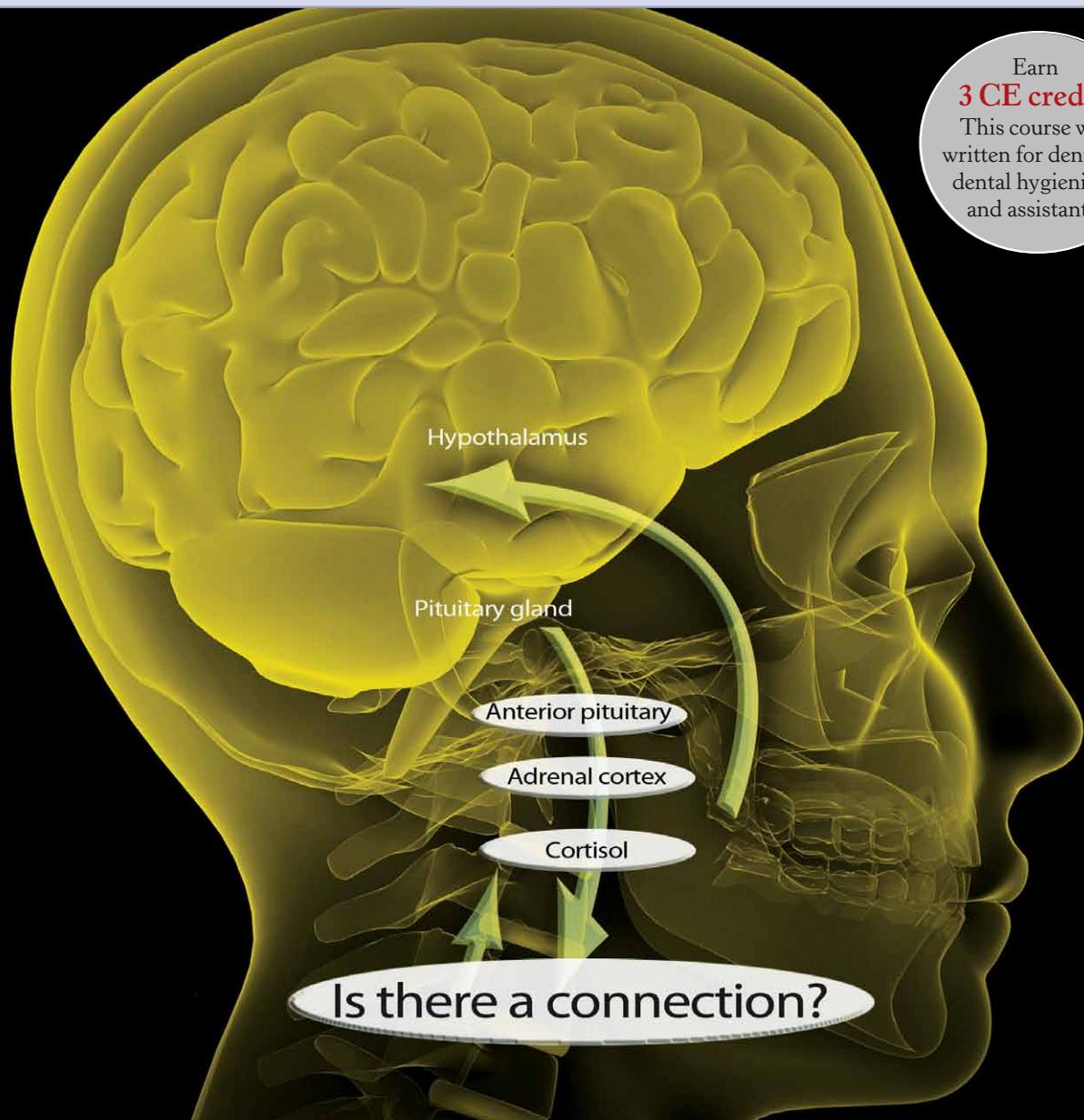


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The Genesis and Advancement of Mouthguards and Mouthpieces

A Peer-Reviewed Publication
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Educational Objectives

The overall goal of this article is to provide the reader with information on oral appliances, mouthguards and mouthpieces. Upon completion of this course, the reader will be able to:

1. List and describe the mouthguard variants available over-the-counter and through the dental office.
2. List and describe the rationale for protective athletic mouthguards and the recommendations on their use.
3. List and describe the rationale and results for the use of oral appliances and mouthguards for the treatment of TMJ and bruxism.
4. List and describe the rationale for the use of performance mouthguards and mouthpieces, and the results that have been obtained using these.

