PARTIAL DENTURE PLANNING WITH SPECIAL REFERENCE TO STRESS DISTRIBUTION

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THE restoration of the partially edentulous mouth presents the challenge to re-establish masticatory efficiency, esthetics, and comfort in a manner which will promote and perpetuate oral health. Since we require that the remaining teeth and edentulous ridges assume abnormal functions and sustain greater stress than was intended of them by nature, we should make the preservation of these tissues one of our paramount objectives. Unfortunately, the field of partial denture service is strewn with ill-fated abutment teeth and appliances which have been short-lived in the transition to full dentures. We are all too familiar with those appliances which have caused progressive loss of the abutment teeth—where new abutments have been utilized and soon lost in their turn. Many of these dentures which were intended to give lengthy service became temporary appliances because important biomechanical factors were ignored in their planning. If the relationship between the biologic behavior of the oral structures and the mechanical influence of the denture is not recognized, the denture often contributes toward the rapid disintegration of the tissues. Failure invariably occurs when the denture subjects the tissues to stresses or loads which are greater than they are able to bear.

The successful partial denture cannot be produced by the skillful application of techniques alone. It must be conceived and constructed upon the knowledge of oral and dental anatomy, biology, histology, pathology, physics, and their allied sciences if the oral tissues are to be preserved and the missing teeth properly restored. The successful denture complements the remaining natural teeth, cooperates with them in function, and extends their useful life. It acts as a physiologic part of the masticatory mechanism.

Before any rehabilitation procedures are attempted, pertinent information must be gathered to provide the evidence necessary to arrive at an accurate diagnosis and develop a sound treatment plan. After the patient's general health, denture history, and attitude are noted, oral and roentgenographic examinations are made and study casts prepared. Since this is the point where

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the success or failure of the case may be determined, it is important that the examination be carefully conducted and be complete in every detail. Many important factors may be observed in examining the oral cavity, adjacent structures, and study casts. Among these are the relationship of the jaws, character of the occlusion, position and mobility of the teeth, condition of the soft tissues, and the need for preparatory treatment.

Mouth preparation should include: a thorough prophylaxis, equilibration of occlusion, removal of diseased or unserviceable teeth, reduction of tori and bulbous tuberosities, elimination of flabby tissue from the ridges, restoration of carious areas, and the recontouring of teeth to create rest seats and to reduce unfavorable undercut areas. Frequently, periodontal treatments are required to return the investing tissues to an optimum condition of health. If the abutment teeth show bone loss or mobility which indicates that, individually, they would not be able to assume the additional burden of stabilizing the denture, they should be joined to adjacent teeth by crowns, bridges, or other restorations. This produces a splinting effect with the teeth mutually reinforcing each other, thereby providing multiple abutments which are well able to withstand stress.

In extensive restoration cases and where occlusal disharmonies are evident or suspected, the study casts must be mounted on an adjustable articulator for proper analysis. A face-bow transfer is used to orient the maxillary cast on the instrument. The mandibular cast is mounted after centric relationship of the mandible to the maxilla has been obtained by the use of a wax index or other means which register the relationship without bringing the teeth into contact. Tooth contact is not allowed because malaligned teeth or interfering cusps tend to guide the mandible out of centric relation, displacing the heads of the condyles from their proper positions in the glenoid fossae.

If examination of the mouth and study casts reveals that the loss or drifting of teeth has actually caused the mandible to assume a position where centric occlusion is not in harmony with centric relation, a new occlusal pattern may have to be established by operative or prosthetic means. The new occlusion must allow the mandible to return to true centric relationship upon closure. When this is done, patient comfort is promoted, and the danger of traumatic reactions about the teeth and within the temporomandibular joint is greatly reduced.

Although a balanced occlusion is not imperative with a full complement of natural teeth, it is desirable in the partially edentulous mouth for equalization of stress. Where cuspal imbalance or interferences are noted in centric or excentric positions, adjustments are made by selective grinding. These corrections should be made in such a way that the desired occlusal vertical dimension is maintained and so there will be balanced occlusal harmony of both natural and artificial teeth in the completed case.

