Anatomy of an occlusal splint

Danny K. Crout, DMD, MS

Occlusal splints, also known as *bite guards, oral orthotics,* and *oral appliances,* are utilized frequently in dental practices. They are commonly used to relax jaw muscles, prevent temporomandibular jaw trauma, protect dentition, and control headaches. How well occlusal splints work is another matter. Numerous studies, when taken as a whole, suggest only a modest indication that they are useful. This review applies principles of neurophysiology to analyze the usefulness of several types of occlusal splint in relation to their design and function. A unique occlusal splint with a design based on neurophysiology is described.

Received: May 27, 2016
Accepted: July 6, 2016

Key words: bite guard, headache, jaw pain, occlusal splint, temporomandibular joint, temporomandibular disorder

GENERAL DENTISTRY SELF-INSTRUCTION CE CREDIT
Exercise 401, p. 60
Subject code: Appliance Therapy (185)

Many different occlusal splints, also known as *bite guards, oral orthotics,* and *oral appliances*, are available, and they vary by design and function. Deciding which appliance is appropriate to use can be confusing. There is little solid evidence to prove the theory behind any design. Evidence-based dentistry on this topic is poor and often misleading. Adjunctive therapy and the intensity of a patient's parafunctional activity are major variables that are not usually discussed when proponents promote the success of a particular occlusal splint. Adjunctive therapies may be more responsible than the occlusal splint itself for any success achieved in treating a temporomandibular disorder (TMD).

While occlusal splints or oral appliances serve many purposes, this article will concentrate mostly on their use in treating TMDs. In nearly every instance of TMD, the patient exhibits muscle hyperactivity of the jaws, head, neck, and shoulders. For this article, the term *TMD* will loosely include temporomandibular joint (TMJ) disorders, headache—including migraines as well as ear, neck, and shoulder pain—dizziness, and other comorbid problems often associated with TMJ and TMD issues. The term *comorbidity* is important with regard to TMD patients, since the etiologies of, for example, headaches or shoulder pain may be similar to, if not the same as, the etiologies of TMJ/TMD problems.[1] Except for major trauma (such as a direct blow to the jaw), most TMJ trauma is the result of chronic microtrauma.

Some guidelines have promoted anterior repositioning appliances (ARAs) as being highly successful in TMJ therapy for capturing discs and decreasing pain.[2] These guidelines have provided statistical data to support the findings. However, the real reasons for success may be hidden in the background. While adjunctive therapies—such as TMJ closed capsular lavage—were mentioned, the credit for success in capturing a TMJ disc was awarded solely to the ARA.[2] A study of ARAs by Simmons & Gibbs suggested that there was more than 70% improvement in those patients whose discs were not captured, even though the original premise for success (capturing the disc) was not met.[3]

Likewise, some investigations of nociceptive trigeminal inhibitors (NTIs) have demonstrated their effectiveness in treating migraines and other headaches.[4,5] However, these articles did not take into account the effectiveness of any adjunctive therapies. The authors of these articles had the option of providing effective adjunctive therapies, including physical therapy, TMJ lavages, trigger point injections, postural training, sleep posture counseling, medications (or the lack of), and equilibration. Adjunctive therapies can have great impact on the success of an occlusal splint or oral appliance. However, the contributions of the intensity of the trauma from parafunctional activities and the expertise of the person providing the adjunctive therapy to this success are hard to measure.

The success of an NTI, ARA, or any other oral appliance is rarely the singular function of an occlusal splint. The greatest factor in successful treatment is correct diagnosis of the etiology. The etiologies and the need for treatment in patients with TMDs tend to center around parafunctional issues, while most occlusal splints are designed to manage functional issues. Understanding the neurology that creates the muscle hyperactivity that is often associated with TMD and parafunction is of primary importance.

Generally, occlusal splints are divided into 2 categories: directive and nondirective. A hybrid of these 2 categories is a neuromuscular-generated occlusal splint using electronics. Directive occlusal splints mechanically pull condyles forward either to recapture anteriorly displaced discs or to place the condyles in a more physiologically acceptable position to prevent the impingement of retrodiscal tissues. The ARA and the Gelb appliance are examples of the directive type.

Most oral appliances are nondirective. A nondirective appliance places the opposing occlusion on a flat or smooth plane in an attempt to avoid dental interferences by having all opposing contacts hit evenly.[6] The objective is to create vertical loading on teeth while eliminating deflective contacts. This approach supposedly allows jaws, discs, and muscles to reach a balanced or more functional state by eliminating horizontal and deflective movements. Since teeth are retained by the appliance, teeth under the appliance cannot move. The gains achieved using an occlusal splint may be insufficient if the teeth have not been incorporated into the therapy. The guards have to be equilibrated for stability and function as changes occur.

The problem with occlusal splints is that parafunctional activity has no respect for oral appliances. Functional activities, on the other hand, have a different neurologic source and thus can be more easily controlled. Bruxism is a parafunctional activity.[7] Many of the neurologic activities associated with a parafunctional activity share a commonality with the etiologies of the comorbidities associated with TMD.[8]

Occlusal splint design and function can be evaluated by combining good science, neurophysiologic principles, and musculoskeletal functions. The physiologic information that follows represents an evidence-based approach to understanding how occlusal splints work. Most of the information presented is common knowledge, but it is often not utilized sufficiently when occlusal splints are designed. Some occlusal splints will be mentioned by category and others will be named specifically. The clinician should be able to extrapolate the information provided to other designs and their clones.

