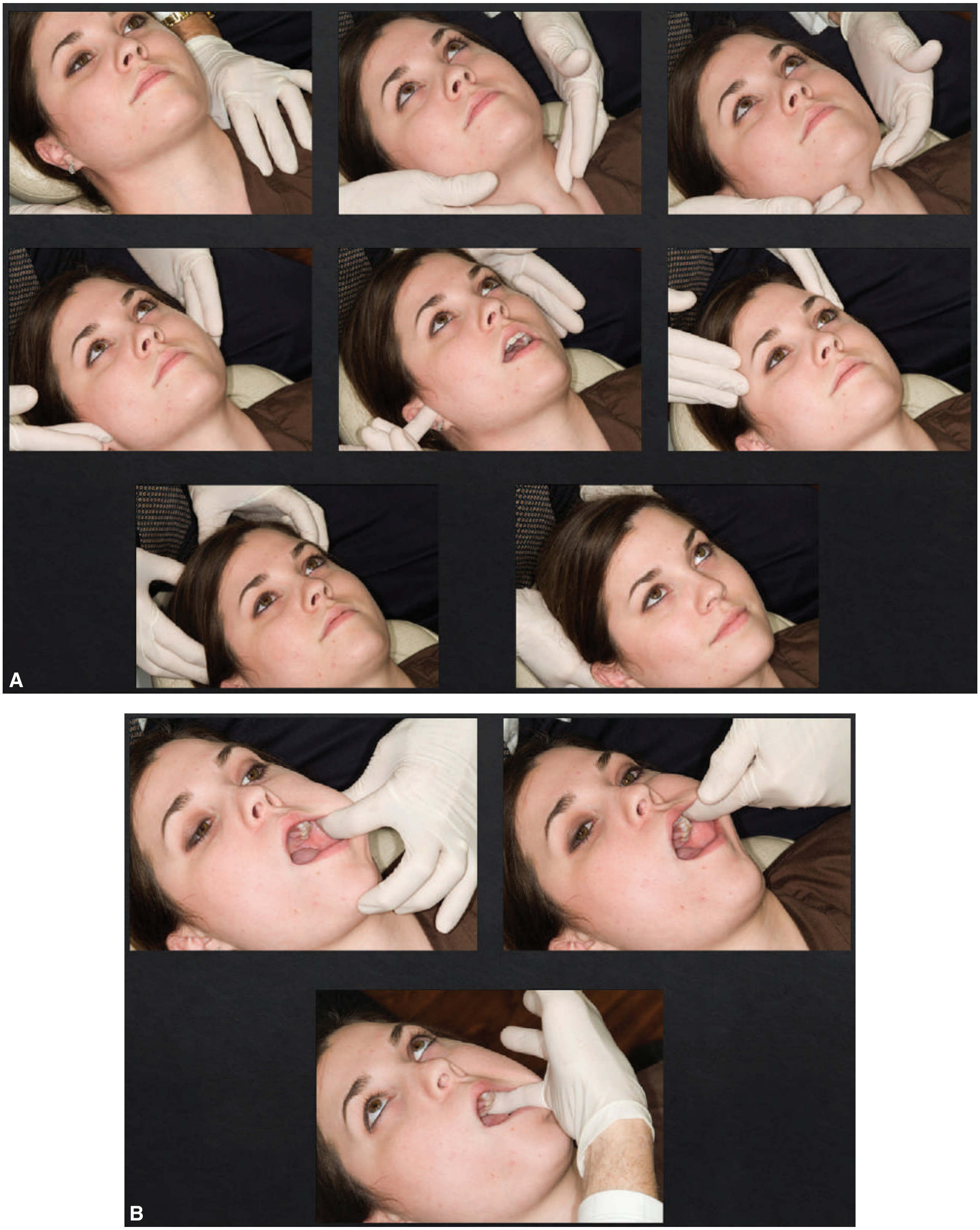


Fig. 4.28 Extraoral/intraoral muscle palpation. (A) Trapezius, infrahyoids, suprahyoids, lateral joint capsule, posterior capsule (retrodiscal), temporalis, skull vertex, occiput. (B) Masseter, coronoid process, structures lateral to the lateral pterygoid.

recorded for comfortable opening, maximum wide opening, right and left excursions and protrusive movements. During opening movements, deviations right or left from a smooth hinging and translation of the mandible should be noted. Evaluation of the maxillomandibular relationship must be recorded from a fully seated condylar position (FSCP)—that is, Angle classification of molar and canine relationships, reverse articulation, midline discrepancy, horizontal and vertical overlap, and open occlusion. On evaluating anterior open occlusion, the measurement must be made from the incisal edge of the mandibular incisors to the cingulum of the opposing maxillary incisor—that is, where the incisal edge of the mandibular incisor should reside in a normal occlusal relationship. Likewise, if any of the anterior teeth are retroclined or proclined, the examiner must imagine transposing the teeth into their "normal" axial inclination before evaluating this relationship (Fig. 4.29). If the discrepancy from Angle class I molar at least 2 mm toward class II ipsilaterally and if there is at least 2 mm open anterior occlusion contralaterally, suspect an internal derangement on that side until further diagnostics rule it out. The reason for the 2 mm dimension is that this is the average thickness of the intermediates zone, which is the load-bearing portion of the articular disc. This is more easily evaluated in young patients before adaptation has occurred or orthodontic treatment has been initiated since tooth movement can mask these discrepancies.

TMJ disc displacement is a ligament issue as the disc tethering ligaments are elongated or torn usually subsequent to a traumatic event.[55] We see more internal derangements in women than men because women have more lax ligaments because of hormonal response on ligament systems for the birth process.[56] In discussing growth and development, macrotrauma before the end of puberty makes us reconsider the cause of some Angle class II presentations. Previously, genetics was considered the major influence of the maxillary-mandibular relationship; however,

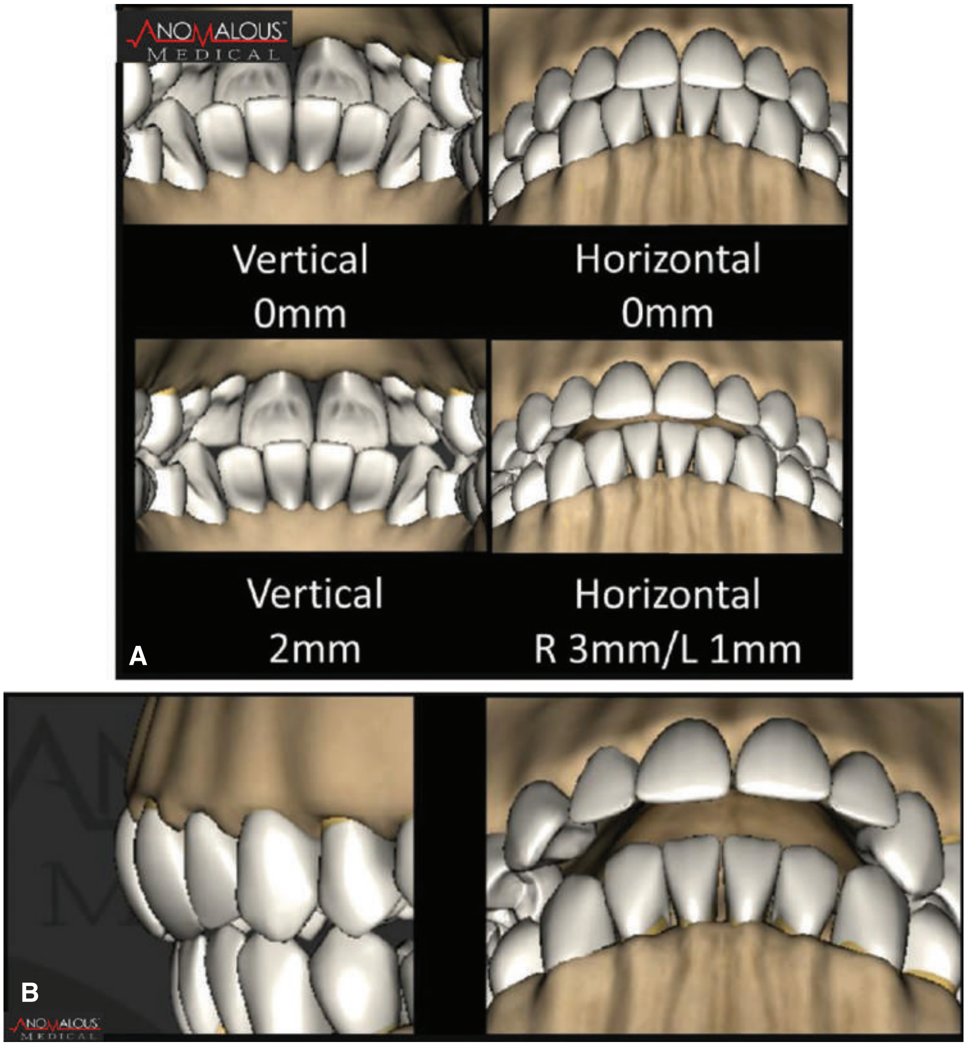


Fig. 4.29 Evaluate anterior tooth contact in a fully seated condylar position, Horizontal (mm), Vertical (mm). (A) Above: Normal vertical 0 mm/horizontal 0 mm vs altered vertical 2 mm/horizontal R3 mm/L 1 mm. (B) Below: 1. Evaluate the axial inclination of the teeth, 2. Create normal axial inclination. (Illustration and Concept: Anomolous Medical, Mark A. Piper, D.M.D., M.D.; Jim McKee, D.D.S.)

emphasis on early injury to the developing joint should now be considered in many patients.[57]

Each condyle has a medial and a lateral pole. The medial pole is loaded during hinging and pivoting movements such as when the teeth occlude and on the working side during lateral excursions. The lateral pole is loaded during translation and orbiting movements. The growth center of the condyle is located on its superior surface, protected by the articular disc.[58,59] This protection is expressed in the success of orthodontic functional appliances that grow the condyle and ramus in disc dislocation positions that reduce the disc versus positions that do not reduce the disc upon forward positioning. Mandibular growth is influenced by the eruption of the permanent first molars into the normal Angle class I relationship. As the maxilla grows forward, the molars attempt to remain in Angle class I occlusion, thus distracting the condyles from the mandibular fossae and stimulating the growth of the condyles posteriorly and superiorly back into the fossae. If this continues through puberty, a normal Angle class I maxilla-mandibular relationship should result. If, however, a traumatic event occurs causing a disc displacement from the medial pole of the condyle, growth may not continue in synchrony with the maxilla resulting in an Angle class II tooth relation because the growth center is no longer protected by the disc, stunting the condyle and ramus development.[60,61] Imaging demonstrates this deficiency of growth quite remarkably. As seen on CBCT imaging in an adult, a normal condyle should, on average, measure approximately 8-mm wide in the sagittal view, approximately 20 mm coronal and fill two-thirds the width of the mandibular fossa. The ramus height should range from 60 to 75 mm and average 65 to 70 mm in length from the superior of the condyle to the angle of the mandible (Fig. 4.30). The deficiency of growth from an early internal derangement should be considered when evaluating a profile of a patient with a retrognathic mandible and a clockwise mandibular growth pattern. If the deficiency of growth occurs unilaterally, it is easy to see the asymmetry clinically with the patient presenting with a deviation of his chin point and dental midline to the affected side (Fig. 4.31).

After growth is complete, an articular disc dislocation at the medial pole will result in a change in vertical dimension at the condyle of approximately 2 mm, which is the approximate vertical width of the intermediate zone of the articular disc when loaded, as the most distal teeth now become the initial contact and fulcrum causing the anterior open occlusion in an FSCP. Again, clinically this can be masked not only with orthodontic therapy but with adaptation by the patient bruxing and clenching as posterior teeth are intruded and worn in the patient's attempt to occlude the full complement of teeth (Fig. 4.32).

The extent of a disc dislocation varies depending on the extent of damage to the ligament system tethering the disc. The Piper stages of disc displacement (Fig. 4.33) have been adopted by clinicians.[62] Stages 1-3B have medial pole coverage and stages 4A-5B have a loss of medial pole coverage. Stage 5 indicates a bone-on-bone situation and is subdivided into acute and chronic presentations. Understanding this concept will aid the practitioner in determining the outcome of restorative treatment for patients with internal TMJ derangements. As one can see from the descriptions, as an articular disc progresses in dislocating, it can go through two stages of popping and two stages of locking, once at the lateral pole and once at the medial pole. That means that when a patient gives a history of having a clicking joint that no longer clicks, it is not a sign of improvement but a progression toward its further dislocation. An important point is that as long as the disc is intact over the medial pole of the condyle (Piper stage 3B or less), the occlusion will be minimally affected by the dislocation and the prognosis of restorative treatment will be relatively predictable as long as no further damage occurs. Once the disc dislocates from the medial pole, the prognosis is questionable.

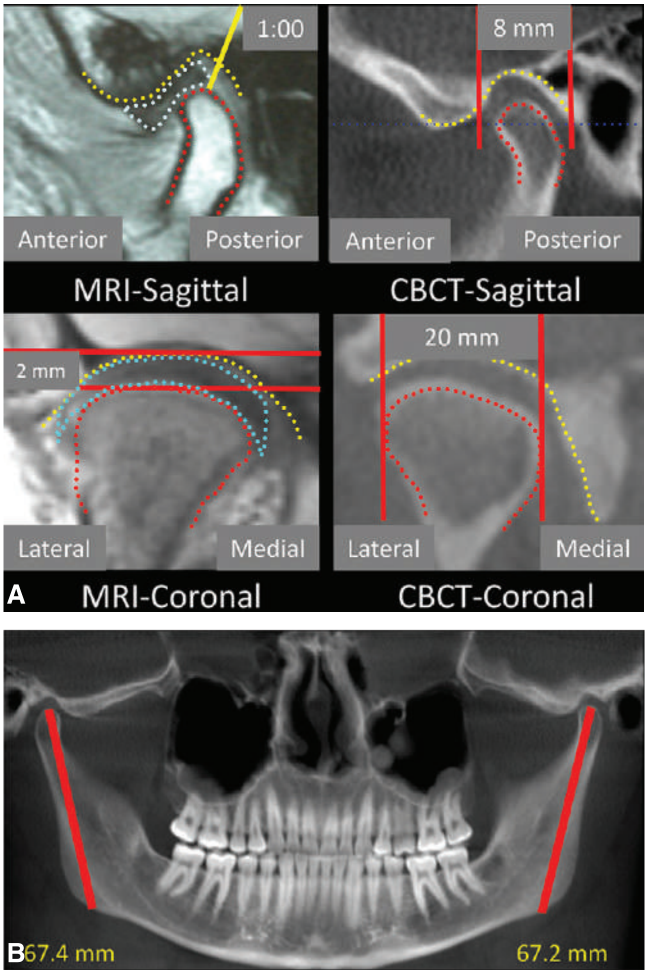


Fig. 4.30 Normal (A) condyle-fossa intracapsular and (B) ramus dimensions. (Illustrations: Jim McKee, D.D.S., Concept: Mark A. Piper, D.M.D., M.D.)

How does the occlusion change relative to the degree of the disc dislocation? As described earlier, the cartilage disc is biconcave with the thinnest portion at its center with a thicker anterior and posterior perimeter (Fig. 4.34). When reading MRI images of the TMJ, it is medical convention to position the anterior aspect of the patient to the left of the examiner with the posterior to the right. Thus, a clock face can be used to describe the position of the posterior edge of the distal band of the disc (Fig. 4.35). In a normal Piper stage 1 example, the disc tethering ligaments are intact and the disc self-centers with the most posterior edge of the distal band

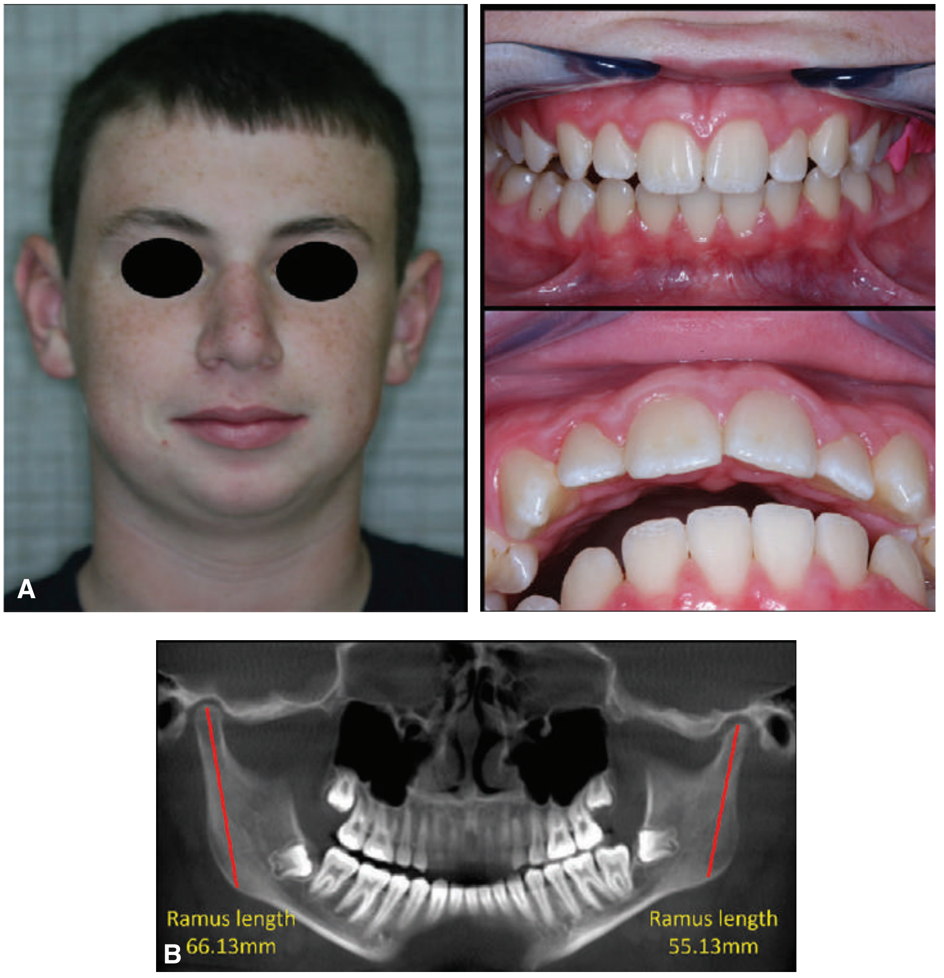


Fig. 4.31 (A and B) Unilateral condyle–ramus growth deficiency. (Illustration: Jim McKee, D.D.S., Concept: Mark A. Piper, D.M.D., M.D.)