VERTICAL DIMENSION

In the writings of Niswonger[1] and Thompson[2,3] and Brodie,[2] we find an essential guide for the vertical dimension to be used for rehabilitation, especially where the occlusion is to be "restored." The investigators found that, for each person, the physiologic rest position of the mandible is constant throughout life. Since this position is not dependent upon age or the presence of teeth, it is a valuable basic landmark. It establishes the lower limit of the free-way space which exists between natural or artificial teeth of opposing arches when the jaw is at rest. Although the amount of this space varies considerably from person to person, it has been shown that the minimum amount of free-way space

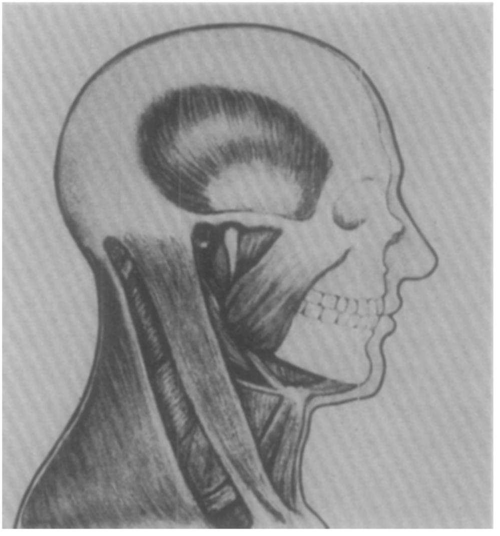


Fig. 1.—The postcervical muscles, muscles of mastication, depressors of the mandible, and infrahyoid muscles form a chain with the cranium, mandible, and hyoid bone interposed. Equilibrium of the muscles at rest maintains the anteroposterior position of the head and the physiologic rest position of the mandible.

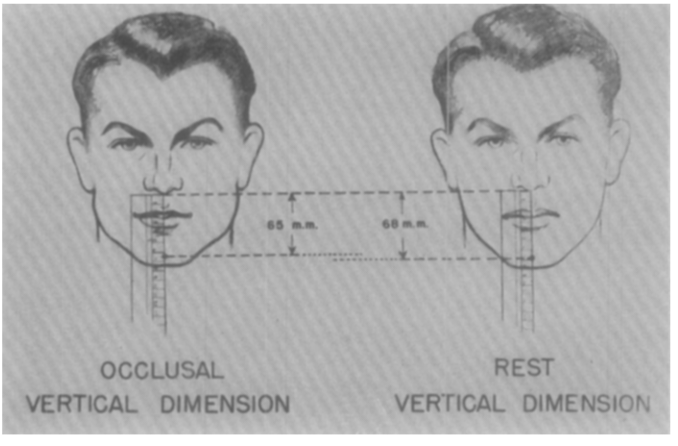


Fig. 2.—The difference between the rest vertical dimension and the occlusal vertical dimension indicates the amount of free-way space present anteriorly in the midline.

which is tolerable is approximately 3 mm. This indicates that the acceptable occlusal vertical dimension for each case should be at least 3 mm. less than the rest vertical dimension. We must remember that, although 3 mm. is considered to be the average minimum free-way space necessary, many patients do require more and that it is always best to compromise on the side of slight overclosure if the tolerable opening is at all in doubt. Reduction of the space

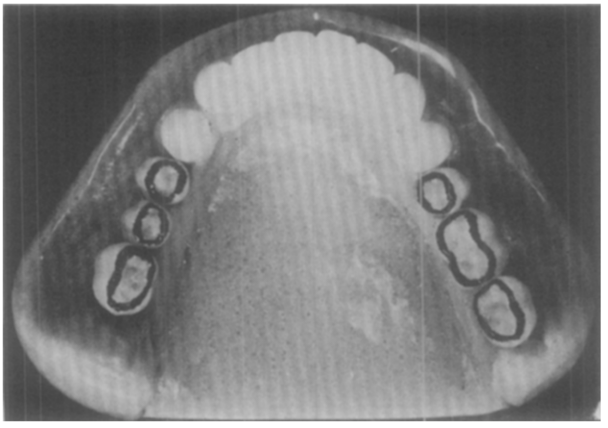


Fig. 3.—Use of the large occlusal area on the right side would result in overloading of the ridge. Proper reduction is obtained on the left by substituting a bicuspid for the first molar.

