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Review article

Biomechanics and clinical implications of complete edentulous state

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ABSTRACT

The edentulous state represents a compromise in the integrity of the masticatory system. It is frequently accompanied by adverse functional and esthetic sequelae, which are varyingly perceived by the affected patient. Perceptions of the edentulous state may range from feelings of inconvenience to feelings of severe handicap because many regard total loss of teeth as equivalent to the loss of a body part. Consequently, the required treatment addresses a range of biomechanical problems that involve a wide range of individual tolerances and perceptions.

1. Introduction

The heterogeneous etiology of edentulism has been tackled on several worldwide fronts by the dental profession, resulting in a reported decrease in the numbers of edentulous persons. Research has demonstrated that several nondisease factors such as attitude, behavior, financial, dental attendance, and characteristics of the health care system play an important role in the decision to become edentulous.[1]

The clinical implications of an edentulous stomatognathic system are considered under the following factors: (1) modifications in areas of support (natural dentition vs. complete denture); (2) functional and parafunctional considerations; (3) changes in morphologic face height, and temporomandibular joint (TMJ); and (4) cosmetic changes and adaptive responses.

2. Modifications in areas of support (natural dentition vs. complete denture)

2.1. Support mechanism for the natural dentition

The masticatory system is made up of closely related morphological, functional, and behavioral components. Their interactions are affected by changes in the mechanism of support for a dentition when natural teeth are replaced by artificial or prosthetic ones.[2]

Teeth function properly only if adequately supported, and this support is provided by the periodontium, an organ composed of soft and hard connective tissues. The periodontium attaches the teeth to the bone of the jaws, providing a resilient suspensory apparatus resistant to functional forces. It allows the teeth to adjust their position when under stress.

The periodontal ligament provides the means by which force exerted on the tooth is transmitted to the bone that supports it. The two principal functions of the periodontium are support and positional adjustment of the tooth, together with the secondary and dependent function of sensory perception. The patient who needs complete denture therapy is deprived of periodontal support, and the entire mechanism of functional load transmission to the supporting tissues is altered.

The occlusal forces exerted on the teeth are controlled by the neuromuscular mechanisms of the masticatory system.[3] Reflex mechanisms with receptors in the muscles, tendons, joints, and periodontal structures regulate mandibular movements. The most prominent feature of physiological occlusal forces is their intermittent, rhythmic, and dynamic nature. The greatest forces acting on the teeth are normally produced during mastication and deglutition, and they are essentially vertical in direction. Each thrust is of short duration, and for most people, chewing is restricted to short periods during the day. Deglutition, by contrast, occurs about 500 times a day (Zemlin, 1998), and tooth contacts during swallowing are usually of longer duration than those occurring during chewing.

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Loads of a lower order but longer duration are produced throughout the day by the tongue and circumoral musculature. These forces are predominantly in the horizontal direction. During rest or inactive periods, the total forces may be of similar magnitude. During mastication, biting forces are transmitted through the bolus to the opposing teeth whether or not the teeth make contact.[4] These forces increase steadily (depending on the nature of the food fragment), reach a peak, and abruptly return to zero. The direction of the forces is principally perpendicular to the occlusal plane. Upper incisors may be displaced labially with each biting thrust, and these tooth movements probably cause proximal wear facets to develop.

It has been calculated that the total time during which the teeth are subjected to functional forces of mastication and deglutition during an entire day amounts to approximately 17.5 minutes[5] (Table 1). More than half of this time is attributable to jaw closing forces applied during deglutition. Therefore, the total time and the range of forces seem to be well within the tolerance level of healthy periodontal tissues. It must be emphasized that the collective forces acting on a prosthetic occlusion are not likely to be controlled or attenuated as effectively as they appear to be by the natural dentition. Consequently, the time-dependent response of complete denture tissue support will manifest itself differently from those changes observed in the natural dentition.

2.2. Support mechanism for complete dentures

2.2.1. Mucosal support and masticatory loads

The area of mucosa available to receive the load from complete dentures is limited when compared with the corresponding areas of support available for natural dentitions. Researchers have computed the mean denture bearing area to be 22.96 cm^2 in the edentulous maxillae and approximately 12.25 cm^2 in an edentulous mandible.[6] Furthermore, the mucosa demonstrates little tolerance or adaptability to denture wearing. This minimal tolerance can still be reduced further by the presence of systemic diseases such as anemia, hypertension, or diabetes, as well as nutritional deficiencies. In fact, any disturbance of the normal metabolic processes may lower the upper limit of mucosal tolerance and initiate inflammation.

2.2.2. Residual ridge

The residual ridge consists of denture-bearing mucosa, the submucosa and periosteum, and the underlying residual alveolar bone. A variety of changes occur in the residual bone after tooth extraction and use of complete dentures.[7] The alveolar bone supporting natural teeth receives tensile loads through a large area of periodontal ligament, whereas the edentulous residual ridge receives vertical, diagonal, and horizontal loads applied by a denture with a surface area much smaller than the total area of the periodontal ligaments of all the natural teeth that had been present.

