



Evolution of occlusion and temporomandibular disorder in orthodontics: Past, present, and future



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Occlusion has been an important consideration in orthodontics since the beginning of the discipline. Early emphasis was placed on the alignment of the teeth, the stability of the intercuspal position, and the esthetic value of proper tooth positioning. These factors remain important to orthodontists, but orthopedic principles associated with masticatory functions must also be considered. Orthopedic stability in the masticatory structures should be a routine treatment goal to help reduce risk factors associated with developing temporomandibular disorders. (Am J Orthod Dentofacial Orthop 2015;147:S216-23)

The role of occlusion and its impact on functional disorders of the masticatory system continues to be a resounding issue in orthodontics. This interest is appropriate because **orthodontists routinely and completely change a patient's occlusal conditions during therapy.** Orthodontic therapy can be likened to a full-mouth reconstruction by a prosthodontist; however, this therapy is accomplished in the natural dentition. Adding to this issue is the fact that most of these changes occur in young, healthy adults, so this is unlike any other dental specialty. It would therefore behoove orthodontists to be cognizant of the effects of these changes, since they will influence masticatory functions for each patient's lifetime.

Over the years, the role of occlusion on temporomandibular disorder (TMD) has been extensively debated, leading to many opinions and much controversy. **The purpose of this article is to review the history of occlusion and TMD as it relates to orthodontics.** Occlusal treatment goals will be reviewed as they relate to joint function. As a nonorthodontist, I am pleased to have this opportunity to share some thoughts on this subject.

Perhaps an outside voice may have a different perspective on this subject.

This article is divided into 5 sections: (1) the history of occlusion and TMD in orthodontics, (2) the role of orthodontic therapy in TMD, (3) current functional treatment goals for orthodontic therapy, (4) future considerations of occlusion for the orthodontist, and (5) conclusions.

HISTORY OF OCCLUSION AND TMD IN ORTHODONTICS

The history of orthodontics must begin with the work of Dr Edward Angle, considered the father of this specialty.¹ He founded the Angle School of Orthodontia in St Louis, Missouri, in 1900. **Dr Angle introduced the term "malocclusion"** to the dental profession as any abnormality in the dental configuration. He developed a classification of malocclusions that is still used today.² He generally divided the occlusion into 3 types: normal, or Angle Class I; a retrognathic jaw, or Angle Class II; and a prognathic jaw, or Angle Class III. These classifications were useful for communications between professionals and for research purposes.

At that time, interest in occlusion was primarily associated with esthetics. Sound occlusal stability with acceptable tooth angulations and centered midlines were needed to establish successful esthetics. Andrews³ proposed 6 basic keys to establishing a sound Angle Class I occlusion; these became well-accepted orthodontic treatment guidelines for finalizing the dental occlusion. Although these guidelines were useful, they had no reference to the joint position. Instead, the orthodontic specialty focused more on various treatment

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philosophies, such as fixed vs removal appliances, functional appliances to affect growth, and extraction vs nonextraction treatment. At that time, most orthodontists were taking their patients' casts, occluding the teeth, and grinding the backs of the casts on a model trimmer. This was done so that the backs of the casts could be placed on a table, and the teeth could be brought together in the maximum intercuspal position. The orthodontist could then evaluate the occlusion, but there was no reference to the patient's joint positions. There was little concern for jaw function.

By the mid-1970s and early 1980s, some orthodontists began to consider the importance of developing a sound occlusal position at the same time that the condyles were in a stable joint position. This concept had been considered for years by prosthodontists, who realized that a stable joint position was essential for a successful prosthodontic reconstruction. At that time, Dr Ronald Roth began to write a series of articles in the orthodontic literature suggesting the importance of joint positions in orthodontic therapy.⁴⁻⁷ According to Roth, orthodontic treatment goals can be divided into 5 categories: facial esthetics, dental esthetics, functional occlusion, periodontal health, and stability.⁸ The uniqueness of Dr Roth's goals was the inclusion of function. One of his suggestions was to use a dental articulator to better evaluate the relationship of the occlusal position to the joint position. He insisted that orthodontists needed to use a dental articulator for treatment planning and managing orthodontic patients. This became a debated and controversial concept. At the time, orthodontists were not routinely using articulators, and they all thought that they were successful with their patients. Why add this technique to improve an already successful treatment?