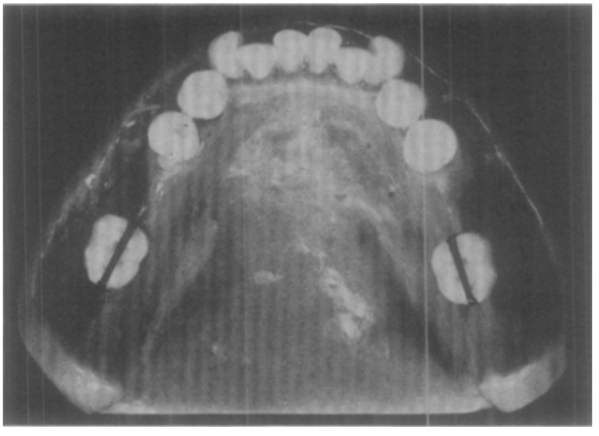
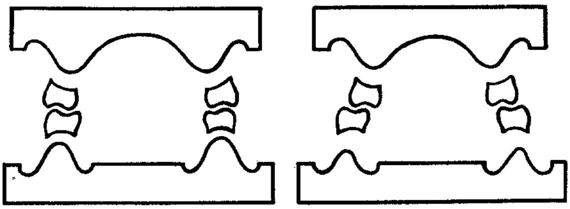


Fig. 4.—Tipping leverages and strain on abutment teeth result when restored teeth are placed outside the ridge. The leverages are eliminated by setting the teeth on the ridge or slightly to the lingual side as shown on the right.

by unduly increasing the vertical dimension of occlusion brings the teeth into premature contact during mastication and swallowing. This repeatedly subjects the periodontal membrane and bone to extremely damaging forces. If dentures are present, the ridges are traumatized and resorption ensues until the minimal free-way space is re-established.

CONTROL OF FORCES OF MASTICATION

No step is more important in planning the denture than that of determining the means by which the forces of mastication may be controlled and distributed most favorably among the remaining teeth and edentulous ridges. If the denture transmits forces which are within the physiologic limit of tolerance of the tissues, the effect will be that of beneficial stimulation. However, if the stresses produce overstimulation, trauma will result, and retrograde processes will follow. The information obtained through the oral and roentgenographic examinations provides the knowledge necessary to determine the ability of the individual teeth and ridges to tolerate the additional loads to be imposed upon them by the denture. This knowledge must be incorporated into the design of the appliance for the ultimate preservation of the tissues.



A. *B.*

Fig. 5.—*A*, Normal ridge and tooth relationships. *B*, Excessive ridge resorption increases the need for crossbite relationships.

The two major factors involved in controlling the forces of mastication are, first, the reduction of the amount of force imparted to the denture during mastication and, second, the wide distribution of the forces to the tissues.

The amount of force imposed upon the denture may be reduced by maintaining the sharpness of tooth cusps and by decreasing the size of the food table. The use of large molds of teeth should be avoided wherever possible. It is preferable to select smaller teeth or to reshape their contours so that minimum buccolingual and mesiodistal dimensions are obtained. Frequently, it is possible to omit certain teeth from the arch or to substitute bicuspids for first molars in the setup. The force imparted to the denture may be further limited by setting the teeth in favorable positions in relation to the ridges. If the teeth are placed directly over the ridges or slightly to the lingual side of the crest of the ridge, denture stability is improved, and troublesome tipping leverages are eliminated. In some instances it is necessary to create end-to-end or crossbite relationships to maintain satisfactory tooth positions. This is often the situation with advancing age, where the dissimilar manner of resorption in opposing dental arches creates a difficult problem. Resorption of the mandibular ridge is rapid from the lingual aspect toward the buccal; this increases the width of the arch. Resorption of the maxilla is more pronounced from the buccal toward the lingual aspect; this decreases its width. The relative widths of the arches, therefore, become progressively less favorable, making the need for crossbite relations more urgent.

DISTRIBUTION OF FORCE

Suitable means for reduction of force having been planned, the next requirement is to determine the most favorable means of controlling and distributing force which the denture does receive. We readily recognize the need to resist forces tending to dislodge the denture. However, there is a general tendency in denture planning to give the factor of retention of the appliance consideration out of proportion to its real importance. Other forces which are potentially more damaging must receive their full share of attention. It is, therefore,

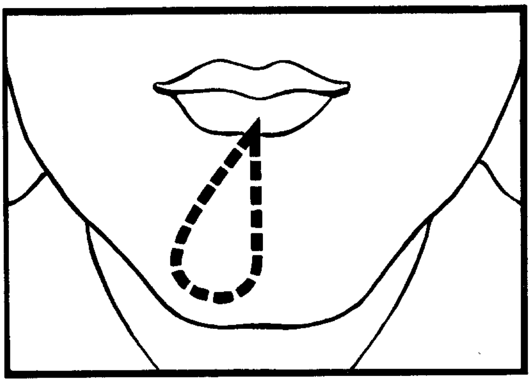


Fig. 6*A*.—A stylized pattern of mandibular movements associated with the chewing cycle.

