Thirteenth Edition

McCracken's

REMOVABLE PARTIAL PROSTHODONTICS





Alan B. Carr
David T. Brown

ELSEVIER

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Preface

In response to the question, "What is the purpose of research?" a recent *Lancet* editorial suggests a redefinition of the purpose of research is critical due to an alarming lack of concordance between a reasoned research purpose and actual research reality.[*] Ian Chalmers provides a clear reasoned purpose of research as being, "to help patients and their clinicians."[†] He goes on to describe 85% waste associated with research meeting this target, and relates this to several root causes: choosing the wrong questions, conducting unnecessary or poorly designed studies, failure to publish in a timely manner or at all, and biased or unusable reports of research.

The editors of this textbook consider the related question each time the publisher requests an update. "What is the purpose of a textbook?" This question becomes increasingly important as technology shapes the behavior of learners and therefore the strategies for enhancing learning. As Chalmers and Glasziou state, we believe the purpose of a textbook is to help patients by helping their providers. A textbook may help providers at various stages of a career.

For first time learners, it helps by presenting a foundation for learning during a period of active and diverse information exposure for the developing clinician. Competing for learners' attention during this phase, presenting content that can be directly applied to first time application scenarios is a challenge for teachers and compels texts be designed to add substance, not waste. For practicing clinicians, a textbook can provide reinforcement of principles useful for clinical decisions and their application; especially if the clinical challenges become more complex for the maturing provider. In this context, a text can serve as a source of continuing reference as clinical experience expands a clinician's expertise in application of basic principles, allowing more in-depth understanding and application.

The editors also recognize that as providers of oral health care, we are part of a changing health care environment. It is evident that our contribution to overall health and well-being of society will be an increasing part of the United States health care value discussion, a discussion that stems from the recognition that care costs and quality are not aligned in the United States. The current "value care" transition from "volume care" places a premium on patient-centered needs/desires, demonstration of beneficial outcomes, and cost containment in a context of care over time. This context fits the care needs addressed by tooth replacement interventions. Management of tooth loss must be considered as a life-long process. Each decision along a patient's "life course" can substantially impact subsequent care opportunities and therefore the decisions made. What is critical to recognize is that the impact of decisions is not equivalent among options.

Consequently, we provide an argument that if removable partial denture–related decisions impart a high risk of comorbidity compared to other options, yet the specific patient situation disallows other options, selective implant utilization with removable partial dentures most often can reduce this detrimental impact. However, the current implant application must take the future potential for complete implant support for tooth replacements into account. In the last edition, we considered that selective use of implants to address movement control concerns for removable partial dentures to be laudable. This not only has not changed but also we stress in the current edition that helping patients understand the benefits of selective implant use to the functional stability is a discussion patients should hear.

> *"Providing implants to support all teeth needing replacement is often preferable if indicated and if the patient can afford to do so. If the patient is unable to pursue an implant-only supported prosthesis, this should not keep him or her from considering an implant, because the patient still may benefit from a carefully selected implant used for critical clinical performance advantage when removable partial dentures are pursued. Additionally, implants can be used for removable partial dentures to allow future implant-only treatment options."*

We continue the previous edition's use of design features that provide a content distinction—shading text intended for more experienced clinicians. In Chapter 10, "Principles of Removable Partial Denture Design," we have attempted to address the continued input from teachers that design of removable partial dentures is a major barrier to learners. In Chapter 10, we have added a basic design strategy for the major tooth loss classifications in the hope that providing a systematic approach with a baseline design protocol may assist this challenge.

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*Horton R: Editorial: what is the purpose of medical research? *Lancet* 381:347, 2013.

†Chalmers I, Glasziou P: Avoidable waste in the production and reporting of research evidence, *Lancet* 374:86-89, 2009.

About the Book

NEW TO THIS EDITION

- Updating of implant-related applications to removable partial dentures
  - Impact on design, care provision, and performance utility
- Removable partial denture design examples provided for basic/most common tooth loss distributions
  - Intending to establish a foundation of understanding and application
  - Stressing the need for *required* tooth modification
    - Suggesting that standardizing this process impacts care delivery efficiency for the provider and dental laboratory

KEY FEATURES

- Content considered beyond the basic level is set within a shaded box
- A wide selection of relevant references is presented at the back of the textbook in Appendix B for quick-and-easy access
- Various philosophies and techniques are presented throughout, facilitating the selection and incorporation of the applicable techniques on a case-by-case basis
- Chapters presented in three logically-sequenced sections:
  - Part I: General Concepts/Treatment Planning
  - Part II: Clinical and Laboratory
  - Part III: Maintenance

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Dr. David T. Brown, Indiana University School of Dentistry, is the Chair of the Comprehensive Care and General Dentistry Department and Professor of Prosthodontics. Dr. Brown is a Summa Cum Laude graduate of The Ohio State University College of Dentistry and received his prosthodontic training at the Mayo Clinic/Mayo Graduate School of Medicine. He has been a full-time faculty member at Indiana University since 1986, teaching in both the predoctoral curriculum and the postgraduate prosthodontic program. Dr. Brown is board certified by the American Board of Prosthodontics. He has been a reviewer for a number of professional journals and is a member of several dental and prosthodontic organizations. He currently serves as a member of the Executive Council for the Academy of Prosthodontics. Dr. Brown maintains a part-time practice limited to prosthodontics.

Contents

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PART

I

General Concepts/ Treatment Planning

CHAPTER

1

Partially Edentulous Epidemiology, Physiology, and Terminology

CHAPTER OUTLINE

This textbook focuses on what the clinician should know about partially edentulous patients to appropriately provide comfortable and useful tooth replacements in the form of removable partial dentures. Removable partial dentures are a component of prosthodontics, the branch of dentistry pertaining to the restoration and maintenance of oral function, comfort, appearance, and health of the patient by the restoration of natural teeth and/or the replacement of missing teeth and craniofacial tissues with artificial substitutes.

Current practice in the management of partial tooth loss involves consideration of various types of prostheses (Figure 1-1). Each type of prosthesis requires the use of various remaining teeth, supporting soft tissues, and/or assigned implants, and consequently demands appropriate application of knowledge and critical thinking to ensure the best possible outcome given patient needs and desires. Although more than one prosthesis may serve the needs of a patient, any prosthesis should be provided as part of overall management that meets the basic objectives of prosthodontic treatment, which include (1) the elimination of oral disease to the greatest extent possible; (2) the preservation of the health and relationships of the teeth and the health of oral and paraoral structures, *which will enhance the removable partial denture design;* and (3) the restoration of oral functions that are comfortable, are esthetically pleasing, and do not interfere with the patient's speech. It is critically important to emphasize that the preservation of health requires proper maintenance of removable partial dentures. To provide a perspective for understanding the impact of removable partial denture prosthodontics, a review of tooth loss and its sequelae, functional restoration with prostheses, and prosthesis use and outcomes is in order.

Familiarity with accepted prosthodontic terminology related to removable partial dentures is necessary. Figures 1-2 and 1-3 provide prosthesis terms related to mandibular and maxillary frameworks, and Appendix A provides a review of

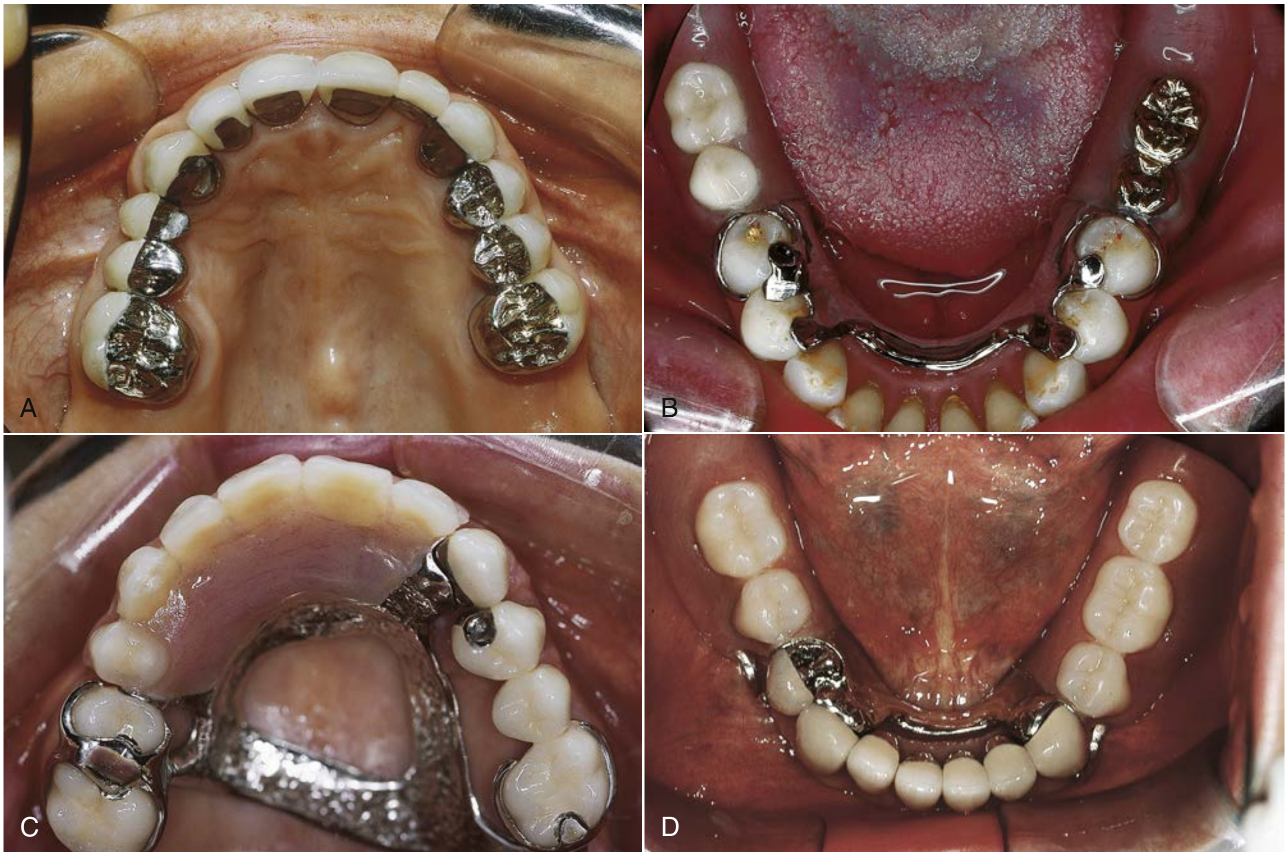

Figure 1-1 **A,** Fixed partial dentures that restore missing anterior (#10) and posterior (#5, #13) teeth. Teeth bordering edentulous spaces are used as abutments. **B,** Clasp-type removable partial denture restoring missing posterior teeth. Teeth adjacent to edentulous spaces serve as abutments. **C,** Tooth-supported removable partial denture restoring missing anterior and posterior teeth. Teeth bounding edentulous spaces provide support, retention, and stability for restoration. **D,** Mandibular bilateral distal extension removable partial denture restoring missing premolars and molars. Support, retention, and stability are shared by abutment teeth and residual ridges.

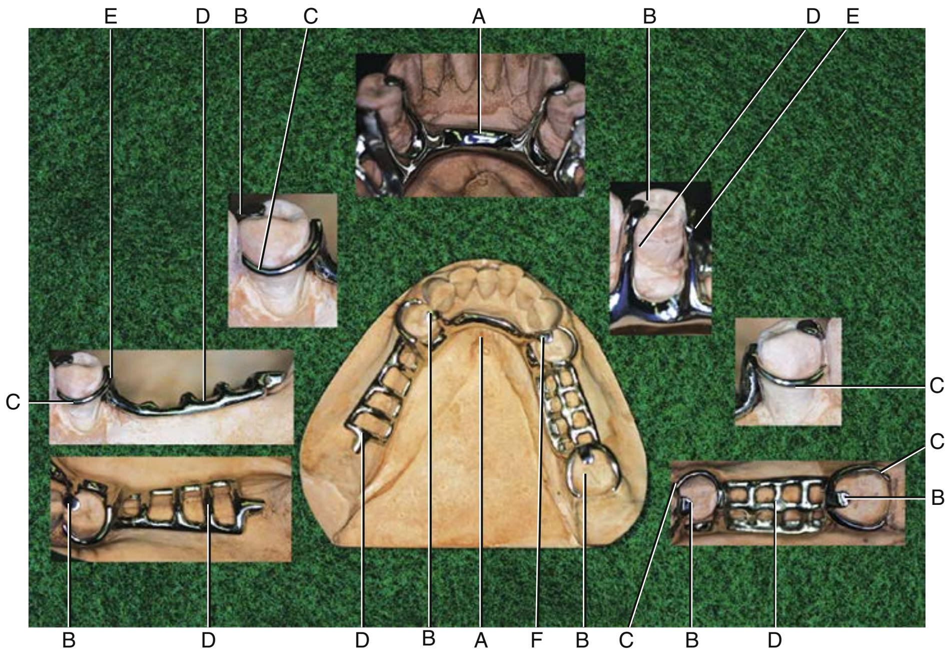

Figure 1-2 Mandibular framework designed for a partially edentulous arch with a Kennedy Classification II, modification 1 (see Chapter 3). Various component parts of the framework are labeled for identification. Subsequent chapters will describe their function, fabrication, and use. *A,* Major connector. *B,* Rests. *C,* Direct retainer. *D,* Minor connector. *E,* Guide plane. *F,* Indirect retainer.

