A common-sense approach to splint therapy

Tim J. Dylina, DDS*
Merced, Calif.

Splint therapy is a proven modality for alleviating the pain of many types of temporomandibular disorders and bruxism, though questions still remain regarding how splints work. In this article, a review of the literature is used to determine an effective splint design for the different degrees of temporomandibular problems. Sufficient credible literature exists to help provide an understanding of and a treatment protocol for the use of splints for temporomandibular disorders and bruxism problems. (J Prosthet Dent 2001;86:539-45.)

INTRODUCTION
Practitioners appreciate a practical approach to all aspects of treatment; splint therapy is no exception. The purpose of this article is to review the current understanding of how splints work, describe various splint types and their uses, and suggest how to ensure their proper design, fabrication, and adjustment.

Splint therapy may be defined as the art and science of establishing neuromuscular harmony in the masticatory system and creating a mechanical disadvantage for parafunctional forces with removable appliances. A properly constructed splint supports a harmonious relation among the muscles of mastication, disk assemblies, joints, ligaments, bones, teeth, and tendons.

SPLINT TYPES AND FUNCTIONS
All splints are classified as either permissive or non-permissive. A permissive splint allows the teeth to move on the splint unimpeded, which in turn allows the condylar head and disk to function anatomically. A nonpermissive splint has a ramp or "indentations" that position the mandible inferiorly and anteriorly and secure it there. Examples of permissive splints include bite planes (anterior jigs, Lucia jig, anterior deprogrammer) (Fig. 1) and stabilization splints (flat plane, Tanner, superior repositioning, and centric relation [CR]) (Fig. 2). An example of a nonpermissive splint is a repositioning splint (anterior repositioning appliance [ARA]) (Fig. 3). Soft splints and hydrostatic splints (Aquilizer; Jumar Corp, Carefree, Ariz.) could be considered pseudo-permissive splints, as their functions are extremely different than those of the permissives.

Properly fabricated splints have at least 6 functions, including the following: (1) to relax the muscles, (2) to allow the condyle to seat in CR, (3) to provide diagnostic information, (4) to protect teeth and associated structures from bruxism, (5) to mitigate periodontal ligament proprioception, and (6) to reduce cellular hypoxia levels.

Fig. 1. Anterior deprogrammer to separate posterior teeth with smooth function on anterior teeth.

Fig. 2. Occlusal view of mandibular stabilization appliance.

Relaxing the muscles
It has been well documented that tooth interferences to the CR arc of closure hyperactivate the lateral pterygoid muscle; posterior tooth interferences during excursive mandibular movements cause hyperactivity of the closing muscles; and the elimination of posterior excursive contacts by anterior guidance significantly

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*Private practice.
chronic symptoms of muscle hyperactivity were lessened significantly with 24-hour splint wear. The effectiveness of splint therapy in reducing pain indexes and muscle hyperactivity is well documented.10-12

Allowing the condyle to seat in centric relation

No report on splints would be complete without an understanding of the role of CR to the healthy stomatognathic system. The Glossary of Prostodontic Terms defines centric relation as “A clinically determined relationship of the mandible to the maxilla when the condyle disk assemblies are positioned in their most superior position in the mandibular fossae and against the distal slope of the articular eminence.”14

For the condyle to completely seat under the disk in this anterosuperior position, the lateral pterygoid must completely relax because of its attachment to the disk through the superior belly. If this muscle stays contracted after hyperactivity, the disk will be pulled anteromedially (along the direction of the muscle origin) and will not seat completely over the condyle. When the disk is loaded in a power bite or through parafunctional activities, the disk, attached muscle, condylar head, condylar ligaments, and retrodiscal tissues can sustain excess force loads and be damaged if the condyle/disk assembly is not properly related to the fossa. Chronic and acute overloading of the condyle/disk assembly when it is out of its normal physiologic position contributes greatly to the catch-all term temporomandibular disorder. Temporomandibular joints are load bearing15-17 and susceptible to overload. When splints were placed in monkeys in one study, a lateral deviation from the CR arc of closure resulted, as did bone density changes in the condyles that were not found when CR splints were used.18 This has led to cartilage breakdown and arthritis in the condylar heads.19

Centric relation is the optimal arrangement of joint, disk, and muscle. A person can function if the arrangement is anterior to this position, but the condyle and disk must be allowed by the dentition to return unimpeded to perform their load-bearing function. This position is consistently repeatable because of the boney stop for the condyle/disk assembly as the condyle hinges on its axis through the medial pole. It is not muscle braced as would be the case if the condyle/disk were down and forward against the articular eminence. To maintain a mechanical advantage, maximal clenching must be performed in this position.Splint therapy must use CR as the ultimate treatment position except in situations where inflammation of the joint makes this position uncomfortable. The patient may use his/her anteroinferior condylar position until the inflammation subsides (approximately 7 days) and be reintroduced to the CR position.