History suggests to us that sometimes outside forces can alter professional directions. This was true in 1987, when a lawsuit was filed by a patient claiming that the orthodontist caused her to suffer with a TMD.^{9,10} To the surprise of the scientific community, the patient won the lawsuit and received a sizable financial compensation. This successful lawsuit created much anxiety in the orthodontic community. Funds were then generated by orthodontic organizations for research needed to more completely understand the relationship, if any, between orthodontic therapy and TMD. The results of these studies will be discussed in the next section.

THE ROLE OF ORTHODONTIC THERAPY IN TMD

As interest in the relationship between TMD and orthodontic therapy grew, speculation also grew. There

were claims of orthodontic therapy's always causing TMD to claims of its never causing TMD. Similar claims were being made for certain types of orthodontic treatment: eg, that extraction of teeth always leads to TMD or never leads to TMD. The problem was that these concepts were based on clinical impressions and not on scientific evidence. The need for evidence was obvious, so the specialty began to study this relationship. By the mid-1990s, a series of studies became available that helped to answer this important question. It is not the purpose of this article to thoroughly review all these studies, but the data did not suggest that orthodontic therapy was a significant risk factor for the development of symptoms of TMD.¹¹⁻¹⁷ A review article has highlighted some of these studies.¹⁸ As these studies were published, orthodontists became more comfortable with the concept that their treatments were not a significant etiologic factor associated with TMD. This perception lowered the general anxiety about the original lawsuit. However, the question that must be asked is how these studies should be interpreted. Certainly, most of these studies were well designed, leading readers to conclude that orthodontic therapy is not a risk factor for TMD. Therefore, one might say that orthodontic therapy is simply unrelated to TMD. Although most orthodontists would be comfortable accepting this concept, such a broad statement is most likely too simple. A second consideration is that all the long-term studies on the relationship between orthodontic therapy and TMD have been accomplished with well-controlled orthodontic therapies. Almost all the studies were performed in university graduate training programs, where orthodontic therapies are well supervised and controlled. Perhaps poorly completed orthodontic therapies do reveal risk factors for TMD. Another consideration in interpreting these results is that many patients receiving the orthodontic therapy were young, healthy, and adaptive. Providing orthodontic therapy in a developing masticatory system may help patients to adapt to the occlusal changes and joint positions, rendering them less likely to have functional problems in the future. This variable has not been well studied and certainly is a consideration when it comes to TMD. Still another consideration in interpreting the results of these studies is that although orthodontic therapy does change the patient's occlusion, the occlusion is only one of several factors that are associated with TMD. A thorough review of the literature shows that there are at least 5 major etiologic factors that can be associated with TMD: occlusion, trauma, emotional stress, deep pain input, and parafunction.¹⁹ In addition to these variables is each patient's adaptability, which is still another factor that has yet to be well investigated.

The concept of patient adaptability is an important issue that is presently being explored. It has been demonstrated that variations in genetic makeup may have significant impacts on pain perception.^{20,21} The gene that encodes for catechol-O-methyl-transferase, an enzyme associated with pain responsiveness, varies in patients. There appear to be 3 clusters of persons who respond differently to a painful stimulus. Some are more sensitive to pain, whereas others are less sensitive. In an interesting prospective cohort study of 186 postorthodontic female patients, those who were genetically found to be in the pain-sensitive cluster developed more symptoms of TMD than did those in the pain-insensitive cluster.²² This suggests that perhaps the actual orthodontic therapy itself was not the significant factor in the developing TMD, but rather it was performing orthodontic therapy in a patient with a genetically determined pain-sensitive haplotype. Perhaps the future will help us to determine which patients are more vulnerable for developing pain disorders, and this might affect treatment options.