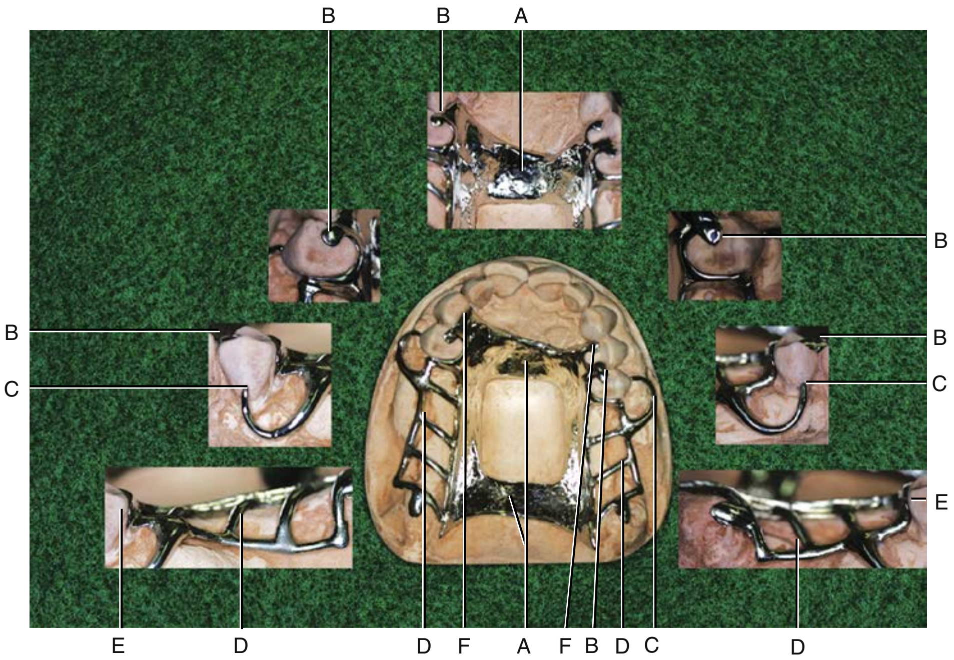

FIGURE 1-3 Maxillary framework designed for a partially edentulous arch with a Kennedy Classification I (see Chapter 3). As in Figure 1-2, component parts are labeled for identification. *A,* Major connector. *B,* Rests. *C,* Direct retainer. *D,* Minor connector. *E,* Guide plane. *F,* Indirect retainer.

selected prosthodontic terms. Additional terminology can be reviewed in *The Glossary of Prosthodontic Terms*[1] and a glossary of accepted terms in all disciplines of dentistry, such as *Mosby's Dental Dictionary,* third edition.[2]

TOOTH LOSS AND AGE

In spite of improvements in preventive dental care, it should come as no surprise that tooth loss and age are linked. A specific tooth loss relationship has been documented with increasing age, because some teeth are retained longer than others. It has been suggested that, in general, an interarch difference in tooth loss occurs, with maxillary teeth demonstrating loss before mandibular teeth. An intra-arch difference has also been suggested, with posterior teeth lost before anterior teeth. These observations are likely related to respective caries susceptibilities, which have been reported (Table 1-1). Frequently, the last remaining teeth in the mouth are the mandibular anterior teeth, especially the mandibular canines, and it is a common finding to see an edentulous maxilla opposing mandibular anterior teeth.

If one accepts that tooth loss and age are linked, how will this affect current and future dental practice? Replacement of missing teeth is a common patient need, and patients will demand it well into their elderly years. Current population estimates show that 13% of the US population is 65 years of age or older. By the year 2030, this percentage is expected to double, with a significant increase also expected worldwide. These individuals are expected to be in better health, and health care strategies for this group should focus on maintenance of active and productive lives. Oral health care is expected to be a highly sought after and significant component of overall health care.

Tooth loss patterns associated with age are also evolving. The proportion of edentulous adults has been reported to be decreasing, although this varies widely by state. However, it has been reported that the absolute number of edentulous patients

TABLE 1-1

Caries Risk Assessment*

Risk Type	Tooth Location	Caries Susceptibility
High Risk	Lower 6 and 7	Mandibular first and second molars
	Upper 6 and 7	Maxillary first and second molars
	Lower 5	Mandibular second premolar
	Upper 1, 2, 4, 5	Maxillary central, lateral incisors Maxillary first and second premolars
Low Risk	Upper 3 and lower 4	Maxillary canine, mandibular first premolar
	Lower 1, 2, 3	Mandibular central, lateral incisors, canines

Data from Klein H, Palmer CE: Studies on dental caries: XII. Comparison of the caries susceptibility of the various morphological types of permanent teeth. *J Dent Res* 20:203-216, 1941.

*If tooth loss parallels caries activity, caries risk may be a proxy for tooth loss.

who need care is actually increasing. More pertinent to this text, estimates suggest that the need for restoration of partially edentulous conditions will also be increasing. An explanation for this is presented in an argument that 62% of Americans of the "baby boomer" generation and younger have benefited from fluoridated water. The result of such exposure has been a decrease in caries-associated tooth loss. In addition, current estimates suggest that patients are keeping more teeth longer, demonstrated by the fact that 71.5% of 65- to 74-year-old individuals are partially edentulous (mean number of retained teeth = 18.9). It has been suggested that partially edentulous conditions are more common in the maxillary arch and that the most commonly missing teeth are first and second molars.

CONSEQUENCES OF TOOTH LOSS

Anatomic

With the loss of teeth, the residual ridge no longer benefits from the functional stimulus it once experienced. Because of this, a loss of ridge volume—both height and width—can be expected unless a dental implant is placed. The ridge volume loss is not predictable for all individuals with tooth loss, because the change in anatomy has been reported to be variable across patient groups. In general, bone loss is greater in the mandible than in the maxilla and more pronounced posteriorly than anteriorly, and it produces a broader mandibular arch while constricting the maxillary arch. These anatomic changes can present challenges to fabrication of prostheses, including implant-supported prostheses and removable partial dentures. Associated with this loss of bone is an accompanying alteration in the oral mucosa. The attached gingiva of the alveolar bone can be replaced with less keratinized oral mucosa, which is more readily traumatized.

Physiologic

What are we replacing when we consider managing missing teeth? We are replacing both the physical anatomic tools for mastication and the oral capacity for neuromuscular functions to manipulate food. Chewing studies have shown that the oral sensory feedback that guides movement of the mandible in chewing comes from a variety of sources. The most sensitive input, which means the input that provides the most refined and precisely controlled movement, comes from periodontal mechanoreceptors (PMRs), with additional input coming from the gingiva, mucosa, periosteum/bone, and temporomandibular joint (TMJ) complex.

Chewing as a learned behavior has a basic pattern of movement that is generated from within the central nervous system. In typical function, this patterned movement is moderated on the basis of food and task needs by oral sensory input from various sources. With loss of the finely tuned contribution from tooth PMRs, the resulting peripheral receptor influence is less precise in muscular guidance, producing more variable masticatory function, and the type of prosthesis selected to replace missing teeth may potentially contribute to functional impediments.

The esthetic impact of tooth loss can be highly significant and may be more of a concern to a patient than loss of function. It is generally perceived that in today's society, loss of visible teeth, especially in the anterior region of the mouth, carries with it a significant social stigma. With loss of teeth and diminishing residual ridge, facial features can change as the result of altered lip support and/or reduced facial height caused by a reduction in occlusal vertical dimension. Restoring facial esthetics in a manner that maintains an appropriate appearance can be a challenge and is a major factor in restoration and maintenance decisions made for various prosthetic treatments.

FUNCTIONAL RESTORATION WITH PROSTHESES

Individuals with a full complement of teeth report some variation in their levels of masticatory function. The loss of teeth may lead patients to seek care for functional reasons if they notice diminished function to a level that is unacceptable to them. The level at which a patient finds function to be unacceptable varies among individuals. This variability increases with accelerating tooth loss. This variability may be confusing to clinicians, who may perceive that they have provided prostheses of equal quality to different patients with the same tooth loss patterns, and yet have received different patient reports of success.

An understanding of these variations among individuals with a full complement of teeth and those with prostheses can help clinicians formulate realistic treatment goals that can be communicated to the patient. A review of oral function, especially mastication, may help interested clinicians better understand issues related to the impact of removable partial denture function.

Mastication

Although functionally considered as a separate act, mastication as part of the feeding continuum precedes swallowing and is not an end in itself. The interaction of the two distinct but coordinated aspects of feeding suggests that some judgment of mastication termination or completeness precedes the initiation of swallowing. Although the mastication–swallowing sequence is obvious, the interaction of the two functions is not widely understood and may be important to prosthesis use when removable partial dentures are considered.

Mastication involves two discrete but well-synchronized activities: (1) subdivision of food by applied force; and (2) selective manipulation by the tongue and cheeks to sort out coarse particles and bring them to the occlusal surfaces of teeth for further breakdown. The initial subdivision or comminution phase involves the processes of selection, which refers to the chance that a particle is placed between the teeth in position to be broken, and breakage, which is the degree of fragmentation of a particle once selected. The size, shape, and texture of food particles provide the sensory input that influences the configuration and area of each chewing stroke. Larger particles are selectively reduced in size more rapidly than fine particles in efficient mastication. The process of mastication is therefore greatly influenced by factors that affect physical ability to reduce food and to monitor the reduction process by neurosensory means.

Food Reduction

Teeth or prostheses serve the role of reducing food to a point that it is ready for swallowing. An index of food reduction is described as *masticatory efficiency,* or the ability to reduce food to a certain size in a given time frame. A strong correlation has been shown between masticatory efficiency and the number of occluding teeth in dentate individuals, which would suggest variability of particle selection related to contacting teeth. Performance measures reveal a great deal of functional variability in patients with similar numbers of contacting teeth, and even greater variability is seen within populations with greater loss of teeth (increasing degrees of edentulousness).

Because occlusal contact area is highly correlated with masticatory performance, the loss of molar teeth would be expected to have a greater impact on measures of performance in that the molar has a larger occlusal contact area. This effect has been demonstrated in individuals with missing molars who reveal a greater number of chewing strokes required and a greater mean particle size before swallowing. The point at which an individual is prepared to swallow the food bolus is another measure of performance and is described as the *swallowing threshold.* Superior masticatory ability that is highly correlated with occlusal contact area also achieves greater food reduction at the swallowing threshold. Conversely, a diminished ability to chew is reflected in larger particles at the swallowing threshold.

These objective measures, which show a benefit to molar contact in dentate individuals, are in conflict with some subjective measures from patients who express no perceived functional problems associated with having only premolar occlusion. This shortened dental arch concept has highlighted that patient perceptions of functional compromise, as well as benefit, should be considered when it is decided whether to replace missing molars. When the loss of posterior teeth results in an unstable tooth position, such as distal or labial migration, tooth replacement should be carefully considered; this is a separate situation from the shortened dental arch concept.

It has been reported that prosthetic replacement of teeth provides function that is often less than that seen in the complete, natural dentition state. Functional measures are closest to the natural state when replacements are fixed partial dentures rigidly supported by teeth or implants, intermediate in function when replacements are removable and supported by teeth, lower in function when replacements are removable and supported by teeth and edentulous ridges, and lowest in function when replacements are removable and supported by edentulous ridges alone.

Objective and subjective measures of a patient's oral function often are not in agreement. It has been shown that subjective measures of masticatory ability are often overrated compared with objective functional tests and that, for complete denture wearers, the subjective criteria may be more appropriate in monitoring perceived outcomes. Some literature reports that removable partial dentures can be described by patients as adding very little benefit over no prostheses. However, these findings may be related to a number of factors, including lack of maintenance of occluding tooth relationships, limitations of this form of dental prosthesis for patient populations that may be unreliable in maintaining follow-up visits, and intrinsic variation in patient response to prostheses.

Food reduction is also influenced by the ability to monitor the process required to determine the point at which swallowing is initiated. As was mentioned earlier, the size, shape, and texture of food are monitored during mastication to allow modification in mandibular movement for efficient food reduction. This has been demonstrated in dentate individuals given food particles of varying size and concentration suspended in yogurt, who revealed that increased concentrations and particle size required more time to prepare for swallowing (i.e., greater swallowing threshold). These findings suggest that the oral mucosa has a critical role in detecting characteristics necessary for efficient mastication. The influence of the removable partial denture on the ability of the mucosa to perform this role in mastication is not known.

CURRENT REMOVABLE PARTIAL DENTURE USE

Given an understanding of the relationship between tooth loss and age, the consequences of tooth loss, and our ability to restore function with removable partial prostheses, what do we know about current prosthesis use for these conditions, and what are some common clinical outcomes? One study estimated 21.4% prosthesis use among individuals aged 15 to 74. In the 55- to 64-year-old group, 22.2% were found to wear a removable partial denture. This age group has the highest use of removable partial dentures among those reviewed. It has been suggested that the use of removable partial dentures among individuals aged 55 years or older is even greater.