Fig. 3. A, Repositioning appliance locking condyle into anteroinferior position. B, Occlusal view of appliance with indentations in acrylic.

reduces elevator muscle hyperactivity.4 It follows that a splint with equal-intensity contacts on all of the teeth, with immediate occlusion of all posterior teeth by the anterior teeth and condylar guidance in all movements, will relax the elevator and positioning muscles. The neuromuscular harmony that follows provides optimal function and predictability to the system. The splint may be thought of as an exquisitely balanced arch of teeth that must function in a similar manner. The literature reveals that very small (50 μm) occlusal interferences can cause changes in coordinated muscle activity.5 The more balanced and frictionless the splint, the better the opportunity for reducing muscle hyperactivity. A muscle that is fatigued through ongoing muscle hyperactivity can present with pain. If the hyperactivity is stopped, the pain caused by this activity usually will disappear.6

Occlusal splints are a means of reversibly altering the occlusion to reduce masticatory muscle activity. Fuchs7 reported the advantages of splint therapy in the reduction of nocturnal EMG masseter activity in patients with temporomandibular disorder (TMD). Beard and Clayton8 also reported reductions in muscle symptoms with splint therapy. Okeson et al9 found that acute or
before permanent changes in the muscle, disk, or supporting tissues take place.

**Providing diagnostic information**

Splint therapy can be an important diagnostic tool to determine wear patterns, bruxism habits, and TMD status. Wear patterns that exist on the splint are reintroduced into the natural dentition when the splint is not worn. A horizontal “grazing” pattern would indicate a different occlusal scheme than a vertical “chopping” bite. Bruxism habits also leave their mark on the surface of the hard acrylic resin splints. In a study by Holmgren et al.,\textsuperscript{20} indentations indicated isometric clenching in 13% of subjects, bilateral mandibular clenching in 71%, unilateral excursi in 13%, and pro- trusive movements in 3%. Information gained from wear patterns on splints helps determine occlusal configurations, material choice, cusp heights and shapes, guidance angulations, axial loads, the envelope of function, and the neutral zone (Fig. 4).

The anatomic and physiologic status of the joint also can be evaluated in part by splint wear. If a patient rapidly becomes comfortable with a splint, it may be an indication that the disorder is muscular. If symptoms worsen with permissive splint wear, this may indicate an internal derangement (disk) problem (perhaps caused by free reign of the condylar head back to the retrodis- cal tissues without housing by the disk) or an error in the initial diagnosis. In and of itself, this information has limitations. However, with a thorough TMD and occlusal examination, such information can be an invaluable piece of the diagnostic puzzle.

**Protecting teeth and associated structures from bruxism**

A CR-balanced nocturnal permissive splint can pro- tect teeth from extensive wear caused by parafunctional activity (bruxism). Studies suggest that bruxism exists in 6.5% to 88% of the population.\textsuperscript{21} Gibbs et al.\textsuperscript{22} found that the highest recorded bite force during bruxism was 975 lbs. and that bite strength in some bruxer-clenchers can be as much as 6 times that of the nonbruxer. The average maximum biting force measured during clenching is 162 lbs.\textsuperscript{23} This data indicates why the forces generated during night activity can destroy the dentition. A splint not balanced in CR will show increased localized wear (usually in the posterior of the splint) (Fig. 5). The sleeper’s attempt to get to CR (the most superior bone-braced position) with the help of the elevator muscles is interrupted by the splint.