Abstract

Modern-day mouthguards and oral appliances have been used since the early 20th century. They are currently in use for protection against athletic injuries; the treatment of TMJ, bruxism and sleep apnea; and athletic performance enhancement. The American Dental Association and the American Academy of Pediatric Dentistry both recommend the use of protective mouthguards to help prevent sports-related injury. The treatment of bruxism was, in fact, the first use of modern mouthguards and was followed by customized designs for protection of the oral structures and to treat specific conditions. More recently there has been a resurgence of interest in athletic performance mouthguards, which have been found in a number of studies to improve reaction time, muscle strength and sensory functions. The purpose of a mouthguard dictates the materials and designs most suitable for optimal results.

Introduction

Mouthguards can be used for protection or function. The first modern use of mouthguards was reported at the beginning of the 20th century, for the treatment of bruxism,¹ and these were later introduced for the prevention of sports-related oral injuries. By the 1920s, protective mouthguards were first mandated for boxers, and in 1962 – almost 40 years later – they were mandated for high school football players.^{2,3} Subsequently, functional mouthguards were designed to treat and manage temporomandibular joint disorders and bruxism, as well as sleep apnea and snoring. Most recently, mouthguards and mouthpieces have been designed and researched with the objective of increasing the strength and performance of athletes.

Mouthguard variants

Available mouthguard designs include over-the-counter stock; boil-and-bite; and custom-fabricated, office-dispensed variants. Each type of mouthguard has advantages and disadvantages, depending on the indication or reason causing the mouthguard to be used. Mouthguards consist of either a rigid or soft, flexible material, or may be “boil-and-bite” thermoplastic resin that allows for some intra-oral customization of the mouthguard. Historically, materials used for mouthguards have included acrylic resin, ethylene vinyl acetate and polyvinylchloride, as well as latex, which has fallen into disfavor due to its inferior physical characteristics.³ An additional consideration with respect to latex is the possibility of a severe allergic reaction in some patients.

Stock over-the-counter mouthguards are available in several sizes and designs, depending on the purpose. These may be constructed from hard acrylic resin – in which case little or no modification is possible, from soft or semisoft plastics that allow for some

intra-oral adaptation to the individual’s alveolar arches and dentition, or from thermoplastic material as with boil-and-bite appliances. To adapt the boil-and-bite material, which typically consists of ethylene vinyl acetate, the individual places it over the dental arch once it has been softened and has cooled sufficiently but before it rehardens. The material should then be evenly manipulated against the dental arches, using the fingers, tongue pressure and biting pressure to provide for an approximate fit.⁴ A fourth variant is a hybrid, consisting of an outer rigid arch with an inner flexible lining layer.

Stock mouthguards are available for protection against sports-related injuries as well as performance, and for the treatment of bruxism, TMJ and alveolar conditions. By their very nature, over-the-counter mouthguards offer only an approximate fit, which can result in poor retention and undesirable bulkiness with little or no possibility of adjustment to improve positioning.^{5,6} They do, however, offer an inexpensive solution for individuals who otherwise may not wear mouthguards when needed.

On balance, in the case of protection against sports-related injuries, a loose but adequate mouthguard is preferable to no mouthguard at all where cost is a barrier. Boil-and-bite mouthguards are the most common stock type, and while, depending on their design, they vary in their effectiveness,⁷ they are considered the best stock solution for protection against oral sports injuries. Nonetheless, boil-and-bite mouthguards offer less protection against impact forces than do custom-fabricated mouthguards used for protection against sports-related injuries.⁸

Office-dispensed/custom-fabricated

Office-dispensed custom mouthguards can be fabricated in the office or by the laboratory. They may be fabricated as rigid, hard acrylic resin or softer, semi-rigid appliances. Custom-fabricated mouthguards are likely to result in the best fit and the most comfortable result;^{4,9} they are also the most expensive. Patrick and van Noort ranked the effectiveness of protective mouthguards, finding laminated mouthguards with outer hard layers and an inner soft layer the most effective and stock mouthguards the least effective. They also concluded from their testing that custom mouthguards decreased in effectiveness after a period of two to five years as the material aged and its properties changed.¹⁰ In fact, boil-and-bite mouthguards also provide a better fit when laboratory fabricated or adapted and dispensed from the dental office. The clinician is able to expertly adapt the thermoplasticized material to offer the best possible fit, ensuring that the thickness is uniform throughout the mouthguard and, in the case of orthodontic patients, ensuring that the mouthguard is appropriately adapted around the orthodontic appliance.