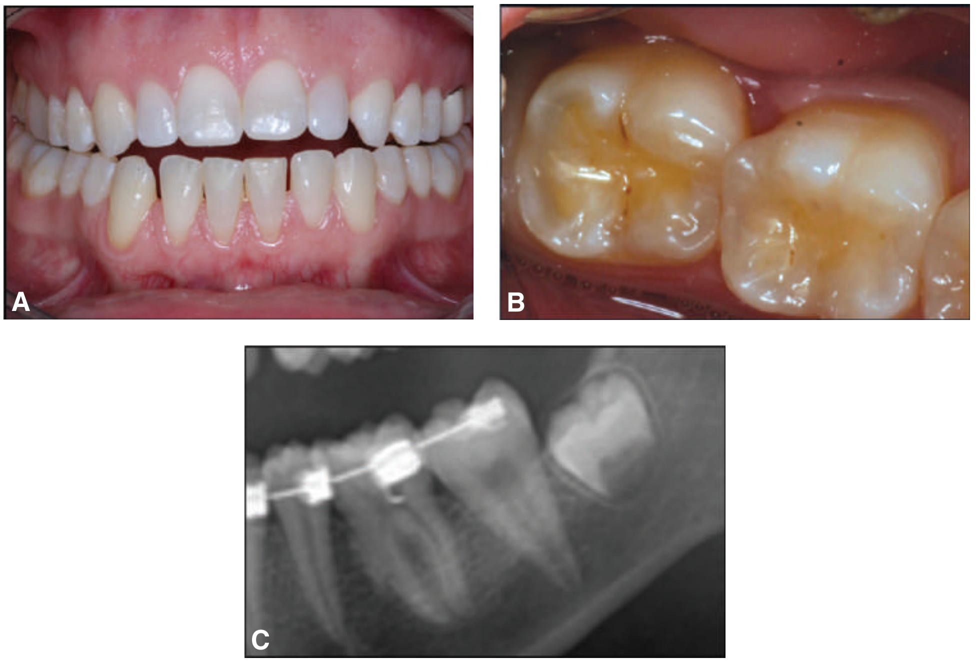


Fig. 4.32 (A) Open anterior occlusion in fully seated condylar position. (B) Worn posterior molars. (C) Intruded or failed eruption of posterior molars. (Illustrations: Jim McKee, D.D.S., Concept: Mark A. Piper, D.M.D., M.D.)

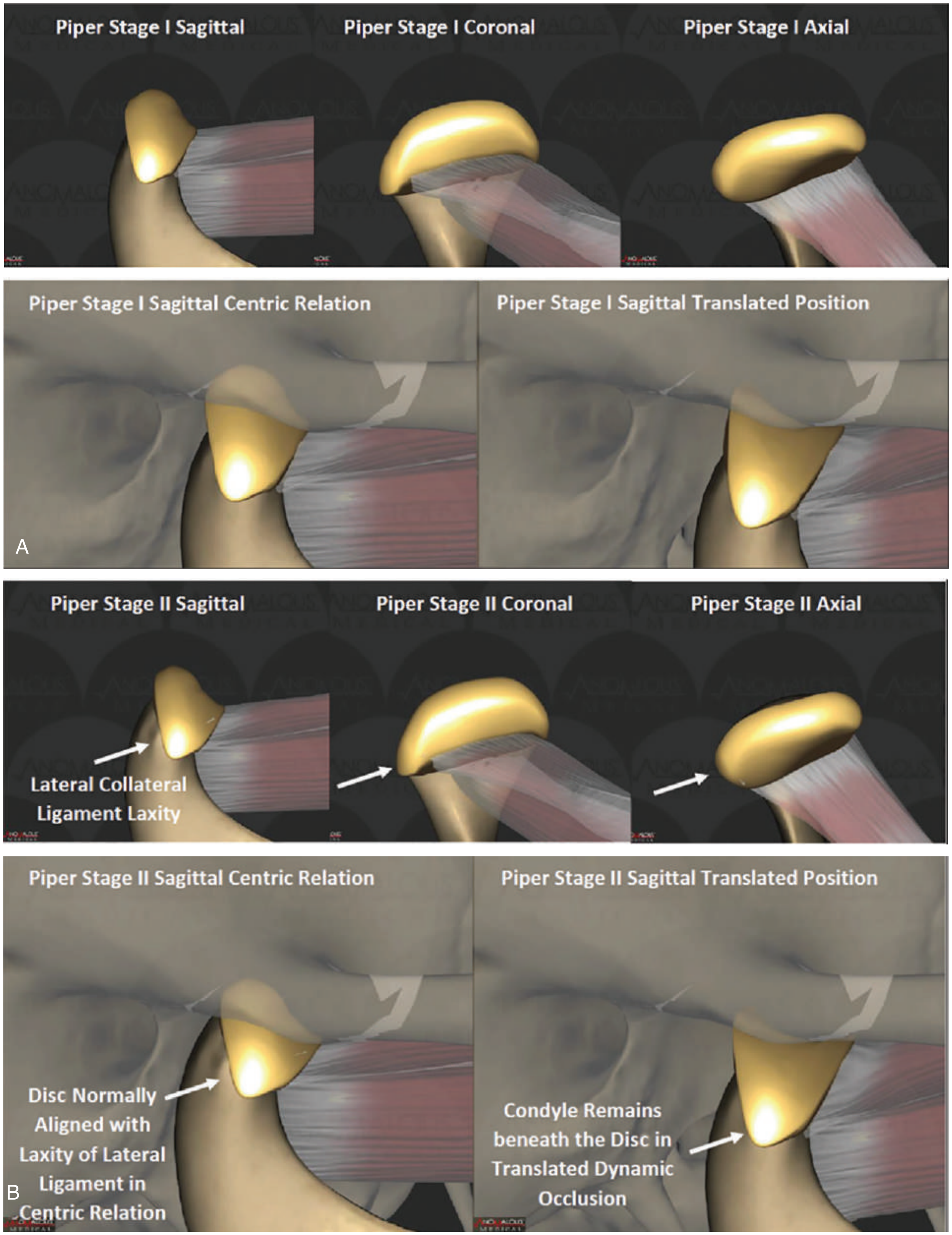


Fig. 4.33 Views of condyle-disc relationships in the Piper classification. (A–D) Stages I–IIIB have medial pole coverage.

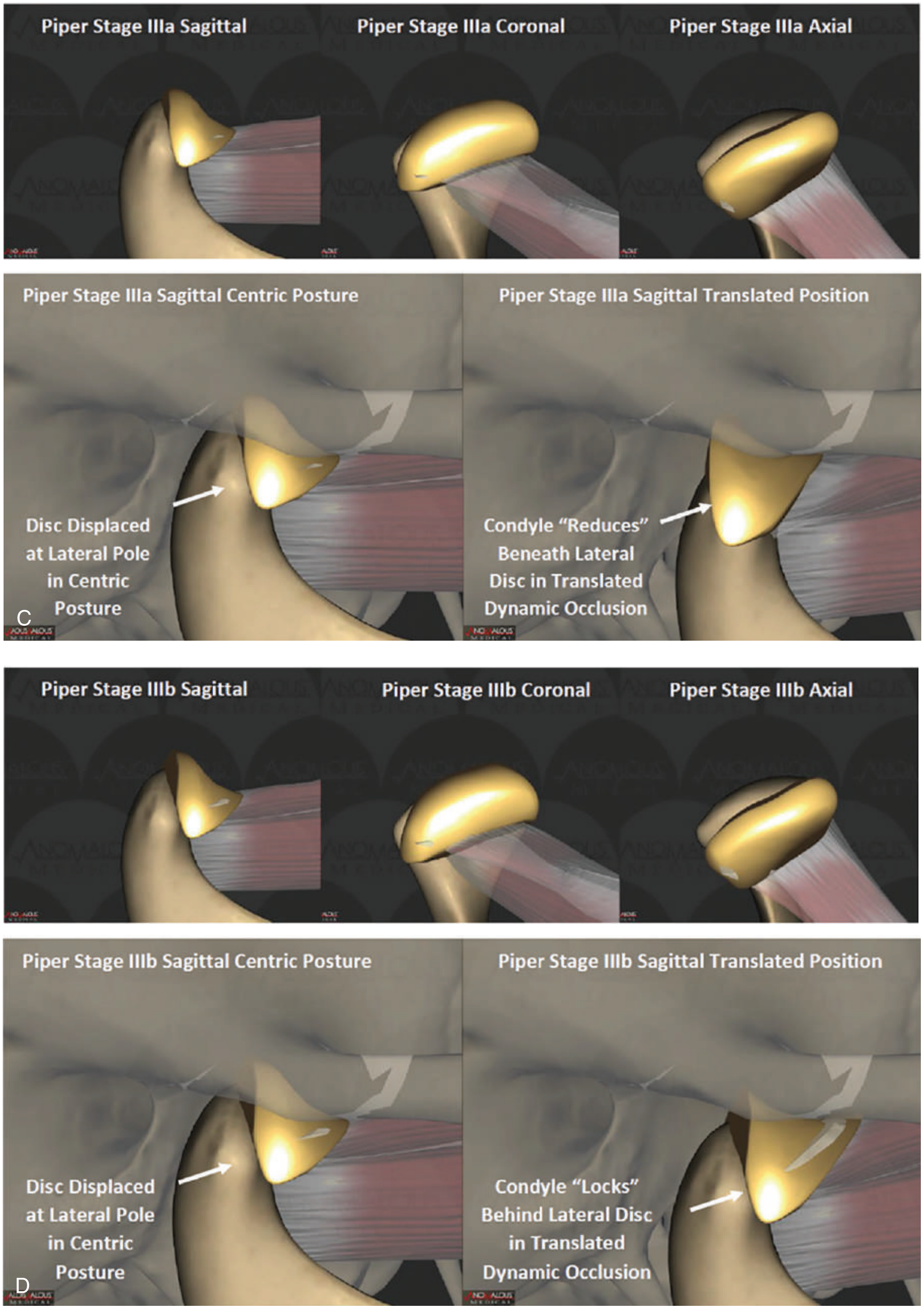


Fig. 4.33 Cont'd (A–D) Stages I–IIIB have medial pole coverage.

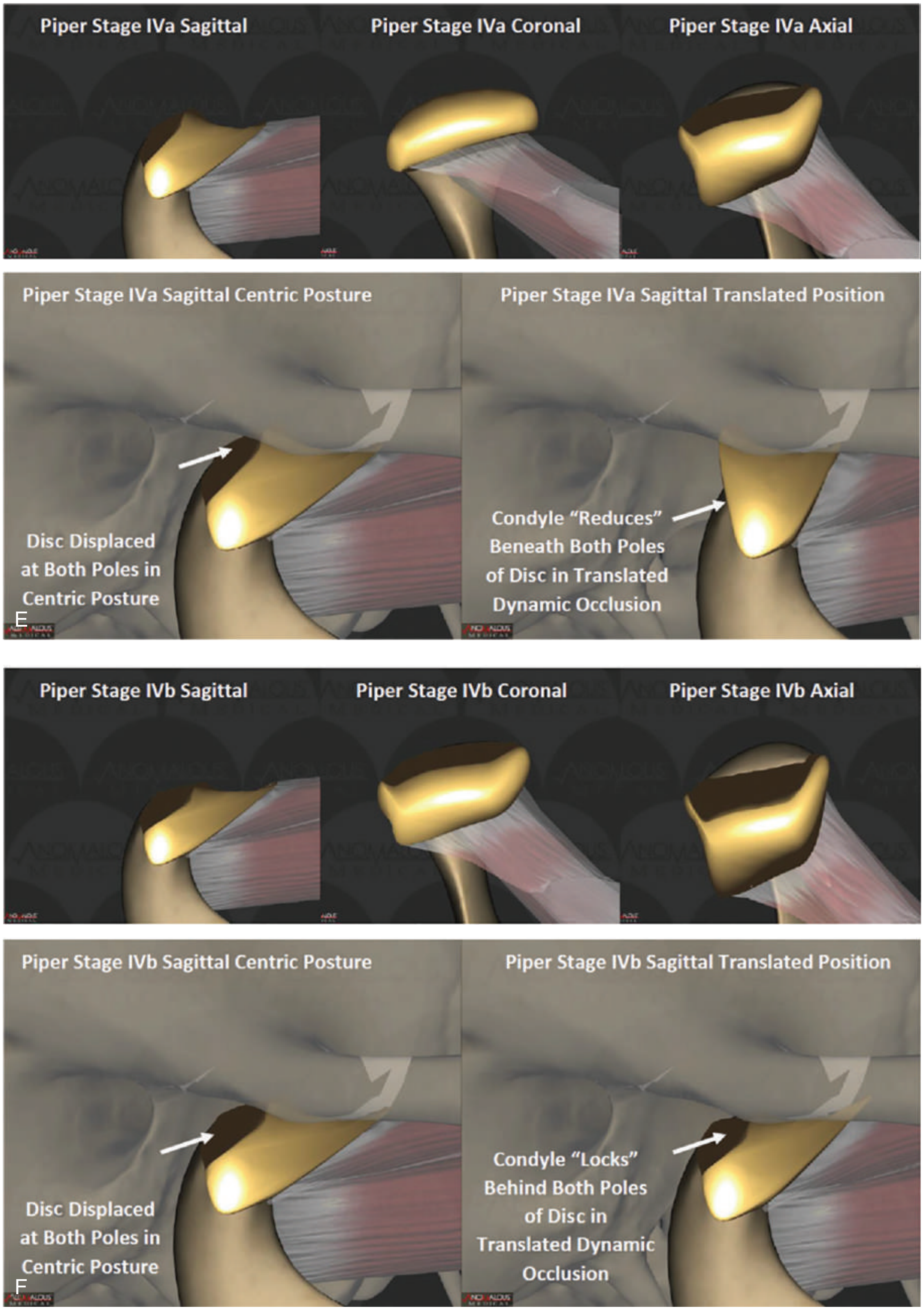


Fig. 4.33 Cont'd (E–H) Stages IVA–VB have a loss of medial pole coverage. Stages I–IV consider the extent of the displacement from the lateral and medial poles of the condyle and whether the disc reduces upon opening or if it causes a closed lock of the mandible. Stage V indicates a bone-on-bone situation and is subdivided into acute and chronic presentations.