Therefore, assuming that orthodontic therapy is completely unrelated to TMD is a relatively naïve thought. The question that really needs to be asked is how orthodontic therapy can be used to minimize any risk factors that relate to TMD. Of the known etiologies of TMD, orthodontic therapy routinely affects only 1 factor: occlusion. However, even occlusal factors are not always related to TMD.^{18,19} So, where does orthodontic therapy fit into the big picture of TMD? Orthodontic therapy routinely alters a patient's occlusion. Since occlusal factors may be a potential source of TMD in some patients, it would seem logical that orthodontists should develop occlusal conditions that will minimize any risk factors that might be associated with TMD. However, developing a sound occlusal relationship does not mean that the patient will always be free of TMD. At least 4 other etiologies are outside the control of the orthodontist. Developing an orthopedically stable occlusal condition should be thought of as minimizing a dental risk factor. It seems logical that since orthodontic therapy will change the patient's occlusion, emphasis should be placed on creating an occlusal condition that will provide the best opportunity for successful masticatory function for the patient's lifetime.

CURRENT FUNCTIONAL TREATMENT GOALS FOR ORTHODONTIC THERAPY

As previously discussed, orthodontists' early concerns regarding occlusion were related to esthetics and intercusp-pal stability. Although these are important considerations

for successful orthodontic therapy, a greater concern for the patient's lifetime is developing a stable functioning masticatory system. A stable masticatory system includes a stable occlusal position in harmony with a stable joint position. To accomplish this, orthodontists need to appreciate basic orthopedic principles that lead to successful function. A lack of harmony between the occlusal position and the joint position may be a risk factor that potentiates dysfunction of the structures.

In establishing the criteria for the optimum orthopedically stable joint positions, the anatomic structures of the temporomandibular joint must be closely examined. The temporomandibular joint is made up of the condyle resting in the articular fossa with the articular disc interposed. The articular disc is composed of dense fibrous connective tissues, devoid of nerves and blood vessels.²³ This allows it to withstand heavy forces without damage or creating a painful stimulus. The purpose of the disc is to separate, protect, and stabilize the condyle in the mandibular fossa during functional movements. The articular disc, however, does not determine the positional stability of the joint. As in any other joint, positional stability is determined by the muscles that pull across the joint and prevent separation of the articular surfaces. The directional forces of these muscles determine the optimum orthopedically stable joint position. This is a basic orthopedic principle that is common to all mobile joints. Every mobile joint has a musculoskeletally stable position: the position stabilized by the activity of the muscles that pull across it. The musculoskeletally stable position is the most orthopedically stable position for the joint and can be identified by observing the directional forces applied by the stabilizing muscles.

The major muscles that stabilize temporomandibular joints are the elevators: temporalis, masseter, and medial pterygoid muscles. The force placed on the condyles by the temporalis muscles is predominantly in a superior direction. The temporalis muscles have some fibers that are oriented horizontally; however, because these fibers must traverse the root of the zygomatic arch, most of the fibers elevate the condyles in a straight superior direction.²⁴ The masseter and medial pterygoid muscles provide forces in a superoanterior direction, which seats the condyles superiorly and anteriorly against the posterior slopes of the articular eminences. These 3 muscles are primarily responsible for joint position and stability, but the lateral pterygoid muscles also contribute to joint stability by stabilizing the condyles against the posterior slopes of the articular eminences.

In the postural position, without influence from the occlusal condition, the condyles are stabilized by the muscle tonus of the elevator and the inferior lateral pterygoid muscles. The temporalis muscles position the