There are currently three main methods for custom fabrication of mouthguards. The first involves taking an impression and sending this together with the prescription for the mouthguard to the laboratory, where the mouthguard is fabricated from hard acrylic resin or a softer, resilient polymer (plastic) material. If the mouthguard is for the treatment of bruxism or other TMJ/alveolar condition, the occlusion should also be registered and sent to the laboratory. This is not necessary for protective sport mouth-

guards. For the second method, impressions are still taken and the resulting stone models are used with vacuum-formed material to create the mouthguard either in the office or in a laboratory. This is in essence similar to the process used for creating bleaching trays. The thermoplastic sheet is softened, and then a vacuum is applied to draw it over the arch and dentition on the stone model to shape it (the stone model may have a separator or be wet to avoid adhesion of the thermoplastic material while it is still soft). Subsequently, the form is left to cool, and then trimming/any adjustments can be made. A similar technique that is an offshoot from vacuum-forming is the use of pressure and heat that enables mouthguards to be laboratory constructed of several layers of material rather than one layer. As with the vacuum-form technique, thermoplastic material is used and heated to soften it, after which, instead of a vacuum, pressure is applied to shape the layers.

For orthodontic patients, it is essential to ensure that the mouthguard is appropriately adapted around the orthodontic appliance.

The remaining method available for construction of mouthguards – specifically, nightguards to protect against bruxism – is a chairside technique whereby mouthguards can be created in one visit without impressions, using single-use arch forms that are placed using a silicone mold and then light-cured (iNterra™, Dentsply Caulk). These have been found to offer good retention and stability, and a recent evaluation of these mouthguards after a period of just over 300 days’ use for parafunction (bruxism) found that all were still well-adapted to the teeth, 96.2% were free of fractures, and 98% had either no wear or acceptable wear.^{11,12}

Table 1. Office-dispensed, custom-fabricated mouthguards

Hard light-cured or cold-cured acrylic
Flexible plastics
Vacuum-formed
Pressure-formed
Laminated
Thermoplastic boil-and-bite

Bruxism

Bruxism occurs in a significant percentage of the general population – self-reported bruxism occurs in approximately 20% of adults in the United States, and up to 20% of children under age 12 are reported by parents to experience sleep bruxism (tooth grinding); these children are also found to exhibit high anxiety scores.^{13,14}

Patients with bruxism parafunctionally clench their jaws and usually also grind their teeth if they brux at night. The two variants of bruxism are known as awake bruxism and sleep bruxism, which is more serious in nature since, unlike awake bruxism, it includes tooth grinding.¹⁵ Symptoms of bruxism can include pain and discomfort in the temporomandibular joints and facial musculature, headache/migraine, and reduced parotid salivary

flow.^{16,17} Loss of tooth structure due to attrition and, potentially, abfraction and a pattern of occlusal wear that includes occlusal pits and that cannot be attributed to normal behavior (i.e., eating, chewing) are all sequelae of bruxism, which may also result in tooth sensitivity.^{18,19,20,21,22} This loss of tooth structure is progressive if the patient’s bruxism is not addressed and over time can result in diminished dental height, which has both functional and esthetic implications, with shorter, stubby teeth and eventually, if untreated, a collapsed appearance of the face. Bruxism may also be a contributing factor in the fracture of restorations.^{23,24}

A number of factors have been cited as contributing to the occurrence and severity of bruxism, with stress generally considered to be a primary factor.¹⁸ Self-reported bruxism was found in a review of the literature by Manfredini to be associated with anxiety, stress and other psychosocial factors. Since night bruxers are typically unaware that they brux, the self-reported bruxers by inference are daytime bruxers. In the case of night bruxers, it is less clear whether psychosocial factors play a role or whether this may be a part of sleep patterns, with conflicting evidence in the literature.²⁵ Other factors for sleep bruxism identified in a review of the literature by Cuccia included heredity, smoking, alcohol and drugs.²⁶

The cornerstone of intervention and the prevention of chronic bruxism, irrespective of potential etiology, is the provision of mouthguard appliances.²⁷ These have proven to be effective in the management of bruxism, with primarily the use of custom-fabricated hard resin nightguards for the prevention of progressive tooth wear and associated problems.²⁸ In their Cochrane review of five randomized and quasi-randomized trials, Mancedo et al. found that the evidence for any effect of an occlusal splint on sleep per se was equivocal, also finding, however, that they may be of benefit against tooth wear.²⁸