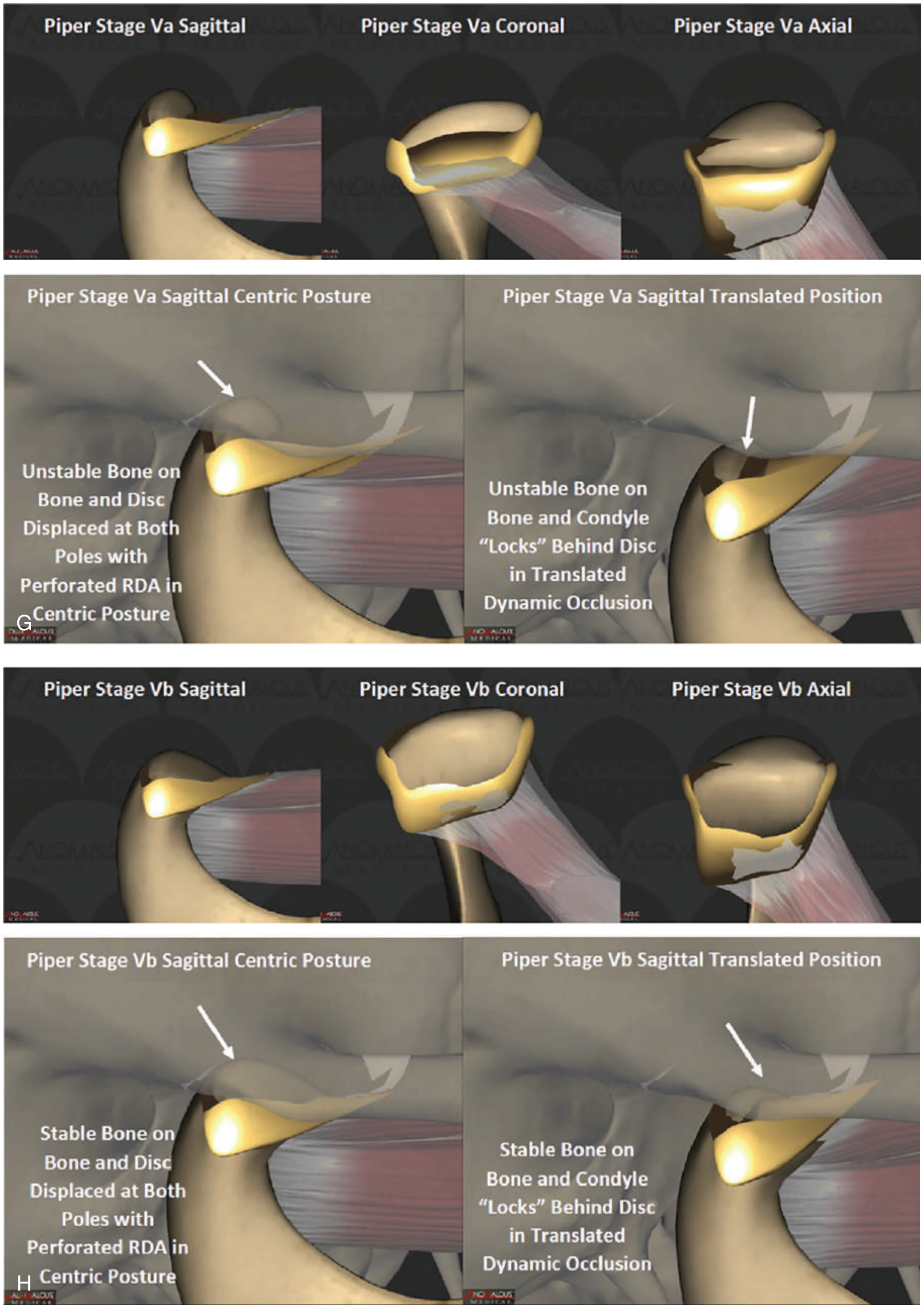


Fig. 4.33 Cont'd (E–H) Stages IVA–VB have a loss of medial pole coverage. Stages I–IV consider the extent of the displacement from the lateral and medial poles of the condyle and whether the disc reduces upon opening or if it causes a closed lock of the mandible. Stage V indicates a bone-on-bone situation and is subdivided into acute and chronic presentations. (Courtesy of Mark A. Piper, MD, DMD, from Anomalous Medical.)

at the 1:00 position and the condyle is located in the center of the mandibular fossa. The condyle is seated superiorly and anteriorly from the forces of the elevator muscles and inactivity of the lateral pterygoids. This is considered normal and is defined as centric relation. Ideally, the teeth have equal simultaneous contact at this FSCP; therefore, centric relation = maximum intercuspation (CR = MI) and the first molars are in an Angle class I relationship. If the ligament system of the articular disc becomes damaged and the disc dislocates off the medial pole to the 12:00 distal band position, the condyle will now be resting on the thickest portion of the disc and will be displaced vertically downward (Fig. 4.36). The change to the occlusion would be that the posterior teeth are separated, and the patient typically complains that the posterior teeth cannot be occluded. Often this can be seen immediately following trauma to the mandible as inflammation occurs in the retrodiscal tissue and the swelling pushes the disc forward.[63] In this scenario, if the ligament system is minimally involved, the disc can re-center after the swelling dissipates as long as the patient does not forcefully attempt to occlude, elongating and tearing ligaments, and further dislocating the disc forward. If the articular disc dislocation progresses to the 11:00 distal band position, the disc is now in a position where it is impeding the condyle from centering in the mandibular fossa. The condyle is now distalized in the horizontal plane and therefore projecting an Angle class II tooth relationship. The condyle's vertical displacement can vary depending on the shape of the portion of the disc it rests on. At a 10:00 distal band position, the condyle is now vertically more intimate with the mandibular fossa that translates to the very back tooth occluding first on that side. With time, this end point disc position will increase the likelihood of clinical signs of significantly worn second molars, fractured second molar cusps, and fractured occlusal porcelain on second molar crowns.

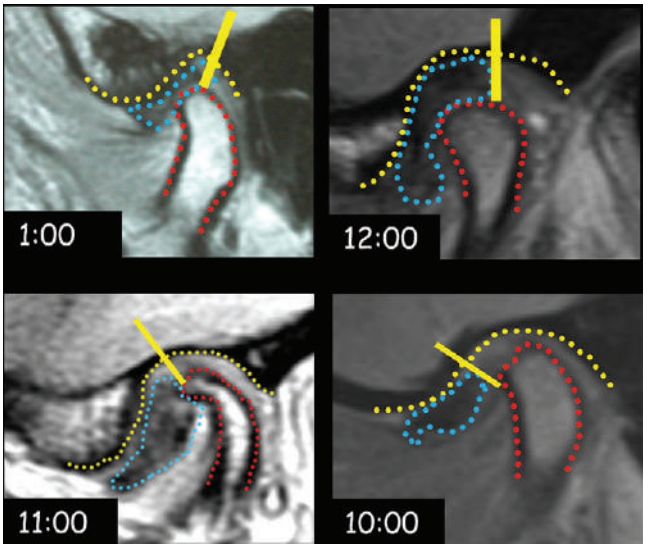


Fig. 4.34 Illustration of progression of disc dislocation relating distal band of the articular disc to a clock face. (Courtesy of Mark A. Piper, MD, DMD, from Anomalous Medical.)

Although history, clinical signs, symptoms, and Doppler auscultation can provide information about a patient's TMJ condition, in some situations it may be important for both the dentist and the patient, prior to implementing restorative procedures, to assess the soft tissue and hard tissue anatomy in the TMJ. Imaging with CBCT and MRI is the only way to achieve this. MRI is the gold standard that allows the dentist to evaluate the current status of the joint and anticipate the prognosis. CBCT will help the dentist understand what has occurred in the past and allows a comparison of the patient's growth and development with what is considered normal.

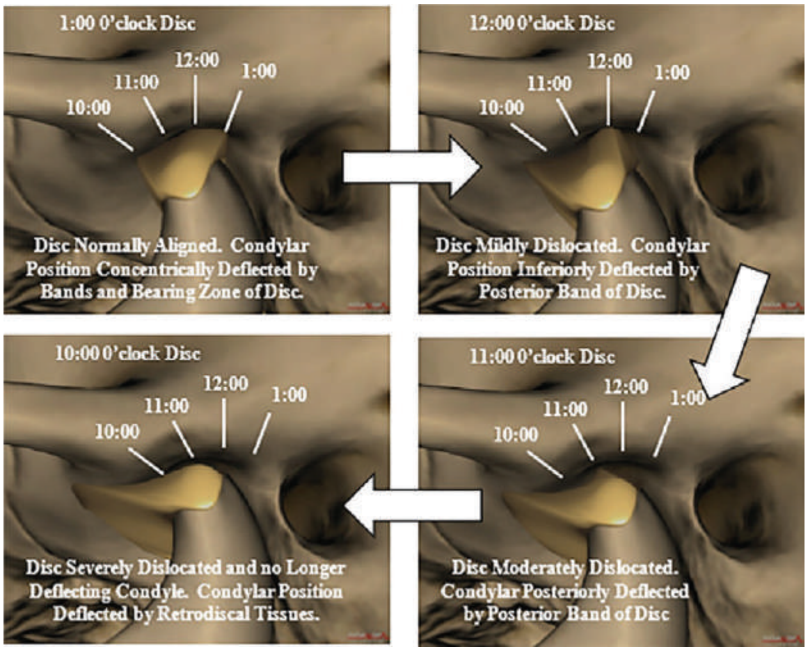


Fig. 4.35 Disc dislocation described by clock-face and subsequent condyle displacement. (Illustration: Jim McKee, D.D.S., Concept: Mark A. Piper, D.M.D., M.D.)

Myofascial Pain Dysfunction

The 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 mandibular function. Often the muscles, and not the TMJ, are the primary sites, 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 psychophysiologic theory,[64] MPD results from bruxism and clenching, whereby chronic muscle fatigue leads to muscle spasms and alterations in mandibular movement. Tooth movement may follow, and the malocclusion becomes apparent when a spasm is relieved. According to this theory, treatment should focus on emotional rather than physical therapy. (2) According to the muscle theory,[65] continuous muscle hyperactivity is responsible for MPD; pain is referred to the TMJ and other areas of the head and neck region. (3) According to the mechanical displacement theory,[66,67] malocclusion of the teeth displaces the condyles, and the feedback from the dentition is altered, resulting in muscle spasm.

Correct diagnosis and management are often complicated by the concurrent presence of multiple causes. 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 to be associated with occlusal interferences (see also section on Definitive Occlusal Treatment in Chapter 6), occlusal treatment should be considered.[67] Such treatment can include tooth movement through orthodontic treatment, elimination of deflective occlusal contacts through selective reshaping of the occlusal surfaces of teeth, or missing tooth restoration and replacement 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. 4.37) fabricated from clear acrylic resin that overlies the occlusal surfaces of one arch. On

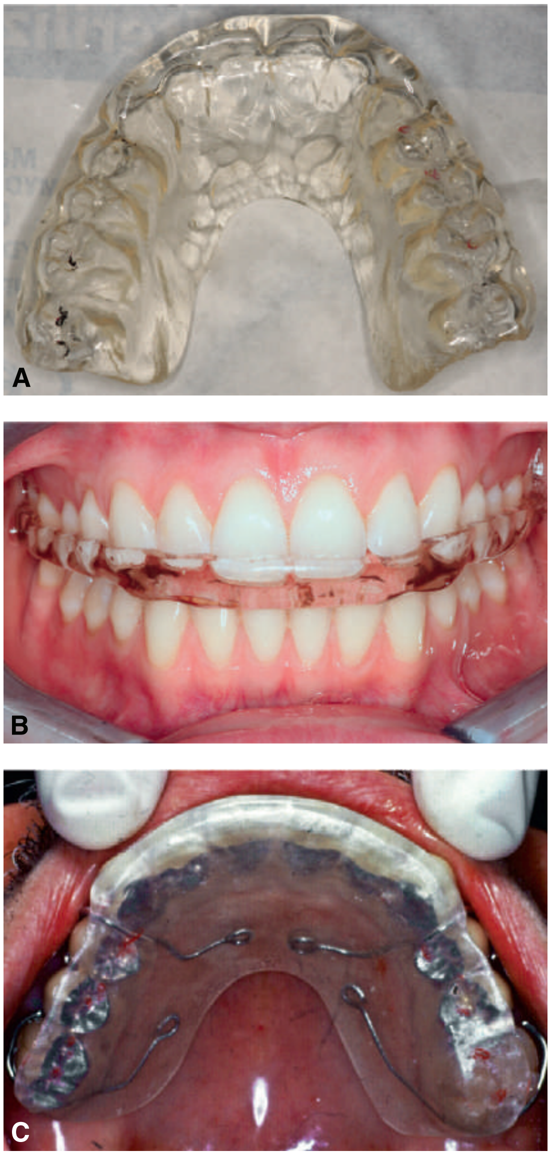


Fig. 4.36 Occlusal device. (A) Appearance of device. (B and C) Device in place. (Courtesy of Dr. W.V. Campagni.)

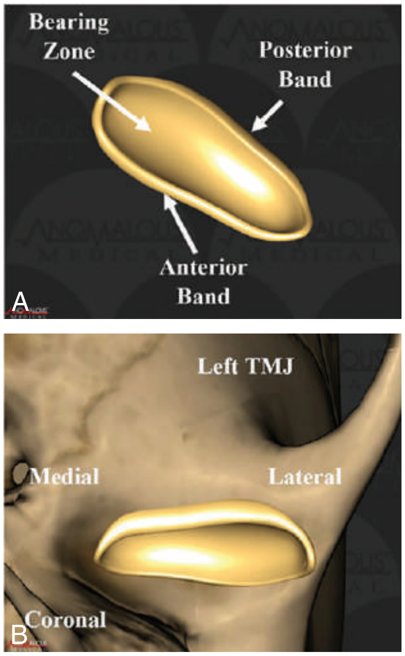


Fig. 4.37 (A and B) Illustration of thicker anterior and posterior bands and the thinner bearing zone of the articular disc. (Courtesy of Mark A. Piper, MD, DMD, from Anomalous Medical.)

a more permanent basis, this can be accomplished through selective occlusal reshaping, tooth movement, the 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

The Glossary of Prosthodontics Terms defines an occlusal device as any removable artificial occlusal surface affecting the relationship of the mandible to the maxillae used for diagnosis or therapy uses.[68] Occlusal devices have been used for occlusal stabilization, for treatment of TMD, reversible diagnostic overlays prior to extensive irreversible interventions, as protection for radiation therapy, for mandibular positioning, for prevention and/or monitoring of dental wear, and for the protection of restorative materials. Although occlusal devices are provided for a broad spectrum of patients and their unique needs, research encourages clinicians to shift away from the paradigm that believed malocclusion or slides between centric occlusion (CO) and maximum intercuspal position (MIP) caused TMD.[69] One randomized controlled trial evaluated the efficacy of professionally made occlusal devices, over-the-counter occlusal devices, and therapy without an occlusal device for 200 participants. After clinical evaluations and patients answering a questionnaire, it was concluded that all patients improved with time. It is unclear if professionally made occlusal devices offered benefits over low-cost store purchased occlusal devices or the self-care without an occlusal device.[70] TMD may be treated without addressing all aspects of a patient's malocclusion. Often, clinicians are faced with clinical decisions with little available guidance from research. In situations where there is little evidence, a generally safe approach is to choose the therapy that minimizes treatment.

In fixed prosthodontics, occlusal devices are routinely prescribed to dental patients with a worn dentition or to protect restorations. Patients must be informed when and for how long to wear the device since if used incorrectly little protective benefit or even irreversible harm can result.

It has been reported that erupting teeth have a daily rhythm of eruption and intrusion.[71] Furthermore, the genes that are associated with bone and periodontal remodeling have been shown to be influenced by a daily circadian rhythm.[72] Consequently, it is recommended not to wear an occlusal device for longer than 8 hours at a time to minimally interfere with a daily cycle of tooth positioning. When an ideal fitting occlusal device is worn for longer periods of time, it may act as an orthodontic appliance causing tooth movement and malocclusions. An 8-hour period usage also corresponds nicely with the 8 hours of sleep that is considered the average time needed for adequate rest. Therefore, in general, the occlusal device will be prescribed to be worn for 8 hours during sleep.

At follow up appointments, the dentist needs to reevaluate the occlusal device's fit, stability, and occlusal contacts. It is during the follow up appointments that the dentist will learn if the time prescribed to wear the device is correct. For example, with a person who is expected to be a bruxer, the dentist does not know when the patient is actually grinding their teeth. There are two types of people that brux their teeth. A nocturnal bruxer will brux their teeth during sleep, whereas a diurnal bruxer will brux during awake hours. Obviously, an occlusal device prescribed to be worn at night will not be effective for a diurnal bruxer. Over time, the teeth will continue to wear away, and the device will lose stability while its occlusal surface will be unworn. In contrast, a device worn at nighttime by a nocturnal bruxer will demonstrate wear on its occluding surface while a good fit and stability are maintained (Figs. 4.38 and 4.39). When wear is detected on the occlusal surface of the occlusal device, the prescribed time for wearing the prosthesis is considered correct. In the absence of wear, it may be necessary to prescribe wearing the device during different hours. If specific times of use are not prescribed, the opportunity to properly assess the success of this therapy may be lost.

Fabrication of Device

There are several satisfactory methods for making an occlusal device. One made from heat-polymerized acrylic resin has the advantage of durability, but autopolymerizing resin used alone

Fig. 4.38 Example of a maxillary occlusal guard at a reevaluation appointment. The device was prescribed to be only worn at night. The occlusal devise has maintained a clinically acceptable fit with the maxillary teeth.

Fig. 4.39 Severe wear is noted on the occlusal surface of the occlusal device along with a perforation in the molar location. The prescribed time for wearing the occlusal device has been confirmed and a new occlusal device in indicated.