Analysis of this study provides some useful information for consideration. Partially edentulous individuals not wearing a prosthesis were six times more likely to have missing mandibular teeth (19.4%) than missing maxillary teeth (2.2%). This might suggest greater difficulty in the use of a mandibular prosthesis. The distribution of prostheses used in this large patient group is shown in Table 1-2. The prostheses in this large study were evaluated on the basis of five

Table 1-2

Distribution of Prostheses

Type of Prosthesis	Distribution	Distribution*
Removable partial dentures	RPD/RPD 9.0%	RPD/−15.3%, −/RPD 4.5%
Complete dentures	CU/CL 3.8%	CU/−20.7%
Combination	CU/RPD 11.5%	RPD/CL 0.3%

CL, Complete lower denture; *CU,* complete upper denture; *RPD,* removable partial denture.
*Natural teeth denoted with dash (−).

Table 1-3

Technical Quality Concerns for Removable Partial Dentures

	Lack Stability	Lack Integrity	Lack Retention	Reline Material/Adhesive	Excessive Wear
Maxillary RPD	43.9%	24.3%	6.2%	3.9%	21.6%
Mandibular RPD	38.2%	13.2%	21.2%	21.6%	7.1%

RPD, Removable partial denture.

technical quality characteristics: integrity, excessive wear of posterior denture teeth, presence of a temporary reline material, tissue conditioner or adhesive, stability, and retention. As seen in Table 1-3, lack of stability was the most common characteristic noted. In the maxilla, lack of stability was seven times more prevalent than lack of retention. In the mandible, lack of stability was 1.8 times more prevalent than lack of retention. In another study, rest form, denture base extension, stress distribution, and framework fit were identified as common flaws associated with poor removable partial dentures. These characteristics are directly related to the functional stability of prostheses, a vital characteristic to evaluate and the characteristic most benefited by the use of a strategically placed dental implant.

NEED FOR REMOVABLE PARTIAL DENTURES

What does all this information mean to us today? It means a number of things that are important to consider. The need for partially edentulous management will be increasing. Patient use of removable partial dentures has been high in the past and is expected to continue in the future as an aging population who retains more teeth will present with more partially edentulous conditions. Some patients who are given the choice between a prosthesis entirely supported by implants or a removable partial denture are not able to pursue implant care. This contributes to higher use of removable partial dentures. Such patients should understand the benefit of a strategically placed implant for the performance of the removable partial denture. Additionally, provision of such implants must consider the usefulness of the placement to a future fixed implant prosthesis.

Finally, these findings suggest that we should strive to understand how to maximize the opportunity for providing and maintaining stable prostheses, because this is the most frequently deficient aspect of removable partial denture service. Consequently, throughout this text, the basic principles of diagnosis, mouth preparation, prosthesis design, fabrication, placement, and maintenance will be reinforced to improve the reader's understanding of care of removable partial denture prostheses.

References

1. The glossary of prosthodontic terms, ed 8. From *The Journal of Prosthetic Dentistry* 94(1):10–92, 2005. Available online. http://www.sciencedirect.com/science/article/pii/S0022391305001757.
2. *Mosby's dental dictionary*, ed 3, St Louis, 2013, Mosby/Elsevier.

CHAPTER

2

Considerations for Managing Partial Tooth Loss

Tooth Replacements from the Patient Perspective

MANAGING TOOTH LOSS OVER TIME

Do we treat or do we manage tooth loss? Is the distinction important as we attempt to help our patients decide which type of prosthesis to choose? For patients who want to know what to expect now and in the future, it is helpful to make this distinction, because it helps them realize that the decision has implications for future needs that may be different between prostheses.

Tooth Replacements from the Patient's Perspective

Tooth loss is a permanent condition in that the natural order has been disrupted, and in this sense it is much like a chronic medical condition. Like hypertension and diabetes, two medical conditions that are not reversible and that require medical management to monitor care to ensure appropriate response over time, tooth replacement prostheses must be managed to ensure appropriate response over time.

The term *management* suggests a focus on meeting needs that may change over time. These needs may be expected or unexpected. Expected outcomes are those that accompany the common clinical course for a type of prosthesis that is related to the tooth-tissue response. This biological toll response is heavily influenced by the type of prosthesis chosen. In addition, various needs due to prosthesis degradation and related to expected time-to-retreatment concerns of life expectancy are seen. Unexpected needs are those that might involve factors related to our control of manipulations (such as tissue damage or abuse, material design flaws, or prosthesis design) or to those out of our control (such as parafunction or accidental trauma).

With this in mind, it is helpful to consider how we approach educating our patients about management of missing teeth from this current point in time over the remainder of their lives. This perspective allows current decisions to be made with a long-term context in mind, and allows decisions to enhance future treatment options.

Most often, a typical sequence is used to discuss tooth replacement options with patients: dental implant–supported prostheses, fixed prostheses, and, finally, removable partial dentures. When removable partial dentures are suggested, they are seldom described in the detail in which fixed or implant prostheses are described, because generally they are considered less like teeth and not as desirable a replacement. The desirability of a prosthesis is important to consider, and because removable partial dentures are less like teeth than other replacements, it is important to recognize what this suggests from the patient's perspective. Additionally, for the patient desiring implant management but unable to elect their use when indicated, discussion for strategic implant use for the benefit of the removable partial denture is important.

For patients who have not had missing teeth replaced, their experiences have involved natural teeth, and discussion regarding their expectations of replacements would best be described within this context. The order with which we provide replacement prosthesis options for consideration is likely developed on the basis of numerous factors, including the following: we may believe that we know what is best for patients, our practice style may not include removable options, we may not have had good experience with removable prostheses and this lessens our confidence in their use, or removable partial dentures do not match our practice resources.

Although these are important factors, the reason to include removable partial dentures in the discussion is related to identifying whether such a prosthesis is viable, and, if so, whether it is the best option for the patient. We discover this only by interacting with our patients regarding their expectations and understanding their capacity to benefit from options of management that have trade-offs unique to each type of prosthesis.

Shared Decision Making

When patients are given information regarding their oral health status, which includes disease and functional deficits, as well as the means to address both, what do they need to hear? To achieve a state of oral health, they need to recognize behavioral issues related to plaque control so that once active disease is controlled, they have an understanding that best ensures future health. For tooth replacement decisions, complex trade-offs in care choice are often required. The "shared decision making" approach addresses the need to fully inform patients about risks and benefits of care, and ensures that the patient's values and preferences play a prominent role in the ultimate decision.

It is recognized that patients vary in their desire to participate in such decisions, thus our active inquiry is required to engage them in discussion. This becomes especially important when elective care, which involves potentially high-burden, costly options with highly variable maintenance requirements, is considered.

When patients wish to participate, it is our responsibility to provide them with specific and sufficient information that they can use to decide between treatment options. Specific information ideally comes from our own practice outcomes, in that such information provides effectiveness information and is provider specific. Sufficient information describes exactly what aspects of care are important to the overall decision. Ultimately, it is our role to help patients consider important differences between different prosthesis types.

What then defines important differences? Multiple outcomes combine to describe the overall impact of prosthetic care for all patients. These include technical outcomes, physical outcomes, esthetic outcomes, various maintenance needs, initial and future costs, and even physiologic outcomes that suggest to what extent prostheses "feel" like teeth.

When tooth replacement prostheses are considered from a patient's perspective, it can be seen that the desire is to replace teeth that serve functional and social roles in everyday life. In considering how well various types of prostheses may meet patients' specific needs, it is helpful to note what features of the original dentition—the gold standard, in this instance—we strive to duplicate in the replacement. Although it is common to find that existing oral conditions do not easily allow complete restoration to the state of a fully dentate patient, considering the respective strengths and weaknesses of the prosthodontic options (compared with this "gold standard") helps in identification of realistic expectations.

In this text, the focus is on a type of replacement prosthesis for patients with an arch with some, but not all, of the teeth missing. Ideally, the replacement prosthesis should provide function with a level of comfort as equivalent as possible to normal dentition. In achieving this, stability while chewing is a primary focus of attention, and we should strive to determine what is required to ensure it. For the patient without posterior teeth, a prosthesis replacing these teeth is at risk for instability due to the edentulous ridge compressible support, therefore consideration of a distal implant to support the posterior segment (the distal extension) can enhance functional stability.

If the prosthesis will be visible during casual speaking, smiling, and/or laughing, it is obvious that the replacement should look as natural as the surrounding environment. In summary, tooth replacement prostheses should provide a combination of several features of natural teeth: acceptable in appearance, comfortable and stable in function, and maintainable throughout their serviceable lifetime at a reasonable cost.

TOOTH-SUPPORTED PROSTHESES

For partially edentulous patients, available prosthetic options include natural tooth–supported fixed partial dentures, removable partial dentures, and implant-supported fixed partial dentures. How well these options restore and maintain the features of natural teeth mentioned previously depends to a large extent on the numbers and locations of the missing teeth. The major categories of partial tooth loss (see Chapter 3) are those (1) with teeth both anterior and posterior to the space (a tooth-supported space), and (2) with teeth either anterior or posterior to the space (a tooth- and tissue-supported space). All prosthetic options listed are available for the tooth-bound space (although they are not necessarily indicated for every clinical situation), but only removable partial dentures and implant-supported prostheses are available for the distal extension (recognizing limited application of cantilevers).

Removable partial dentures can be designed in various ways to allow use of abutment teeth and supporting tissue for stability, support, and retention of the prosthesis. In terms of tooth-bound spaces, the removable partial denture is like a fixed partial denture because natural teeth alone provide direct resistance to functional forces. Because natural teeth support the prosthesis, it should not move under these functional forces. In this condition, the interface between, or relationship of, the removable partial denture framework and the abutment teeth should be designed to take advantage of tooth support—similar to the relationship between a fixed partial denture retainer and a prepared tooth. This means that it should provide positive vertical support (rest preparations) and a restrictive angle of dislodgment (opposing guide planes). Put another way, when the removable partial denture is selected for a tooth-bound situation, stability under functional load should be as well controlled as a fixed partial denture when appropriate tooth preparation is provided. Because removable partial denture clasps do not completely encircle the tooth, as a fixed partial denture retainer does, they must be designed to engage more than half the circumference to allow the prosthesis to maintain position under the influence of horizontal chewing loads. It should be obvious that careful planning and execution of the necessary natural tooth contour modifications are required to ensure movement control and functional stability for removable partial dentures supported by teeth. Similarities between the prosthesis-tooth interface for fixed partial dentures and for removable partial dentures are highlighted to emphasize the modification principles required to ensure stability for movement control in removable partial dentures. Over time, natural tooth support can be maintained as with the fixed partial denture. Chapter 14 helps to explain how this is accomplished when natural tooth modifications or surveyed crowns are produced.

TOOTH- AND TISSUE-SUPPORTED PROSTHESES

For removable partial dentures that do not have the benefit of natural tooth support at each end of the replacement teeth (extension base removable partial dentures), it is necessary that the residual ridge be used to assist in the functional stability of the prosthesis. When a removable partial denture is selected for a tooth- and tissue-supported arch, the prosthesis must be designed to allow functional movement of the base to the extent expected by the residual ridge mucosa. This mucosa movement is variable, but for healthy residual ridge (masticatory) mucosa, movement from 1 to 3 mm can be expected. Consequently, unlike with the tooth-bound space, tooth modification for the tooth- and tissue-supported prosthesis must be designed with the dual goal of framework tooth contact to allow appropriate functional stability from the tooth but with allowance for the anticipated vertical and/or horizontal movement of the extension base. This introduces the concept of anticipated movement with a prosthesis and the requirement that we have a role in designing prostheses to appropriately control movement. Additionally, because tissue support in the tooth- and tissue-supported removable partial denture predictably changes over time, to adequately manage partial tooth loss with a removable prosthesis, we must carefully monitor our patients to maintain support and ensure maximum prosthetic function.

The clasp-retained partial denture is the most commonly used removable partial denture (Figure 2-1). It is capable of providing physiologically sound treatment for most patients who need partial denture restorations. Although the clasp-retained partial denture has disadvantages, its advantages of lower cost and shorter fabrication time ensure that it will continue to be widely used. Following are some possible disadvantages of a clasp-retained partial denture:

1. Strain on the abutment teeth is often caused by improper tooth preparation or clasp design and/or loss of tissue support under the distal extension partial denture bases.
2. Clasps can be unesthetic, particularly when they are placed on visible tooth surfaces without consideration of esthetic impact.
3. Caries may develop beneath clasp and other framework components, especially if the patient fails to keep the prosthesis and the abutments clean.

Despite these disadvantages, the use of removable prostheses may be preferred when tooth-bounded edentulous spaces are too large to be restored safely with fixed prostheses, or when cross-arch stabilization and wider distribution of forces to supporting teeth and tissues are desirable. Fixed partial dentures, however, should always be considered and used when indicated.