Holmgren et al.\textsuperscript{20} have shown that splints do not stop bruxism but do redistribute the load borne by the teeth and masticatory system. Their study duplicated the findings of Gentz\textsuperscript{24} and Kydd and Daly.\textsuperscript{25} Piper\textsuperscript{26} recommended using a 12- to 15-mm-thick splint (incisal edge to incisal edge) to decrease clenching efficiency. A thick splint should be considered for chronic bruxers with morning muscle pains (Fig. 6). Studies of pos- tural position\textsuperscript{11} tend to support Piper’s contention.
Mitigating periodontal ligament proprioception

Proprioceptive fibers contained in the periodontal ligaments of each tooth send nerve messages to the central nervous system. They indicate the amount of force on individual teeth and can trigger muscle patterns to protect teeth from overload. A splint can balance proprioception and even lessen it to mitigate proprioceptive output. Hellsing27 has shown experimentally how muscle changes immediately with tooth contact and that periodontal afferent feedback (proprioception) must be responsible for this rapid adaptation. Hannam et al28 also found that in cats, stimulation of pressure receptors in the periodontal membrane led to a jaw-opening reflex. This helps clarify why the teeth must be kept in balance with the condyle/disk assembly to maintain neuromuscular harmony in the associated muscles.

Reducing cellular hypoxia levels

In a study by Nitzan,29 pressure was measured in the superior joint space of patients with articular disk displacements. When they clenched maximally, recorded pressures reached up to 200 mm Hg. When a flat plane appliance was placed, no significant pressure (no capillary hyperfusion pressure) was recorded. This lends credence to stabilization splint therapy from a molecular point of view.

SPLINT CHARACTERISTICS

The characteristics of a successful splint should include stability; balance in CR; equal intensity stops on all teeth; immediate posterior disclusion; a “skating rink” surface; smooth transitions in lateral, protrusive, and extended lateral excursions (crossover); comfort during wear; and reasonable esthetics. Patient compliance also contributes to splint success.

A splint that moves in the mouth cannot provide the stability necessary for a definitive, immobile surface prepared for heavy forces from all directions. The laboratory must fabricate a splint so that it comes on and off with a slight undercut to ensure a firm fit. The patient should feel no sense of tightness on any of the teeth when the splint is seated; if that is not the case, tooth hypersensitivity usually will follow. The length of the splint on the lingual and buccal is dependent on the need for retention as a result of tooth size and shape. The shorter and thinner the splint is on the lingual, the better the patient compliance, the more distinct the speech, and the more comfortable the tongue posture will be. The buccal flanges must be thick enough to be strong but not impinge on the neutral zones. Thinness can create discomfort or lip “trapping.”

Fabrication in a hard, heat-polymerized acrylic resin will facilitate the establishment and adjustment of contact points. Orthodontic acrylic resin is user-friendly, easy to adjust, and soft enough not to hyperactivate periodontal ligaments. It also can be polished to a high luster for a low-friction surface. Methyl methacrylates are relatively easy to work with but maintain a strong odor and exhibit a granular composition that is harder to polish and adjust. The soft rubber resilient materials used for sports guards possess none of the characteristics important to splint therapy and have no effective use in this arena. The literature has shown that they may even increase bruxism.30 Hydrostatic “pseudo” splints work to separate the teeth and reduce muscle hyperactivity for short periods while full-coverage splints are being fabricated. Long-term use of the former is not recommended. Ultra splint resin (Astron Dental Products, Lake Zurich, Ill.) is suggested for patients with allergies to orthodontic acrylic resins.

The laboratory needs explicit instructions for the fabrication of any intraoral appliance. Maxillary and mandibular appliances have completely different designs, though they function the same. All teeth contact in CR on a maxillary appliance. A mandibular appliance often will have cuspid-to-cuspid contact in CR, with the maxillary anterior teeth not touching. Many TMD patients have a significant horizontal overlap; to extend the mandibular acrylic resin to contact the maxillary teeth would be unsightly, physically uncomfortable, and unnecessary. Since the oral cavity is a dynamic system and the movement of the jaw is nearly always forward, the anterior teeth will be in constant contact with the splint. This area must be balanced by having the patient move in protrusive, lateral, and mediolateral movements, marking the areas, and establishing anterior guidance principles already mentioned.

Mandibular appliances are the popular choice for active patients who wear splints 24 hours per day, as they do not show or affect speech as much as maxillary appliances. On the other hand, the maxillary appliance is an attractive choice for night wear, as all of the teeth are in contact with equal intensity, and the 13% of the population that bruxes isometrically will have these forces more equally balanced. Other reasons for the choice of one arch over the other include arch irregularities, the patient’s profession, and the potential for gagging. It is appropriate for the patient to have a mandibular appliance for day wear and a maxillary appliance for the night (Fig. 7).