One of the firm facts relating to edentulous patients is that wearing dentures is almost invariably accompanied by an undesirable and irreversible bone loss. The magnitude of this bone loss is extremely variable. So the dentist must take care for the preservation and protection of any remaining teeth to minimize or avoid advanced residual ridge reduction. The compromised support is further complicated because complete dentures move in relation to the underlying bone during function. So the construction of complete denture should be formulated to minimize the force transmitted to the supporting structure or to decrease the movement of the prosthesis in relation to them.

There are two physical factors involved in denture retention that are under the control of the dentist and are technique driven. One is the maximal extension of the denture base and the other maximal intimate contact of the denture base and its basal seat.

Muscular factors can be used to increase retention and stability of the dentures. In fact, the buccinator, the orbicularis oris, and the intrinsic and extrinsic muscles of the tongue are the key muscles that the dentist harnesses to achieve this objective by means of impression techniques. The design of the labial buccal and lingual polished surface of the denture and the form of the dental arch are considered in balancing the forces generated by the tongue and perioral musculature.

Table 1
Calculation of total time of oral tissue under chewing force per day.

Chewing	
Actual chewing time per meal	450 s
Chewing time for 4 meals/d	1800 s*
1 chewing stroke	0.3 s
Total time of chewing forces/d (1 chewing stroke × 4 meals)	540 s (9 min)
Swallowing	
During meals	
Duration of 1 deglutition	1 s
During chewing 3 deglutitions/min	1800 s* (30 min) × 3/3 = 30 s
One-third of force than the occlusal force	(0.5 min)
In between meals	
Daytime 25 s/h (16 h)	400 s (6.6 min)
Night-time 10 s/h (8 h)	80 s (1.3 min)
Total	1050 s (17.5 min)

3. Function: mastication and other mandibular movements

Mastication consists of a rhythmic separation and apposition of the jaws and involves biophysical and biochemical processes, including the use of the lips, teeth, cheeks, tongue, palate, and all the oral structures to prepare food for swallowing. During masticatory movements, the tongue and cheek muscles play an essential role in keeping the food bolus between the occlusal surfaces of the teeth. The teeth must be placed within the confines of a functional balance of the musculature involved in controlling the food bolus between the occlusal surfaces of the teeth.

Clinical experience suggests that the quality of the prosthetic service may have a direct bearing on the denture wearer's masticatory performance. The maximal bite force in denture wearers is five to six times less than that in dentulous individuals.[8] Edentulous patients are clearly handicapped in masticatory function, and even clinically satisfactory complete dentures are a poor substitute for natural teeth.

The pronounced differences between persons with natural teeth and patients with complete dentures are conspicuous in this functional context: (1) the mucosal mechanism of support as opposed to support by the periodontium; (2) the movements of the dentures during mastication; (3) the progressive changes in maxillomandibular relations and the eventual migration of dentures; and (4) the different physical stimuli to the sensor motor systems.

The denture-bearing tissues are constantly exposed to the frictional contact of the overlying denture bases. Dentures move during mastication because of the dislodging forces of the surrounding musculature. These movements manifest themselves as displacing, lifting, sliding, tilting, or rotating of the dentures. Furthermore, opposing tooth contacts occur with both natural and artificial teeth during function and parafunction when the patient is both awake and asleep.

Apparently, tissue displacement beneath the denture base results in tilting of the dentures and tooth contacts on the nonchewing side. In addition, occlusal pressure on the dentures displaces soft tissues of the basal seat and allows the dentures to move closer to the supporting bone. This change of position under

pressure induces a change in the relationship of the teeth to each other.

3.1. Parafunctional considerations

Parafunctional habits involving repeated or sustained occlusion of the teeth can be harmful to the teeth or other components of the masticatory system.[9] Teeth clenching is common and is a frequent cause of the complaint of soreness of the denture-bearing mucosa. In the denture wearer, parafunctional habits can cause additional loading on the denture-bearing tissues (Table 2).

The initial discomfort associated with wearing new dentures is known to evoke unusual patterns of behavior in the surrounding musculature. Frequently, the complaint of a sore tongue is related to a habit of thrusting the tongue against the denture. The patient usually is unaware of the causal relationship between the painful tongue and its contact with the teeth.

4. Changes in morphology (face height), occlusion, and the TMJs

Maxillomandibular morphological changes take place slowly over a period of years and depend on the balance of osteoblastic and osteoclastic activity. The articular surfaces of the TMJs are also involved, and at these sites, growth and remodeling are mediated through the proliferative activity of the articular cartilages. In the facial skeleton, any dimensional changes in morphological face height or the jawbones because of the loss of teeth are inevitably transmitted to the TMJs.