The removable partial denture retained by internal attachments eliminates some of the disadvantages of clasps, but it has other disadvantages, one of which is higher cost, which makes it more difficult to obtain for a large percentage of patients who need partial dentures. However, when alignment of the abutment teeth is favorable and periodontal health and bone support are adequate, when the clinical crown is of sufficient length and the pulp morphology can accommodate the required tooth preparation, and when the economic status of the patient permits, an internal attachment prosthesis provides an unquestionable advantage for esthetic reasons. When this

Figure 2-1 **A,** Maxillary and mandibular clasp-retained removable partial dentures. All clasps are extracoronal retainers (clasps) on abutments. **B,** Prostheses from **(A)** shown intraorally in occlusion. **C,** Maxillary prosthesis using intracoronal retainers and full palatal coverage. The male portions of the attachments are shown at the mesial position of the artificial teeth and will fit into intracoronal rests. **D,** Internal attachment prosthesis in the patient's mouth. Note the precise fit of male and female portions of the attachments.

situation exists, carefully weighing tooth attachment versus implant attachment options is required (see Removable Partial Dentures and Implants, Chapter 12).

In most instances, if the extracoronal clasp-retained partial denture is designed properly, the only advantage of the internal attachment denture is esthetic, because abutment protection and stabilizing components should be used with both internal and external retainers. However, economics permitting, esthetics alone may justify the use of internal attachment retainers, especially when a crown is indicated for non–removable partial denture reasons.

Injudicious use of internal attachments can lead to excessive torsional load on the abutments supporting distal extension removable partial dentures, especially in the mandible. The use of hinges or other types of stress breakers is discouraged in these situations. It is not that they are ineffective, but that they are frequently misused. As an example, in the mandibular arch, a stress-broken distal extension partial denture does not provide for cross-arch stabilization and frequently subjects the edentulous ridge to excessive trauma from horizontal and torquing forces. Therefore a rigid design is preferred, and some type of extracoronal clasp retainer is still the most logical and the most frequently used. It seems likely that its use will continue until a more widely-acceptable retainer is devised.

As mentioned in Chapter 1, the most commonly cited problem associated with removable partial dentures is instability. Healthy natural teeth should not move when used; therefore we should strive to provide and maintain as stable a prosthesis as possible given the means available. How do we ensure functional stability? By understanding that a removable partial denture can move under function (because it is not cemented to teeth like a fixed partial denture). We should take steps to prescribe the necessary prosthetic fit to teeth (and tissue) to control movement as much as possible.

This entails providing appropriate natural tooth mouth preparations, ensuring an accurate frame fit at tooth and tissue, providing a simultaneous contacting relationship between natural and prosthetic opposing teeth, and providing and maintaining optimum support from the soft tissue and teeth. It also may require strategic use of implants to control distal extension movement.

As we will review in Chapter 4, control of the anticipated movement of your prosthesis is addressed by assigning the appropriate component part of the prosthesis to contact/engage the tooth or tissue in a manner that allows movement and removal of the prosthesis. Are there movements that we should control that are more important than others? Although we recognize the need to resist movement away from the teeth and tissue to keep prostheses from falling out of mouths, the most damaging forces are those resulting from functional closure during chewing (and in some patients, parafunction). Consequently, control of combined vertical (tissue-ward) and horizontal movement is most critical and places a premium on tooth modifications (rest and stabilizing component preparations) and verification of adequate fit of the frame to the teeth.

THE PHASES OF PARTIAL DENTURE SERVICE

Partial denture service may be conceptually divided into phases. The first phase involves making the appropriate diagnosis, deciding a removable partial denture is indicated, and providing patient education regarding removable partial denture expectations over time. The second phase includes treatment planning, design of the partial denture framework, treatment sequencing, and execution of mouth preparations. The third phase is the provision of adequate support for the distal extension denture base. The fourth phase is establishment and verification of harmonious occlusal relationships and tooth relationships with opposing and remaining natural teeth. The fifth phase involves initial placement procedures, including adjustments to the contours and bearing surfaces of denture bases, adjustments to ensure occlusal harmony, and a review of instructions given the patient to optimally maintain oral structures and provided restorations. The sixth and final phase of partial denture service consists of follow-up services by the dentist through recall appointments for periodic evaluation of the responses of oral tissue to restorations and of the acceptance of restorations by the patient. The context of each phase is discussed in greater detail in the respective chapters of this book.

Diagnosis and Education of the Patient

The term *patient education* is described in *Mosby's Dental Dictionary* as "the process of informing a patient about a health matter to secure informed consent, patient cooperation, and a high level of patient compliance."

The dentist and the patient share responsibility for the ultimate success of a removable partial denture. It is folly to assume that a patient has an understanding of the benefits of a removable partial denture unless he or she is so informed. It is also unlikely that the patient has the knowledge to avoid misuse of the restoration or is able to provide the required oral care and maintenance procedures to ensure the success of the partial denture unless he or she is adequately advised.

The finest biologically-oriented removable partial denture is often doomed to limited success if the patient fails to exercise proper oral hygiene habits or ignores recall appointments. Preservation of the oral structures, one of the primary objectives of prosthodontic treatment, is compromised without the patient's cooperation in oral hygiene and regular maintenance visits.

Patient education should begin at the initial diagnosis and should continue throughout treatment. This educational procedure is especially important when the treatment plan and prognosis are discussed with the patient. Limitations imposed on the success of treatment through failure of the patient to accept responsibility must be explained before definitive treatment is undertaken. A patient usually does not retain all the information presented in the oral educational instructions. For this reason, patients should be given written suggestions to reinforce the oral presentations.

Treatment Planning, Design, Treatment Sequencing, and Mouth Preparation

Treatment planning and design begin with thorough medical and dental histories. The complete oral examination must include both clinical and radiographic interpretation of (1) caries, (2) the condition of existing restorations, (3) periodontal conditions, (4) responses of teeth (especially abutment teeth) and residual ridges to previous stress, and (5) the vitality of remaining teeth. In addition, evaluation of the occlusal plane, the arch form, and the occlusal relations of the remaining teeth must be meticulously accomplished by clinical visual evaluation and diagnostic mounting. After a complete diagnostic examination has been accomplished and a removable partial denture has been selected as the treatment of choice, a treatment plan is sequenced and a partial denture design is developed in accordance with available support.

The dental cast surveyor (Figure 2-2) is an absolute necessity in any dental office in which patients are being treated with removable partial dentures. The surveyor is instrumental in diagnosing and guiding the appropriate tooth preparation and verifying that the mouth preparation has been performed correctly. There is no more reason to justify its omission from a dentist's armamentarium than there is to ignore the need for roentgenographic equipment, the mouth mirror and explorer, or the periodontal probe used for diagnostic purposes.

Several moderately priced surveyors that adequately accomplish the diagnostic procedures necessary for designing the partial denture are available. In many dental offices, this most important phase of dental diagnosis is delegated to the commercial dental laboratory either because this invaluable diagnostic tool is absent or because the dentist feels

Figure 2-2 Dental cast surveyor facilitates the design of a removable partial denture. It is an instrument by which parallelism or lack of parallelism of abutment teeth and other oral structures, on a stone cast, can be determined *(magnified view shows parallel guide plane surface)*. Use of the surveyor is discussed in later chapters.

inexperienced or is apathetic. This situation places the technician in the role of diagnostician. Any clinical treatment based on the diagnosis of the technician remains the responsibility of the dentist. This makes no more sense than relying on the technician to interpret radiographs and to render a diagnosis.

After treatment planning, a predetermined sequence of mouth preparations can be performed with a definite goal in mind. It is mandatory that the treatment plan be reviewed to ensure that the mouth preparation necessary to accommodate the removable partial denture design has been properly sequenced. Mouth preparations, in the appropriate sequence, should be oriented toward the goal of providing adequate support, stability, retention, and a harmonious occlusion for the partial denture. Placing a crown or restoring a tooth out of sequence may result in the need to restore teeth that were not planned for restoration, or it may necessitate remaking a restoration or even seriously jeopardizing the success of the removable partial denture. Through the aid of diagnostic casts on which the tentative design of the partial denture has been outlined and the mouth preparations have been indicated in colored pencil, occlusal adjustments, abutment restorations, and abutment modifications can be accomplished.

Support for Distal Extension Denture Bases

The third of the six phases in the treatment of a patient with a partial denture involves obtaining adequate support for distal extension bases. Therefore it does not apply to tooth-supported removable partial dentures. With the latter, support comes entirely from the abutment teeth through the use of rests.

For the distal extension partial denture, however, a base made to fit the anatomic ridge form does not provide adequate support under occlusal loading (Figure 2-3). Neither does it provide for maximum border extension nor accurate border detail. Therefore some type of corrected impression is necessary. This may be accomplished by several means, any of which satisfy the requirements for support of any distal extension partial denture base.

Foremost is the requirement that certain soft tissue in the primary supporting area should be recorded or related under some loading so that the base may be made to fit the form of the ridge when under function. This provides support and ensures maintenance of that support for the longest possible time. This requirement makes the distal extension partial denture unique in that support from the tissue underlying the distal extension base must be made as equal to and compatible with the tooth support as possible.

A complete denture is entirely tissue supported, and the entire denture can move toward the tissue under function. In contrast, any movement of a partial denture base is inevitably a rotational movement that, if toward the tissue, may result in undesirable torquing forces to the abutment teeth and loss of planned occlusal contacts. Therefore every effort must be made to provide the best possible support for the distal extension base to minimize these forces.

Usually no single impression technique can adequately record the anatomic form of the teeth and adjacent structures and at the same time record the supporting form of the mandibular edentulous ridge. A method should be used that can record these tissues in their supporting form or in a supporting relationship to the rest of the denture (see Figure 2-3). This may be accomplished by one of several methods that will be discussed in Chapter 16.

Establishment and Verification of Occlusal Relations and Tooth Arrangements

Whether the partial denture is tooth supported or has one or more distal extension bases, the recording and verification of occlusal relationships and tooth arrangement are important steps in the construction of a partial denture. For the tooth-supported partial denture, ridge form is of less significance than it is for the tooth- and tissue-supported prosthesis, because the ridge is not called on to support the prosthesis. For the distal extension base, however, jaw relation records should be made only after the best possible support is obtained for the denture base. This necessitates the making of a base or bases that provide the same support as the finished denture. Therefore the final jaw relations should not be recorded until after the denture framework has been returned to the dentist, the fit of the framework to the abutment teeth and opposing occlusion has been verified and corrected, and a corrected impression has been made.

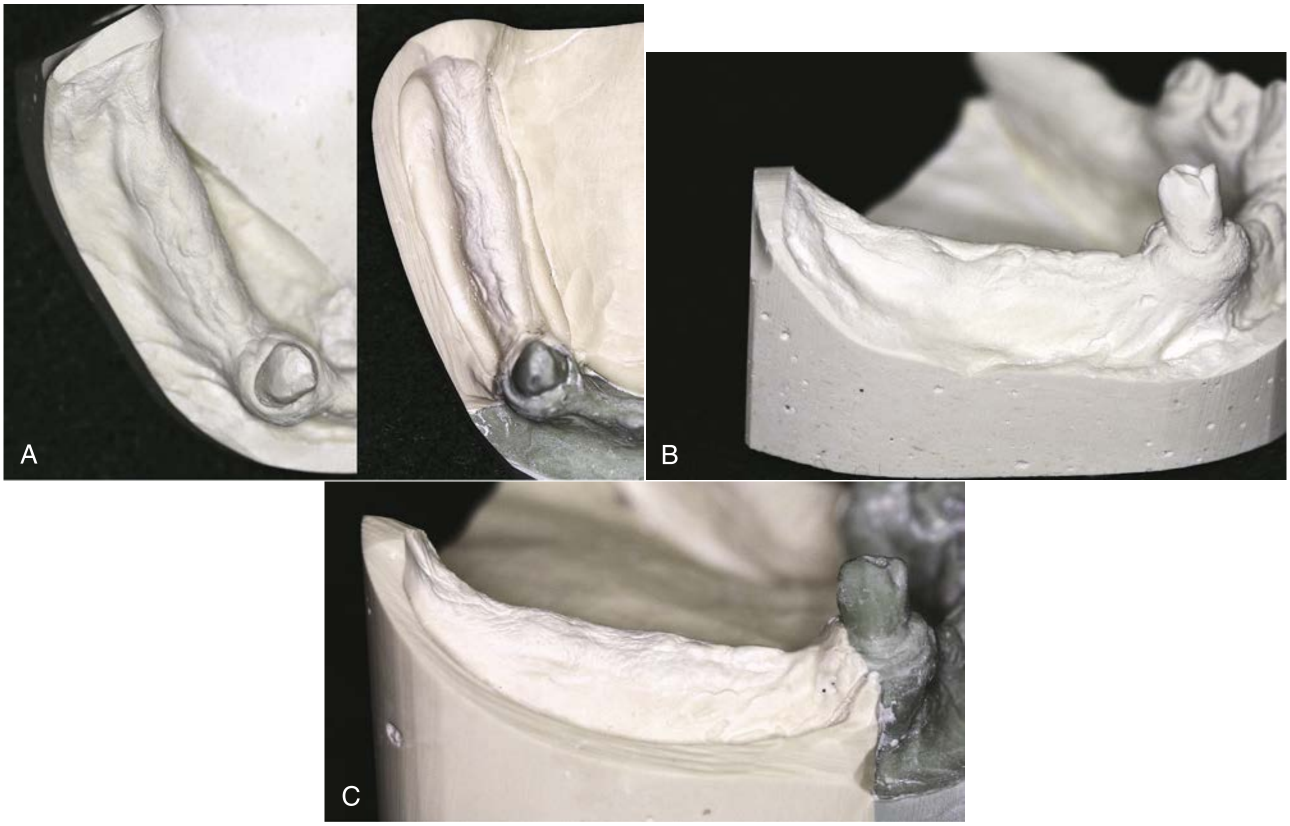

Figure 2-3 **A,** Occlusal view of a cast from a preliminary impression, which produced an anatomic ridge form *(left)*, and an altered cast of the same ridge showing a functional or supportive form *(right)*. The altered cast impression selectively placed pressure on the buccal shelf region, which is the primary stress-bearing area of the mandibular posterior residual ridge. **B,** Buccal view of anatomic ridge form. **C,** Buccal view of functional or supportive ridge form. Note that the supportive form of the ridge clearly delineates the extent of coverage available for a denture base and is most different from the anatomic form when the mucosa is easily displaced.