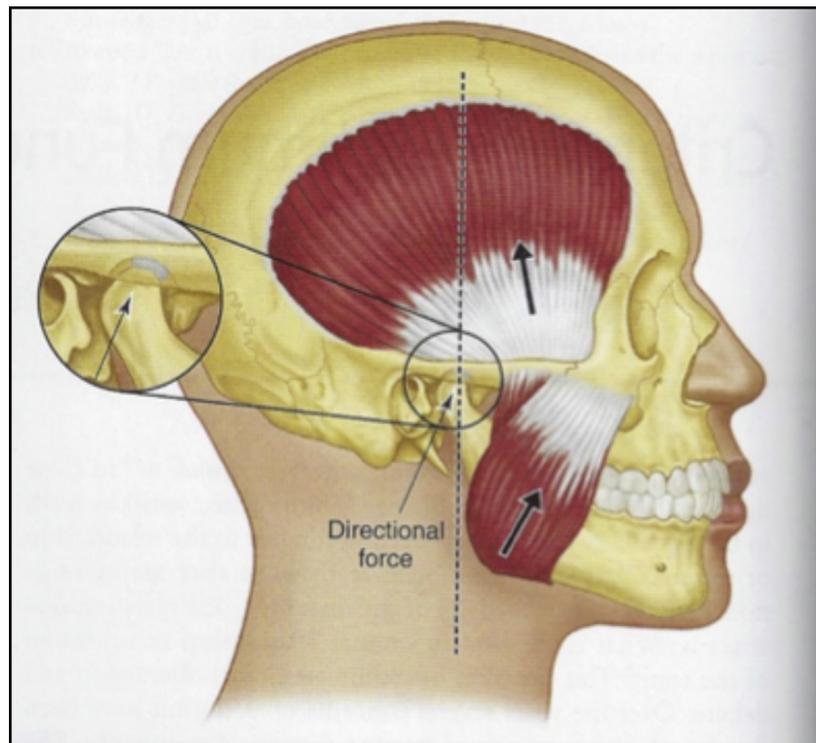


Fig 1. The directional forces applied to the condyles (*upper thick arrow*) by the temporal muscles are to seat the condyles in a superior position in the fossae. The directional forces applied to the condyles by the masseter and the medial pterygoid muscles (*lower thick arrow*) are to seat the condyles in a superior anterior position in the fossae (*thin arrow*). When these forces are combined with the lateral pterygoid muscle (not shown), the condyles are seated into their superior and anterior positions in the fossae against the posterior slopes of the articular eminences. Reprinted with permission from Okeson,¹⁹ p. 74.

condyles superiorly in the fossae. The masseter and the medial pterygoid muscles position the condyles superoanteriorly. Tonus in the inferior lateral pterygoid muscles positions the condyles anteriorly against the posterior slopes of the articular eminences (Fig 1).

Therefore, **the most orthopedically stable joint position as dictated by the muscles is where the condyles are located in their most superoanterior positions in the articular fossae, resting against the posterior slopes of the articular eminences.** This description is not complete, however, until the positions of the articular discs are considered. Optimum joint relationships are achieved only when the articular discs are properly interposed between the condyles and the articular fossae. Therefore, the complete definition of the most orthopedically stable joint position is when the condyles are in their most superoanterior positions in the articular fossae, resting against the posterior slopes of the articular eminences, with the articular discs properly interposed. This position is the most musculoskeletally stable position of the mandible.

An easy and effective method of locating the musculoskeletally stable position is the bilateral manual manipulation technique.^{19,25} This technique begins with the patient lying back and the chin pointed upward (Fig 2, A). Lifting the chin upward places the head in an easier position to locate the condyles near the musculoskeletally stable position. The dentist sits behind the patient and places the 4 fingers of each hand on the lower border of the mandible at the angle. The small finger should be behind the angle, with the remaining fingers on the inferior border of the mandible. The fingers must be located on the bone and not in the soft tissues of the neck (Fig 2, B and C). Next, both thumbs are placed over the symphysis of the chin so that they touch each other between the patient's lower lip and chin (Fig 2, D and E). When the hands are in this position, the mandible is guided by upward force placed on its lower border and angle with the fingers, while at the same time the thumbs press downward and backward on the chin. The overall force on the mandible is directed so that the condyles will be seated