BOX 4.1 Comparison of Occlusal Devices

Indirect Technique (Laboratory Fabricated)

- 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

Direct Technique (Autopolymerized)

- Can be performed in one appointment
- Involves using the mouth as an articulator, which can introduce errors
- Thinness and flexibility of vacuum-formed matrix, necessitating more coverage for stability
- Chipping and breaking: need for chairside repairs
- Stain, odors, and excess wear because of porosity of acrylic
- Duplicability of device in heat-polymerized resin for greater durability

Courtesy Dr. J.E. Petrie.

or in conjunction with a vacuum-formed matrix can serve equally well. Autopolymerizing resin is useful when the dentist needs to make a device at chairside. Laboratory made devices can be waxed and processed in acrylic resin of designed and 3D-printed from a digital file. In Box 4.1, the indirect and direct techniques are compared.

Direct Procedure With a Vacuum-Formed Matrix

1. Adapt a sheet of clear thermoplastic resin to a diagnostic cast, with the use of 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 teeth, the device must be kept well clear of the gingival margins (Fig. 4.40A). 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. Using the bimanual manipulation technique, guide the mandible into centric relation (see Chapter 2). Hinge the mandible to make shallow indentations in the resin (see Fig. 4.40B).
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 provide smooth, even contacts during protrusive and lateral excursions, as well as a definite occlusal stop for each incisor in centric relation (see Fig. 4.40C). Confine protrusive contacts to the incisors and lateral contacts to the laterotrusive canines (see Fig. 4.40D). 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 mandibular 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 (see Fig. 4.40E). Polymerization can be accelerated by placement of the device on the cast in warm water in a pressure pot (see Fig. 4.40F).
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 (see Fig. 4.40G). 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 (see Fig. 4.40H).
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. Obtain accurate casts and an interocclusal record (Fig. 4.41A 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 (see Fig. 4.41C–E).
3. Stainless wire clasps (see Fig. 4.41F) and two sheets of baseplate wax are adapted to the maxillary cast (see Fig. 4.41G).
4. Develop an anterior ramp (see Fig. 4.41H) and establish evenly distributed occlusal contact with the mandibular teeth (Fig. 4.41I).
5. Wax sprues are added to the posterior aspect of the completed waxed device (see Fig. 4.41J).
6. Laboratory silicone is adapted over the waxup (see Fig. 4.41K and L).

Fig. 4.40 (A–H) Direct procedure for the fabrication of an occlusal device.

7. After the wax is boiled off the cast, reposition the clasps and lute them in place with some sticky wax (see Fig. 4.41M and N).
8. Apply a separating agent to the cast (see Fig. 4.41O).
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 (see Fig. 4.41P and Q).
10. Place the model in a pressure pot and allow the resin to cure (see Fig. 4.41R).
11. After the cast is reattached to the articulator, mark and adjust occlusal contacts until a mutually protected articulation is established (see Fig. 4.41S and T).
12. Remove the completed occlusal device (see Fig. 4.41U) from the cast, and polish it before 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

Fig. 4.41 (A–U) Technique for occlusal device fabrication with autopolymerizing resin.

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-polymerized resin.
5. Rearticulate and adjust the occlusion.
6. Remove the stone cast with a shell abrasive unit. Polish the external surfaces on a lathe with pumice and an appropriate polishing compound.
7. Store in 100% humidity.

3D Printed Occlusal Device

The step-by-step additive manufacturing of a 3D printed occlusal device is illustrated on a maxillary arch. To promote occlusal stability, the occlusal device is routinely made for the maxillary dental arch because it is easier to obtain contacts on all teeth. However, patients who need to wear their device during daytime hours will have better phonetics if a mandibular device is made.

Optical Impression

A detailed description on how to make optical impressions is discussed in Chapter 14. Once the maxillary and mandibular arches are scanned, a digital buccal scan needs to be made (see Chapter 14). The digital buccal scan needs to be made at the proposed occlusal vertical dimension for the patients when the device is worn. A general guideline is to make an occlusal device no thinner than 2 mm, increasing the occlusal vertical dimension 2 mm between the most posterior opposing teeth. Clinicians have many ways to separate the teeth for a given increase occlusal dimension. Some use wax of a known thickness and others use an anterior device (see Chapter

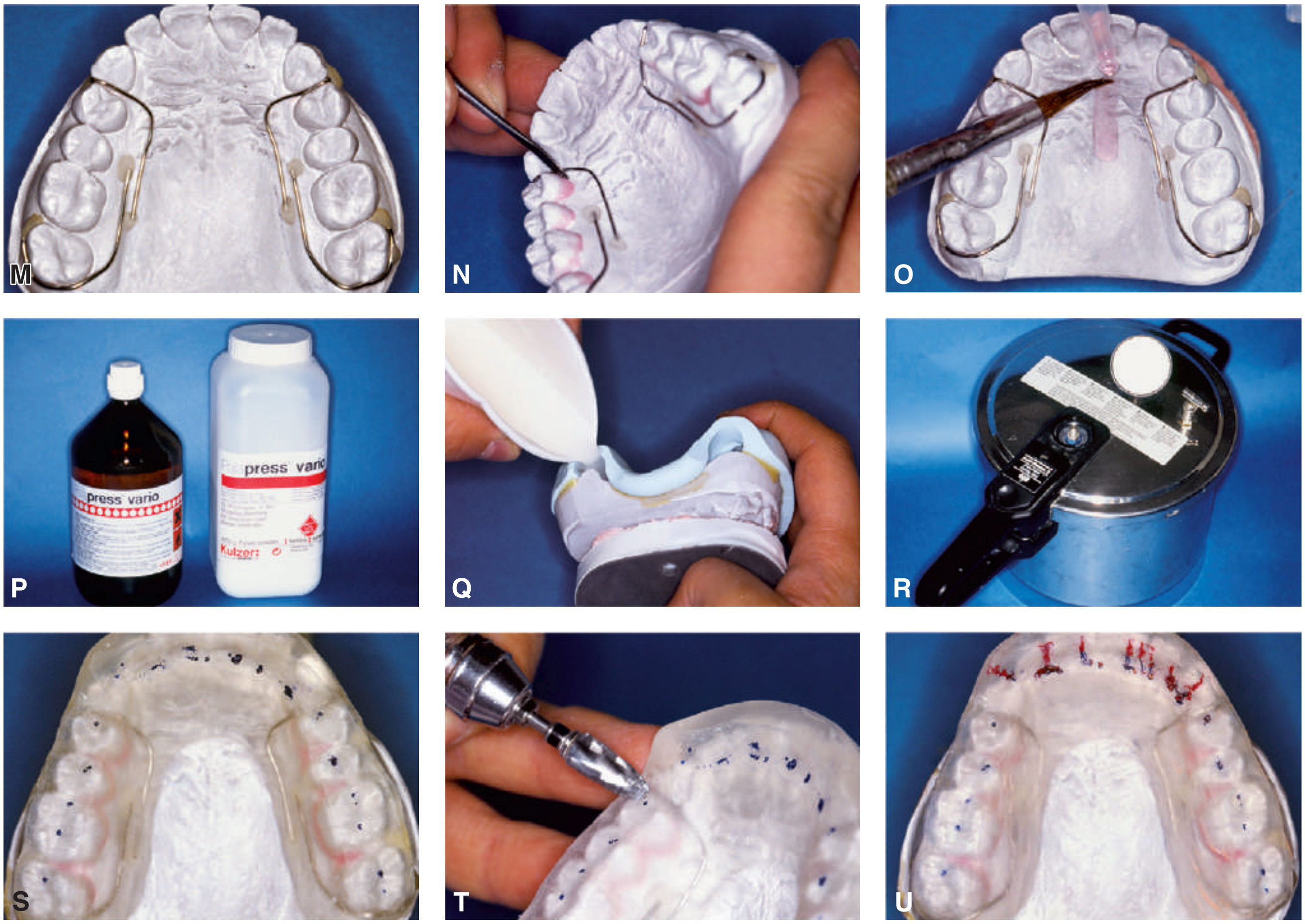


Fig. 4.41 Cont'd

2). A leaf gauge is a practical way to increase the occlusal vertical dimension; however, patients with TMD may experience some discomfort (Figs. 4.42 and 4.43).

Occlusal Device Digital Design

Once the optical scans and occlusal record at a given increased occlusal vertical dimension are obtained, the file can be imported into a digital design program. The program used in the following illustration is from 3Shape A/S; however, many programs with similar intuitive workflow are available.

1. Align the occlusal plane of the maxillary arch to the virtual occlusal plane with three fiducial markers. One between the two central incisors and one on each first molar (Fig. 4.44).
2. Some software programs will give an option to evaluate the patient's occlusion on a digital articulator. Within the software program, it is possible to increase or decrease the occlusal vertical dimension by opening the articulator or uniformly changing the intra-arch space between the casts (Fig. 4.45). Since articulators are developed using average values, such alteration of the occlusal dimension has some inherent inaccuracies. A higher level of precision results if the increase of the occlusal vertical dimension is done clinically before obtaining the intraoral scans.
3. Determine the path of insertion for the occlusal device. The green dot in Fig. 4.46 indicates the axis of the path.
4. The software program will automatically block out undercuts based on the selected path of insertion (Fig. 4.47).
5. Manually draw the finish line of the occlusal device. The buccal finish line should approximate the height of contours of the posterior teeth but not contact the periodontal tissues. In the anterior, it will just overlap the incisal edges (Fig. 4.48A and B). To increase strength and achieve occlusal contact with the mandibular anterior teeth, the finish line will need to cross the anterior palate.
6. Select the occlusal scheme of the occluding surface of the device (Fig. 4.49). The posterior occlusion is flat. However, its anterior shape can be designed to incorporate anterior guidance, flat, or negative guidance. Generally, a flat occlusal plane is adequate for maintaining occlusion and allows freedom of mandibular move ments for the patient. Anterior guidance in an occlusal device may wear into flat occlusal planes. Maintenance of anterior guidance for some patients can be time consum ing and costly.
7. The software program will propose a thickness and occlusion for the occlusal device. The operator then confirms the generated design or can alter it with virtual waxing (Figs. 4.50–4.52).
8. The file of the approved occlusal device design is then saved as a standard tessellation language (STL) file (Fig. 4.53).

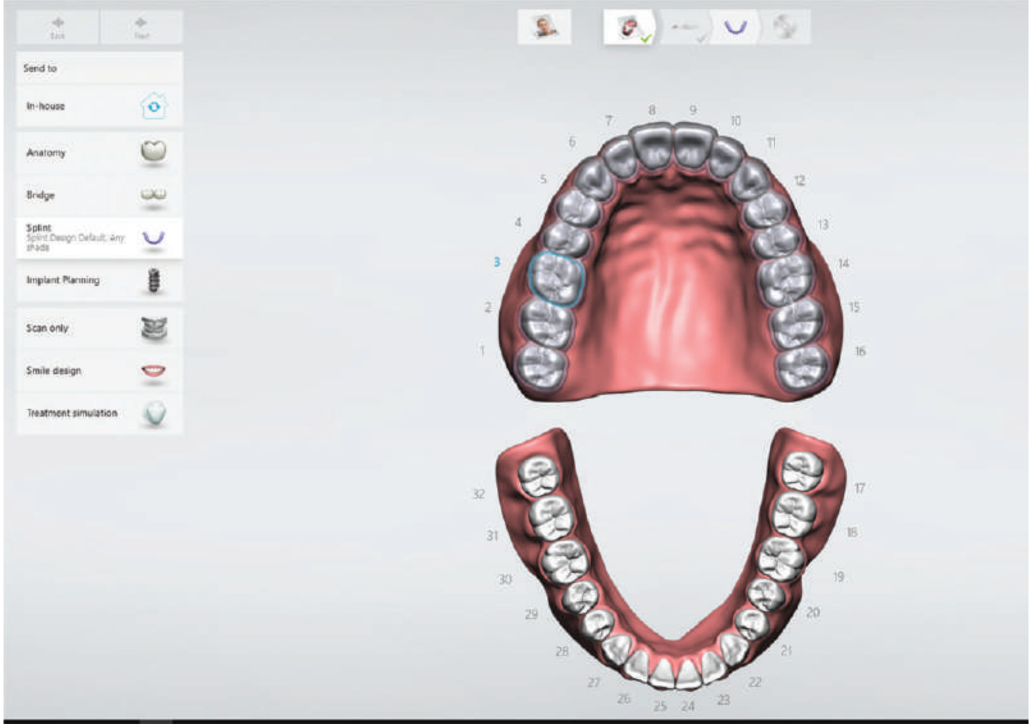


Fig. 4.42 Patient case set up home page indicating which dental arch the occlusal device will be designed for. (Courtesy of Charles Bennett, CDT.)

Fig. 4.43 Optical scan of maxillary and mandibular arches articulated in centric relation at the desired occlusal vertical dimension. (Courtesy of Charles Bennett, CDT.)

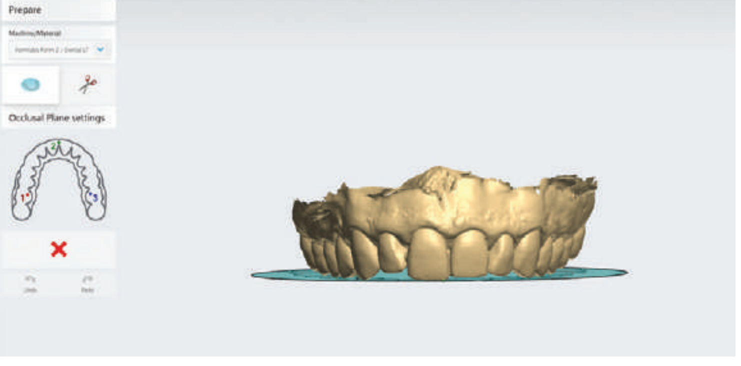


Fig. 4.44 The occlusal plane is set based off of three reference points. One on each maxillary first molar and the third on a central incisor. (Courtesy of Charles Bennett, CDT.)

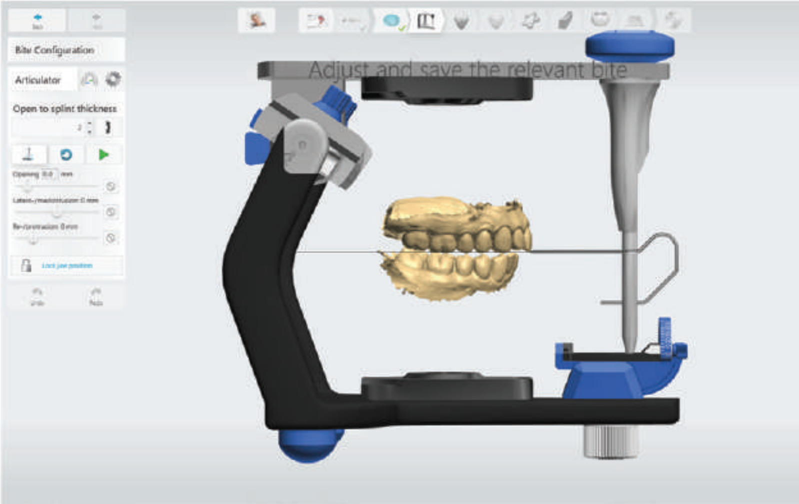


Fig. 4.45 Virtual casts are evaluated on an articulator. If there is not enough space, the articulator can be opened, or the space can be equally increased in both anterior and posterior areas. (Courtesy of Charles Bennett, CDT.)

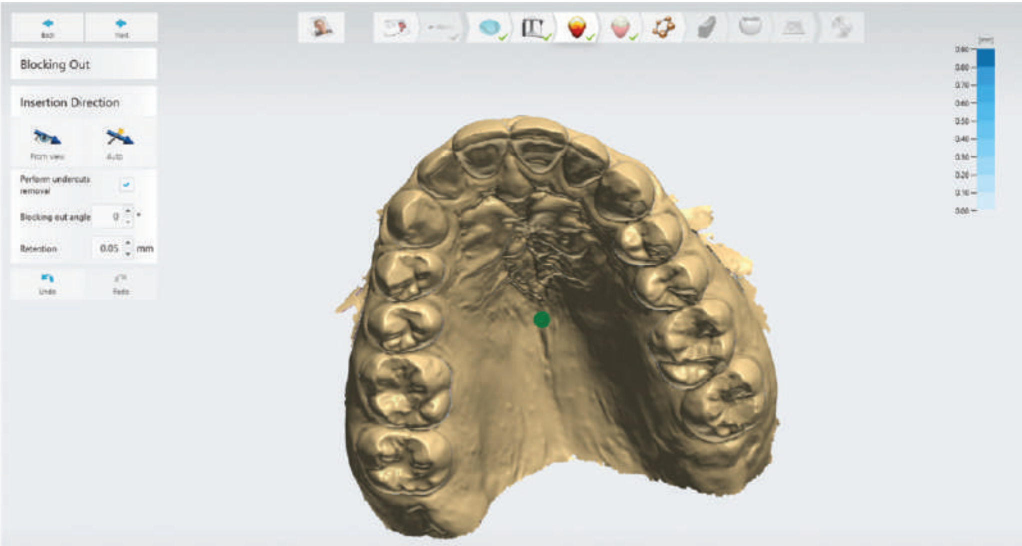


Fig. 4.46 Establishment of the path of insertion. (Courtesy of Charles Bennett, CDT.)