Then a new resin base or a corrected base must be used to record jaw relations.

Occlusal records for a removable partial denture may be made by the various methods described in Chapter 18.

Initial Placement Procedures

The fifth phase of treatment occurs when the patient is given possession of the removable prosthesis. Inevitably it seems that minute changes in the planned occlusal relationships occur during processing of the dentures. Not only must occlusal harmony be ensured before the patient is given possession of the dentures, but the processed bases must be reasonably perfected to fit the basal seats. It must be ascertained that the patient understands the suggestions and recommendations given by the dentist for care of the dentures and oral structures and understands about expectations (based on the “shared decision making” discussion) in the adjustment phases and the use of restorations. These facets of treatment are discussed in detail in Chapter 21.

Periodic Recall

Initial placement and adjustment of the prosthesis certainly is not the end of treatment for the partially edentulous patient. Periodic reevaluation of the patient is critical for early recognition of changes in oral structures to allow steps to be taken to maintain oral health. These examinations must monitor the condition of the oral tissue, the response to tooth restorations, the prosthesis, the patient’s acceptance, and the patient’s commitment to maintain oral hygiene. Although a 6-month recall period is adequate for most patients, more frequent evaluation may be required for some. Chapter 21 contains some suggestions concerning this sixth phase of treatment.

REASONS FOR FAILURE OF CLASP-RETAINED PARTIAL DENTURES

Experience with the clasp-retained partial denture made by the methods outlined has proved its merit and justifies its continued use. The occasional objection to the visibility of retentive clasps can be minimized through the use of wrought-wire clasp arms. Few contraindications for use of a properly designed clasp-retained partial denture are known. Practically all objections to this type of denture can be eliminated by pointing to deficiencies in mouth preparation, denture design and fabrication, and patient education. These include the following:

Diagnosis and treatment planning

1. Inadequate diagnosis
2. Failure to use a surveyor or to use a surveyor properly during treatment planning

Mouth preparation procedures

1. Failure to properly sequence mouth preparation procedures
2. Inadequate mouth preparations, usually resulting from insufficient planning of the design of the partial denture or failure to determine that mouth preparations have been properly accomplished
3. Failure to return supporting tissue to optimum health before impression procedures are performed
4. Inadequate impressions of hard and soft tissue

Design of the framework

1. Failure to use properly located and sized rests
2. Flexible or incorrectly located major and minor connectors
3. Incorrect use of clasp designs
4. Use of cast clasps that have too little flexibility, are too broad in tooth coverage, and have too little consideration for esthetics

Laboratory procedures

1. Problems in master cast preparation
   a. Inaccurate impression
   b. Poor cast-forming procedures
   c. Incompatible impression materials and gypsum products
2. Failure to provide the technician with a specific design and necessary information to enable the technician to execute the design
3. Failure of the technician to follow the design and written instructions

Support for denture bases

1. Inadequate coverage of basal seat tissue
2. Failure to record basal seat tissue in a supporting form

Occlusion

1. Failure to develop a harmonious occlusion
2. Failure to use compatible materials for opposing occlusal surfaces

Patient-dentist relationship

1. Failure of the dentist to provide adequate dental health care information, including details on care and use of the prosthesis
2. Failure of the dentist to provide recall opportunities on a periodic basis
3. Failure of the patient to exercise a dental health care regimen and respond to recall

A removable partial denture designed and fabricated so that it avoids the errors and deficiencies listed is one that proves the clasp-type partial denture can be made functional, esthetically pleasing, and long lasting without damage to supporting structures. The proof of the merit of this type of restoration lies in the knowledge that (1) it permits treatment for the largest number of patients at a reasonable cost; (2) it provides restorations that are comfortable and efficient over a long period of time, with adequate support and maintenance of occlusal contact relations; (3) it can provide for healthy abutments, free of caries and periodontal disease; (4) it can provide for the continued health of restored, healthy tissue of the basal seats; and (5) it makes possible a partial denture service that is definitive and not merely an interim treatment.

Removable partial dentures thus made will contribute to a concept of prosthetic dentistry that has as its goal the promotion of oral health, the restoration of partially edentulous mouths, and elimination of the ultimate need for complete dentures.

CHAPTER 3

Classification of Partially Edentulous Arches

CHAPTER OUTLINE

Requirements of an Acceptable Method of Classification
Kennedy Classification
Applegate's Rules for Applying the Kennedy Classification

Even though recent reports have shown a consistent decline in the prevalence of tooth loss during the past few decades, significant variation in tooth loss distribution remains. It would be most helpful to consider which combinations of tooth loss are most common and to classify these for the purpose of assisting our management of partially edentulous patients.

A classification that is based on diagnostic criteria has been proposed for partial edentulism.[1] The purpose of this system of classification is to facilitate treatment decisions on the basis of treatment complexity. Complexity is determined from four broad diagnostic categories that include location and extent of the edentulous areas, condition of the abutments, occlusal characteristics and requirements, and residual ridge characteristics. The advantage of this classification system over others in standard use has yet to be documented.

The Kennedy method is probably the most widely accepted classification of partially edentulous arches. In an attempt to simplify the problem and encourage more universal use of a classification, and in the interest of adequate communication, the Kennedy classification will be used in this textbook. The student can refer to the Selected Reading Resources section in Appendix B for information relative to other classifications.

Although classifications are actually descriptive of the partially edentulous arches, the removable partial denture that restores a particular class of arch is described as a denture of that class. For example, we speak of a Class III or Class I removable partial denture. It is simpler to say "a Class II partial denture" than it is to say "a partial denture restoring a Class II partially edentulous arch."

Several classifications of partially edentulous arches have been proposed and are in use. This variety has led to some confusion and disagreement concerning which classification best describes all possible configurations and should be adopted.

The most familiar classifications are those originally proposed by Kennedy, Cummer, and Bailyn. Beckett, Godfrey, Swenson, Friedman, Wilson, Skinner, Applegate, Avant, Miller, and others have also proposed classifications. It is evident that an attempt should be made to combine the best features of all classifications so that a universal classification can be adopted.

REQUIREMENTS OF AN ACCEPTABLE METHOD OF CLASSIFICATION

The classification of a partially edentulous arch should satisfy the following requirements:

1. It should permit immediate visualization of the type of partially edentulous arch that is being considered.
2. It should permit immediate differentiation between the tooth-supported and the tooth- and tissue-supported removable partial denture.
3. It should be universally acceptable.

KENNEDY CLASSIFICATION

The Kennedy method of classification was originally proposed by Dr. Edward Kennedy in 1925. It attempts to classify the partially edentulous arch in a manner that suggests certain principles of design for a given situation (Figure 3-1).

Kennedy divided all partially edentulous arches into four basic classes. Edentulous areas other than those that determine the basic classes were designated as modification spaces (Figure 3-2).

The following is the Kennedy classification:

Class I — Bilateral edentulous areas located posterior to the natural teeth

Class II — A unilateral edentulous area located posterior to the remaining natural teeth

Class III — A unilateral edentulous area with natural teeth remaining both anterior and posterior to it

Class IV — A single, but bilateral (crossing the midline), edentulous area located anterior to the remaining natural teeth

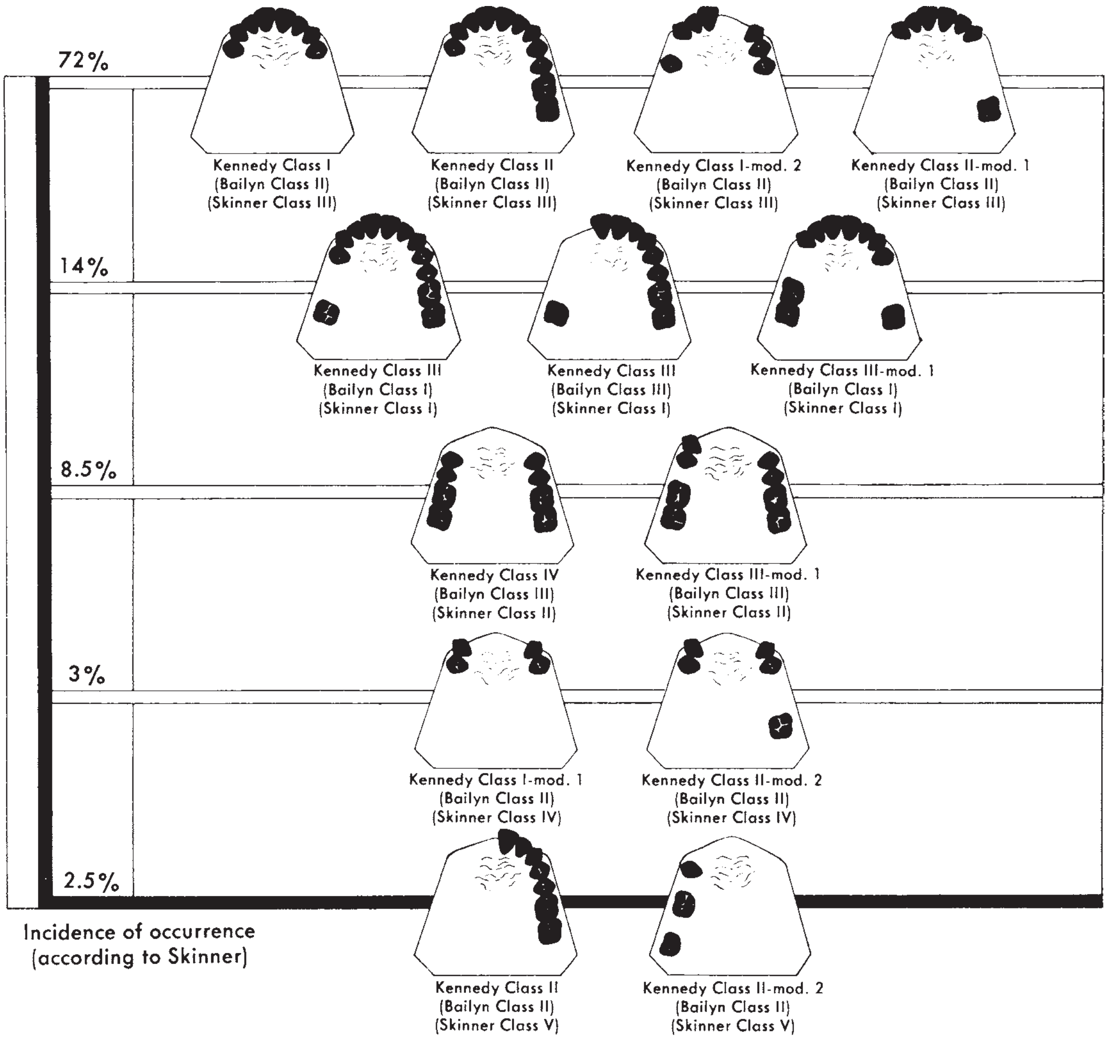

Figure 3-1 Representative examples of partially edentulous arches classified by the Kennedy method.