Figure 1. Oral appliances for bruxism/TMJ disorders



Oral Appliances for TMJ Disorders

Oral appliances are provided to patients with TMJ pain and TMJ disorders where inflammation or intra-capsular derangements are present. Conceptually they involve repositioning of the arches relative to each other. These appliances are used either during the

day or at night (or both), depending on the clinical findings and indication. There are two fundamental types of appliances used to treat TMJ disorders – stabilizing splints and repositioning appliances.²⁹ As with the mouthguards described earlier in this article, splints can be stock hard or boil-and-bite or custom-fabricated appliances with the same relative advantages and disadvantages with respect to accuracy, fit, comfort and expense. Daytime custom-fabricated anterior repositioning appliances have been found to result in significant long-term improvements in TMD patients.³⁰ Day and night appliances can be used for the treatment of tension headaches, muscle contraction and reduced jaw opening.³¹ Indications for these appliances include inflammatory temporomandibular joint disorder and TMJ disc displacements. Nonadjustable and adjustable oral appliances are available, with one custom-fabricated oral appliance using both upper and lower arch coverage that can be adjusted vertically and anteroposteriorly for the treatment of TMD and bruxism.

Day and night appliances can be used for the treatment of tension headaches, muscle contraction and reduced jaw opening.

Oral Appliances for Sleep Apnea

One of the most common uses of night mouthguards is for the treatment of sleep apnea and snoring. Fundamentally, these appliances all work by repositioning the mandible forward. As verified by prospective studies utilizing magnetic resonance imaging and computerized tomography, this opens up the upper airways by increasing the diameter of the oropharynx and the velopharynx, which in turn improves ventilation (the inhalation and absorption of oxygen and the release of exhalation of carbon dioxide).

Figure 2. Oral appliances for the treatment of sleep apnea and snoring



Results of studies researching this concept have led to the conclusion that the design of the oral appliance – i.e., the amount of forward repositioning of the mandible – determines the amount of upper airway opening that can be achieved.^{32,33,34}

Table 2. Repositioning and velopharynx opening (Zhao et al.)

	Minimum change	Mean change
0 mm	4.00 mm ² +/- 7.25	3.27 mm ² +/- 9.36
2 mm	6.64 mm ² +/- 6.87	8.45 mm ² +/- 7.59
4 mm	12.00 mm ² +/- 10.02	17.73 mm ² +/- 16.29
6 mm	18.18 mm ² +/- 11.52	24.45 mm ² +/- 22.84
8 mm	21.00 mm ² +/- 11.35	35.82 mm ² +/- 19.90

Many different types of appliances have been used for the treatment of sleep apnea, ranging from simple over-the-counter hard or boil-and-bite mouthguards to custom-fabricated designs.

Nonadjustable oral appliances reposition the mandible at a set distance forward from its original position and can be fitted to the upper or lower arch (or both). Adjustable custom-fabricated oral appliances are also available.

Protective Athletic Mouthguards

Sports-related injuries are commonplace in children and adults, including orofacial and dental injuries, with up to 39% of all dental injuries estimated to be sports-related and with young school-age children being the most vulnerable.⁴ Adults are also affected: one epidemiologic study in adults in Switzerland found that, over a 10-year period, more than 20% of all dental trauma was sports-related.³⁵ In another study of 561 adults in New Zealand, 21.7% of all maxillofacial fractures were due to sports injuries, with the highest number attributable to rugby, cycling, cricket and soccer.³⁶