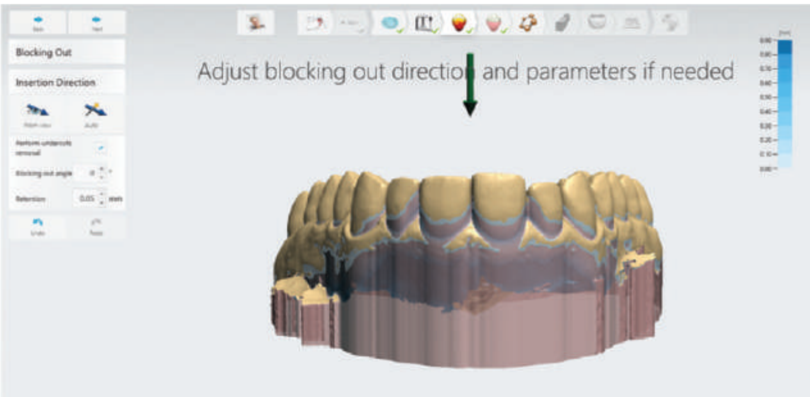


Fig. 4.47 Based off of the established path of insertion, undercuts are digitally blocked out. (Courtesy of Charles Bennett, CDT.)

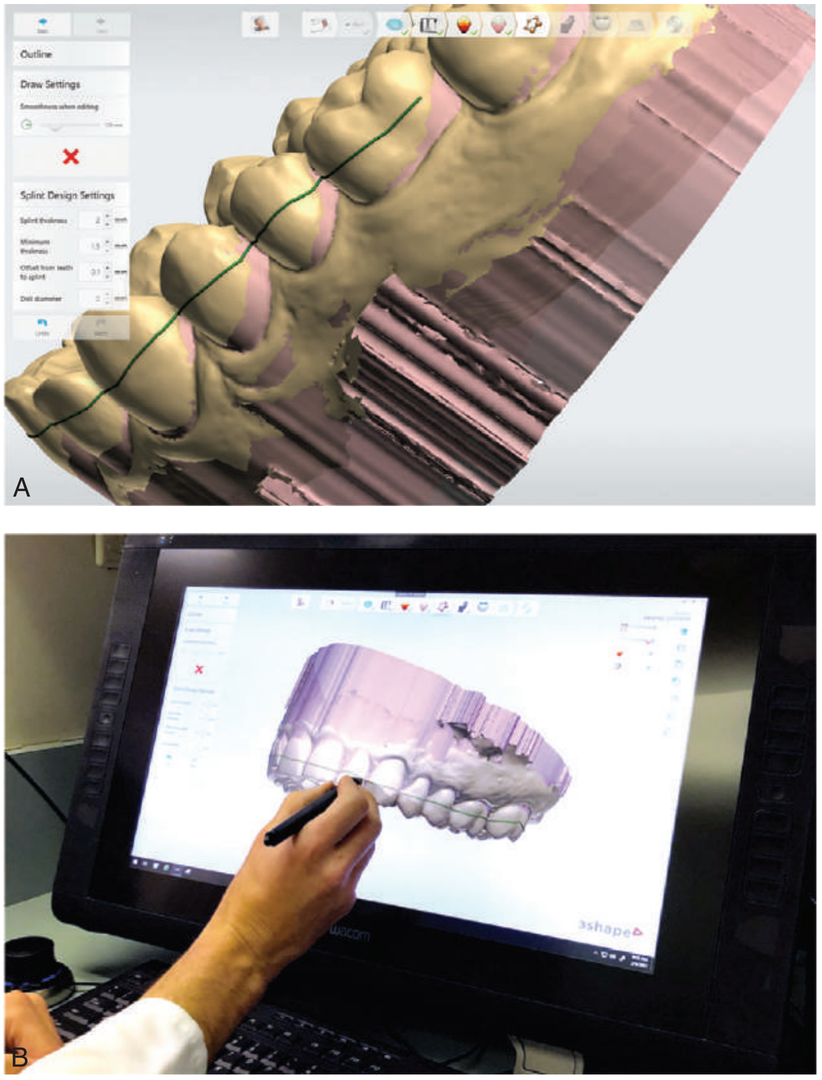


Fig. 4.48 Occlusal device outline form is drawn with a computer mouse (A) or can be drawn with a stylus pen on a computer touch screen (B). (Courtesy of Charles Bennett, CDT.)

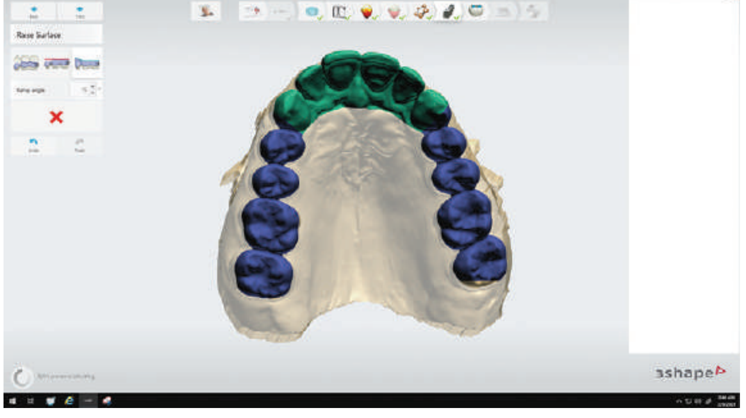


Fig. 4.49 The occlusion can be designed with a flat plane, anterior guidance, or no anterior contact. The given design is flat in the posterior with anterior guidance. (Courtesy of Charles Bennett, CDT.)

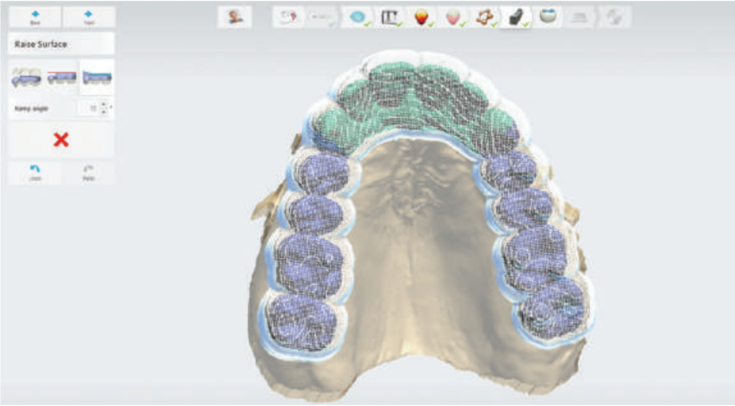


Fig. 4.50 Amount of anterior guidance can be adjusted in degrees. (Courtesy of Charles Bennett, CDT.)

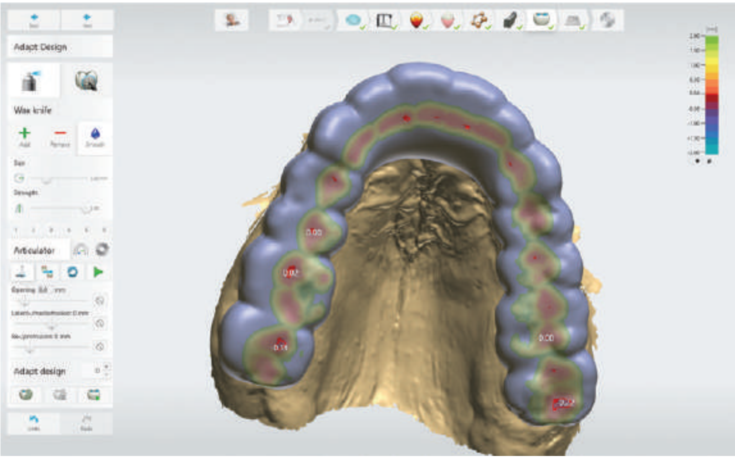


Fig. 4.51 Occlusal analysis: red areas indicate amount of contact from mandibular teeth. Virtual waxing may be accomplished to idealized clinicians' preferences. (Courtesy of Charles Bennett, CDT.)

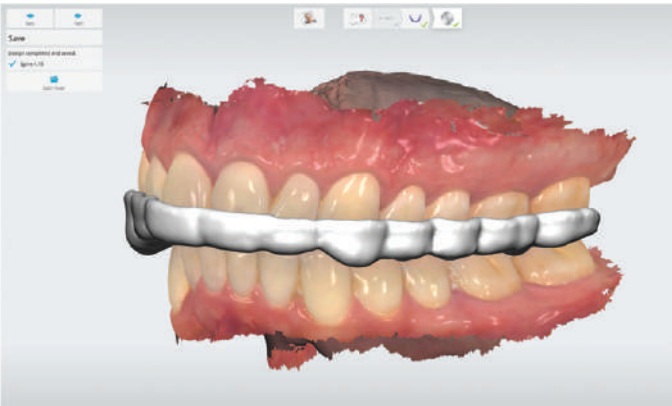


Fig. 4.52 Definitive design. (Courtesy of Charles Bennett, CDT.)

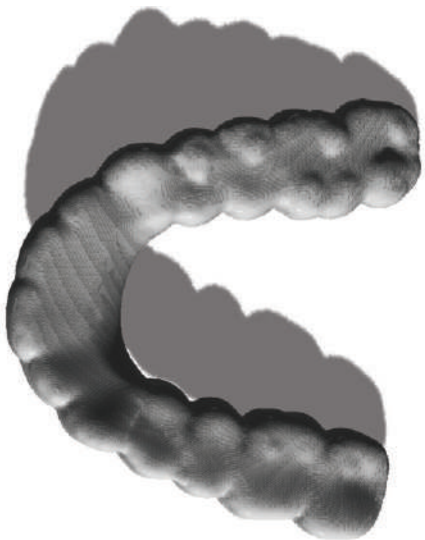


Fig. 4.53 The occlusal device design is converted to an STL file. (Courtesy of Charles Bennett, CDT.)

3D Printing Occlusal Device

1. Machine mix the manufacturer specific photo sensitive resin for an occlusal device (Fig. 4.54).
2. Import the STL file of the occlusal device into a slicer program. A slicer program converts the 3 D design into a list of commands for the 3D printer.
3. Within the program, determine the orientation of the occlusal device for printing and place supports (Fig. 4.55). The supports give rigidity to the object during manufacturing. Position the supports on the camio surface of the occlusal device to facilitate finishing and polishing without compromising the intaglio fit.

Fig. 4.54 Printing resin is machine mixed.

Fig. 4.56 3D printer with its enclosure hood up. It prints in the X, Y, and Z axes.

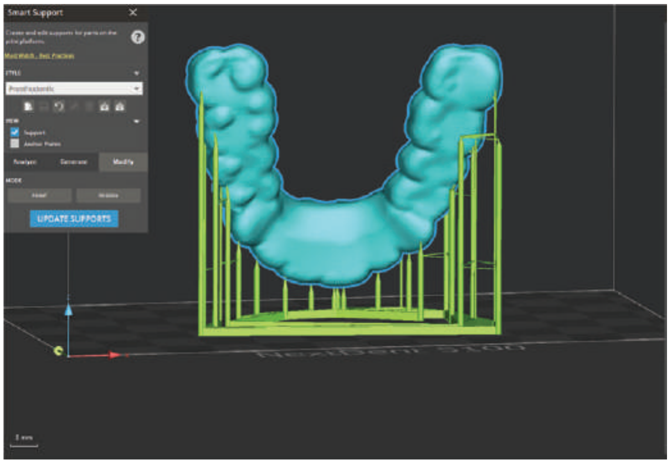


Fig. 4.55 STL file imported into slicer program. A slicer program converts the 3D design into a list of commands for the printer. The slicer also can place supports to 3D object to increase rigidity of overhangs during manufacturing.

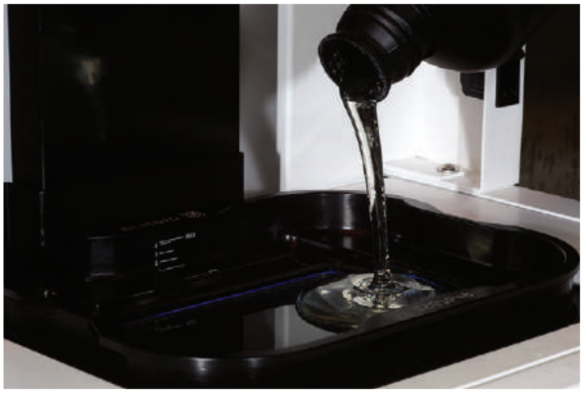


Fig. 4.57 Machine mixed photosensitive resin is poured into the clean vat or tank of the 3D printer.

4. Pour the machined mixed resin into the 3D printer tank, also known as the vat, and position the build plate over the resin tank (Figs. 4.56–4.58).
5. Print the occlusal device (Fig. 4.59).
6. Remove the occlusal device from the build plate with a printer-specific removal punch instrument into a bath of 99.8% isopropyl alcohol. Once the occlusal device is removed from the build plate, the supports are easily removed by hand. The occlusal device is then cleaned in two separate baths of alcohol with an acid brush (Figs. 4.60 and 4.61).
7. Remove the occlusal device from the second alcohol bath and allow to bench dry for 10 minutes.
8. Place the dried occlusal device into a UV light polymerization unit for 15 minutes (Fig. 4.62).
9. Finish and polish the definitive 3D printed occlusal device using standard resin polishing instruments and techniques.

Attention to Detail

Regardless of the device chosen, success depends very much on meticulous attention to detail during the fabrication and delivery. When a direct device is made, 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 mandible can be easily manipulated into the centric relation position before resin is added to the posterior region to record the posterior occlusal stops. 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 of frustration and excessive adjustments at the time of clinical delivery of the occlusal device.

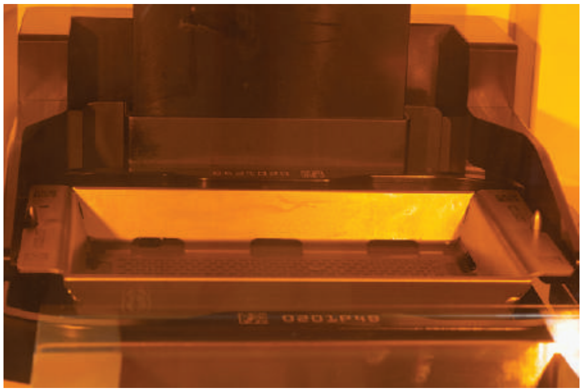


Fig. 4.58 Printer's build plate or print bed positioned above the resin vat.

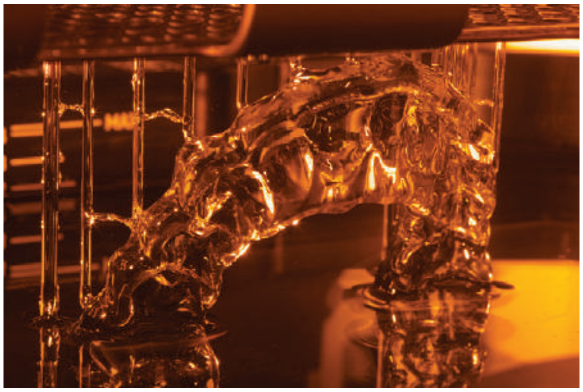


Fig. 4.59 Occlusal device being printed in layers. Note how supports retain the device to the build plate as it elevates.

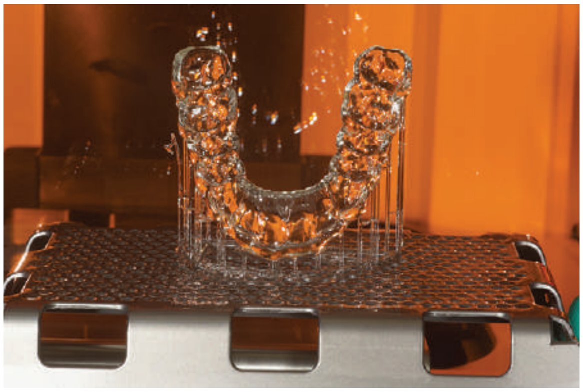


Fig. 4.60 Completed printed device still on the build plate, removed from the enclosure.

Follow-Up

After the device is delivered to the patient, uniform distribution of occlusal contacts must be verified, and the device corrected as necessary. The patient is instructed to wear the device 24 hours a day, removing it only for meals and for oral hygiene purposes, and to return at regular weekly and biweekly intervals (or sooner if a problem is perceived) for modification. A reduction in discomfort suggests that definitive occlusal adjustment (see Chapter 2) or restorative dentistry, or both, will probably be successful. If device therapy fails to relieve discomfort, further

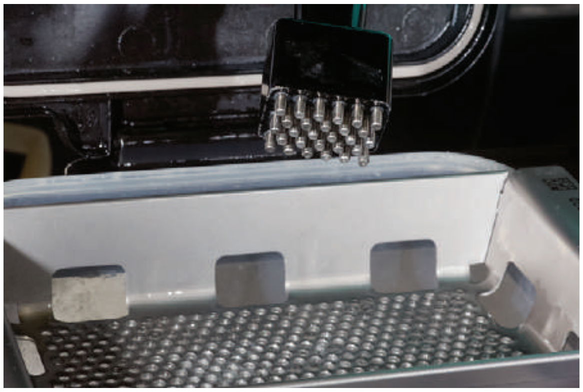


Fig. 4.61 A specific punch pushes the supports off the build plate. The occlusal device falls into a bath of 99.8% isopropyl alcohol.