Physiology of occlusion

Teeth usually do not touch except during chewing, swallowing, or speech. The touch time in 24 hours totals less than 20 minutes. Teeth do not supraerupt in the remaining time. If the teeth are allowed to touch once daily, as in eating, posterior teeth do not supraerupt while an anterior segmental appliance is worn. It takes up to 8 days without contact for supraeruption to begin.[9]

Except in cases of an anterior open bite, the interocclusal rest (freeway) space between incisors averages 1-3 mm.[10] The range can vary widely during the day, but a permanent violation of the range is not well tolerated, especially if the vertical dimension is changed appreciably.[11] This space is necessary for eating and speech. To maintain this space, the elevator and depressor muscles of the jaw must be slightly and equally contracted in an agonist-antagonist position.

Posterior teeth, when loaded, stimulate periodontal nerves, which in turn cause the temporal muscles to contract. With parafunctional clenching, unlike functional loading, the brain does not distinguish whether teeth are loaded on themselves or acrylic resin. Loading of anterior teeth can generate some activity in the anterior temporalis muscle, but not the stronger middle and posterior bellies, which are loaded by teeth closer to the pivot or fulcrum (TMJ condyles).

Canines have the longest roots, are surrounded by the densest alveolar bone, and have the greatest number of periodontal nerves compared to other teeth. Canines are the only anterior teeth that are supposed to load with the posterior teeth in centric relation occlusion (CRO) and maximum intercuspation (MI). Incisors, with their conically shaped roots in fairly porous alveolar bone, function to incise food and disengage posterior teeth with incisal guidance. Mechanical leveraging is significantly reduced when incisal guidance removes posterior dental contacts. Incisors are not designed to withstand hard, prolonged loading activity. Canines, in their very dense alveolar bone, are designed to withstand hard vertical and lateral forces. The dense nerve innervation of the canines, when stimulated, is thought to be responsible for a calming or quelling effect on the elevator muscles.[12] While this appears to be the case, the clinical evidence to prove this hypothesis is still pending.

Patients who have obtuse jaw angles place harder forces on molar teeth due to the direction or vector of the muscle contractions. Conversely, square jaw angles place greater forces anteriorly than the average jaw angle. This knowledge is useful when the clinician is restoring teeth, planning orthodontic therapy, or designing occlusal splints.

Swallowing occurs 1500-2000 times per day when a person is in the awakened state but only 15-20 times while an individual is sleeping (mostly to swallow saliva).[13] Tongue thrusting during swallowing contributes to anterior open bites during the awakened state. Heavy clenching on molars, on the other hand, occurs more often during sleep. Tongue thrusting contributes both to vertical intrusion and to lingual or palatal movements of molars through elevator muscle forces and cheek-tongue imbalances, respectively.

Clenching on deflective cusps creates an even greater problem for condylar positioning. The lateral and medial pterygoid muscles can become very active in an effort to avoid traumatic contacts. When an anterior segmental appliance is used, molars tend to return to equilibrium if they were intruded. Additionally, condyles are not influenced by traumatic occlusion and can seat more correctly in the fossae. The arc of closure (pivot) is changed slightly, often with the result that the most posterior molars contact first. This gives the appearance of supraeruption when there is an increase in the anterior open bite.[4]

Neurophysiologic considerations for occlusal splint design

Posture

All muscles have a normal resting length established by the muscle spindle fibers and Golgi tendon organs.[11,14] In the presence of constant unilateral or unbalanced muscle contraction as the result of poor body posture, a new muscle memory may form, changing the muscle resting length. For example, people who type text messages while in a poor posture position can develop a condition commonly known as *text neck*. Chronically poor posturing leads to the development of myofascial and muscle trigger points (tight, irritable bands of muscle fibers). Trigger points usually cause pain, which may contribute to TMD and headache problems.[15]

Muscles with trigger points can become hard and ischemic (knots). Vascular flow, maintained by the sympathetic nervous system, is decreased. Trigger points are often difficult for massage therapists to eliminate and may be made worse by muscle-building exercises recommended by physical therapists or weight trainers. Anesthetic injections into the jaw, head, neck, and shoulder muscles may be necessary to obtain resolution of trigger points.[16,17] Postural counseling is also essential for prevention.

Continuously stretched muscles, on the other hand, contract to reestablish their normal resting lengths through their muscle spindle fibers and Golgi tendon body functions.[11,14] This is especially true when parafunctional activity is present. The return to normal working length is the reason for relapse when certain occlusal splints are used. For instance, a thick occlusal splint (such as a vertical distractor), especially if it is posteriorly loaded, can create a posterior open bite. The posterior opening will be in direct proportion to the intensity of the parafunctional clench, the time the appliance is worn, and the thickness of the appliance. This outcome is commonly seen with the use of ARAs, posterior segmental appliances, and oral sleep appliances.[18-21] It is also common when 2 TMD appliances are worn at the same time, as this can significantly overextend the interocclusal rest space.

Loading forces

The nearer a tooth is to the condyles and elevator muscles, the greater the force. A molar is subjected to much greater loads than a canine or incisor. Loaded teeth stimulate muscle activity. Full-coverage flat stabilization occlusal splints are loaded with greater force around the molars. Equal contacts throughout the surface of an occlusal splint do not equate to equal forces on teeth. Therefore, a relatively thin full-coverage flat stabilization occlusal splint can easily break over the second molar area, a commonly seen event.