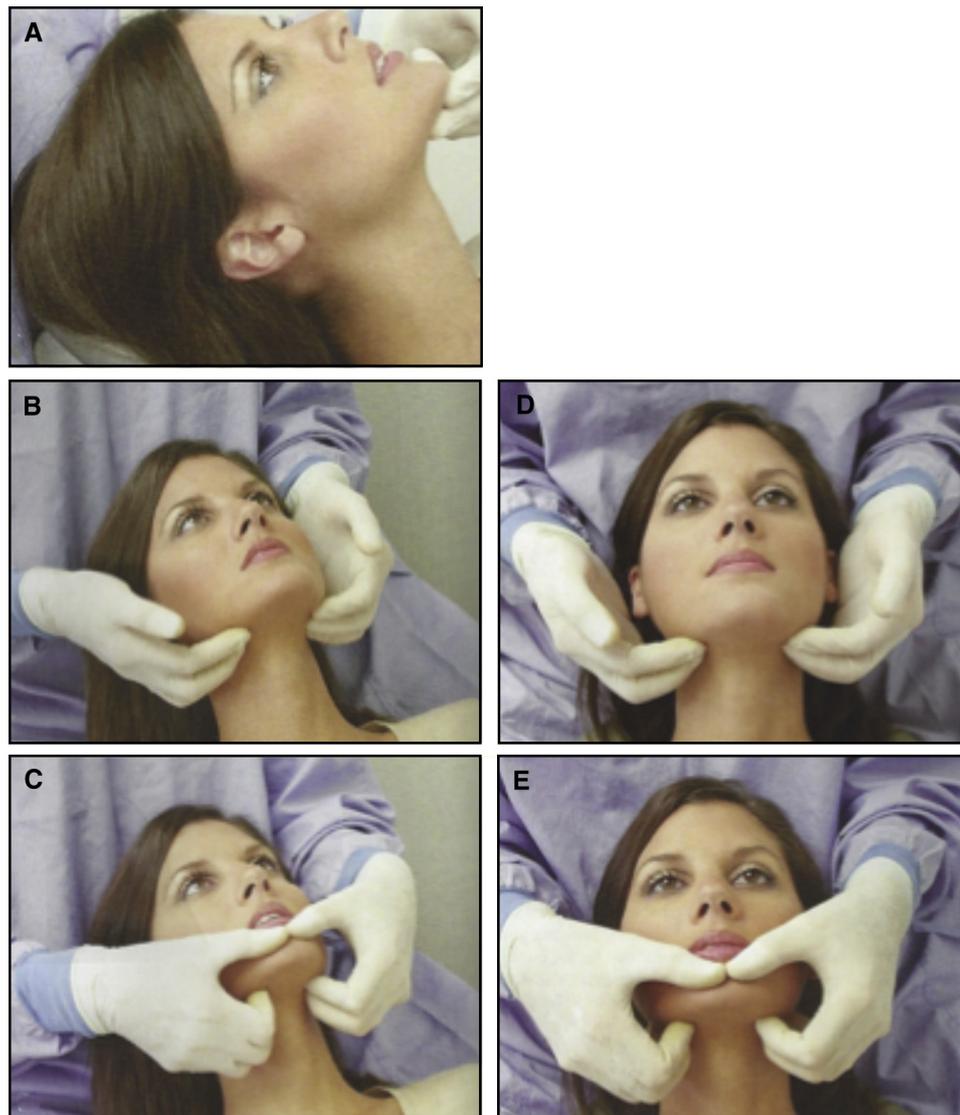


Fig 2. **A**, Successfully guiding the mandible into the musculoskeletally stable position begins with having the patient recline and directing the chin upward. **B**, The 4 fingers of each hand are placed along the lower borders of the mandible. The small finger should be behind the angle, with the remaining fingers on the inferior border of the mandible. An important point is to place the fingers on the bone and not in the soft tissues of the neck. **C**, The thumbs meet over the symphysis of the chin. **D** and **E**, Downward force is applied to the chin, while superior force is applied to the angle of the mandible. The overall affect is to set the condyle superiorly and anteriorly in the fossae, as depicted in Figure 1. Reprinted with permission from Okeson,¹⁹ p. 196.

in their most superoanterior position braced against the posterior slopes of the eminences. **Firm but gentle force is needed to guide the mandible so as not to elicit any protective reflexes.**

Locating the musculoskeletally stable position begins with the anterior teeth no more than 10 mm apart to ensure that the temporomandibular ligaments have not forced translation of the condyles. The mandible is

positioned with a gentle arcing until it freely rotates around the musculoskeletally stable position. This arcing consists of short movements of 2 to 4 mm. Once the mandible is rotating around the musculoskeletally stable position, **force is firmly applied by the fingers to seat the condyles in their most superoanterior positions.**

In this superoanterior position, the condyle-disc complexes are in the proper relationship to accept forces.