Twenty-four-hour splint wear is recommended because of the forces generated when teeth come together during swallowing and chewing. Swallowing forces exceed chewing forces,25 occur approximately 2000 times per day, and happen all
day. If possible, the splint should be worn when the patient eats.

Anterior repositioning splints were originally designed to "recapture" the disks by protruding the mandibular jaw forward until the condyle popped back on the disk and "locked" it into position. Although the disk may have been temporarily better aligned with the condyle out of the fossa, the physiologic parameters necessary for the functioning of the lateral pterygoids and the retrodisical tissues (vascular knee) were not addressed. Clark found good clinical success with this modality, and Anderson et al even suggested its superiority to flat plane appliances. Longer studies by Lundh and Westesson have shown that the clicking that initially stopped with these appliances returned in a large percentage of the patients, which indicates that the intended function of anterior repositioning splints was not accomplished. In patients who did not experience further clicking, the disk may have been permanently pushed out to the side on the lateral pole instead of recapturing the disk.

Success in alleviating pain with these appliances can be impressive, but it also can be explained. If the jaw is brought down and forward, the condyle will not impinge on the inflamed retrodisical tissues, which are a major source of pain. Anterior repositioning splints may be a valid treatment for short-term use (no more than 10 days) in trauma cases when stabilization splints tend to increase pain by allowing the condyle free access to inflamed tissues in the retrodisical area. However, anterior repositioning splints tend to introduce posterior open bites in long-term wearers (when the appliance does not cover the anterior teeth), and heroic orthodontics or restorative dentistry is required to close the teeth into their new anteroinferior muscle-braced position (Fig. 8). One would have to discount the anatomic and physiologic principles of the masticatory system to believe that an anterior repositioning appliance should be a standard modality for TMD disorders of any kind (other than acute short-term trauma).

CHOOSING THE CORRECT SPLINT

Determination of the appropriate type of splint therapy depends on the specific diagnosis of the temporomandibular disorder and a thorough understanding of the anatomy of the condyle/disk complex.

Muscle incoordination is determined by muscle palpation, joint loading, range-of-motion measurements, joint palpation, occlusal evaluation, and Doppler diagnosis. Patients present with painful symptoms in the facial muscles, headaches, limited ranges of motion, frequent joint inflammation, and occlusal interferences to CR; infrequent clicking on jaw movement also may be present. This anatomic asymmetry is reversible if caught in time and treated with bite plane therapy or permissive splint therapy in Phase I (reversible treatment) and with appropriate Phase II therapy (additive or subtractive occlusal therapy, restorative dentistry, orthodontics, maxillofacial surgery, and segmental alveolar surgery) to restore balance from/to the CR position.
Muscle and disk incoordination has the same signs and symptoms as muscle incoordination except reciprocal clicking or a history of reciprocal clicking that stops. Diagnosis may include sagittally corrected tomograms. Patients often present with the medial pole of the condyle intact under the disk with the lateral pole of the disk damaged from loading or stretching and subsequent ligament laxity. Most symptoms may be reversible if caught in time, though the reversibility of clicking depends on the shape of the distorted disk and the fibrosis of the lateral pterygoid muscle. Treatment usually includes permissive splint therapy and Phase II therapy for stabilization because of the weak ligament structure.

With advanced muscle and disk incoordination, symptoms may be the same as in previous stages, though jaw locking, painful joint noises, and increases in pain with splint therapy may be evident. These patients often have a long history of joint noises without pain that have become painful. Pain on loading with bimanual manipulation is evident and may be extreme. Diagnostic techniques include sagittally corrected tomograms and magnetic resonance images. Surgical intervention may be necessary depending on the location and degree of displacement of the disk. These stages are irreversible but may be managed to a pain-free state with appropriate medications, splint therapy, and Phase II therapy.