This tendency of posteriorly loaded flat occlusal splints to fracture is one reason that anteriorly loaded occlusal splints have become very popular. However, anteriorly loaded occlusal splints can carry their own unique set of problems by loading on the incisors. Pivot appliances over the last molars do not work (as force is on the wrong side of the fulcrum) unless an upward manual force is used on the chin.[22] Full-coverage flat stabilization occlusal splints do not work well if there is no canine rise or incisal guidance for the lateral pterygoid muscles to use in order to disengage the hard, destructive vertical forces created by the temporalis muscles.[23] One full-coverage stabilization occlusal splint uses an incisal and 2 separate molar disoccluding elements (a tripod design). While it may be easy to make 3 equal contacts, the loading forces are not equal. The hard, concentrated, vertical forces on the molars cannot be disengaged without anterior disocclusion to remove the molar contacts. A hard force on a single opposing molar can easily intrude it.

The tripod design appliance may look benign but is potentially dangerous if used when parafunctional activity is present. This is another example of use of a functional appliance in an attempt to control a parafunctional activity (bruxism). The wrong etiology is being addressed.

Nociceptive reflexes

Nociceptive (guarding) reflexes help prevent occlusal trauma. The NTI appliances utilize this concept.[4] During bedtime wear, reflexive guarding (nociceptive reflexes) are all but absent. These reflexes are present during the awakened state. The NTI only lives up to its name during daytime wear. Clark et al noted that clenching forces can be up to 14 times harder during sleep.[24] The description of an NTI as a *tension suppression system* during sleep is valid because of its ability to prevent vertical loading by the temporalis muscles, which are (per cubic inch) some of the most powerful muscles in the body.

Incisors that have labial or lingual tilting are difficult to load vertically, which further diminishes NTI use. A potential problem with incisal loading is that it causes intrusion if the interocclusal rest space is violated or the intensity of clenching is strong. Use of an incisal clip can potentially intrude the premaxillary bone, along with its teeth.

Incisors should not touch in CRO or MI, since there is a potential to create a wedging effect that pushes the mandible (condyles) posteriorly, placing pressure on the retrodiscal tissues (nerves and vascular) while thinning the posterior disc. This can lead to disc displacement.[25] Often, in response, the head moves in a forward posture in which the ears extend beyond the mid-shoulders. The anterior digastric and geniohyoid muscles, via a stretch, pull the mandible posteriorly to avoid incisal contacts. This is an example of how teeth can adversely affect posture.[11,26,27]

The other response to incisal contact in CRO and MI is protrusion of the jaw so that the incisors are in end-to-end occlusion, freeing the mandible. Incisal wear is usually present. This act may remove the condylar pressure, but it fatigues the lateral pterygoid muscles.

Reflex guarding and nociceptive memory of incisal contact often persist even during occlusal splint wear. Most of the time, reflex guarding ceases after equilibration of the incisors to free them of contact in CRO and MI.

Parafunctional activities

Bruxism and eating are very different entities even though they share the same muscles. Eating is a functional activity governed by the alpha motor neurons under the direction of the cortex. Bruxism, on the other hand, is a parafunctional activity governed by the gamma efferent pathways of the hypothalamus as well as the reticular and limbic systems.[23] Neural input for the gamma efferent pathways that lead to parafunctional activity involves multiple other neural inputs prior to involving the hypothalamus.[23] The present article will not cover the inputs from the cortical, extrapyramidal, limbic, and sympathetic nervous systems that stimulate and sustain parafunctional activity. Broadly speaking, however, parafunctional activity can be stimulated by many factors, such as pain, decreased oxygen saturation, sleep disorders, emotional stress, medications, and muscle trigger points, to name a few.

The masseter and medial pterygoid muscles are elevator muscles that work on command. The temporalis muscles, especially the middle and posterior bellies, are powerful elevator muscles that contract when the periodontal ligaments and nerves of the posterior teeth are stimulated via loading during clenching and eating. Strong vertical forces during clenching cause the lateral pterygoid muscles to move the jaw laterally or protrusively in an attempt to disengage the harmful vertical loading (as a survival technique).[4] If incisal guidance or canine rise cannot disengage the vertical load sufficiently, excessive dental wear can occur on the incisors and canines. This process is called *bruxism*. If the cusps are too steep to mount proper lateral or protrusive movements by the lateral pterygoid muscles, or the forces of the temporalis muscles are too strong, the lateral forces can flex teeth at the crown-root interface through isometric forces. This process is known as *engaging*.

The crestal bone, if thin, can be broken down by lateral forces. This breakdown leads to gingival creep and dentin exposure. Hard vertical loading usually increases alveolar bone growth and thickening. Gingival creep will stop when the bone becomes thick enough to resist further breakdown. A fulcrum effect against the thicker, more resistant bone can be created, eventually leading to abfractions.

Hygienists and dentists may mistakenly diagnose this wear as toothbrush abrasion. Periodontal and restorative procedures may eventually fail if the etiologies of bruxism and engaging are not addressed.