With such a relationship, guiding the mandible to this position should not produce pain. If pain is elicited, it is possible that some type of intracapsular disorder exists. When there is pain, an accurate mandibular position will probably not be found. Therefore, the reason for this pain needs to be investigated and managed before any orthodontic therapy.

The most orthopedically stable position just described does not consider the stabilizing effects of the structures at the other end of the mandible: the teeth. The occlusal contact pattern of the teeth also influences the stability of the masticatory system. When the condyles are in their most stable positions in the fossae and the mouth is closed, the teeth should occlude in their most stable relationship. The most stable occlusal position is the maximal intercuspation of the teeth. This occlusal relationship furnishes maximum stability for the mandible and minimizes the amount of force placed on each tooth during function.

In summary, the criteria for optimum orthopedic stability in the masticatory system would be to have even and simultaneous contact of all possible teeth when the mandibular condyles are in their most superoanterior position, resting against the posterior slopes of the articular eminences, with the discs properly interposed. In other words, the musculoskeletally stable position of the condyles coincides with the maximum intercuspation positions of the teeth.

One additional consideration in describing the occlusal condition is the fact that the mandible can move eccentrically, resulting in tooth contacts. These lateral excursions allow horizontal forces to be applied to the teeth, and horizontal forces are not generally well accepted by the dental supportive structures; yet, the complexity of the joints requires some teeth to bear the burden of these less-tolerated forces. When all the teeth are examined, it becomes apparent that the anterior teeth are better candidates to accept these horizontal forces than the posterior teeth because they are farther from the force vectors; this results in less force to these teeth. Of all the anterior teeth, the canines are the best suited to accept the horizontal forces during eccentric movements.²⁶⁻²⁸ They have the longest and largest roots and therefore the best crown-to-root ratio.²⁹ They are also surrounded by dense compact bone, which tolerates the forces better than does the medullary bone around the posterior teeth.³⁰

The laterotrusive contacts need to provide adequate guidance to immediately disclude the teeth on the opposite side of the arch (mediotrusive or nonworking side). When the canine is not available for this guidance, a group function should be provided. Efforts should be made to avoid nonworking-side guidance, since this

may introduce joint instability during certain eccentric parafunctional activities. When the mandible moves forward into protrusive contact, the anterior teeth should also provide adequate contact or guidance to disarticulate the posterior teeth.

The following is a summary of the conditions that provide optimum orthopedic stability in the masticatory system. This represents orthodontic treatment goals for all patients.

1. When the mouth closes, the condyles should be in their most superoanterior position (musculoskeletally stable), resting on the posterior slopes of the articular eminences with the discs properly interposed. In this position, there should be even and simultaneous contact of all posterior teeth. The anterior teeth may also contact but more lightly than the posterior teeth.
2. When the mandible moves into laterotrusive positions, there should be adequate tooth-guided contacts on the laterotrusive (working) side to immediately disclude the mediotrusive (nonworking) side. The canines (canine guidance) provide the most desirable guidance.
3. When the mandible moves into a protrusive position, there should be adequate tooth-guided contacts on the anterior teeth to immediately disclude all posterior teeth.
4. When the patient sits upright (in the alert feeding position) and is asked to bring the posterior teeth into contact, the posterior tooth contacts should be heavier than the anterior tooth contacts.³¹

When planning treatment for a patient, the musculoskeletally stable position should be located, and the relationship of the maxillary and mandibular teeth should be observed in this mandibular position. Since the orthodontic treatment goal is to develop the maximum intercuspation position of the teeth in this mandibular position, the orthodontist should select the proper orthodontic strategies that will accomplish this goal. In some instances, the orthodontist may find it useful to mount the patient's casts on an articulator in the musculoskeletally stable position to better visualize the occlusal relationship. This can be especially helpful with a significant intra-arch discrepancy. I do not believe that it is necessary to mount every orthodontic case on an articulator. In most growing patients, the orthodontic therapy will most likely be completed before the final maturation of the condyle-fossa relationship. The orthodontist must always be aware of the musculoskeletally stable position of the condyles and finalize the occlusion in relationship to this position. However, the final precision of the position in a developing adolescent is most