Articular surfaces undergo a slow but continuous remodeling throughout life. Such remodeling is probably the means whereby the congruity of the opposing articular surfaces is maintained, even in the presence of dimensional or functional changes in other parts of the facial skeleton.

The reduction of the residual ridges under complete dentures and the accompanying reduction in vertical dimension of occlusion tend to cause a reduction in the total face height and a resultant mandibular prognathism. In fact, in complete denture wearers, the mean reduction in height of the mandibular residual alveolar ridge measured in the anterior region may be approximately four times greater than the mean reduction occurring in the maxillary residual alveolar process.[10]

4.1. Occlusion

The occlusion of complete dentures is designed to harmonize with the primitive and unconditioned reflex of the patient's unconscious swallow.[11] Tooth contacts and mandibular bracing against the maxillae occur during swallowing by complete denture patients. This suggests that complete denture occlusions must be compatible with the forces developed during deglutition to prevent disharmonious occlusal contacts that could cause trauma to the basal seat of dentures. During swallowing, the mandible is close to, in centric relation, or the position of maximum mandibular retrusion relative to the maxillae at the established vertical dimension of occlusion. It is conceded, nevertheless, that most functional natural tooth contacts occur in a mandibular position anterior to centric relation, a position referred to as centric occlusion.

However, in complete denture prosthodontics, the position of planned maximum intercuspation of teeth is established to coincide with the patient's centric relation.[12] The coincidence of centric relation and centric occlusion is consequently referred to as centric relation occlusion (CRG).

The centric occlusion position occupied by the mandible in the dentate patient cannot be registered with sufficient accuracy when the patient becomes edentulous. Consequently, clinical experience suggests that the recording of centric relation is the starting point in the design of an artificial occlusion.

Centric relation at the established vertical dimension has potential for change. This change is brought about by alterations in denture-supporting tissues and facial height, as well as by morphological changes in the TMJs. An appreciation for the dynamic nature of centric relation in denture-wearing patients, particularly in an aging context, recognizes the changing functional requirements of the masticatory system.

4.2. TMJ changes

The basic physiological relationship among the condyles, the disks, and their glenoid fossae appears to be maintained during maximal occlusal contacts and during all movements guided by occlusal elements.[13] The dentist should seek to maintain or restore this basic physiological relation. The border movements of the mandible are reproducible, and all other movements take place within the confines of the classic "envelopes of motion".[14] The reproducibility of the posterior border path is of tremendous practical significance in the treatment of patients undergoing prosthodontics.[15] It has also been reported that impaired dental efficiency resulting from partial tooth loss and absence of or incorrect prosthodontic treatment can influence the outcome of temporomandibular disorders.

5. Aesthetic, behavioral, and adaptive responses

5.1. Aesthetic changes

There is little doubt that tooth loss can adversely affect a person's appearance. Patients seek dental treatment for both functional and aesthetic or cosmetic reasons, and dentists have been successful in restoring or improving many a patient's appearance[16] (Table 3).

5.2. Behavioral and adaptive responses

The process whereby an edentulous patient can accept and use complete dentures is complex. It requires adaptation of learning, muscular skill, and motivation and is related to the patient's expectations. The patient's ability and willingness to accept and learn to use the dentures ultimately determine the degree of success of clinical treatment. Learning means the acquisition of a new activity or change of an existing one. The facility for learning and coordination appears to diminish with age. Advancing age tends to be

Table 2
Force generated during mastication and parafunction.

	Direction	Duration and magnitude
Mastication	Mainly vertical	Intermittent and light diurnal only
Parafunction	Frequently horizontal as well as vertical	Prolonged, possibly excessive Both diurnal and nocturnal

Table 3
Aesthetic changes associated with the edentulous state.

- Deepening of nasolabial groove
- Loss of labiodentals angle
- Narrowing of lips
- Increase in columella–philtral angle
- Prognathic appearance

accompanied by progressive atrophy of elements in the cerebral cortex, and a consequent loss in the facility of coordination occurs. A distinct need exists for dentists to be able to understand a patient's motivation in seeking prosthodontic care and to identify problems prior to starting treatment.[17]

Emotional factors are known to play a significant role in the etiology of dental problems. The interview and clinical examination are obvious ways to observe the patient and form the best treatment relationship. Successful management begins with identification of anticipated difficulties prior to when treatment starts and with careful planning to meet specific needs and problems. Dentists must train themselves to reassure the patient, to perceive the patient's wishes, and to know how and when to limit the patient's expectations.[18]

6. Conclusion

The role of prosthodontists is to gain an understanding of the changes in the form and function of the mouth and jaws, brought about by the total loss of teeth and the possible social and behavioral consequences of tooth loss. They should be able to critically evaluate the influence of complete dentures on the remaining soft tissues and the underlying bony structures so that it helps in understanding the scope and limitations of complete dentures together with the biocompatibility and physical properties of the materials used in their construction.

Conflicts of interest

The author has no conflicts of interest relevant to this article.

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