Condylar position

Lateral and protrusive movements of the condyles help lubricate the TMJ. Application of hard vertical force (clenching) on the TMJs prevents disc lubrication by displacing the synovial fluid. This can lead to disc breakdown, resulting in crepitus from rough or perforated discs.[28]

Tall or thick occlusal splints are often used to help distract the condyles vertically to prevent hard disc loading. This approach may not work well, since the intrusion of posterior teeth can occur when interocclusal rest space is violated. Intrusion of teeth occurs when muscles attempt to regain their original normal working length by contracting.[23] When reestablishing the muscle's working length and vertical dimension of occlusion, the brain appears to treat the occlusal splint as if it were the mandibular teeth. Unfortunately, the condyles return to where they started, but now there is a posterior open bite. When patients are subjected to orthodontics, extensive restorations, or occlusal rehabilitation purely as a result of wearing an occlusal splint, ethical concerns arise. Some patients need these services, but they should not be "made" to need them.

Airway opening

Oral sleep appliances move the jaw vertically and protrusively to open the airway. This positioning also helps the oropharyngeal airway tissues become more rigid so that they are less likely to collapse. Oral sleep appliances also pull the tongue forward.[29]

Decreased oxygen saturation, even with a 2%-4% drop, irritates the brain.[30] Decreased oxygen saturation is one of the most significant factors that promote both bruxism and restless or interrupted sleep. By increasing the oxygen flow, an oral sleep appliance helps reduce this reason for clenching.

If the sleep apneic patient has no TMD or TMJ problems, the trauma created by an oral sleep appliance may be minimal. Sleep appliances are usually worn 6-8 hours a day, while an ARA is worn full time (in some cases, even while eating).[2] The amount of time worn and the intensity of clenching make an ARA much more traumatic than an oral sleep appliance. Some oral sleep appliance designs are far less traumatic than others, especially those that can minimize temporal muscle activity.

Trigger points

Approximately 90% of muscle tension–type headaches come from the neck and shoulders.[15] Most patients who have jaw pain also have neck and shoulder pain, which can lead to headaches. The neck and shoulder muscles are usually tender to pressure and exhibit knot-like areas. As mentioned previously, these knots, known as *trigger points,* are tight bands of irritable and ischemic muscle tissue that are maintained by the sympathetic nervous system.[23] Trigger points can refer pain beyond their sites, often causing discomfort at a site significantly removed from its source. The cervical nerves and the fifth cranial nerves combine at the spinal tract nucleus of cranial nerve V (located from C1 to C4 and possibly lower) to send pain messages to the cortex after going through the thalamus.[31]

While an occlusal splint may alleviate headaches, the real challenge in treating muscle tension–type and migraine headaches is in eliminating the muscle trigger points and tight muscles in the neck and shoulders. In the author's opinion, proper oxygen saturation during sleep, good hydration, the absence of narcotics, and good posture are essential to controlling migraines. No occlusal splint by itself will prevent headaches; adjunctive therapies for the neck and shoulder muscles must be provided. Postural counseling—to include posture during work, leisure, and sleep—is crucial to keeping these muscles from overactivity. Trigger point injection of a local anesthetic without a vasoconstrictor, followed by stretching, is an excellent adjunctive therapy.[32] Muscle relaxants and anti-inflammatory medications give symptomatic relief only.

Occlusion

Occlusion as a source of TMD (particularly TMJ) problems has long been a controversial topic. Certain dental schemes are more vulnerable to trauma, including deep overbites, open bites (anterior and posterior), unilateral crossbites, lingually inclined teeth, overjets, and the absence of more than 7 teeth.[11] Teeth that have deflective cusps can move the condyles from their best physiologic position in the fossae into an accommodated position for the sake of the best dental fit. This overworks the lateral and medial pterygoid muscles.[15]

Dentists commonly equilibrate or adjust occlusal splints to improve stability and jaw (condylar) position, but many are reluctant to equilibrate teeth to accomplish the same goals. Equilibration should be thought of as adjunctive therapy in the same manner as trigger point injections or closed TMJ capsular lavage. Full-coverage appliances act as retainers, in that they hamper teeth from obtaining neutral or balanced positions. Equilibration removes these deflective cusps. Properly equilibrated teeth remain stable when they are in harmony with the muscles, TMJs, and other teeth. Wearing an occlusal splint to relax muscles prior to equilibration is essential in most cases.

Electronic muscle relaxation

Neuromuscular dentistry uses electronics to relax the jaw muscles.[33] This can be an effective technique. However, use of the same electronics, such as a transcutaneous electrical nerve stimulation unit, to establish a bite registration for an occlusal splint (or for reconstructive dentistry) can cause problems, as muscles are not relaxed equally. Easily accessible muscles, such as the anterior temporalis, masseters (deep and superficial), and trapezius muscles, can be relaxed easily. Other muscles, including the middle and posterior temporalis muscles as well as the lateral and medial pterygoid muscles, are not directly accessible. Needlepoint probes can be utilized to gain access to these muscles so they can be relaxed electrically, but this process creates trauma. The bands within muscles (such as trigger points) can be hard to access electrically. As a result, all jaw muscles may not be relaxed fully or equally.

For instance, when in balance, the elevator and depressor muscles create the interocclusal rest space. However, if only the elevator muscles are relaxed electronically, the agonist-antagonist effect of the interocclusal rest space is lost (opened too much). The lateral pterygoid muscles, which cannot be accessed without needle probes, keep the jaw pulled forward while increasing the vertical opening. The interocclusal rest space is increased too much, negatively affecting the normal muscle resting length. The depressor muscles of the jaw are left untouched. Interocclusal rest spaces of 10 mm are common with protruded jaws. This is not normal physiology, since the rest position range has been artificially achieved.