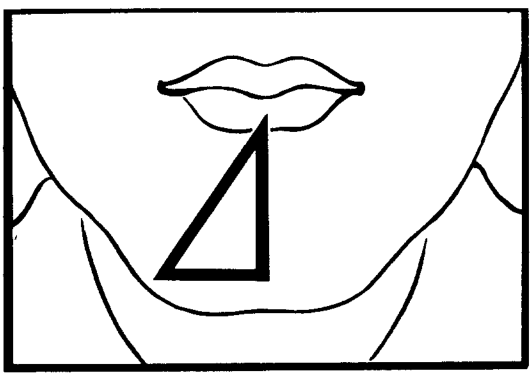


Fig. 6*B*.—Simplification of the chewing pattern into three major directions of movement.

necessary to analyze all of the forces set up during mastication to determine the manner in which the stresses are imparted to the denture and passed on to the teeth and edentulous ridges. When this is done, we are better able to determine suitable means of countering these forces.

While the term "forces of mastication" indicates the dynamic forces generated during function, it does not carry with it a graphic picture of the character of the forces. They are better understood and described when associated with the various movements of the mandible during mastication.[4]

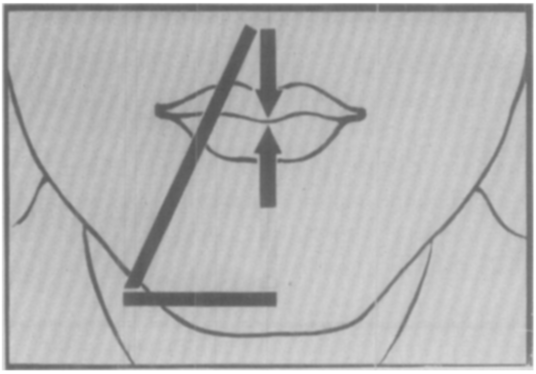


Fig. 6C.—The opening movement of the mandible is accompanied by vertical forces which tend to dislodge the denture. Resistance to these forces is retention.

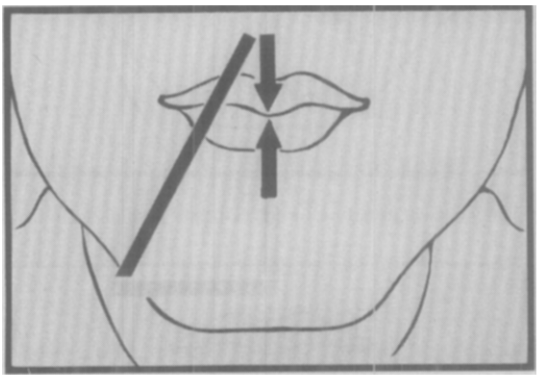


Fig. 6D.—The lateral swing of the mandible to the working side is accompanied with very little force. It may be disregarded in denture planning.

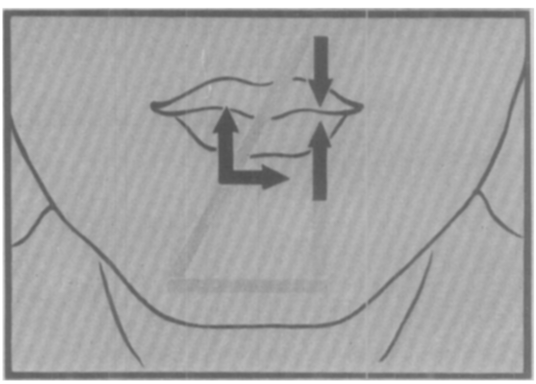


Fig. 6E.—Force set up by the third movement to penetrate the bolus of food is comprised of two main components. Resistance to the horizontal component is termed bracing, while resistance to the vertical component is called support.

For descriptive purposes we may assume that there are three principal directions of movement of the mandible during chewing. The first is a vertical drop of the jaw as the mouth opens to position a bolus of food. This movement is accompanied by forces which tend to dislodge the denture. These are countered by direct and indirect retainers on the appliance. The second direction of movement occurs as the mandible approaches the bottom of the vertical opening movement and swings laterally to engage the food on the working side. Very little force is associated with this movement, so it is disregarded in denture planning. The third, and final, movement is diagonally upward and inward as the bolus is penetrated and the teeth are returned toward centric occlusion. The force set up by this action is comprised of two main components, one horizontal, the other vertical. When these components of force are imposed upon the denture, they are transmitted by the denture to the tissues in the same manner that the weight of a man standing on a ladder is transmitted by the bottom of the ladder to the ground and by the top of the ladder to the surface against which it leans. In the case of the denture, various parts of the appliance pass the forces on to the teeth and ridges which must accept the additional vertical and horizontal loads.