Figure 3. Basketball injury – fractured central incisor



Courtesy of Mark Roettger DDS, FASD

Figure 4. Baseball injury - avulsed central incisor



Courtesy of Mark Roettger DDS, FASD

A 1998 study of high school athletes competing in soccer, basketball and wrestling found that all three sports resulted in a high incidence of orofacial injury, ranging from 27.6% to 72.3%, with a higher incidence during games than during practice. At the time of the study, only 6% of the athletes surveyed claimed to wear protective mouthguards.³⁷ Protective mouthguards absorb the impact that the alveolar process and dentition may be subjected to, reducing the likelihood of injury.⁹ A 2005 review of the literature on sports-related injuries in basketball players also found that games resulted in more injuries than practice did, and specifically that the use of mouthguards reduced orofacial and dental injuries.³⁸ Meta-analyses of a number of studies have suggested that athletes are at 1.6 to 1.9 times greater risk of sports-related injuries if they do not wear protective mouthguards.³ While protective mouthguards have been shown to reduce the risk of sports-related orofacial and dental injuries, there is no consistent evidence showing that mouthguards offer protection against neurocognitive injuries or concussion,³ and one study of 180 such injuries in students found that there was no difference in the severity of symptoms between those who did and those who did not use mouthguards.³⁹ Athletes have complained that protective athletic mouthguards are uncomfortable to wear and cumbersome and that mouthguards contribute to difficulty in breathing.⁴⁰ Francis and Brasher found in their study that although airflow was restricted more by double-arch than by single-arch mouthguards, the athletes subjectively complained equally about both.⁴¹

Figure 5. Protective athletic mouthguards



The recognized value and success of protective mouthguards in preventing sports-related oral injuries has led to their endorsement by many organizations. While only four sports require mandated use of mouthguards by The National Federation of State High School Associations (football, field and ice hockey, and lacrosse), the American Dental Association recommends their use for almost 30 sports, and protective mouthguards are endorsed by the Academy for Sports Dentistry.^{7,42,43} The American Academy of Pediatric Dentistry policy on protective mouthguards includes support for the continued use of protective mouthguards in sports activities for children and adolescents and the use of “properly-fitted mouthguards in other organized

sporting activities that carry risk of orofacial injury.”⁴⁴ The Council on Scientific Affairs and the Council on Access, Prevention and Interprofessional Relations of the American Dental Association “recommend that athletically active people of all ages use a properly fitted mouthguard in any sporting or recreational activity that may pose a risk of injury.”⁷

Protective mouthguards protect the alveolar process and dentition from impact forces, reducing the likelihood of injury.

Performance Mouthguards

Athletic mouthguards have evolved into two separate categories – standard protective mouthguards and performance mouthguards/mouthpieces. The potential to simultaneously offer protection and enhance athletic performance is attractive. Research on the potential effects of mouthguards on performance began in the late 1950s, more than 30 years after the introduction of protective mouthguards, with a study by Stenger.⁴⁵ The use of performance mouthguards involves repositioning the mandible – such mouthguards are also known as mandibular orthopedic repositioning appliances (MORA). The main principle suggested for the use of a MORA is that musculature position of the head and neck, and intermaxillary position, influence tension and therefore muscle strength. Their effect has been attributed to efficient respiration, increased visual acuity, muscular strength and lack of discomfort associated with clenching during strenuous activities. Performance mouthguards (MORA) have been investigated and reported in the literature, with the primary focus placed on muscle strength and endurance.

Early research

In a study by Fuchs in 1981, it was concluded that the use of a wax bite that repositioned the arches vertically by 3 mm resulted in an increase in isometric strength of the arms and feet in the 40 female subjects.⁴⁶ Kaufman conducted a double-blind study of football players, finding self-reported strength improvement and fewer serious injuries.⁴⁷ Other early studies also concluded that the use of a mouthguard resulted in increased performance (endurance and strength).^{48,49,50} In contrast, Yates et al. in 1984 found no difference in large-muscle group strength with no mouthguard, a placebo mouthguard or a MORA, and suggested that there was no effect.⁵¹ A double-blind study involving eight subjects investigated changes in muscle groups in subjects with TMJ disorder, finding no differences in the test or placebo group.⁵² Wang et al. referred to the many early studies on the use of MORAs to enhance performance, and to the controversy in this area. In their small study in 1986, they tested shoulder abduction strength and electrical impulses generated in upper body muscle groups as well as maximum voluntary contraction of these muscles in a supported rest position. They found that the electrical activity was significantly greater when subjects wore a MORA than when they did not, suggesting that use of a MORA resulted in increased upper body muscle activity.⁵³ One study con-

ducted in the 1980s that was double-blind and placebo-controlled resulted in the conclusion that repositioning the mandible with a Gelb appliance resulted in significantly increased shoulder strength compared to normal centric occlusion (i.e., with no appliance) and that there was no effect using a placebo.⁵⁴