Relapse is a common problem when neuromuscular dentistry is used for bite registration.[34,35] The term *neuromuscular* suggests something natural or normal. Use of electronic devices to make occlusal splints or perform restorative dentistry without establishing a harmonious muscle balance is anything but normal.

Use of occlusal splints to lessen parafunctional activity

The use of bite guards or oral appliances to treat TMD and a long list of associated jaw problems has spanned more than a century. Dentists have accepted their role in helping to quell TMJ disorders and jaw pain, although success is usually variable and unpredictable. Multiple studies have compared full-coverage flat plane stabilization appliances with ARAs.[36,37] Too often, neither design works well, because these appliances are functionally based. There is merit in covering malocclusions while giving the occlusal splint canine rise and incisal guidance, as with flat plane stabilization appliances. There is also merit in recapturing discs or at least pulling the condyles from the impinged nerves and vessels of the retrodiscal tissues, as with ARAs. A 90-day comparative study showed that flat plane occlusal splints did not work as well as ARAs. However, the positive results of the ARAs tended to deteriorate when use was stopped after 90 days of wear.[37] After more than 90 days of wear, the ARA can start causing irreversible changes, including posterior open bites, bone changes, and traumatic incisal contacts.[21] This usually forces the patient into phase II therapy.

Parafunctional activities of the jaw muscles have little in common with the functional activities of the jaw that use the same muscles. An interruption of trauma and elevator muscle contraction must occur to stop bruxism or at least control it. If the posterior teeth cannot be loaded, the stimulation for temporalis muscles to contract is minimized. When there is no traumatic vertical posterior loading, the lateral pterygoid muscles do not have a need to function since their job has been eliminated. Masseter muscles may, however, continue flexing and maintain the clench. Elevator muscles may contract when the interocclusal rest space is significantly violated (opened). These are characteristics of parafunctional activity originating in the brain. Functional activity usually does not act this way.

When the load is put on anterior teeth via a disoccluder, the modification in leverage reduces masseter and medial pterygoid muscle contractions dramatically.[38] Much of this advantage is lost if the interocclusal rest space is significantly violated by the insertion of a thick, anteriorly loaded appliance. The mandibular incisors often have stepped incisal edges, which requires an additional appliance, resulting in a further increase of the opening.

Parafunctional activity is common, experienced by most patients to some degree during their lives.[39,40] Parafunctional activities must be eliminated or controlled before extensive restorative treatment is undertaken. Ignoring or minimizing the effects of parafunctional activity when doing full-mouth rehabilitations may force the restoring dentist to create occlusal splints every few months. Patients may continue their bruxism on their occlusal splints, even if the teeth and TMJs fit and function perfectly. Dentists unfortunately sometimes treat *parafunctional* problems with occlusal splints that are designed for *functional* problems. Bruxism is a parafunctional activity; thus it must be diagnosed as such.[23]

A protective occlusal splint should be a neurophysiologic device that minimizes muscle activities of the jaw. In other words, an occlusal splint should work in harmony with the brain. It should not be a mechanical "bully" that positions condyles as its primary objective. Likewise, an occlusal splint should not be created from an electrical device that fails to capture the neurologic balance of the jaw muscles and their agonist-antagonist relationships when the jaw is at rest. Since teeth should not be loaded more than 20 minutes in 24 hours, an appliance worn on the teeth should not be loaded longer than 20 minutes.

Loading posterior teeth on an occlusal splint stimulates muscle contractions. Landing incisors on anterior disoccluding elements, even if they include the canines, can carry its own set of problems. Landing or loading on incisors is not physiologic.

Maxillary Anterior Passive Appliance

The Maxillary (or, in some cases, *Mandibular*) Anterior Passive Appliance (MAPA) attempts to perform all the positive duties of an occlusal splint without exhibiting any of the negative aspects. The MAPA is well suited for patients with functional and parafunctional activities, as it seeks to minimize the muscle activity of the jaws. The disoccluding elements are located over the canine areas and are loaded vertically by the opposing canines contacting in centric relation (CR) (Fig 1). In the scope of this article, *CR* refers to condyles loaded on, or as close as possible to, their discs. The development of CRO is part of therapy. The

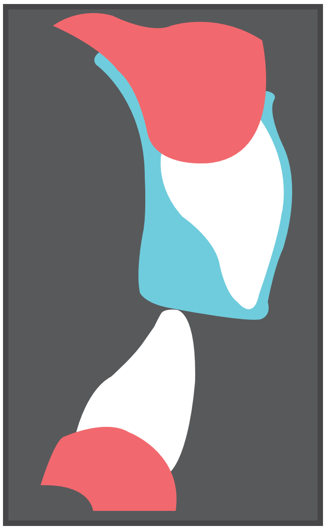

Fig 1. Mandibular canine contacting the disoccluding element.

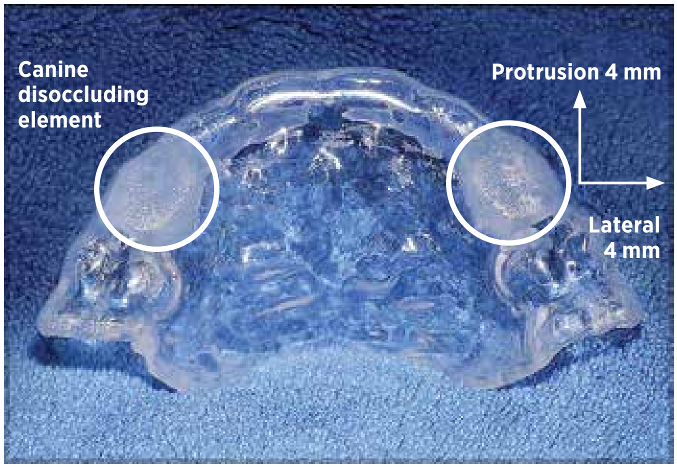

Fig 2. Maxillary Anterior Passive Appliance (MAPA). The appliance fits within the interocclusal rest space. The appliance is passive when the jaw is at rest. There are no anterior or posterior contacts.