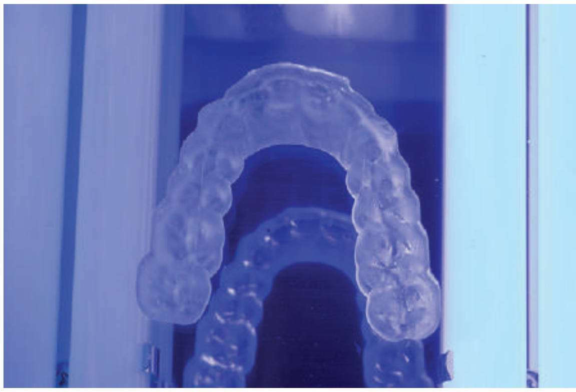


Fig. 4.62 The clean occlusal device is removed from the second bath and allowed to bench dry for 10 minutes before placing in an alternative UV light source for 15 minutes of post-polymerization.

evaluation and diagnosis of the causes and parameters of the chief complaint should be pursued. A potential diagnostic "red flag" is a patient who initially reports improvement in symptoms but then reports a worsening of the initially resolved complaints. In many of these situations, the possibility of patient noncompliance warrants investigation. In the event that extensive fixed prosthodontics treatment is planned for such an individual, clinicians should proceed cautiously.

DIGITAL SYSTEMS

Manufacturers have made tremendous strides in capturing dynamic mandibular movement and reproducing such in digital format (see Chapter 2). The challenge remains to correctly capture the combined effect of posterior and anterior determinants and to reproduce movement accurately. A limitation of data from computed tomography, MRI, and CBCT imaging is that they are static representations. The SICAT Function software system is designed to combine data from three-dimensional radiographic analysis, optical capture, and dynamic mandibular movement recording. This information can be used for diagnostic purposes or to generate a mandibular repositioning device in harmony with the integrated dataset (Fig. 4.63). Supporting scientific data remain limited at present.

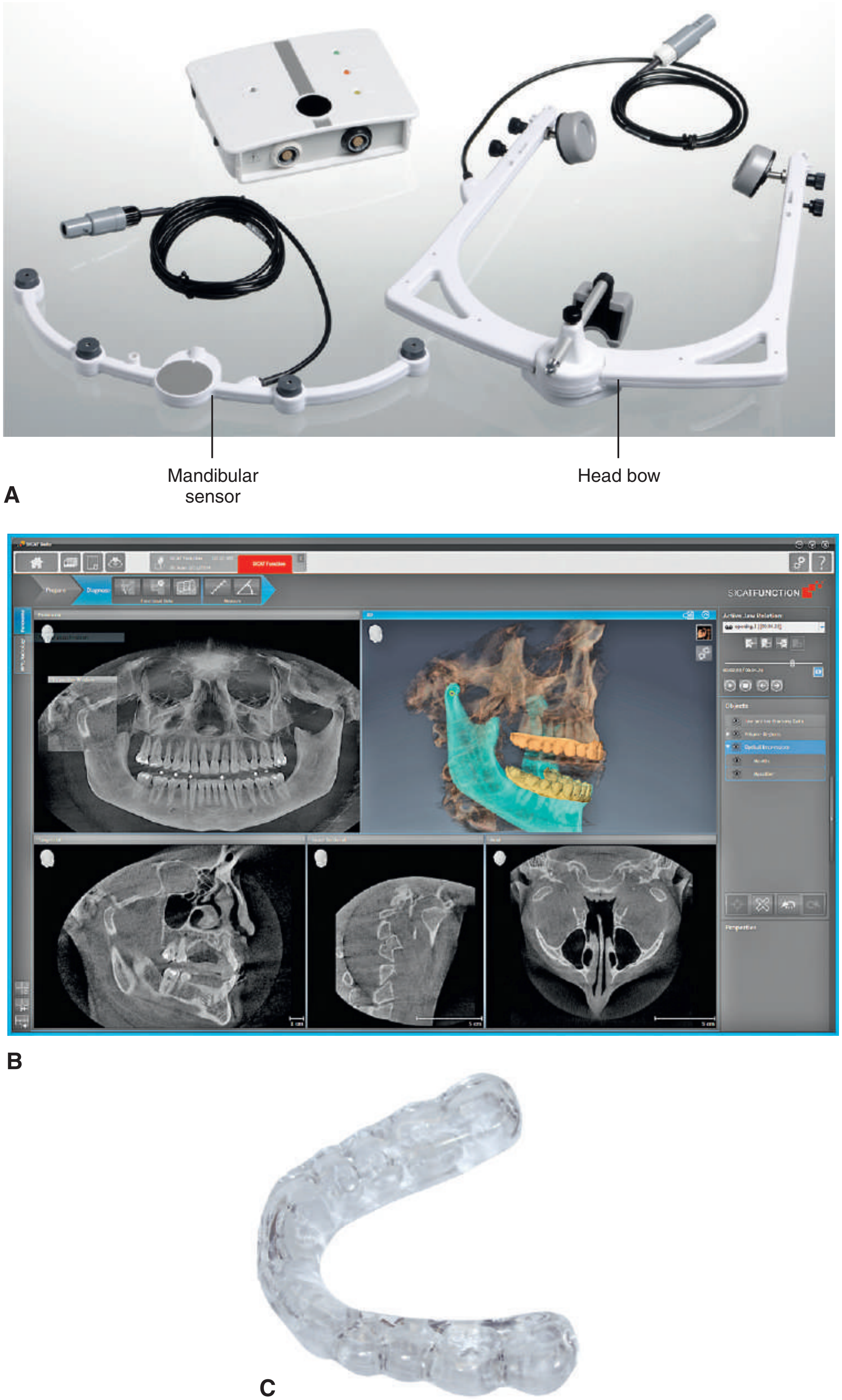


Fig. 4.63 The SICAT Function software system integrates diagnostic information from a three-dimensional radiographic system, a mandibular motion tracking system with optical impressions (CEREC, Sirona). (A) The SICAT Jaw Motion Tracker recording equipment. (B) SiCAT Function software sample screen. The manufacturer reports patient-specific three-dimensional presentation of mandibular motion at any point of the mandible, as well as dynamic reproduction of the condyle-fossa relationship. (C) SICAT Optimotion treatment device fabricated on the basis of the three-dimensional radiographic data, the optical surface scan data, and the recorded movement data. (Courtesy of SICAT GmbH & Co. KG, Bonn, Germany.)

SUMMARY

Mandibular movement depends on certain anatomic limitations. The extremes, called *border movements*, are subject to restriction by the TMJs, 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.

In patients with complete dentures, a balanced occlusion provides stability because there is even contact between all the teeth in each excursion. This is potentially destructive in dentate patients and is contraindicated for fixed prosthodontic treatment. In a unilaterally balanced (group function) occlusion, eccentric occlusal contact occurs only between posterior teeth on the laterotrusive (working) side. This occlusal arrangement may be indicated when it is important to distribute the load over multiple teeth. Mutually protected articulation offers the most desirable load distribution. In this arrangement, centric relation coincides with the maximum intercuspation position, and the relationship of the maxillary and mandibular anterior teeth (the anterior guidance), which results in posterior disclusion in all excursive movements, is instrumental in its success.

In the presence of pathologic processes that are 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 are the differences 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.

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5

Periodontal Considerations

Rick K. Biethman and Daniel Melker

PREVALENCE

Periodontal textbooks comprehensively describe periodontal disease causes, diagnosis, treatment planning, and treatment options and explain in detail the many interactions between oral and systemic health.[1,2] This chapter focuses instead on a review of those portions of periodontal diagnosis and therapy that pertain to comprehensive fixed prosthodontic treatment.

Periodontal therapy is extremely effective. Today, few individuals lose their teeth as a result of untreatable periodontal disease (Fig. 5.1). This statistic may appear to contradict the often-repeated axiom that most tooth loss is caused by periodontal disease. However, individuals with access to proper dental care can retain even compromised teeth for extended periods of time.[3–7] According to data from the 2009 and 2010 National Health and Nutrition Examination Survey (NHANES),[8,9] only 38.5% of adults in the United States have one or more teeth affected by moderate to severe periodontal disease. The criterion for the diagnosis of moderate to severe periodontal disease was one site with attachment loss of 3 mm or more and pocket depth of 4 mm or more.

Long-term periodontal maintenance studies have shown that of patients with moderate to severe disease referred for periodontal treatment, more than half did not lose a single tooth in two decades of periodontal maintenance, and 75% lost fewer than three teeth.[3,6] This suggests that when proper periodontal treatment is provided, most adults (90% to 95%) will not lose teeth because of periodontal disease. However, although periodontally compromised teeth can be retained over long periods of time, such teeth may not provide a solid foundation to support a fixed dental prosthesis.

When periodontally compromised teeth are lost, such often results from lack of access to effective care. A strong correlation exists between poverty, lack of education, and the presence of periodontal disease.[8,9] The prevalence of periodontal disease among poor patients is 6% higher than in the overall population.[10] Cost of care is a major obstacle in the prevention of tooth loss. Too often, periodontal disease is left untreated because of the patient's inability to afford proper care.

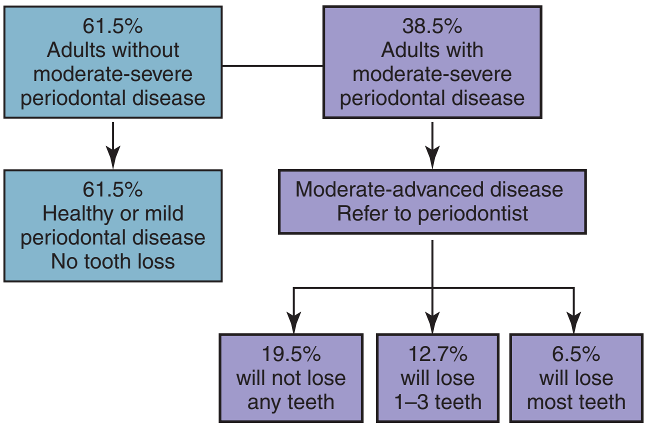

Fig. 5.1 Combined data from the 2010 National Health and Nutrition Examination Survey (NHANES)[8] and from Hirschfeld and Wasserman's[3] report on 22 years of periodontal maintenance. Approximately 2.5% of the U.S. population (6.5% of the 38.5%) have a severe form of periodontal disease that responds poorly to current therapy.

TREATMENT OF PERIODONTITIS

Periodontal disease progresses from gingivitis to periodontitis when connective tissue attachment is lost. Periodontal disease may be characterized by alternating periods of quiescence and exacerbation. The extent to which a periodontal lesion progresses before it is treated determines the amount of bone and connective tissue attachment loss that occurs. This subsequently affects the prognosis of the tooth with regard to restorative demands.

Effective periodontal care incorporates three components: (1) effective daily plaque removal by the patient, (2) active therapy to remove calculus, endotoxins, and pathologic bacteria from the root surfaces and pocket, and (3) preventive periodontal maintenance therapy (supportive periodontal therapy [SPT]) every 2 to 6 months.[11] Few patients are consistently successful in removing all plaque accumulation. However, a healthy immune system has been shown to be able to compensate for the presence of some residual plaque.[12]

Periodontal disease is site specific; the distal surface of a tooth may exhibit disease while its mesial surface is healthy (Fig. 5.2).[13] The logical implication is that diagnosis and treatment must also be site specific. Enhanced salivary diagnostic testing has the ability to indicate active bone loss and to detect pathologic bacteria.[14,15] However, most of these tests are more general, indicating whole mouth values, and high costs preclude their routine use. The most cost-effective, reliable, site-specific indicators of periodontal health are comparison of pocket depths, attachment levels, bleeding on probing (BOP), and tooth mobility over time (Fig. 5.3).[16–18]

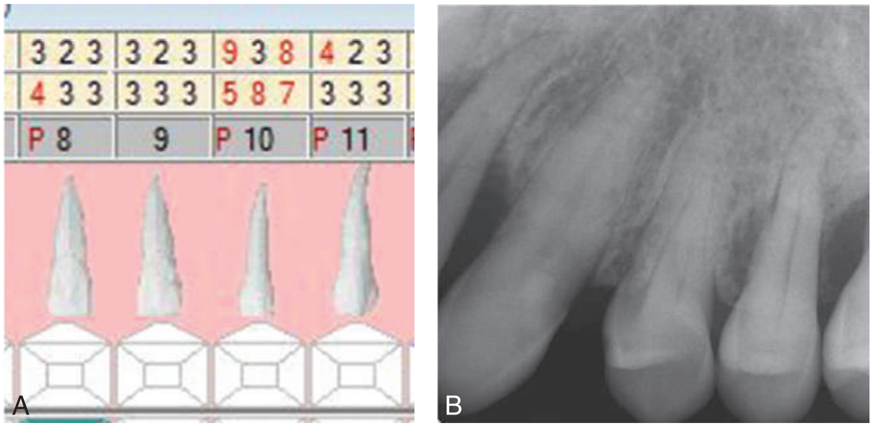

Fig. 5.2 Site-specific nature of periodontal disease. (A) Pocket depths of teeth #8 to #11. (B) Severe bone loss is visible on tooth #10, and yet the mesial surface of tooth #11 exhibits only minor changes.

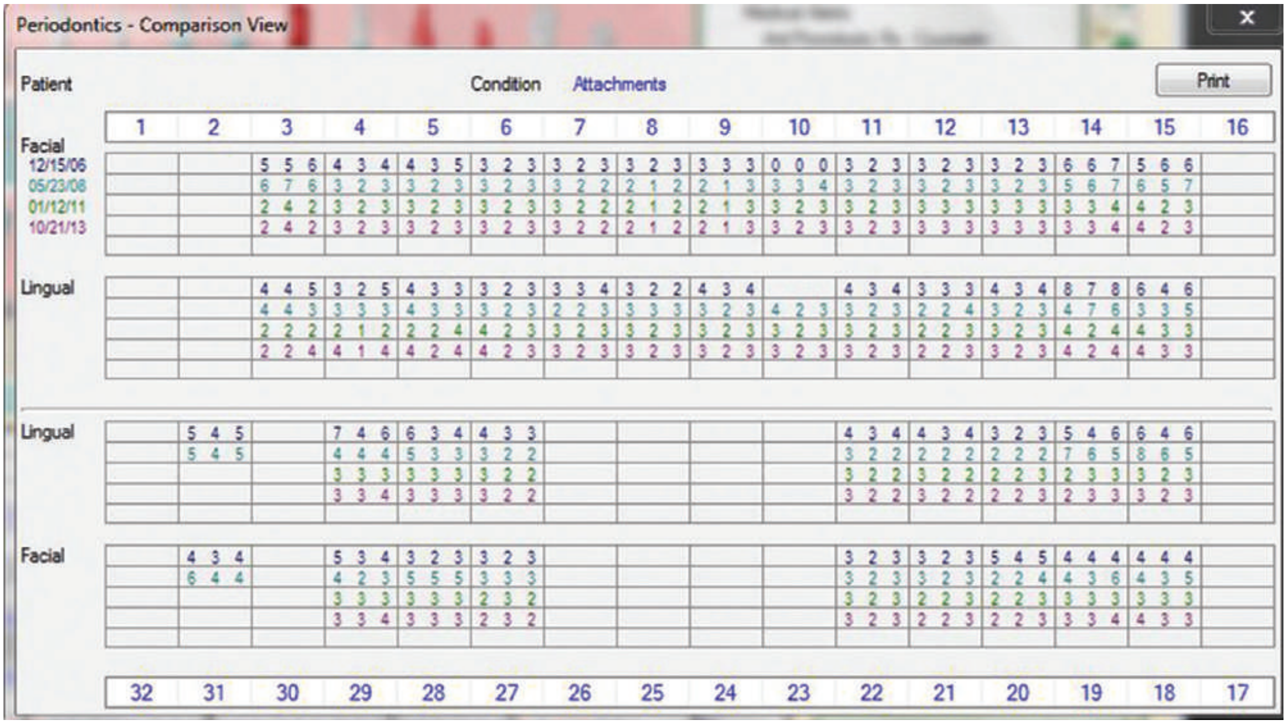

Fig. 5.3 Comparison of stable attachment levels over a 7-year period of supportive periodontal therapy.

Scaling and root-planing (SC/RP) remains the foundation of periodontal treatment.[19,20] During active therapy, it results in the greatest gain in attachment level of all possible therapeutic techniques, reasonable pocket depth reduction, decreased BOP, and an improvement in microbial composition. It has been shown to be cost effective, and negative side effects are minimal in comparison with those of all other techniques.[21] The objective is to achieve a clean root surface, which can be accomplished with hand instrumentation, an ultrasonic scaler, or a laser. What is important is the quality of the root debridement, not the tool used to achieve the clean surface. Antibiotics are often useful in eliminating pathogenic bacteria not accessible with mechanical therapy.