In considering the problem of countering the forces, we may refer to resistance to horizontal forces as *bracing*, while resistance to vertical forces against the teeth and ridges is called *support*. The term *retention* refers to resistance to dislodging vertical force. We may say then that there are three major factors involved in opposing the action of the forces of mastication. They are: bracing, support, and retention.

BRACING

Abutment teeth and ridges may be placed under great stress by horizontal forces set up during the diagonal closing movement of the mandible. These forces, which may be imparted by direct horizontal thrusts or by the shifting of free-end saddles, are potentially very damaging to oral tissues. On this account, the forces must be dispersed by bracing in such a manner that no tissue is taxed beyond its biologic limit.

As a means of distributing the force and reducing strain in localized areas, all connectors between saddles, clasps, and other parts of the denture are made rigid. By doing this, we obtain the effect seen in the classical example of the fourteen-unit fixed bridge which gave years of service, in spite of the fact that it had only four abutments. The rigidity of this type of appliance caused the teeth to act in unison during mastication, thus preventing damage to any single tooth. Likewise, when rigid connectors are used on the partial denture, force imparted to any point on the denture is transmitted throughout the appliance and delivered to all of the teeth and the edentulous ridges. Here, as with the fixed restoration, the mutual assistance of all parts greatly reduces the hazard of trauma.

In planning distribution of force by the partial denture, it is well to keep in mind the relative abilities of the tissues to bear stress. The denture design should either allow concentration of force in areas of greatest tolerance or provide wide distribution of force to insure that each tooth or area receives only the fractional part of the load it can withstand without damage. With poor ridges and weak teeth, it is imperative to obtain optimum ridge coverage and to utilize additional teeth for bracing.

In those cases where we find that some of the abutments are relatively stronger than the others, the denture should be planned to deliver more of the horizontal thrust to the strongest teeth. Through the proper selection of retainers we can control the amount of force delivered to an abutment to some extent. This is possible because the different degrees of flexibility possessed by various types of clasps give each a different bracing potentiality. For instance, the cast circumferential clasp is relatively rigid and well suited to the strongest abutment teeth. It transmits most of the force it receives directly

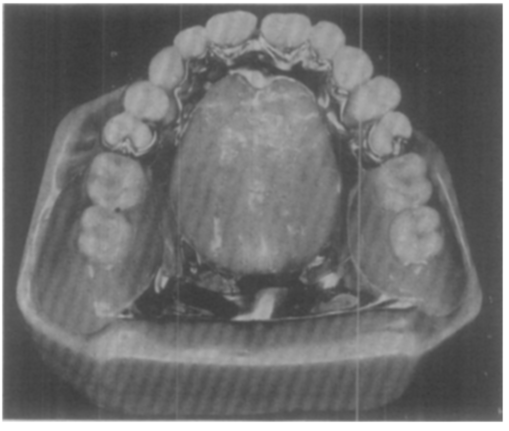


Fig. 7.—The denture is well braced because rigid primary and secondary bars transmit horizontal force to most of the remaining teeth and to large areas of the edentulous ridge through the extensive saddles.

to the tooth and so provides the best bracing effect. In contrast to this, many of the Roach-type clasps transmit force with less impact because of the flexibility of their arms. These clasps have wide use because, by increasing or decreasing the flexibility, the amount of force transmitted may be varied to suit the biologic tolerance of the abutments. And finally, the least amount of force is delivered with the least impact when the unreinforced wrought-wire clasp is used. Although these clasps provide the poorest bracing, they are ideally adapted to protect the weakest abutment teeth. Frequently, tooth stability is improved rather than adversely affected by the denture when the clasps have been properly selected and applied.

The value of saddles or other bases for further bracing should not be overlooked. They provide an excellent means of utilizing the slopes of ridges, the rugae area of the palate, and the surfaces of the tuberosities to oppose horizontal forces. For the best bracing effect, saddles should be extended to give wide coverage comparable to that used for a complete denture in the same relative area.

When extensive saddles are used with rigid connectors and properly selected clasps, effective bracing is obtained, torque is reduced, and horizontal forces are controlled.