Fig 3. Patient wearing a MAPA, which is thin and nearly invisible.

disoccluding elements are relatively flat and extend several millimeters for balanced protrusive and same-side lateral movements (Fig 2). Steep overbites may require slightly inclined disoccluding elements, because flat ones may be so high that they violate the interocclusal rest space. Other than in the case of a deep overbite (where there may be a slight horizontal force during an excursion), all forces on the MAPA are vertical, even in excursions. The canines land on the disocclusion elements; therefore, there are no horizontal force issues, as sometimes can be found with incisal disoccluders.

The MAPA is passive; it touches nothing until loaded, such as when the wearer clenches. The canine disoccluding elements are usually less than 2 mm thick. The average height of the interocclusal rest space is usually greater than that. There should be no posterior tooth contacts when the patient clenches (only canine contacts). The incisors are not allowed to touch in the CR-CRO position but are allowed (although not required) to touch in protrusive movements. It is crucial for the canine disoccluding elements of the MAPA to have good posterior tooth spacing and no hint of posterior contacts, even in excursive movements.

Retentive coverage usually extends from first premolar to first premolar, covering all teeth anteriorly with modifications for retentive pathways. Most of the rugae are covered as well. The use of just enough dental coverage for retention allows the uncovered teeth to move to a neutral or balanced position between the cheek and tongue muscles and opposing teeth. As the jaw muscles relax, the condyles can also seek their neutral or home position. Placing vertical loads on canines using a MAPA is far more conducive to disc recapture than with other occlusal splints. This procedure allows TMJs to return home naturally, in the absence of trauma, to a stable position.

A directive occlusal splint, in contrast, recaptures discs mechanically. It may capture one disc while straining the retrodiscal ligaments of the other. The results are rarely natural or lasting when discs are recaptured through the use of a mechanical device. Extensive therapy is usually needed to maintain the capture.[41,42]

If discs cannot be recaptured in a reasonable time with the MAPA, closed lavage is helpful. Occasionally, factors such as severely damaged retrodiscal ligaments or tears in the disc prevent recapture of the disc. Maxillary anterior passive appliances are effective occlusal splints to maintain a captured disc after plication surgery, because they create a more passive environment necessary for healing.

The retentive material of the MAPA is thin and clear. It is nearly invisible, and the author has found that the patient's speech is usually perfect after 2 days (Fig 3). The MAPA should be removed when the patient eats as well as for cleaning. The patient can drink hot or cold beverages with the MAPA in place. The MAPA is worn full time until all or most of the following requirements are met: condyles are in their proper position with their discs in place; occlusion is stable and functional; and muscles of the jaws, neck, and shoulders are more relaxed and free of muscle trigger points. Sleep, work, and sitting postures must be corrected by the patient as preventive therapy. Bedtime wear begins only after most of the requirements for success have been met. Nocturnal wear can be indefinite, since parafunctional activities originate in the brain and they are far more intense during sleep. In some cases, parafunctional activities can be difficult to stop because of their multifactorial origins; they can only be controlled.

Depending on the patient's cooperation and the dentist's expertise in therapy, the MAPA is usually worn full time (24 hours a day, 7 days a week), except for eating and cleaning, for 6-8 weeks. Full-time wear can be extended if there is significant retrodiscal ligament damage. Some patients may need more time for tissue, disc, and bone healing. Results using a MAPA, on average, take 2-4 appointments after the MAPA insertion appointment. Most of the author's cases are completed in 2 months. In the author's experience (insertion of more than 5000 MAPAs), no patient who had previously worn a different occlusal splint has wanted to return to the original occlusal splint design, and compliance has been outstanding. The probable reason that the results are more effective and consistent is that they are obtained in harmony with the body's neurophysiologic functions.

There is no chance of dental supraeruption during use of the MAPA if the posterior teeth cannot touch. The MAPA is removed for eating, which represents most of the dental touch time in 24 hours. Teeth may move, but only to a more neutral and stable position.

The MAPA eliminates the vertical forces on posterior teeth. In domino fashion, it eliminates the need of the lateral pterygoid muscles to disocclude the posterior teeth in parafunctional clenching simply because they are not loaded. The masseter and medial pterygoid muscles are still free to contract but are held to within a fraction of their maximum contraction due to mechanical leveraging. Landing on canines minimizes mechanical leveraging because the canines are so far removed from the pivot and elevator muscles (except for the anterior temporalis muscle). As mentioned previously, canines, which have the longest roots of any teeth and are located in the densest alveolar bone, can withstand heavy loads (especially vertical ones). The incisors, as a result of their location in porous bone, cannot. Additionally, the dense neural innervation surrounding the canine roots is proposed to have a quelling effect on the jaw elevator muscles (in the form of a negative feedback loop).[12]

In the author's experience, patients find the MAPA to be a comfortable occlusal splint to wear. It is nearly invisible and does not impede speech. It fits within the interocclusal rest space and only engages when needed. Otherwise, it is passive. The objective of keeping the posterior teeth from touching while not exceeding the interocclusal rest space is crucial to the function of the MAPA.