SC/RP is definitive therapy for most patients. Any therapy that brings about resolution of inflammation—such as improved oral hygiene, antibiotic therapy, SC/RP, laser therapy, or surgery—will result in gingival recession if bone has been lost. The extent of recession is extremely important to the restorative dentist when precise margin location and gingival symmetry are necessary to achieve a desired esthetic result (Fig. 5.4).

The most frequent indications for surgical periodontal therapy are (1) continued bone loss in a patient who has had SC/RP and is on a 2- to 3-month periodontal maintenance schedule[22] and (2) the need for fixed prosthodontic treatment that will result in either a subgingival crown margin inaccessible

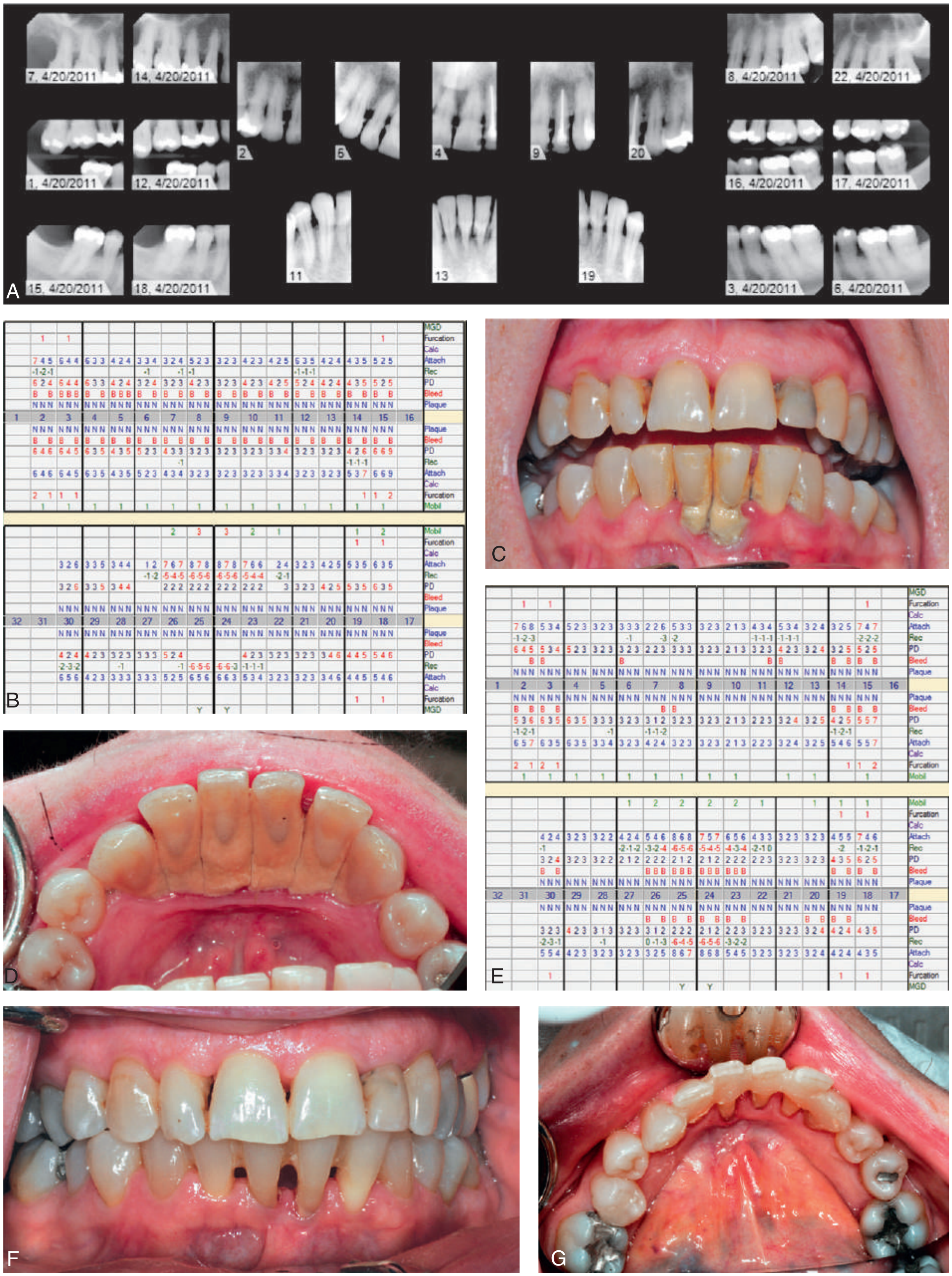

Fig. 5.4 Periodontal charting showing resolution of periodontal infection with scaling and root planing (SC/RP) results in a reduction in inflammation and gingival recession. (A and B) Pre-SC/RP radiographs and data showing generalized moderate-to-severe periodontitis. (C and D) Initial presentation. (E) Post-SC/RP reevaluation data, demonstrating pocket reduction and gingival recession. (F and G) Post-SC/RP appearance, with clinical reduction in inflammation and gingival recession. (C, D, F, and G, Courtesy Dr. Spencer Shoff.)

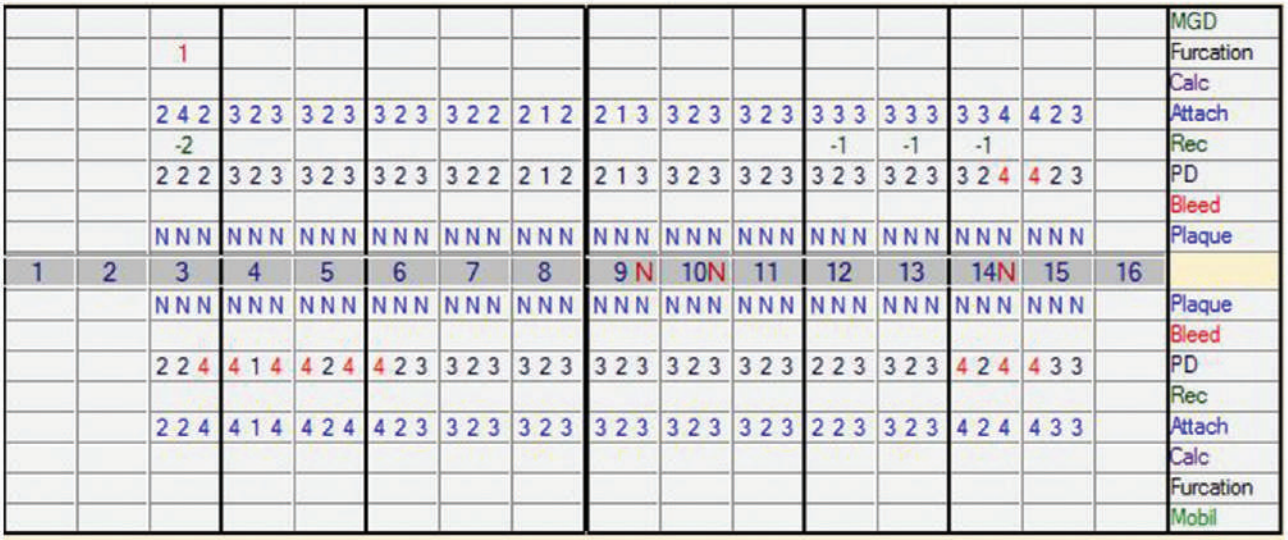

Fig. 5.5 Comparison of bleeding upon probing at individual sites over time.

for cleaning, or a short clinical crown that will have inadequate retention or resistance form.[23] Surgical procedures are designed to allow meticulous cleaning of the root surfaces and to reduce pockets through removal of gingiva or regrowth of bone. However, unless followed by frequent SPT, plaque will accumulate in the surgical sites, periodontal disease will recur, and significant attachment will be further lost.[24] Short-term positive changes from various surgical therapies ameliorate over time. After 7 years, results of all therapies, including SC/RP, are similar when considering pocket reduction, attachment levels, and tooth retention.[25,26] Frequent SPT underlies successful periodontal therapy. Without frequent SPT, almost all periodontal therapy will fail.

The time interval for frequent SPT varies according to the individual patient. In most successful long-term studies, 2 to 3 months has been the standard time interval between SPT appointments.[27] The appointment interval is then lengthened or shortened according to the results for the individual patient. Treatment at each SPT appointment should be based on comparisons of pocket depths, attachment levels, the presence of BOP, and mobility at the current appointment with those of the previous appointment (Fig. 5.5). An increase of pocket depths or loss of attachment of 2 mm is a reliable indicator that continued periodontal destruction is occurring.[19] The absence of BOP is a reliable indicator of health.[28] Continued BOP at the same site is the best predicator of future attachment loss (Fig. 5.6).[29] Increasing mobility indicates the need for careful analysis of the occlusion and/or endodontic status of the tooth if pocket depths and attachment levels have not changed. Obtaining complete periodontal data at every SPT appointment changes the appointment from a nonspecific teeth cleaning to a site-specific program to maintain periodontal health.

An overlooked benefit of SPT is the concurrent reduction in dental caries that occurs with frequent periodontal maintenance. Several researchers evaluated interproximal caries in teenagers. They found that oral hygiene instruction, chlorhexidine rinses, and fluoride rinses performed every 2 weeks had almost no effect

Frequency consecutive BOP	Predictive accuracy of future bone loss
0	2%
2	12%
5	93%

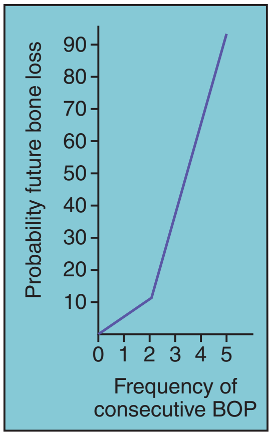

Fig. 5.6 The absence of bleeding on probing *(BOP)* is a reliable indicator of periodontal health. Continued BOP at the same site greatly increases the risk of future bone loss.

TABLE 5.1 Caries Reduction

Intervention	Significant Reduction in Interproximal Caries
Oral hygiene instruction every 2 weeks	No
Chlorhexidine rinses every 2 weeks	No
Fluoride rinses every 2 weeks	No
Professional tooth cleaning every 2 weeks	Yes

on new carious lesions. A professional cleaning every 2 weeks reduced new carious lesions significantly (Table 5.1). In another study, children (aged 3 to 13) of adult patients being treated for periodontal disease were evaluated. These children received cleanings every 6 months for 20 years. No periodontal destruction was seen, and the average rate of caries was one lesion per child over the 20-year interval.[30–32]

Axelsson et al evaluated the effects of SPT every 2 to 3 months in adults. Fifteen years earlier, they had treated 375 adults with SC/RP and caries control. All patients were recalled every 2 to 3 months for 6 years. Of these patients, 95% were stable, with no additional caries or periodontal destruction. For those patients, the recall interval was lengthened to one to two times per year. The 5% of patients who exhibited additional periodontal destruction or new carious lesions continued their recall interval of every 2 to 3 months. After 15 years, all patients who had completed the prescribed recall intervals had maintained a low caries rate and exhibited almost no additional periodontal destruction.[33] A reasonable approach to prevent future caries and periodontal disease is a 2- to 3-month SPT interval for all patients who exhibit active caries or periodontal disease. If the patient experiences no additional caries or periodontal breakdown after 2 years, the SPT interval can be lengthened to 4 to 6 months. The key component of SPT is the meticulous record keeping in which caries, pocket depths, attachment levels, BOP, and mobility at the current appointment was compared with those at the previous appointment; changes are made as necessary.

BOX 5.1 Criteria for Consideration in Determining a Periodontal Prognosis

Overall Clinical Factors
Patient's age
Disease severity
Plaque control
Patient compliance
Finances available

Local Factors
Plaque and calculus
Subgingival restorations
Tooth crowding
Root resorption

Tooth Mobility

Systemic and Environmental Factors
Smoking
Systemic disease or condition
Genetic factors
Stress
Dry mouth

Anatomic Factors
Short, conical roots
Root concavities
Developmental grooves
Root proximity
Furcation involvement

Prosthetic and Restorative Factors
Abutment selection
Caries
Nonvital teeth

PROGNOSIS

When prosthetic replacement of missing teeth is necessary, an accurate prognosis of the remaining teeth is essential. The prognosis is the best guess of the course or outcome of the periodontal disease. It comprises (1) the prognosis for the overall dentition and (2) the prognosis for individual teeth. A tentative prognosis is made after a thorough review of the patient's medical and dental histories and clinical findings (Box 5.1). In general, identification of patients with extreme prognoses—either good or hopeless—is reasonably straightforward in comparison with determining a prognosis for patients with prognoses in between. The various guidelines available to predict the future of a tooth with a poor or questionable prognosis are unreliable. Historically, a tooth was considered to have a poor prognosis if it had 50% attachment loss or a class II furcation; a tooth had a questionable prognosis if it had more than 50% attachment loss, a class II or class III furcation, or a poor crown-to-root ratio or poor root form.[34]

The dentist refines the prognosis after observing the response to initial periodontal therapy. Initial therapy includes SC/RP, improvement in oral hygiene, and replacement or recontouring of defective restorations that compromise plaque removal. Initial therapy reduces the bacteria in the sulcus, detoxifies the root surface, and eliminates micro-environments that harbor bacteria, such as calculus and defective restorations. If defective restorations are not corrected as part of initial therapy, the healing response will be stunted. Caries near the gingiva, marginal overhangs, and open contacts should all be corrected before or at the time of SC/RP for optimal gingival healing (Fig. 5.7). In patients who respond to initial therapy with significant reductions in pocket depths and in BOP, the prognosis is significantly more positive.[35,36]

Time is on the dentist's side in further evaluation of the overall dentition and of specific teeth. When other problems allow, patients should undergo SPT every 2 to 3 months during the first year after initial phase therapy. All urgent dental needs are addressed, and the patient's oral hygiene and maintenance compliance are evaluated during this year. The changes recorded in periodontal health are compared to the reevaluation data. This third refinement of prognosis enables much more accurate planning, allowing comprehensive restorative therapy to be initiated at that time.[37–40]

Teeth with a poor or questionable prognosis can be maintained for many years. Periodontal disease is site specific, and in most instances, a periodontally compromised tooth does not affect the health of adjacent teeth.[41] When possible, the restorative plan can allow such teeth to remain in place, while only teeth or implants with a good or fair prognosis can be used to support a prosthesis to replace missing teeth. It may be possible to maintain the teeth in a periodontally compromised but otherwise intact dentition for an extended period of time. However, if that same patient is missing teeth and now requires comprehensive restorative dentistry, strategic extractions may be necessary to improve prosthetic predictability (Fig. 5.8).

If strategic extractions are indicated, it is advisable to consider whether such teeth can serve as interim abutments[42,43] (Fig. 5.9) or for implant site development through orthodontic forced eruption (OFE) (Fig. 5.10).[44] Both procedures may enhance bone and gingival tissue augmentation. Tooth extraction is always followed by some loss of crestal bone and gingiva (Fig. 5.11). Before the advent of implants, teeth with a hopeless prognosis were simply extracted. In contrast, retention of teeth, even if temporary, can help retain and augment tissue in anticipated implant sites, improving future esthetics and implant considerations.[45]

Connective Tissue

The importance of an abundance of thick, dense connective tissue to the long-term prognosis can no longer be debated.

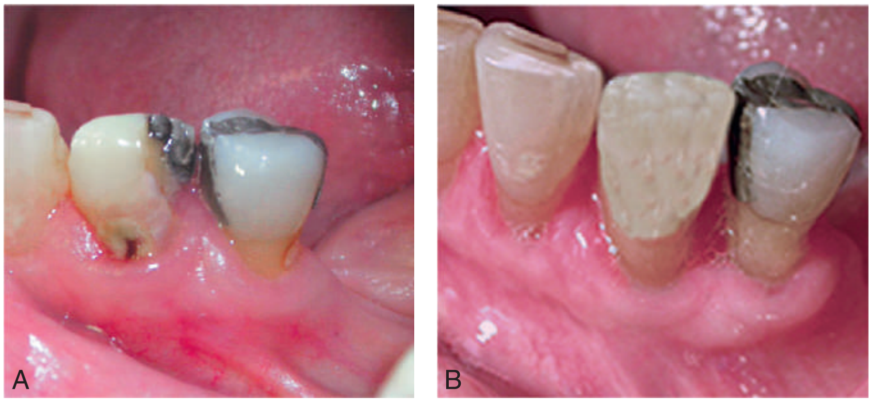

Fig. 5.7 To promote maximum gingival healing after scaling and root planing, open contacts, defective restorations, and dental caries (A) must be corrected (B) during the initial phase of periodontal therapy.