Early studies conducted during the 1970s and 1980s varied in their use of placebos, controls, and whether or not they were blind (or double-blind). Gelb et al. concluded that they were often poorly designed and that more recent studies supported the hypothesis that athletic performance and muscle strength are improved with the use of a MORA.^{55,56} Forgione et al. reviewed the data available as of 1991 and concluded that study designs varied, with some using different mandibular positions and others using strength as a generic term, testing mainly isokinetic strength, or deducing a nonexistent placebo effect. After reviewing all available published and unpublished studies, they concluded that it was likely that, specifically, isometric strength was improved using the MORA in a functionally determined position for subjects with mixed occlusions and malocclusion.⁵⁷ Forgione et al. also published the results of a test in subjects with relative weakness, when biting, to the isometric deltoid press. The MORA resulted in a significant increase in this peak strength compared to use of a bite-raising mouthguard or no mouthguard. No placebo effect was observed. The investigators concluded that there is a relationship between bite and isometric strength.⁵⁸

Later studies

More recent studies were conducted during the 1990s and later. One randomized, crossover design study measured visual acuity, concentration, reaction time, dexterity and coordination, finding no difference between use of a MORA or not; the effect on strength was not reported.⁵⁹ Cetin et al. studied the effect of the MORA on strength and anaerobic performance in taekwondo athletes, examining handgrip and hamstring strength, isometric strength of the lower extremity and back, sprint time, and jumping height following squatting. The Wingate Anaerobic Test and Hamstring Isokinetic Peak Torque were used for power (strength) measurements. They concluded that average and peak power significantly increased with use of the MORA and that the mouthguard had no negative effects.⁶⁰ Other controlled studies conducted over the last 12 years have also found increases in strength when using repositioning oral appliances designed for that purpose.^{61,62} A small study in 2008 led to the investigators concluding that the perceived negative impact of mouthguards on breathing, speaking, concentration and athletic performance was subjective. After four weeks, the study subjects indicated less interference with these parameters. It was also found that peak minute ventilation and oxygen uptake were comparable, but that the maximum workload improved slightly during exercise with use of the mouthguard compared to no mouthguard use (no placebo).⁶³ In addition, in the Francis and Brasher study where athletes complained about breathing with protective mouthguards, it was found, paradoxically, that physiological parameters improved when the athletes were wearing mouthguards during heavy exercise; while oxygen consumption decreased, the

forced expiratory air volume and peak expiratory flow rates also decreased and the authors concluded that the use of mouthguards resulted in physiologically more efficient breathing during heavy exercise.⁴¹ Milani et al. investigated the effect of a MORA on vision and found that in subjects who had been wearing a MORA, there were temporary positive changes in visual focusing that disappeared after a period of time and that did not occur in control subjects not wearing an appliance.⁶⁴

Investigators concluded that the use of mouthguards resulted in physiologically more efficient breathing during heavy exercise.

The Effects of Performance Oral Appliances

The effects of performance oral appliances are related to the “fight or flight” response and neurophysiological feedback mechanisms; the release of cortisol – the so-called stress hormone – and lactate levels have been found to play a role. Cortisol is released in response to physical exertion (i.e., stress), and it is believed that significant increases in this hormone result in physiological alterations that include reductions in performance and endurance, decreased metabolism, and immunosuppression.⁶⁵ When stressed, corticotropin-releasing factor (CRF) is released, which stimulates the release of adrenocorticotrophic hormone (ACTH), which in turn results in increased levels of cortisol being released. Stress results in clenching of the teeth, and, following the results of studies with functional MRIs, is hypothesized to be involved in feedback mechanisms that result in increased levels of cortisol (a glucocorticosteroid that is intended to release energy), adrenaline and noradrenaline through activation of the autonomic nervous system, including the hypothalamus.⁶⁶

Significant increases in cortisol levels result in physiological alterations that include reductions in performance and endurance, decreased metabolism, and immunosuppression.

It has also been found that nonfunctional biting (such as with an oral appliance) can impede this feedback mechanism.⁶⁷ It is further hypothesized that by repositioning the mandible, the patency of nerves and arteries in the TMJ is improved, increasing blood flow and the perfusion of oxygen to the tissues, which in turn may improve function and strength.^{68,69}

Figure 6. Home impression performance mouthguard



Contemporary studies

Contemporary studies have been conducted using an elastomeric oral appliance that was specifically designed to accommodate optimal positioning of the mandible based on this rationale. This oral appliance consists of a mouthguard designed either as a mandibular appliance covering the posterior teeth or as a full-coverage upper arch appliance. In either case the appliance acts as a wedge, repositioning the mandible and increasing the bite opening more posteriorly and less anteriorly; this reduces pressure on the TMJ when the individual clenches, thereby reducing the negative impact of stress on performance. The technology used for the changes in performance reported in these contemporary studies has been incorporated into both a full-coverage mouthguard designed for use in contact sports, as well as into a mouthpiece for noncontact sports that maximizes comfort while still offering appropriate protection.