SPLINT DESIGN WITH FUNCTIONAL CONSIDERATIONS

Understanding the function of the masticatory system provides an excellent basis for splint design. A set of teeth (the splint) is needed that has equal intensity contact on all the teeth, provides immediate posterior discusion by the anterior teeth and condylar guidance, and is as frictionless as possible for neuromuscular harmony and subsequent healing. The stabilization splint meets these needs. It can be placed on either arch as long as the basic requirements are met. The splint must allow the condyle to achieve the CR position. This can be achieved with bimanual manipulation, which was fostered by Dawson and has proven to be the most reliable and repeatable method for achieving CR with inexperienced practitioners.

A stabilization splint is not unique if the teeth and/or inflammation result in an incomplete condylar seating. The splint could be considered a set of teeth with occlusal interferences. Therefore, the splint must be continually monitored and adjusted. When the muscle relaxes and/or inflammation subsides, the position of the teeth on the splint changes. When readjustment of the splint to the CR position is accomplished, the teeth and condyle/disk assembly achieve neuromuscular harmony. This explains why patients feel some initial relief from almost anything put in their mouths yet stop improving after the initial 1 to 2 weeks. If the interferences on the splint are continually chased by rebalancing into CR, the patient will grow comfortable and stay that way. The more skilled the practitioner becomes with this balance and timing, the more rapidly the patient can progress. The technique inevitably works; however, lack of attention to detail or the skill level of the doctor may influence success.

In a study by Holmgren et al, changes were seen on the splint (in the form of indent) in 61% of patients at every 2-week evaluation. The remaining 39% of the patient pool experienced changes from time to time. The majority of splint wearers need to be seen more often than every 2 weeks for initial adjustments. A suggested protocol would include adjustments at 24 hours, 54 hours, 7 days, 2 weeks, and 1 month after seating. When no movement on the splint is seen at adjustment appointments and symptoms are reduced, the intervals between adjustments can be extended as long as any reversal of symptoms is countered with an immediate adjustment appointment. After 3 months with no changes on the splint, a comfortable musculature, and no pain on loading, the patient is ready for evaluation of phase II therapy.

SPLINT FABRICATION

Practitioners beginning a career in treating bruxers or TMD patients may become frustrated while trying to seat a new splint in a reasonable period of time. Laboratorios often provide a prosthesis from a maximum intercuspsation (M1) occlusion that presents high on the distal of the splint and ends up having a hole ground all the way through the acrylic resin in an attempt to balance the occlusal relation. Without an accurate CR occlusal record, accurate models of all occluding surfaces, and a reliable face-bow transfer, seating time will be longer and occasionally impossible because of excessive or inadequate acrylic resin. With precise laboratory instruction and records, seating and adjusting should take no longer than 10 minutes. In-house fabrication allows the practitioner to quickly and efficiently develop the prosthesis that the diagnosis demands. If this is not possible, precise communication with a commercial dental laboratory is necessary to provide the quality prosthesis mandatory for treatment success.

WHAT SPLINTS CANNOT DO

Splints cannot do 3 basic things: unload the joint, prevent bruxism, or "heal" the patient. Some authors and lecturers have stated that splints function to unload the joints and therefore take pressure off the disk. This theory has been disproved by Kuboki et al and cannot be explained anatomically or physiologically. The elevator muscles are located behind the most
posterior tooth and therefore ensure that the joint will always be loaded when the elevators contract. The unloading theory is probably used to protect the validity of splint designs that are ineffective in their theorized function. Such splints open the vertical dimension and minimally decompress the condylar head when not loaded to reduce superior tissue pressures. They also may increase temporomandibular joint loading\(^7\) that results from greater maximum muscle efficiency.

Splints do not prevent bruxism; they balance the force distribution to the entire masticatory system. They can decrease the frequency but not the intensity of bruxing episodes.\(^20\) Splints also do not heal patients; they give patients the opportunity to heal themselves. The patient pays not for the fabrication of a splint only but also for the care, skill, and judgment of the practitioner whose goal is to enable healing through appropriate design, monitoring, and adjustment.

SUMMARY

There is sufficient credible literature to support the use of splint therapy to reinstitute neuromuscular harmony in a compromised masticatory system. Dental practitioners have a responsibility to understand and provide this treatment, monitor the condition, and refer the patient to another practitioner if necessary.

REFERENCES


Reprint requests to:
Dr. Tim J. Dylina
360 E. YOSEMITE AVE. #400
MUSCOVE, CA 95340
FAX (209)723-4823
E-MAIL: Timgoli@ao.com
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0022-3913/2001/$15.00 = 0. 10/1/18878