During closing, the opposing canines should land on the canine disoccluding elements of the MAPA evenly from a CR position (or as close as possible to a CR position). Establishing a centric jaw relationship for bite registrations can be difficult in TMD patients who have pain or strong occlusal guarding reflexes. To overcome this, the dentist should ask the patient to place the tip of his or her tongue on the soft palate while biting evenly on the second molars without protruding. The patient should practice this action several times. This establishes a reasonably loaded CR position from which to obtain a good bite registration. This CR position may change slightly as the discs are recaptured and the muscles relax. The goal is to place the mandible in its correct orthopedic position relative to the rest of the head. The MAPA requires minimum adjustments if all design criteria are met.

The MAPA should never be worn during heavy lifting. Bracing with all teeth engaged during lifting is an entirely different neuromuscular event and is not normally associated with TMD, although weightlifters whose condyles and teeth have a CR and MI discrepancy can create significant TMJ trauma.

The MAPA can be easily made in a dentist's own laboratory and completed chairside. The canine disoccluding elements are made with composite materials that are precisely added (bonded) to a vacuum-formed 0.060- or 0.080-inch hard splint material and shaped for function. The author recommends that the clinician have a certified laboratory (Pittman Dental Laboratory) make at least the first 5 MAPAs. While the design is relatively simple, it is very technique sensitive. Contact with posterior teeth must be avoided while canine contact is maintained just within the interocclusal rest space. It is recommended that 3 mm of protrusive and lateral excursions be included to allow for canine travel. These components are all critical for success.

Conclusion

Occlusal splint design should incorporate neurophysiologic and musculoskeletal principles to ensure that the appliance functions as intended, particularly for the treatment of TMD. The MAPA is a highly effective passive occlusal splint, but, like any occlusal splint, it is not singularly successful without proper adjunctive therapies.

Author information

Dr Crout is in private practice limited to orofacial pain and dental sleep medicine, Spartanburg, South Carolina.

Disclosure

The author receives a small royalty for each MAPA Pittman Dental Laboratory makes. The name *MAPA* is a trademark owned by the author.

References

1. Diagnosis and management of TMDs. In: de Leeuw R, Klasser GD, eds. *Orofacial Pain: Guidelines for Assessment, Diagnosis, and Management.* 5th ed. Chicago: Quintessence Publishing; 2013:127-186.
2. Simmons HC 3rd; Board of Directors, American Academy of Craniofacial Pain. Guidelines for anterior repositioning appliance therapy for the management of craniofacial pain and TMD. *Cranio.* 2005;23(4):300-305.
3. Simmons HC 3rd, Gibbs SJ. Recapture of temporomandibular joint disks using anterior repositioning appliances: an MRI study. *Cranio.* 1995;13(4):227-237.
4. Boyd JP, Shankland W, Brown C, Schames J. Taming destructive forces using a simple tension suppression device. *Postgrad Dent.* 2000;7(3):1-4.
5. Shankland WE 2nd. Migraine and tension-type headache reduction through pericranial muscular suppression: a preliminary report. *Cranio.* 2001;19(4):269-278.
6. Israel HA, Diamond B, Saed-Nejad F, Ratcliffe A. The relationship between parafunctional masticatory activity and arthroscopically diagnosed temporomandibular joint pathology. *J Oral Maxillofac Surg.* 1999;57(9):1034-1039.
7. Glossary. In: Simmons HC 3rd, ed. *Craniofacial Pain: A Handbook for Assessment, Diagnosis, and Management.* Chattanooga, TN: Chroma Production; 2009:309.
8. Mehta N. Muscle disorders. In: Kaplan AS, Assael LA, eds. *Temporomandibular Disorders: Diagnosis and Treatment.* Philadelphia: Saunders; 1991:118-141.
9. Kinoshita Y, Tonooka K, Chiba M. The effect of hypofunction on the mechanical properties of the periodontium in the rat mandibular first molar. *Arch Oral Biol.* 1982;27(10):881-885.
10. Ramfjord S, Ash MM. *Occlusion.* 3rd ed. Philadelphia: Saunders; 1983:26-28.