Figure 7. Boil-and-bite performance mouthguards and mouthpiece



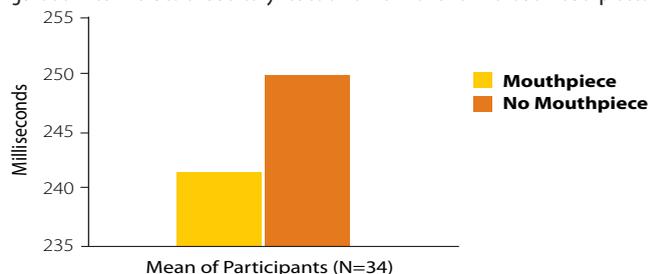
Figure 8. Custom performance mouthguard and mouthpiece*



*Office-dispensed; both require impression and dentist's prescription for laboratory fabrication

Grip strength was found to increase in 93% of females and 67% of males in a total of 123 subjects. A subset of these subjects (n=17) was examined for heart rate (a proxy for endurance), with lower heart rates in 50% of the subset.⁷⁰ In a separate study, use of this oral appliance resulted in statistically significant increases in muscle strength measured while participants performed curl and bench press exercises with increases of 17% and 11%, respectively.⁷¹ The same oral appliance has been found to reduce cortisol levels by 49% during exercise in more than 50% of study participants (n=18), thereby reducing the stress response and improving performance.⁷² Auditory reaction times were also found to improve with use of this oral appliance in a small controlled study at the Citadel, where subjects were asked to respond as soon as they saw the visual (n=13) or auditory (n=34) test signal in a total of 60 trials. While the improvements in visual reaction time were not significant, the improvements in auditory reaction time were more pronounced, with a statistically significant improvement (241.44 ms with the mouthpiece vs. 249.94 ms without it).⁷¹

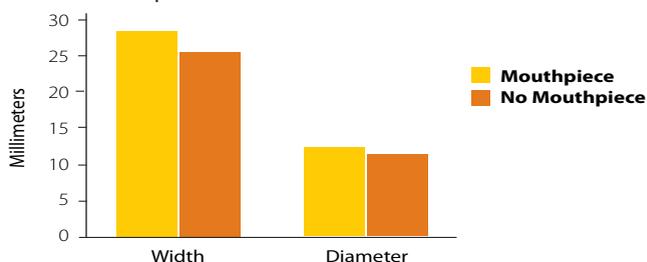
Figure 9. Mean values of auditory reaction time with and without mouthpiece.



Source: Garner and Miskimin. Effects of mouthpiece use on auditory and visual reaction time in college males and females.

Lactate levels have also been found to be influenced. Using the same wedge oral appliance (upper full-arch), Garner and McDivitt found that lactate levels were significantly reduced in study subjects (n=24) (4.01 mmol/L with mouthpiece vs. 4.92 mmol/L without the appliance) after 30 minutes of running at 85% of maximum heart rate.⁷³ Since lactate is a breakdown product of lactic acid and is a measure of energy used and exertion, this suggests that breathing may be enhanced and energy needs reduced, which in turn may improve endurance and strength and result in increased availability of energy to skeletal muscles.⁷⁴ In a subsequent pilot study the same investigators found increased width of the oropharynx opening when subjects used the oral appliance, and other investigators have also found this phenomenon.^{33,75}

Figure 10. Mean values of oropharynx width and diameter with and without a mouthpiece.



Source: Garner and McDivitt. Effects of mouthpiece use on airway openings and lactate levels in healthy college males.

Research continues to be conducted at major institutions on the design and efficacy of performance mouthguards and mouthpieces, and understanding the biochemical and physical mechanisms involved. At the same time, there is renewed interest in determining if designs can be fabricated that would not only provide oral protection and improve performance, but that could provide protection against neurocognitive injuries (concussion) and benefits for health. It can also be anticipated that manufacturing standards will be proposed and recommended through the National Operating Committee on Standards for Athletic Equipment (NOSCAE) for athletic mouthguards and mouthpieces.