SUPPORT

The second major component of force associated with the diagonal closing movement of the mandible is directed vertically toward the ridges and the occlusal surfaces of the teeth. The means by which this force should be distributed to the tissues is the subject of considerable controversy. The greatest difference of opinion concerns the best method of utilizing tooth and ridge support when free-end saddle extensions are employed. The literature reveals that three major schools of thought seek to provide a solution to the problem.[5] One believes that functional basing of the denture will give the most satisfactory

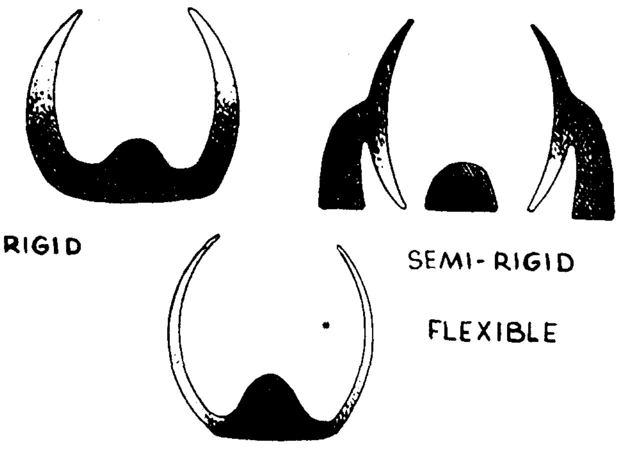


Fig. 8.—Clasps classified for descriptive purposes according to the degree of flexibility they possess in relation to each other.

results by making maximum use of the resilient mucosa. Another feels that stress must be broken between the saddle and the abutment for protection of the tooth. The third finds that wide distribution of force is essential to success. This latter method is undoubtedly employed more than all others combined by both the prosthetic specialist and the general practitioner. Because of its wide acceptance and adaptability to all classes of practice, the theories of broad distribution for the control and reduction of stress will be discussed here.

The problem in the dispersal of the vertical forces of mastication is to obtain stability of the denture without overstimulation and destruction of the tissues supporting the appliance. If the support is insufficient, excessive movement of the denture results, with settling of the saddles and loosening of the abutments. The vertical forces must therefore be positively controlled and countered by combined tooth and mucosa support through the use of multiple rests and adequate saddles.

The rest acts not only as a stop to stabilize against movement of the denture, but also as a means of transmitting vertical force to the abutment. Since the stress is ultimately borne by the periodontium, it should be delivered to as many teeth as is practicable by the occlusal rests of clasps and by additional rests placed especially for dispersal of stress.

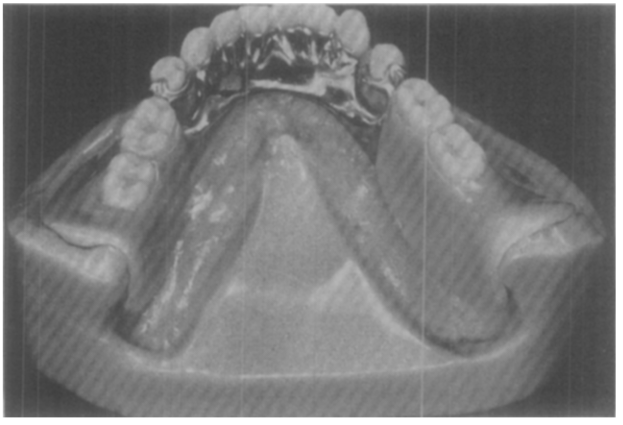


Fig. 9.—Wide distribution of vertical stress is obtained by the use of a rigid connector with broad saddles and properly applied rests. The lingual plate permits bracing against numerous teeth and provides indirect retention.

The direction in which the forces are applied to the abutment is extremely important. It has been shown that the investing tissues can best tolerate stress which is directed parallel to the long axis of the tooth. On this account the rest seat is prepared at right angles and as close to the central axis of the tooth as possible so as to direct the force in the most favorable manner. This is readily accomplished in cast restorations where a box-type preparation can be made. However, precautions must be taken when placing the rest seat in the enamel. By cutting the seat spoon-shaped, the risk of penetrating the enamel is minimized, and the area is made somewhat self-cleansing. Polishing of the preparation reduces the hazard of decalcification.

Rests should not be placed upon unprepared sloping lingual or incisal surfaces of individual anterior teeth because, when masticating forces are applied to the denture, the rests tend to skid down the inclined surfaces, producing a wedging effect capable of rapidly moving the abutments out of position. Anterior teeth must receive the same careful preparation as do the posterior teeth for the placement of rests. The step-type seat may be made in the mesial or distal angle of the tooth for the use of an incisal rest, or the seat may be placed in the enamel of the cingulum for a lingual rest. Although both of these rests control the direction of force when they are properly applied, each has an outstanding disadvantage. The incisal rest has the objection of being too far removed from the central axis, while the lingual rest is limited in use because the thinness of the cingulum enamel makes development of a positive seat difficult, if not impossible, in many instances. A more ideal preparation may be made in an inlay placed in the proximal and lingual surfaces of the abutment tooth. The forces are then positively controlled, and the hazard of caries is eliminated.