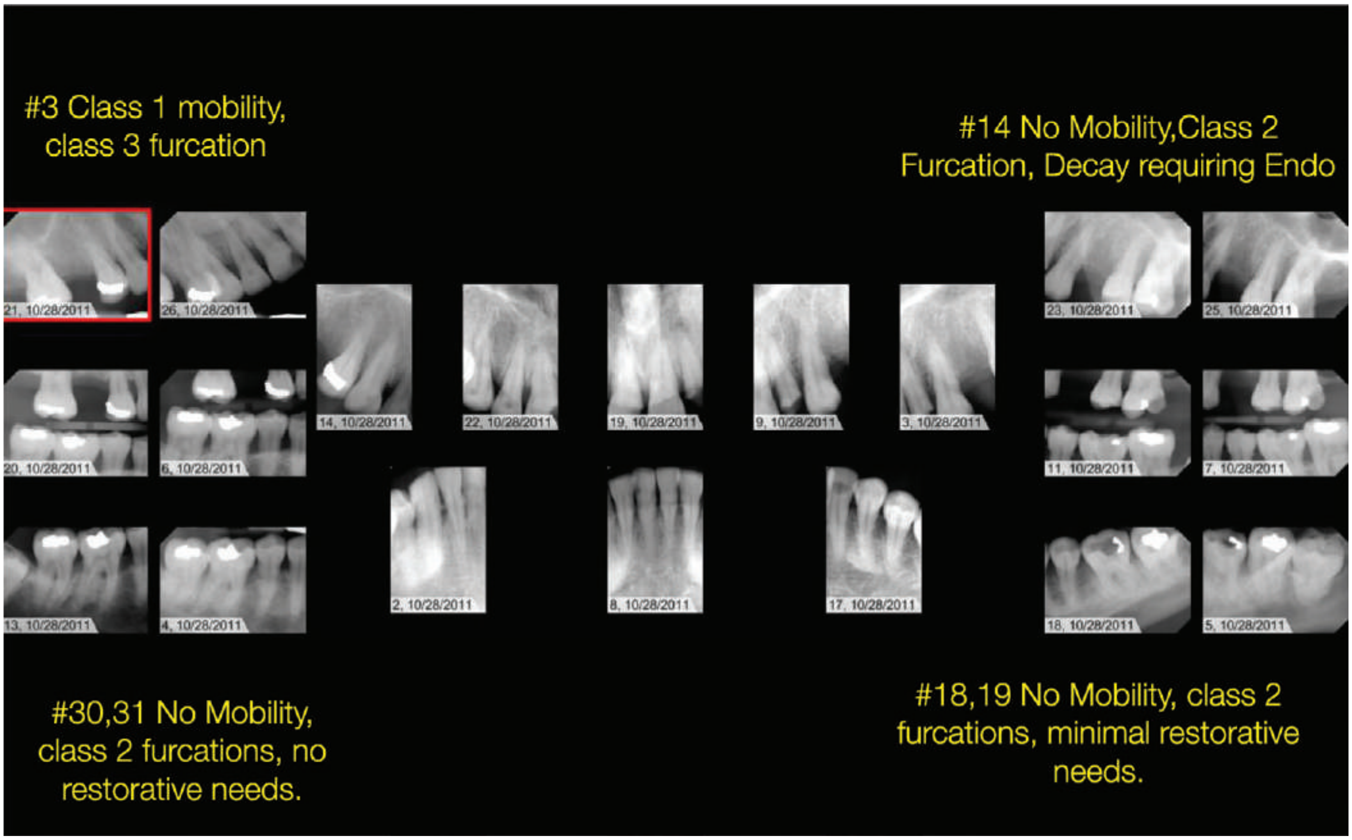

Fig. 5.8 The mandibular arch has an intact dentition with minimal restorative needs, and all teeth should be retained and maintained as long as possible, even with advanced periodontal destruction associated with the molars. The maxillary arch has similar periodontal destruction but now requires extensive restorative treatment and selective extractions are necessary to ensure acceptable longevity of the prostheses.

Decreased gingival inflammation, reduced BOP, and less bone loss have been observed around prosthetically restored natural teeth and implants when dense connective tissue is present.[46,47] Ideally, 5 mm of dense connective tissue of which 3 mm is attached should be present (Fig. 5.12). In situations where less connective tissue is present, a gingival augmentation procedure is indicated. The importance of thick, dense connective tissue was recognized in the 60s for natural teeth. However, in the mid-80s, the arrival of the mandibular fixed hybrid implant supported restoration made many question its importance. That unique restoration with its restorative interface placed 3 mm above the gingiva and dense, flat and abundant bone, achieved excellent long-term predictability even in cases without dense, thick connective tissue. This led many to question the need for dense connective tissue. As implant prosthodontics evolved and implants were used to replace missing teeth in other areas of the mouth and the

Fig. 5.9 The maxillary right central incisor and maxillary left lateral incisor are used as interim abutments to support a fixed interim restoration that protects the surgical site during healing after the bony augmentation procedure. (From Misch CE. *Contemporary Implant Dentistry*. 3rd ed. St. Louis: Mosby; 2008.)

restorative interface was placed at the gingival crest, subgingivally, or with less cleansable designs, complications developed. The consensus today recognizes the value of thick, dense connective tissue to protect the alveolar bone whenever the restorative interface will challenge plaque control.

BIOLOGIC WIDTH

The normal gingival attachment consists of nearly 1 mm of a strong connective tissue attachment to the root cementum and about 1 mm of a weaker epithelial adhesion to a clean, smooth surface.[48] The combination of connective tissue attachment and epithelial adhesion is termed biologic width. Two millimeters is the minimum amount of space that the gingiva needs to attach to the root. In health, sulcus depth varies between 1 mm on the facial and lingual aspects and 2 to 3 mm interproximally (Fig. 5.13). These numbers are averages and do

Fig. 5.10 A maxillary right central incisor with a hopeless prognosis can be orthodontically forced to erupt to develop additional bone and gingival tissue before extraction. (A) Initial recession. (B) Simulated gingival position after 3 months of orthodontic treatment.

Fig. 5.11 Congenital absence of maxillary lateral incisors. (A) The maxillary right central incisor failed and was removed. Note the loss of bone and gingiva *(arrow)* in the right anterior maxilla, where two adjacent teeth are missing. (B) The bone and gingiva are better preserved *(arrow)* in the left anterior maxilla, where only a single tooth is missing. The patient had a thin biotype; therefore, gingival and bone changes were severe.

Fig. 5.12 A minimum of 5mm of keratinized tissue of which 3mm are attached to periosteum are necessary on teeth and implants that are restored with a fixed prosthesis.

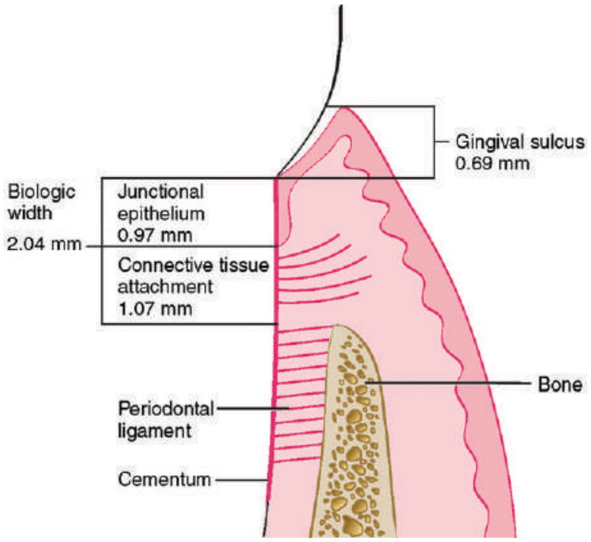

Fig. 5.13 Average values for biologic width. Any encroachment into this 2.04-mm space will result in an inflammatory reaction. (From Newman MG, et al. *Carranza's Clinical Periodontology*. 10th ed. St. Louis: Saunders; 2006.)

not characterize every patient.[49] Average values are adequate to understand the concept of biologic width; however, the true biologic width for an individual patient can only truly be determined by establishing gingival health and allowing the biologic width to establish on its own. Probing through the attachment to the bone level and subtracting the sulcus depth to determine the biologic width as advocated by some is unpredictable in areas of thin bone, such as the facial surfaces of most teeth because the rounded end of a periodontal probe may not stop on the bone crest and may glance past. In patients with thin bone, some suggest the use of a local anesthetic needle with the bevel facing away from the tooth to sound the thin bony crest of anterior teeth.

MARGIN PLACEMENT

Preparation finish lines can be supragingivally, equigingivally, or subgingivally, that is intrasulcularly. Supragingival and equigingival margins are easier to prepare, make an impression, and finish to a smooth polished surface. This facilitates effective plaque removal and the maintenance of gingival health. In some circumstances, previous restorations, existing caries, esthetics, or retention and resistance form needs dictate a subgingival margin.

In comparison with an intact tooth surface, all restorations exhibit open, rough margins that favor plaque retention. The more supragingival the restoration margin is located, the easier the access for plaque removal, and the healthier the gingival tissue will be.[50,51] A toothbrush can clean only 0.5mm subgingivally, floss can clean up to 2.5mm below the gingiva, and a water irrigation device can alter bacterial composition up to 4mm below the gingiva (Fig. 5.14; Table 5.2). The majority of patients rely on toothbrushing as their only form of oral hygiene.[52]

Subgingival margins are problematic and should be avoided when possible.[53] Periodontally, a subgingival margin always results in a gingival inflammatory response.[54] This inflammatory response ranges from a mild, subclinical inflammation to an overt inflammatory response with swelling, redness, tenderness, bleeding, and possibly bone loss. The degree of inflammatory response is determined by many factors. Two of these factors, the patient's overall systemic health and the patient's gingival biotype, are beyond a dentist's control. However, by being aware of the patient's systemic health and biotype (defined later in the chapter), the dentist can make choices before the decision to place a subgingival restoration. The factors under a dentist's control include the extent to which the preparation margin is placed farther apically, the quality of the marginal fit, and the smoothness of the subgingivally placed restorative material.

Margins that fit in the acceptable range and that are placed in a cleansable area provoke only a mild, subclinical inflammatory response. Margins that are significantly open harbor a large number of bacteria and provoke a larger inflammatory response (Fig. 5.15). Metal, ceramic, and resin margins are equally compatible with gingival health when polished to the same degree of smoothness. The emergence profile of the restoration should follow the tooth anatomy apical to the margin. Gingival health is better maintained if the crown is slightly undercontoured rather than overcontoured (see Chapter 7). Historically the most frequent reason for overcontouring restorations was insufficient tooth reduction, which forces the technician to overbuild the contours.[55,56] However, contemporary tooth preparation designs are attempting to preserve more enamel and cervical tooth struction. A general consideration is that a minimum of 3mm of attached dense connective tissue should be present to predict acceptable gingival health when a restorative margin will be placed subgingivally.

Guidelines for Subgingival Margin Placement

A general guideline is that tooth preparation finish lines should not be placed in the periodontal attachment if at all possible. If intrasulcular placement is essential, it should be at no more than half the depth of the gingival sulcus (see Chapter 7). In a healthy periodontal sulcus, the tip of a probe extends approximately 0.5mm into the epithelial attachment. The base of the healthy sulcus is the most coronal portion of the epithelial attachment, and the restorative margin cannot encroach on this attachment. Therefore, if the sulcus probe is 1mm, the restoration cannot extend any more than 0.5mm subgingivally without encroaching upon the attachment (biologic width). A

Fig. 5.14 Depths of plaque removal for various oral hygiene devices. Subgingival irrigation with water or chlorhexidine is more effective in reducing marginal bleeding and bleeding on probing than supragingival rinsing with chlorhexidine (see Table 5.3). (A) The Waterpik Classic Water Flosser. (B) The Waterpik Cordless Water Flosser. (C) Pulsation creates two zones of hydrokinetic activity. (D) Irrigator tips. From left to right: standard jet tip, Pik Pocket subgingival irrigation tip, and cannula. (A and B, Courtesy Water Pik, Inc., Fort Collins, Colorado. C and D, From Newman MG, et al. *Carranza's Clinical Periodontology*. 10th ed. St. Louis: Saunders; 2006.)

TABLE 5.2 Depths of Plaque Removal for Various Oral Hygiene Devices

Device	Depth of Subgingival Cleaning
Toothbrush	0.5 mm
Floss	2.5 mm
Water irrigation device	4.0 mm

shallow healthy sulcus is also less susceptible to recession than are inflamed periodontal tissues. A 3-mm healthy interproximal sulcus allows the margin to be placed 1.0 to 1.25 mm subgingivally. However, the deeper the sulcus, the greater is the potential for gingival recession after any treatment.[57,58]

Common restorative considerations that dictate placement of margins below the gingiva include (1) creating adequate resistance and retention form, (2) allowing the margin to be placed on sound tooth structure apical to any excavated carious lesion or existing restoration, and (3) masking the tooth/restoration interface in order to mask a color change between the restoration and the tooth. Margins placed deeper than 1 mm below the gingival crest create a greater challenge in preparing a smooth margin, obtaining an accurate impression, evaluating the marginal fit of the final restoration, and in removal of residual cement; these difficulties will hinder future plaque removal and logically result in increased gingival inflammation (Fig. 5.16).

Tooth preparation finish lines that are within the attachment create an inflammatory response. Some in the field of dentistry coin the inflammatory response as a biologic width violation (BWV). The response to crown margin placed within the periodontal attachment is a function of the bone thickness. Sites with thin bone may exhibit bone loss due to the inflammatory process. Sites with thick bone most often result in a chronic inflammation without bone loss. Biological with violations frequently occur at the mesiofacial or the distofacial line angles of maxillary anterior teeth treated with fixed restorations and in the posterior proximal sites due to caries extension.[59]

TABLE 5.3 Reduction of Inflammation and Plaque Biofilm

Study	Duration	*N*	Agent Used	% Bleeding Reduction	% Gingivitis Reduction	% Plaque Biofilm Reduction
Al-Mubarak et al[91]	3 months	50	Water	43.8	66.9	64.9
Barnes et al[92]	4 weeks	105	Water	36.2–59.2	10.8–15.1	8.8–17.3
Brownstein et al[93]	8 weeks	44	CHX (0.06%)	52–59	25.4–31.1[a]	14.3–19[a]
			Water	NR		NR
Burch et al[94]	2 months	47	Water	57.1–76.6	NR	52–55.7
Chaves et al[95]	6 months	105	CHX (0.04%)	54	26	35
			Water	50	26	16
Ciancio et al[96]	6 weeks	61	Essential oils[b]	27.6	54–55.7	23–24
			Water and alcohol 5%	13.6–31.2	59.8–61.9	9.6–13.3
Cutler et al[97]	2 weeks	52	Water	56	50	40
Flemmig et al[101]	6 months	175	CHX (0.06%)	35.4	42.5	53.2
			Water	24	23.1	0.1
Flemmig et al[100]	6 months	60	Acetylsalicylic acid 3%		8.9	55.6
			Water	50	29.2	0
Felo et al[98]	3 months	24	CHX (0.06%)	62	45	29
Fine et al[99]	6 weeks	50	Essential oils[b]	14.8–21.7	NR	36.8–37.7
			Water	7.5–10.6	NR	15.5–18.4
Jolkovsky et al[102]	3 months	58	CHX (0.4%)	NR	33.1	51.6
			Water	NR	18.6	25.6
Lobene et al[103]	5 months	155	Water	NR	52.9	7.9
Newman et al[104]	6 months	155	Water	22.8	17.8	6.1
			Water and zinc sulfate (0.57%)	8.8	6.5	9.2
Sharma et al[105]	4 weeks	128	Water	84.5	NR	38.9
Walsh et al[106]	8 weeks	8	CHX (0.2%)	NR	45	77
			Quinine salt	NR	14	0

CHX, Chlorhexidine; *NR*, not reported.
[a]Percentages were reported for differences between CHX and water irrigation groups.
[b]Reported the range for prophy and nonprophy groups.
From Jahn CA, Jolkovsky D. Sonic and ultrasonic instrumentation and irrigation. In: Newman MG, et al., eds. *Carranza's Clinical Periodontology.* 11th ed. St. Louis: Saunders; 2012.

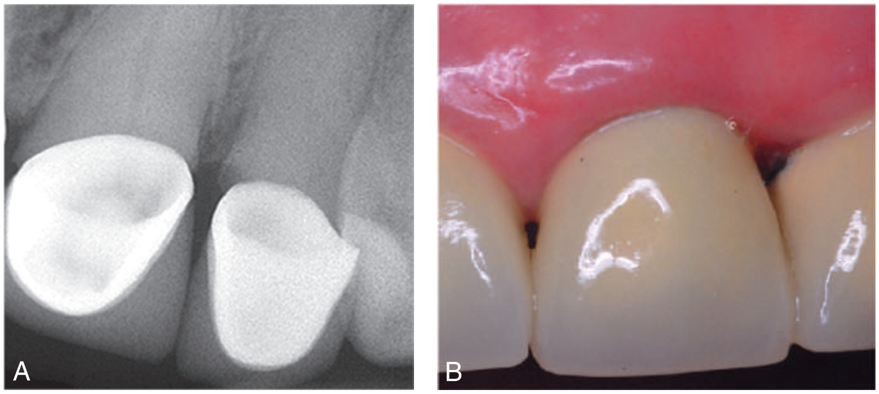

Fig. 5.15 Open margins noted on mesial and distal maxillary left central and lateral incisors result in a significant inflammatory response with bone loss and destruction of the interdental papilla. (A) Radiographs. (B) Appearance.