likely accomplished by the physiology of form and function as the young adult matures. In other words, the orthodontist must provide an occlusal condition that is within the patient's physiologic tolerance or adaptability. In a growing patient, it would be reasonable to assume that this is within several millimeters of the musculoskeletally stable position of the joint. Once the orthodontic therapy is finalized, the patient's individual loading during function will normally assist in stabilizing the masticatory system. The only point in question is how adaptable the patient's masticatory structures are. Of course, this is unknown; therefore, the orthodontist needs to always strive to develop the occlusal position as close to the musculoskeletally stable position as possible. In difficult cases, an articulator may be useful in achieving this goal. However, an articulator is merely a tool that can assist in achieving the goal, not a magical instrument that will ensure success.

In adult patients, it may be more important to precisely locate the orthopedically stable position, since growth and adaptability are less likely. The articulator may be of greater assistance in these patients, but once again articulators are not always needed. The clinician needs to assess the dental relationships and then determine whether an articulator will assist in accomplishing the treatment goals. The articulator is only as accurate as the operator who takes the records and mounts the casts.

FUTURE CONSIDERATIONS OF OCCLUSION FOR ORTHODONTISTS

One might think that the study of occlusion is static. Certainly, much emphasis has already been placed on the static relationship of the teeth from esthetic and tooth-contact perspectives. The static relationship of the teeth is not greatly related to functional problems such as TMD.¹⁹ What has yet to be investigated is how the occlusal-contact patterns of the teeth affect the dynamic functions of the masticatory system. There is a need to better understand how orthopedic stability or instability affects the dynamic functions of the masticatory system: chewing, swallowing, and speech. Additional questions arise as to how and when parafunctional activities become contributors to the breakdown of the system. Over the years, we have made many statements and assumptions regarding occlusion, parafunction, and TMD, but most are unsubstantiated by scientific evidence. We need to challenge the present concepts with studies that can provide evidence about mechanisms so that more effective treatments can be provided to our patients.

In addition, there is a great need to investigate the variability of a patient's innate ability to adapt to change.

Every experienced clinician knows that most patients seem to successfully adapt to changes in their dental structures. However, some patients do not. A better understanding of this adaptability would lead to a better selection of treatment methods and more accurate predictions of outcomes, but investigating this concept is certainly not an easy task. Many variables probably contribute to adaptability. A few factors may include the patient's biology, learned experiences, and psychologic conditions (ie, obsessive-compulsive disorders). As previously discussed, genetic factors can play a role in TMD and other pain conditions,^{20,32,33} and in some patients these are specifically associated with orthodontic therapy.²²

CONCLUSIONS

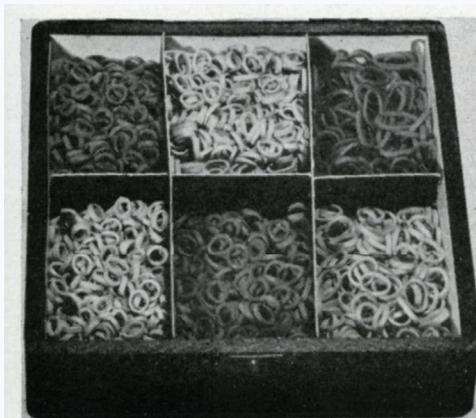
Occlusion has been an important consideration in orthodontics since the beginning of the discipline. Early on, emphasis was placed on the alignment of the teeth, the stability of intercuspal positions, and the esthetic value of proper tooth positioning. These factors remain important to orthodontists, but more recently orthopedic principles associated with masticatory functions have emerged as a consideration. Establishing an orthopedically stable relationship between the occlusal position of the teeth and the joint position is important for proper masticatory function throughout the patient's lifetime. Although in most situations orthodontic therapy neither causes nor prevents TMD, the orthodontist is in an excellent position to provide orthopedic stability in the masticatory structures. Treatment goals directed toward establishing orthopedic stability in the masticatory structures should be a routine part of all orthodontic therapy. Achieving these goals will most likely reduce the patient's risk factors for developing TMD.

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