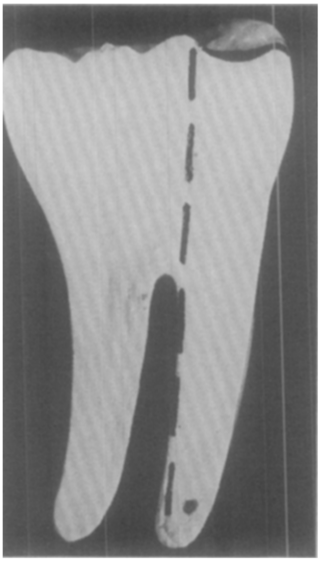


Fig. 10*A*.—The floor of the rest seat is made spoon shaped and at right angles to the long axis of the tooth.

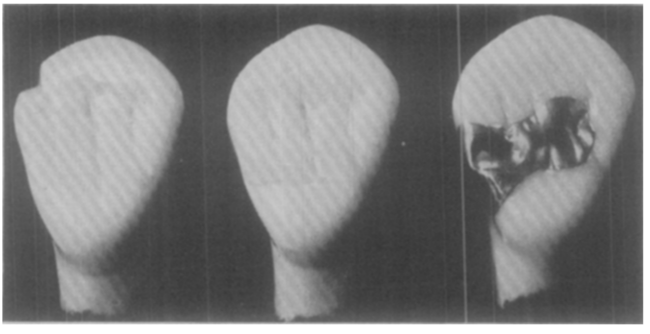


Fig. 10*B*.—Cuspid teeth prepared for the use of incisal and lingual rests.

While individual teeth which support rests always require previous preparation, groups of strong anterior teeth may occasionally be used without alteration to resist vertical stresses. By placing lingual straps, lingual plates, or palatal plates upon the cingula of these groups of teeth, the forces are dispersed over a large area. Although the load falls upon the teeth at an angle, trauma is prevented because the force is split into small components which can be tolerated by the periodontal membrane and bone surrounding each tooth.

The support gained from edentulous ridges gives the denture much of its stability, particularly where free-end saddles are employed. The saddles must be well adapted and fully extended to utilize all of the support available. The snowshoe effect, gained through wide coverage, protects the tissues by spreading vertical force over a large area. When the support is inadequate where the denture is borne largely by the resilient mucosa, a pump-handle action of the saddle occurs. This places the ridges and abutment teeth under excessive stress. If the adequacy of the support is questionable because of poor ridges or weak teeth, it is well to reconsider the size of the food table, tooth position, and other factors to determine further means of reducing the load which the tissues must resist.

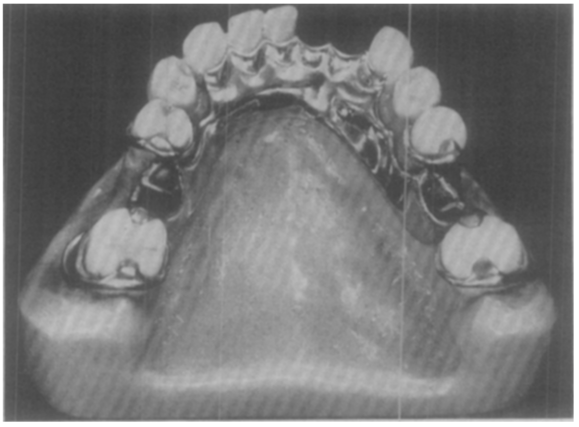


Fig. 11.—Vertical stress distribution is obtained by the use of multiple rests and the lingual plate. Force applied to the replaced incisors will be borne by all of the remaining anterior teeth.

While opposing stress, the denture which is properly supported by the teeth and mucosa will produce a beneficial stimulation of the tissues. The integrity of the periodontium and ridges will be preserved, and accuracy of adaptation will be prolonged.

RETENTION

The term retention indicates resistance to gravity, the pull of sticky foods, and the displacing effects of the tongue and cheeks on the partial denture during the opening movement of the mandible. The forces working to unseat the denture are not great in magnitude, but their constant or frequent application gives them the ability to cause damage. Adverse effects occur as a result of uncontrolled transmission of stress by the retainers to the abutments.