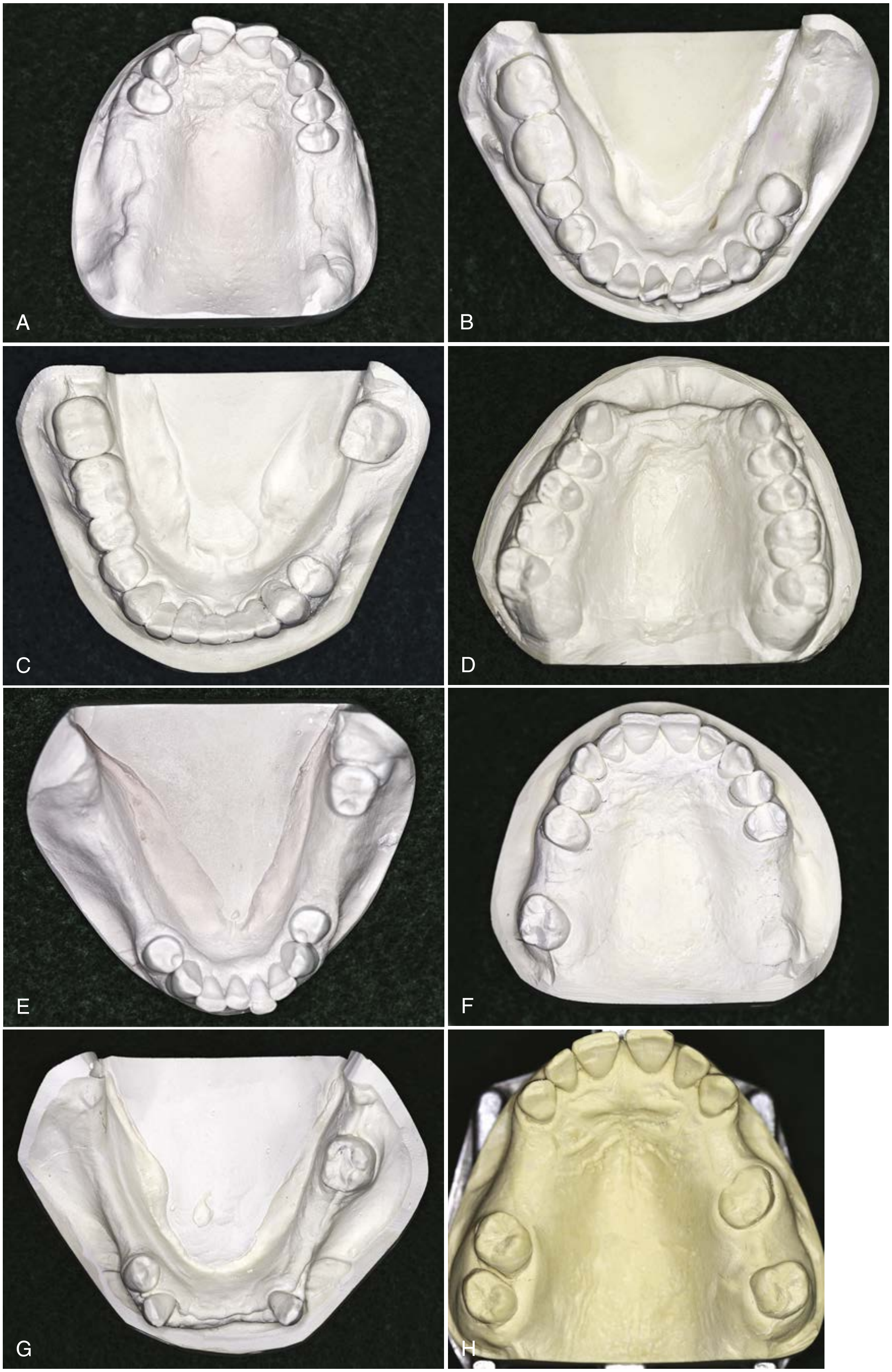

Figure 3-2 Kennedy classification with examples of modifications. **A,** Class I maxillary arch. **B,** Class II mandibular arch. **C,** Class III mandibular arch. **D,** Class IV maxillary arch. **E,** Class II, modification 1 mandibular arch. **F,** Class II, modification 1 maxillary arch. **G,** Class II, modification 2 mandibular arch. **H,** Class III, modification 2 maxillary arch.

Box 3-1

RULES GOVERNING APPLICATION OF THE KENNEDY METHOD

Rule 1

Classification should follow rather than precede any extractions of teeth that might alter the original classification.

Rule 2

If a third molar is missing and is not to be replaced, it is not considered in the classification.

Rule 3

If a third molar is present and is to be used as an abutment, it is considered in the classification.

Rule 4

If a second molar is missing and is not to be replaced, it is not considered in the classification (e.g., if the opposing second molar is likewise missing and is not to be replaced).

Rule 5

The most posterior edentulous area (or areas) always determines the classification.

Rule 6

Edentulous areas other than those that determine the classification are referred to as *modifications* and are designated by their number.

Rule 7

The extent of the modification is not considered, only the number of additional edentulous areas.

Rule 8

No modification areas can be included in Class IV arches. (Other edentulous areas that lie posterior to the single bilateral areas crossing the midline would instead determine the classification; see Rule 5.)

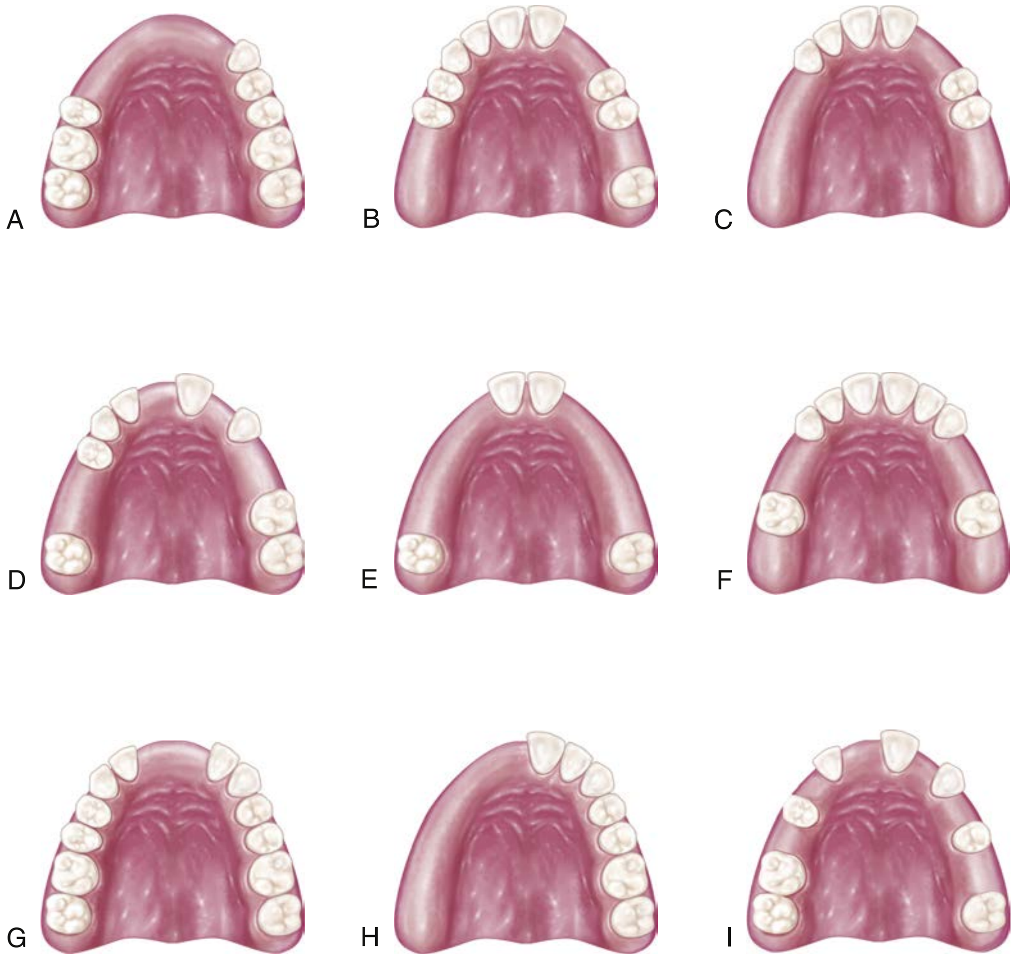

Figure 3-3 Nine partially edentulous arch configurations. Identify each. Answers can be found at the end of this chapter, after the Reference section.

One of the principal advantages of the Kennedy method is that it permits immediate visualization of the partially edentulous arch and allows easy distinction between tooth-supported versus tooth- and tissue-supported prostheses. Those schooled in its use and in the principles of partial denture design can readily relate the arch configuration design to be used in the basic partial denture. This method permits a logical approach to the problems of design. It makes possible the application of sound principles of partial denture design and is therefore a logical method of classification. However, a classification system should not be used to stereotype or limit the concepts of design.

Additionally, because the use of a strategically placed implant can provide an extension base (the support similar to a tooth in a tooth-born segment), it may be helpful to our understanding, communication, and design to consider implant designations in future classifications (Kennedy Class Ii/i, Class IIi, Class IVi, and so on).

APPLEGATE'S RULES FOR APPLYING THE KENNEDY CLASSIFICATION

The Kennedy classification would be difficult to apply in every situation without certain rules for application. Applegate provided eight rules that govern application of the Kennedy method (Box 3-1).

Although some confusion may occur initially as to why Class I should refer to two edentulous areas and Class II should refer to one, the principles of design make this distinction logical. Kennedy placed the Class II unilateral distal extension type between the Class I bilateral distal extension type and the Class III tooth-supported classification because the Class II partial denture must embody features of both, especially when tooth-supported modifications are present. Because it has a tissue-supported extension base, the denture must be designed similarly to a Class I partial denture. Often, however, a tooth-supported, or Class III, component is present elsewhere in the arch. Thus the Class II partial denture rightly falls between the Class I and the Class III, because it embodies design features common to both. In keeping with the principle that design is based on classification, the application of such principles of design is simplified by retaining the original classification of Kennedy.

Figure 3-3 presents a chance to assess your skills. Review the figure and classify the partially edentulous arches illustrated. The answers are provided at the end of this chapter.

Reference

1. McGarry TJ, Nimmo A, Skiba JF, et al.: Classification system for partial edentulism, *J Prosthodont* 11(3):181–193, 2002.

Answer to Figure 3-3

A. Class IV
B. Class II, modification 2
C. Class I, modification 1
D. Class III, modification 3
E. Class III, modification 1
F. Class III, modification 1
G. Class IV
H. Class II
I. Class III, modification 5

CHAPTER

4

Biomechanics of Removable Partial Dentures

CHAPTER OUTLINE

As was stated in Chapter 1, the goal is to provide useful, functional removable partial denture prostheses by striving to understand how to maximize every opportunity for providing and maintaining a stable prosthesis. Because removable partial dentures are not rigidly attached to teeth, the control of potential movement under functional load is critical to providing the best chance for stability and patient accommodation. The consequence of prosthesis movement under load is an application of stress to the teeth and tissue that are contacting the prosthesis. It is important that the stress not exceed the level of physiologic tolerance, which is a range of mechanical stimulus that a system can resist without disruption or traumatic consequences. In the terminology of engineering mechanics, the prosthesis induces stress in the tissue equal to the force applied across the area of contact with the teeth and/or tissue. This same stress acts to produce strain in the supporting tissue, which results in load displacement in the teeth and tissue. The understanding of how these mechanical phenomena act within a biological environment that is unique to each patient can be discussed in terms of biomechanics. In the design of removable partial dentures, with a focus on the goal of providing and maintaining stable prostheses, consideration of basic biomechanical principles associated with the unique features of each mouth is essential. Oral hygiene and appropriate prosthesis maintenance procedures are required for continued benefit of optimum biomechanical principles.

BIOMECHANICS AND DESIGN SOLUTIONS

Removable partial dentures by design are intended to be placed into and removed from the mouth. Because of this, they cannot be rigidly connected to the teeth or tissue. This makes them subject to movement in response to functional loads, such as those created by mastication. It is important for clinicians who provide removable partial denture service to understand the possible movements in response to function and to be able to logically design the component parts of the removable partial denture to help control these movements. Just how this is accomplished in a logical manner may not be clear to a clinician who is new to this exercise. One method of helping to organize design thought is to consider it as an exercise in creating a design solution.

Designing a removable partial denture can be considered similar to the classic, multifaceted design problem in conventional engineering, which is characterized by being open ended and ill structured. *Open ended* means that problems typically have more than one solution, and *ill structured* means that solutions are not the result of standard mathematical formulas used in some structured manner. The design process, which is a series of steps that lead toward a solution of the problem, includes identifying a need, defining the problem, setting design objectives, searching for background information and data, developing a design rationale, devising and evaluating alternative solutions, and providing the solution (i.e., decision making and communication of solutions) (Box 4-1).

The rationale for design should logically develop from analysis of the unique oral condition of each mouth under consideration. However, it is possible that alternative design "solutions" could be applied, and it is the evaluation of perceived merits of these various designs that seems most confusing to clinicians.

The following biomechanical considerations provide a background related to principles of the potential movement associated with removable partial dentures, and the subsequent chapters covering the various component parts describe how these components are applied in designs to control the resultant movements of prostheses.

Box 4-1

DESIGN PROCESS FOR REMOVABLE PARTIAL DENTURES

Need

Tooth replacement

Definition of Problem

Provision of stable removable prosthesis

Objectives

Limited functional movement within tooth-tissue tolerance

Background Information

Forces of occlusion, tissue "load-displacement" character and potential for movement, biomechanical principles applied to specific features of this unique mouth, removable partial denture component parts assigned to control movement

Choice of a Solution (among Alternatives) for Application

Based on prior experience, principles and concepts learned from school and textbooks, and applicable clinical research

BIOMECHANICAL CONSIDERATIONS

The supporting structures for removable partial dentures (abutment teeth and residual ridges) are living things that are subjected to forces. Whether the supporting structures are capable of resisting the applied forces depends on (1) what typical forces require resistance, (2) what duration and intensity these forces have, (3) what capacity the teeth, implant(s) and/or mucosae have to resist these forces, (4) how material use and application influence this teeth-tissue resistance, and (5) whether resistance changes over time.

Consideration of the forces inherent in the oral cavity is critical. This includes the direction, duration, frequency, and magnitude of the force. In the final analysis, it is bone that provides the support for a removable prosthesis (i.e., the alveolar bone by way of the periodontal ligament and the residual ridge bone through its soft tissue covering). If potentially destructive forces can be minimized, then the physiologic tolerances of the supporting structures are not exceeded and pathologic change does not occur. The forces that occur with removable prosthesis function can be widely distributed and directed, and their effect minimized by appropriate design of the removable partial denture. An appropriate design includes the selection and location of components in conjunction with a harmonious occlusion.