11. Dawson PE. *Evaluation, Diagnosis, and Treatment of Occlusal Problems.* 2nd ed. St Louis: Mosby; 1989:67, 110-123, 353.
12. Hannam AG. Musculoskeletal biomechanics in the mandible. In: McNeil C, ed. *Current Controversies in Temporomandibular Disorders.* Chicago: Quintessence Publishing; 1991.
13. Hazelbaker A. To clip or not to clip: assessing and treating tongue-tie. Paper presented at: American Academy of Craniofacial Pain 30th Annual International Clinical Symposium; July 31, 2015; Lake Buena Vista, FL.
14. Ramfjord SP, Blankenship JR. Increased occlusal vertical dimension in adult monkeys. *J Prosthet Dent.* 1981;45(1):74-83.
15. Okeson JP. *Bell's Orofacial Pain.* 5th ed. Chicago: Quintessence Publishing; 1995:13-44, 280, 311-312.
16. Hong CZ. Considerations and recommendations regarding myofascial trigger point injection. *J Musculoskel Pain.* 1994;2(1):29-59.
17. Fricton JR, Sheldon GG. Muscle disorders. In: Pertes RA, Sheldon GG, eds. *Clinical Management of Temporomandibular Disorders and Orofacial Pain.* Chicago: Quintessence Publishing; 1995:100-103.
18. Gibbs CH, Mahan PE, Lundeen HC, et al. Occlusal forces during chewing—the influence of biting strength and food consistency. *J Prosthet Dent.* 1981;46(5):561-567.
19. Pertes RA. Occlusal appliance therapy. In: Pertes RA, Sheldon GG, eds. *Clinical Management of Temporomandibular Disorders and Orofacial Pain.* Chicago: Quintessence Publishing; 1995:197-204.
20. Widmalm SE. Use and abuse of bite splints. *Compend Contin Educ Dent.* 1999;20(3):249-254, 256, 358-259.
21. Kai S, Kai H, Tabata O, Tashiro H. The significance of posterior open bite after anterior repositioning splint therapy for anteriorly displaced disk of the temporomandibular joint. *Cranio.* 1993;11(2):146-152.
22. Kilpatrick SR. Use of the pivot appliance for the treatment of temporomandibular joint disorders. *Cranio Clin Int.* 1991;1(2):107-115.
23. Okeson JP. *Management of Temporomandibular Disorders and Occlusion.* 4th ed. St Louis: Mosby; 1998:39-41, 158, 184-187, 474-502.
24. Clark GT, Sakai S, Merrill R, Flack VF, McArthur D, McCreary C. Waking and sleeping temporalis EMG levels in tension-type headache patients. *J Orofac Pain.* 1997;11(4):298-306.
25. Castaneda R. Occlusion. In: Kaplan AS, Assael LA, eds. *Temporomandibular Disorders: Diagnosis and Treatment.* Philadelphia: Saunders; 1991:40-49.
26. Isberg AM, Isacsson G. Tissue reactions of the temporomandibular joint following retrusive guidance of the mandible. *Cranio.* 1986;4(2):143-148.
27. Bumann A, Lotzmann U, Mah J. *TMJ Disorders and Orofacial Pain: The Role of Dentistry in a Multidisciplinary Diagnostic Approach.* Stuttgart: Thieme; 2002:135.
28. Stegena B, deBont LG. TMJ disc derangements. In: Laskin DM, Greene CS, Hylander WL. *TMDs: An Evidence-Based Approach to Diagnosis and Treatment.* Chicago: Quintessence Publishing; 2006:129-130.
29. Talley RL. Dental sleep medicine. In: Simmons HC 3rd, ed. *Craniofacial Pain: A Handbook for Assessment, Diagnosis, and Management.* Chattanooga, TN: Chroma Production; 2009:234.
30. Bonato R. Sleep studies. What does all that information really mean and what is really important? Paper presented at: American Academy of Craniofacial Pain 30th Annual International Clinical Symposium; August 1, 2015; Lake Buena Vista, FL.
31. Mannheimer JS, Dunn J. Cervical spine. In: Kaplan AS, Assael LA, eds. *Temporomandibular Disorders: Diagnosis and Treatment.* Philadelphia: Saunders; 1991:50-94.
32. Waldman SD. *Atlas of Pain Management Injection Techniques.* Philadelphia: Saunders; 2000.
33. Simmons HC 3rd, Stack BC, Moses AJ. Temporomandibular disorders. In: Simmons HC 3rd, ed. *Craniofacial Pain: A Handbook for Assessment, Diagnosis, and Management.* Chattanooga, TN: Chroma Production; 2009:131-134.
34. Cooper BC, Rabuzzi DD. Myofacial pain dysfunction syndrome: a clinical study of asymptomatic patients. *Laryngoscope.* 1984;94(1):68-75.
35. Dao TTT, Feine JS, Lund JP. Can electric stimulation be used to establish a physiologic occlusal position? *J Prosthetic Dent.* 1988;60(4):509-514.
36. Anderson GC, Schutte JK, Goodkind PJ. Comparative study of two treatment methods for internal derangement of the temporomandibular joint. *J Prosthetic Dent.* 1985;53(3):392-397.
37. Lundh H, Westesson PL, Kopp S, Tillström B. Anterior repositioning splint in the treatment of temporomandibular joints with reciprocal clicking: comparison with a flat occlusal splint and an untreated control group. *Oral Surg Oral Med Oral Pathol.* 1985;60(2):131-136.
38. Wiygul JP. Maxillary full coverage appliance. *Cranio Clin Int.* 1991;1(2):39-53.
39. Manfredini D, Guarda-Nardini L, Winocur E, Piccotti F, Ahlberg J, Lobbezoo F. Research diagnostic criteria for temporomandibular disorders: a systemic review of axis I epidemiologic findings. *Oral Surg Oral Med Oral Pathol Oral Radio Endod.* 2011;112(4):453-462.
40. da Silva CG, Pachêco-Pereita C, Porporatti AL, et al. Prevalence of clinical signs of intra-articular temporomandibular disorders in children and adolescents: a systemic review and meta-analysis. *J Am Dent Assoc.* 2016:147(l):10-18.
41. Gelb M, Gelb H. Gelb appliance: mandibular orthopedic repositioning therapy. *Cranio Clin Int.* 1991;1(2):81-89.
42. Simmons HC 3rd. Orthodontic finishing after TMJ disk manipulation and recapture. *Int J Orthod.* 2002:13(1):7-12.