To prevent soreness, movement, or loosening of the teeth by clasps, it is necessary to counter the force imparted by each clasp arm with a reciprocating arm on the opposite side of the tooth. The second arm must be strong enough to oppose the forces which are applied against it and must engage more than

180 degrees of the circumference of the tooth to retain the abutment in position. An additional advantage of this encirclement is that it cradles tilted teeth and neutralizes their natural tendency to tip farther.

Nowhere is the need for proper reciprocation more necessary than in the clasping of single anterior teeth. Here, if a rest seat does not positively prevent the lingual arm of the clasp from skidding gingivally on the inclined surface of the tooth, wedging occurs in a labial direction. If the reciprocating arm is not provided or is inadequate, the periodontal membrane and labial plate of bone may be subjected to traumatic stresses which can lead to the eventual loss of the tooth.

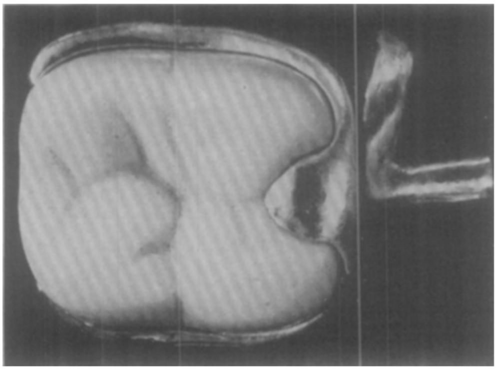


Fig. 12.—Clasp arms embrace more than 180 degrees of the tooth's circumference, and remain passive unless actively retaining the denture.

Minor but annoying symptoms occasionally develop after the denture has been worn for a short period of time because of pressure from the clasps. If the balance between the arms of a clasp is upset by processing errors, careless adjustment, or accident, stress is exerted which produces soreness and a slight shifting of the abutment. In contrast, the well-designed and well-adjusted clasp assumes a passive or static condition after the clasp arms have passed over the height of contour and into the retentive areas of the tooth. No pressure is then exerted by the clasps except when they are actively retaining the denture.

The pull of sticky foods and gravity exert a strong influence to unseat the denture from the ridges during mastication. When this pull is exerted on free-end saddles, the saddle acts as a working arm or lever whose fulcrum is the adjacent clasped tooth. The leverage amplifies the effect of the dislodging force and places the tooth under rocking stresses unless the rotating movement of the denture is restrained. Fortunately, the movement is easily controlled by the use of indirect retainers, which may be any extensions of the denture beyond the fulcrum point. Precautions must be observed, however, in the use of extension fingers such as those commonly employed to control rotation. They should not be placed indiscriminately on the lingual slopes of individual anterior teeth because they produce undesirable thrusts similar to rests improperly placed on these teeth. Here again, it is preferable to use lingual or palatal plates to distribute the force to additional teeth.

The stabilizing effect of well-constructed direct and indirect retainers protects the teeth, increases efficiency, and gives the patient a greater sense of confidence in the use of the denture.

CONCLUSION

No stereotyped technique or method of replacement is possible in partial denture practice because of the myriad of variations which occur in partially edentulous mouths. Each case must be evaluated according to its own physical and physiologic requirements and restored according to sound fundamental principles.

Our training and experience have given us our present concept of restoration by relating the mechanical influence of the denture to the biologic behavior of the tissues. In applying this concept, we have the advantage of new materials and techniques which enable us to fabricate with fine precision any type of restoration which the case may require. However, we are seriously limited from further progress by lack of research to reveal the entire influence of the denture upon the oral structures. Many pertinent questions which may have a direct bearing on the rate and extent of advancement in this field remain to be answered. For example, we should learn from the compilation of scientific data: (1) How much can the functional stress on abutment teeth actually be altered by changes in denture design? (2) Does the breaking of stress materially contribute to prolonged preservation of tissues, or does it favor eventual retrograde changes because of overstimulation of the ridges? (3) Exactly how much is the vertical chewing force lessened when the size of the food table is reduced by one-fourth? (4) What are the exact horizontal and vertical forces resulting from masticatory function when various types of anatomic and nonanatomic teeth are used?

The answers to these and many other questions must be provided to eliminate the unknown factors which play such a vital part in the success or failure of our partial denture service.

Ultimate findings may prove our present concepts to be in error in some respects, but they will provide us with an accurate guide, and perhaps a new approach, to solution of the problems we encounter. However, in the interim we must continually strive to further our aim of providing the best possible restorative service with the knowledge currently available to us.

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