Unquestionably the design of removable partial dentures necessitates mechanical and biological considerations. Most dentists are capable of applying simple mechanical principles to the design of a removable partial denture. For example, the lid of a paint can is more easily removed with a screwdriver than with a half dollar. The longer the handle, the less effort (force) it takes. This is a simple application of the mechanics of leverage. By the same token, a lever system represented by a distal extension removable partial denture could magnify the applied force of occlusion to the terminal abutments, which would be undesirable. Use of a dental implant in such a case reduces, and may eliminate, the opportunity for such force magnification.

IMPACT OF IMPLANTS ON MOVEMENTS OF PARTIAL DENTURES

Similar to the process of considering how an individual tooth is best used in removable partial denture design to control prosthesis movement, use of an implant should be directed toward the most beneficial movement control. Although possible roles for implant use include all three desired principles demonstrated by prostheses—support, stability, and retention—the major functional demand is imposed by chewing, and therefore the greatest benefit of implant use involves resisting instability by improving support. Minimizing rotation about an axis in a Kennedy Class I or II arch, or any long modification span, is important to consider.

SIMPLE MACHINES

An understanding of simple machines applied to the design of removable partial dentures helps to accomplish the objective of preservation of oral structures. Without such understanding, a removable partial denture can be inadvertently designed as a destructive machine.

Machines may be classified into two general categories: simple and complex. Complex machines are combinations of many simple machines. The six simple machines are lever, wedge, screw, wheel and axle, pulley, and inclined plane (Figure 4-1). Of the simple machines, the lever, the wedge, and the inclined plane should be avoided in the design of removable partial dentures.

In its simplest form, a lever is a rigid bar supported somewhere along its length. It may rest on the support or may be supported from above. The support point of the lever is called the *fulcrum,* and the lever can move around the fulcrum (Figure 4-2; see Figure 6-6).

The rotational movement of an extension base type of removable partial denture, when a force is placed on the denture base, is illustrated in Figure 4-3. It rotates in relation to the three cranial planes because of differences in the support characteristics of the abutment teeth and the soft tissue covering the residual ridge. Even though the actual movement of the denture may be small, a lever force may be imposed on abutment teeth. This is especially detrimental when prosthesis maintenance is neglected. Three types of levers are used: first, second, and third class (see Figure 4-2). The potential of a lever system to magnify a force is illustrated in Figure 4-4.

A cantilever is a beam supported at one end that can act as a first-class lever (Figure 4-5). A cantilever design should be avoided (Figure 4-6). Use of a dental implant is one strategy to provide tooth replacement and avoid the cantilever. Examples of other lever designs and suggestions for alternative designs to avoid or minimize their destructive potential are illustrated in Figures 4-7 and 4-8. The most efficient means of addressing the potential effects of a lever is to provide a rigid element at the unsupported end to disallow movement. This is the most beneficial use of dental implants in conjunction with removable partial dentures and should be considered when support capacity for a distal extension is considered significantly poor.

A tooth is apparently better able to tolerate vertically directed forces than nonvertical, torquing, or horizontal forces. This characteristic is observed clinically, and it seems rational that more periodontal fibers are activated to resist the application of vertical forces to teeth than are activated to resist the application of nonvertical forces (Figure 4-9).

Again, a distal extension removable partial denture rotates when forces are applied to the artificial teeth attached to the extension base. Because it can be assumed that this rotation must create predominantly nonvertical forces, the location of

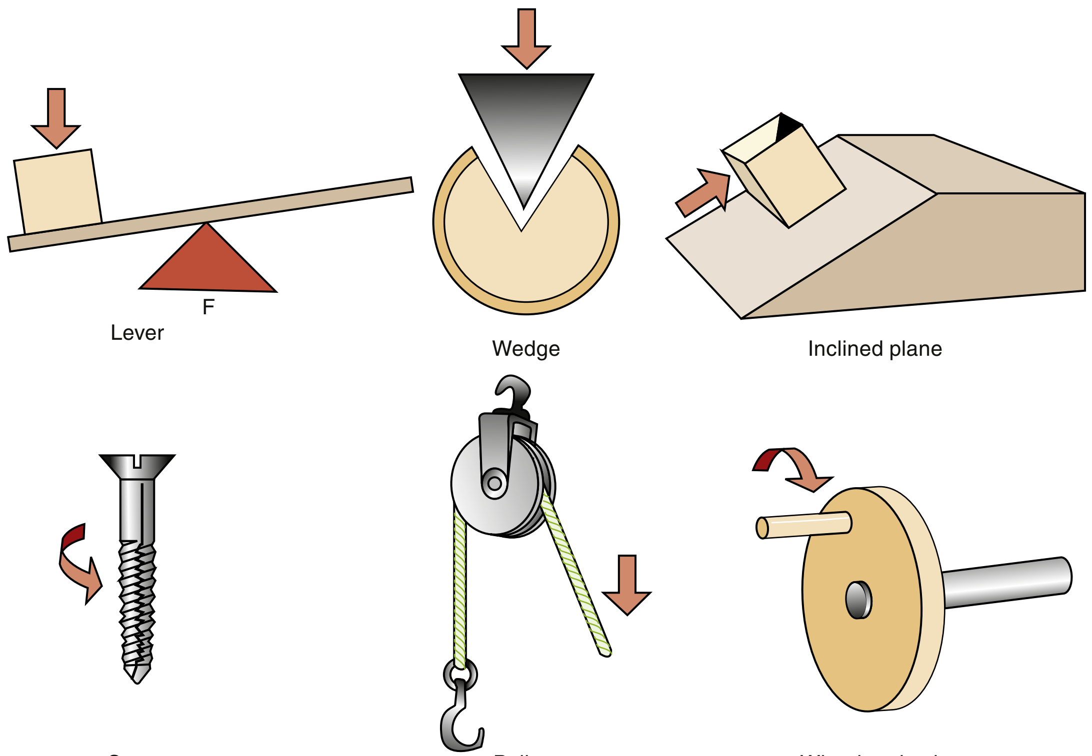

Figure 4-1 The six simple machines include lever, wedge, inclined plane, screw, pulley, and wheel and axle. The fulcrum, wedge, and inclined plane are matters of concern in removable partial denture designs because of the potential for harm if they are not appropriately controlled. *F,* Fulcrum.

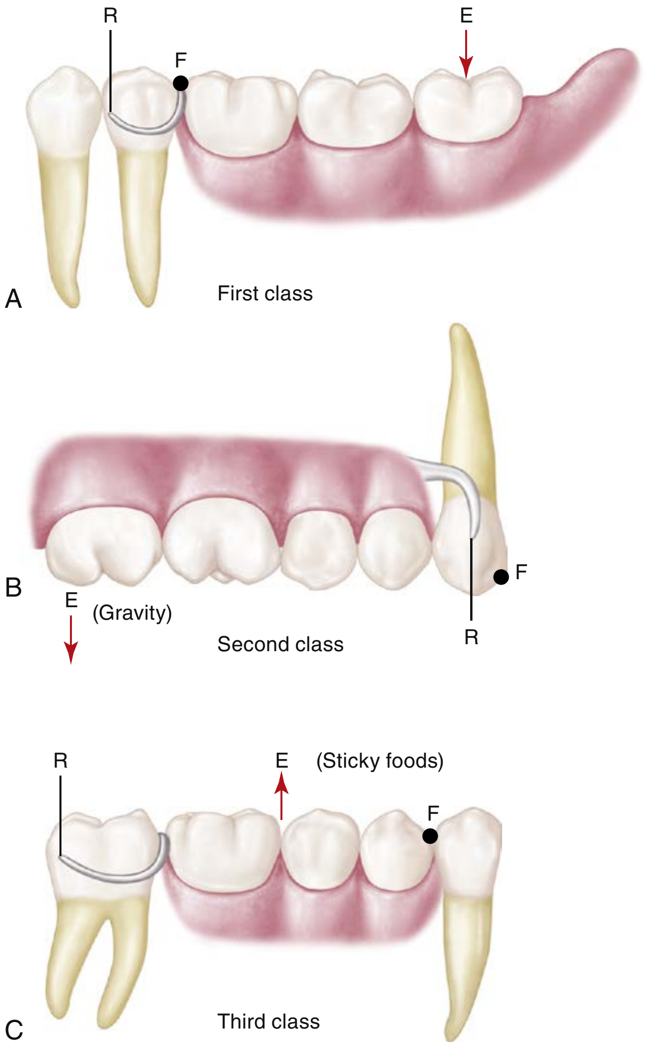

Figure 4-2 **A** to **C,** The three classes of levers. Classification is based on location of the fulcrum *(F)*, resistance *(R)*, and direction of effort (force) *(E)*. In dental terms, *E* can represent the force of occlusion or gravity; *F* can be a tooth surface such as an occlusal rest; and *R* is the resistance provided by a direct retainer or a guide plane surface.

stabilizing and retentive components in relation to the horizontal axis of rotation of the abutment becomes extremely important. An abutment tooth will better tolerate nonvertical forces if these forces are applied as near as possible to the horizontal axis of rotation of the abutment (Figure 4-10). The axial surface contours of abutment teeth must be altered to locate components of clasp assemblies more favorably in relation to the abutment's horizontal axis (Figure 4-11).

POSSIBLE MOVEMENTS OF PARTIAL DENTURES

If it is presumed that direct retainers are functioning to minimize vertical displacement, rotational movement will occur about some axis as the distal extension base or bases move toward, away, or horizontally across the underlying tissue. Unfortunately, these possible movements do not occur singularly or independently but tend to be dynamic and all occur at the same time. The greatest movement possible is found in the tooth/mucosal tissue–supported prosthesis because of reliance on the distal extension supporting tissue to share the functional loads with the teeth. Movement of a distal extension base toward the ridge tissue will be proportionate to the quality of that tissue, the accuracy and extent of the denture base, and the applied total functional load. A review of prosthesis rotational movement that is possible around various axes in the mouth provides some understanding of how component parts of removable partial dentures should be prescribed to control prosthesis movement.

One movement is rotation about an axis through the most posterior abutments. This axis may pass through occlusal rests or any other rigid portion of a direct retainer assembly located occlusally or incisally to the height of contour of the primary abutments (see Figures 4-6 and 4-7). This axis, known as the *fulcrum line,* is the center of rotation as the distal extension base moves toward the supporting tissue when an occlusal load is applied. The axis of rotation may shift toward more anteriorly placed components, occlusal or incisal to the height of contour of the abutment, as the base moves away from the supporting tissue when vertical dislodging forces act on the partial denture. These dislodging forces result from the vertical pull of food between opposing tooth surfaces, the effects of moving border tissue, and the forces of gravity against a maxillary partial denture. If it is presumed that the direct retainers are functional and that the supportive anterior components remain seated, rotation—rather than total displacement—should occur. Vertical tissue-ward movement of the denture base is resisted by the tissue of the residual ridge in proportion to the supporting quality of that tissue, the accuracy of the fit of the denture base, and the total amount of occlusal load applied. Movement of the base in the opposite direction is resisted by the action of the retentive clasp arms on terminal abutments and the action of stabilizing minor connectors in conjunction with seated, vertical support elements of the framework anterior to the terminal abutments acting as indirect retainers. Indirect retainers should be placed as far as possible from the distal extension base, affording the best possible leverage against lifting of the distal extension base.

A second movement is rotation about a longitudinal axis as the distal extension base moves in a rotary direction about the residual ridge (see Figure 4-3). This movement is resisted primarily by the rigidity of the major and minor connectors and their ability to resist torque. If the connectors are not rigid, or if a stress-breaker exists between the distal extension base and the major connector, this rotation about a longitudinal axis applies undue stress to the sides of the supporting ridge or causes horizontal shifting of the denture base.

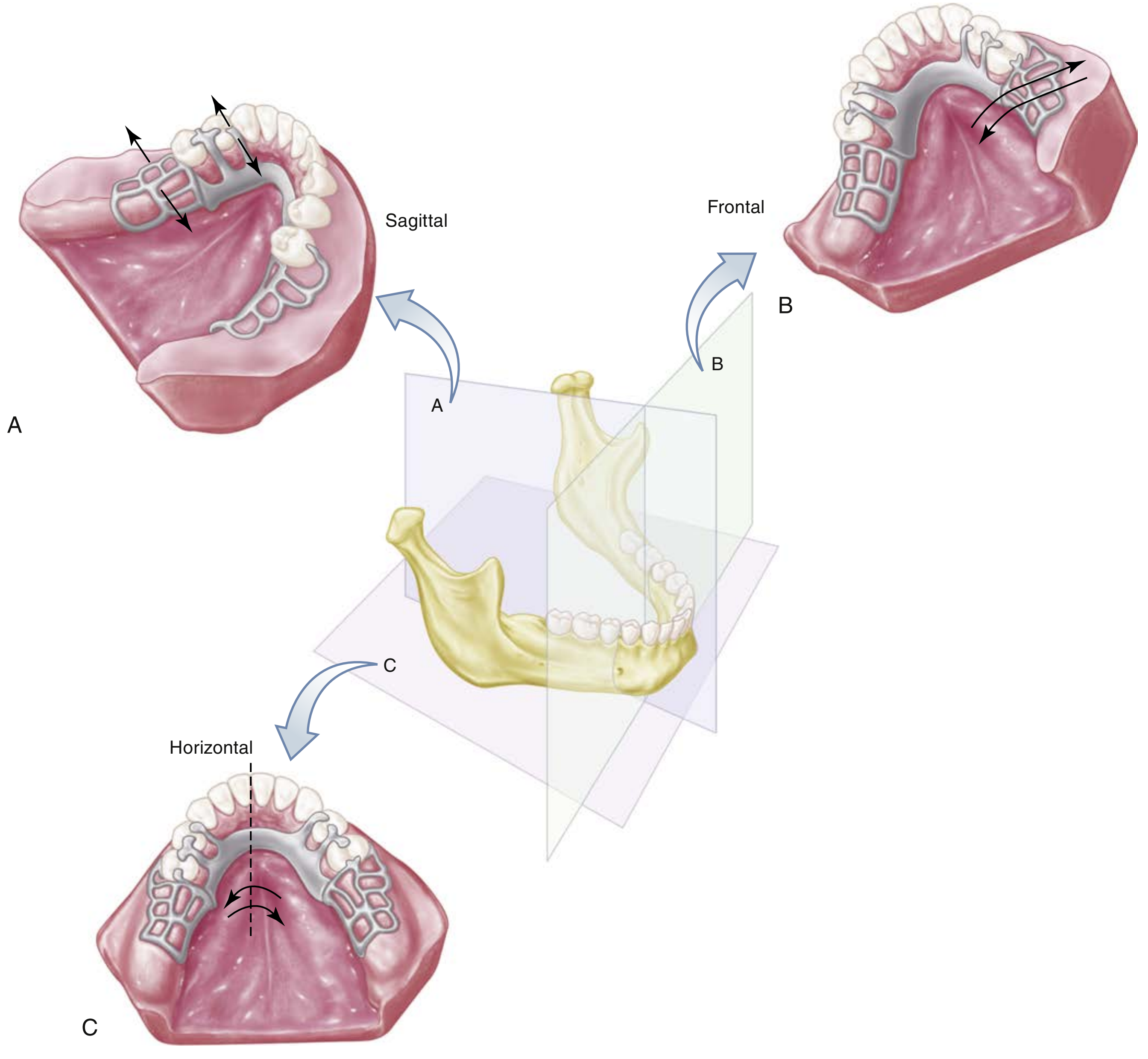

FIGURE 4-3 Distal extension removable partial dentures will rotate when force is directed on the denture base. Differences in displaceability of the periodontal ligament of the supporting abutment teeth and soft tissue covering the residual ridge permit this rotation. It would seem that rotation of the prosthesis occurs in a combination of directions rather than in a unidirectional way. The three possible movements of distal extension partial dentures are **(A)** rotation around a fulcrum line passing through the most posterior abutments when the denture base moves vertically toward or away from the supporting residual ridges; **(B)** rotation around a longitudinal axis formed by the crest of the residual ridge; and **(C)** rotation around a vertical axis located near the center of the arch.

A third movement is rotation about an imaginary vertical axis located near the center of the dental arch (see Figure 4-4). This movement occurs under function because diagonal and horizontal occlusal forces are brought to bear on the partial denture. It is resisted by stabilizing components, such as reciprocal clasp arms and minor connectors that are in contact with vertical tooth surfaces. Such stabilizing components are essential to any partial denture design, regardless of the manner of support and the type of direct retention employed. Stabilizing components on one side of the arch act to stabilize the partial denture against horizontal forces applied from the opposite side. It is obvious that rigid connectors must be used to make this effect possible.

Horizontal forces always will exist to some degree because of lateral stresses that occur during mastication, bruxism, clenching, and other patient habits. These forces are accentuated by failure to consider the orientation of the occlusal plane, the influence of malpositioned teeth in the arch, and the effects of abnormal jaw relationships. Fabricating an occlusion that is in harmony with the opposing dentition and that is free of lateral interference during eccentric jaw movements may minimize the magnitude of lateral stress. The amount of horizontal movement occurring in the partial denture therefore depends on the magnitude of the lateral forces that are applied and on the effectiveness of the stabilizing components.

In a tooth-supported partial denture, movement of the base toward the edentulous ridge is prevented primarily by

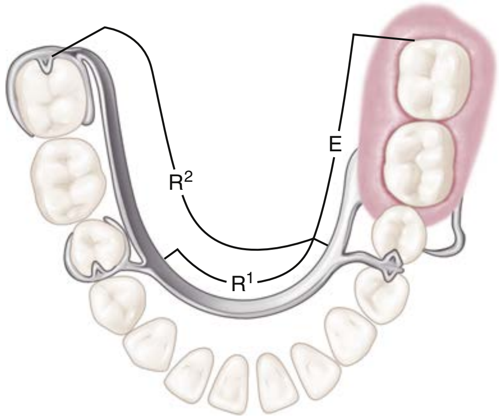

FIGURE 4-4 The length of a lever from fulcrum *(F)* (see Figure 4-7) to resistance *(R)* is called the *resistance arm*. That portion of a lever from the fulcrum to the point of application of force *(E)* is called the *effort arm*. Whenever the effort arm is longer than the resistance arm, mechanical advantage favors the effort arm, proportionately to the difference in length of the two arms. In other words, when the effort arm is twice the length of the resistance arm, a 25-lb weight on the effort arm will balance a 50-lb weight at the end of the resistance arm. The opposite is also true and helps illustrate cross-arch stabilization. When the resistance arm is lengthened (cross-arch clasp assembly placed on a second molar *[R²]* versus a second premolar *[R¹]*), the effort arm is more efficiently counteracted.

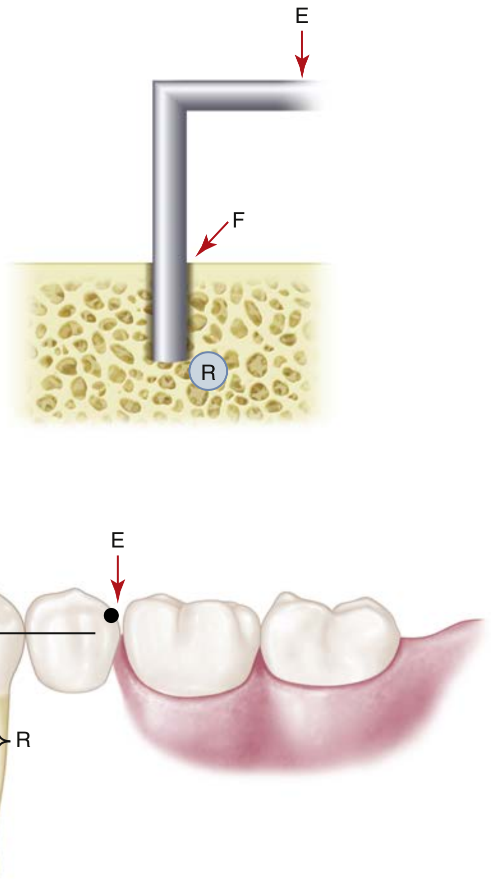

FIGURE 4-5 A cantilever can be described as a rigid beam supported only at one end. When force is directed against the unsupported end of the beam (as in this rest placed on a cantilevered pontic), the cantilever can act as a first-class lever. The mechanical advantage in this illustration favors the effort arm.

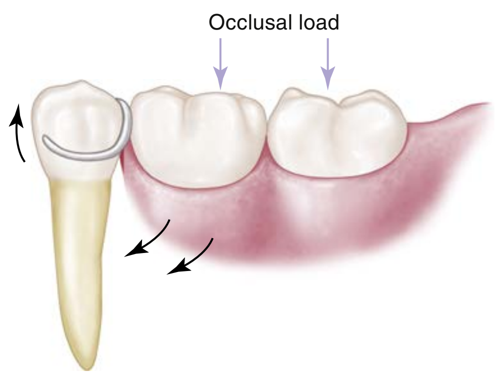

FIGURE 4-6 Design often seen for a distal extension removable partial denture. A cast circumferential direct retainer engages the mesiobuccal undercut and is supported by the disto-occlusal rest. If it is rigidly attached to the abutment tooth, this could be considered a cantilever design, and detrimental first-class lever force may be imparted to the abutment if tissue support under the extension base allows excessive vertical movement toward the residual ridge.

the rests on the abutment teeth and to some degree by any rigid portion of the framework located occlusal to the height of contour. Movement away from the edentulous ridge is prevented by the action of direct retainers on the abutments that are situated at each end of each edentulous space and by the rigid, minor connector stabilizing components. Therefore the first of the three possible movements can be controlled in the tooth-supported denture. The second possible movement, which occurs along a longitudinal axis, is prevented by the rigid components of the direct retainers on the abutment teeth and by the ability of the major connector to resist torque. This movement is much less in the tooth-supported denture because of the presence of posterior abutments. The third possible movement occurs in all partial dentures. Therefore stabilizing components against horizontal movement must be incorporated into any partial denture design.

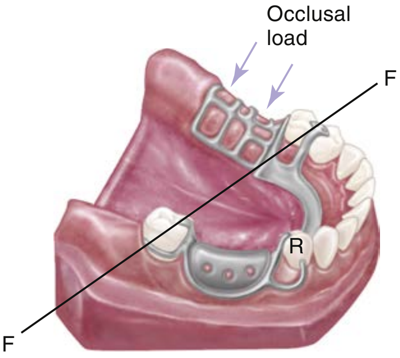

Figure 4-7 As is shown in Figure 4-6, the potential for first-class lever action can also exist in Class II, modification 1 designs for removable partial denture frameworks. If a cast circumferential direct retainer with a mesiobuccal undercut on the right first premolar were used, force placed on the denture base could impart upward and posteriorly moving force on the premolar, resulting in loss of contact between premolar and canine. Tissue support from the extension base area is most important to minimize the lever action of the clasp. The retainer design could help accommodate more of an anteriorly directed force during rotation of the denture base in an attempt to maintain tooth contact. Other alternatives to the first premolar design of the direct retainer would include a tapered wrought-wire retentive arm that uses mesiobuccal undercut, or that just has a buccal stabilizing arm above the height of contour.

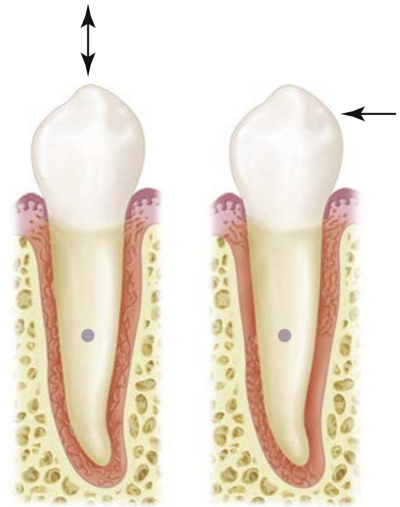

Figure 4-9 More periodontal fibers are activated to resist forces directed vertically on the tooth than are activated to resist horizontally (off-vertical) directed force. The horizontal axis of rotation is located somewhere in the root of the tooth.

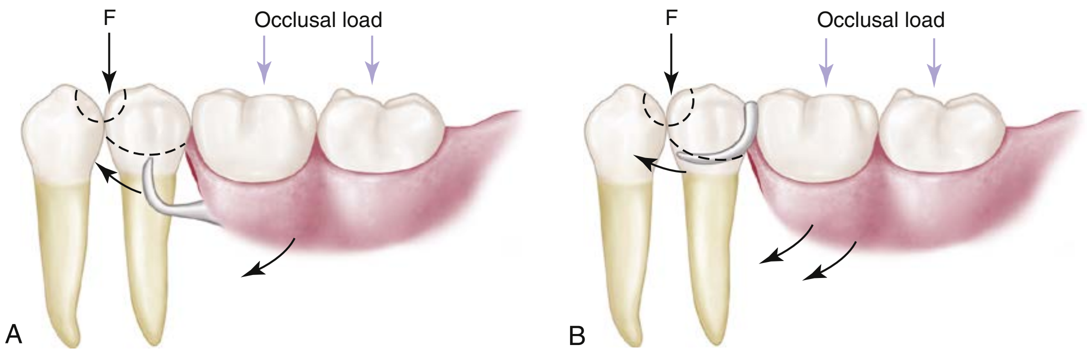

Figure 4-8 Mesial rest concept for distal extension removable partial dentures. With recognition that clasp movement occurs with functional displacement of the distal extension base, the primary aim of a mesial rest is to alter the fulcrum position and resultant clasp movement, disallowing harmful engagement of the abutment tooth. **A,** Bar type of retainer, minor connector contacting the guiding plane on the distal surface of the premolar, and mesio-occlusal rest used to reduce cantilever or first-class lever force when and if the denture rotates toward the residual ridge. **B,** Tapered wrought-wire retentive arm, minor connector contacting guiding plane on the distal surface of the premolar, and the mesio-occlusal rest. This design is applicable when the distobuccal undercut cannot be found or created or when the tissue undercut contraindicates placement of a bar-type retentive arm. This design would be kinder to the periodontal ligament than would a cast, half-round retentive arm. Again, tissue support of the extension base is a key factor in reducing the lever action of the clasp arm. *Note:* Depending on the amount of contact of the minor connector proximal plate with the guiding plane, the fulcrum point will change.