Summary

Mouthguards have evolved into preventive and treatment devices for a number of indications and can be stock rigid or semi-adjustable or custom-fabricated. Mouthguards were first used to prevent and treat bruxism, then as protective devices in contact sports. Over time, protective mouthguards were recommended for players of noncontact sports and investigations were conducted on the

potential for performance mouthguards. Recent investigations support the use of mouthguards for all the purposes described in this article, including protection and functional as well as improved performance. Contemporary performance devices include both mouthguards and mouthpieces, and there is continued interest and research being conducted in this area.

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Dr. William L. Balanoff received his dental degree from Northwestern University and his masters in craniofacial research from Nova Southeastern University. He is an adjunct assistant clinical professor at University of Tennessee and a former assistant clinical professor at Nova Southeastern University teaching postgraduate prosthodontics; specifically implant surgery and reconstruction to the prosthodontic residents. Dr. Balanoff is the owner of a multilocation fee for service group practice in the south Florida area. He is on staff at Broward General Hospital and North Broward Hospital with privileges for implant surgery and reconstruction. Dr. Balanoff can be reached at William.Balanoff@Clearchoice.com

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Questions

- The first modern use of mouthguards was reported for _____.
 - treatment of sleep apnea
 - poor performance
 - treatment of bruxism
 - prevention of sports injuries
- Protective mouthguards were first mandated for _____ in the _____.
 - rugby players; 1930s
 - soccer players; 1920s
 - boxers; 1920s
 - none of the above
- Available mouthguard designs include _____ mouthguards.
 - over-the-counter stock
 - custom-fabricated
 - boil-and-bite
 - all of the above
- Latex mouthguards _____.
 - are popular and have no contraindications
 - are still in favor but cannot be used for patients with allergies to latex
 - have fallen into disfavor and can result in severe allergic reactions in some patients
 - none of the above
- Stock over-the-counter mouthguards are available for _____.
 - improvements in performance
 - treatment of bruxism and TMJ disorders
 - protection against sports-related injuries
 - all of the above
- Boil-and-bite mouthguards are the _____, and are considered the _____ stock solution for protection against oral sports injuries.
 - least common stock type; poorest
 - least common stock type; best
 - most common stock type; poorest
 - most common stock type; best
- Patrick and van Noort found _____ the most effective.
 - single layer mouthguards
 - laminated mouthguards with soft layers
 - laminated mouthguards with outer soft layers and inner hard layers
 - laminated mouthguards with outer hard layers and inner soft layers
- Custom mouthguards have been found to _____ in effectiveness after a period of _____.
 - decrease; one to two years
 - decrease; two to five years
 - increase; one to two years
 - increase; two to five years
- Boil-and-bite mouthguards provide a better fit when _____.
 - laboratory fabricated
 - adapted in the laboratory
 - adapted and dispensed from the dental office
 - a or c
- If a mouthguard is for the treatment of bruxism or other TMJ/alveolar condition, _____.
 - only a soft mouthguard should be used and only at night
 - only a hard mouthguard should be used and only during the day
 - the occlusion should be registered
 - none of the above
- Creating a mouthguard with a _____ technique is essentially the same as the technique used for bleaching trays.
 - lamination
 - pressure-form
 - vacuum-form
 - boil-and-bite
- Mouthguards for the treatment of bruxism _____.
 - can be created in the laboratory
 - can be purchased over-the-counter
 - can be fabricated chairside in one visit
 - all of the above
- A recent study found that _____ of chairside-fabricated mouthguards had no wear or acceptable wear after more than 300 days.
 - 68%
 - 78%
 - 88%
 - 98%
- Up to _____ of all dental injuries are estimated to be sports-related.
 - 19%
 - 29%
 - 39%
 - 49%

Continued on p.10

Questions (continued)

15. Protective mouthguards _____.
- absorb the impact that the dentition may be subjected to
 - absorb the impact that the alveolar process may be subjected to
 - reduce the likelihood of injury
 - all of the above
16. One epidemiologic study found that _____ of dental injuries were sports-related over a 10-year period.
- 10%
 - 15%
 - 20%
 - 25%
17. Meta-analyses of a number of studies have suggested that athletes are at _____ greater risk of sports-related injuries if they do not wear protective mouthguards.
- 1.0 to 1.3 times
 - 1.3 to 1.6 times
 - 1.6 to 1.9 times
 - 1.9 to 2.3 times
18. The National Federation of State High School Associations mandates the use of protective mouthguards for _____.
- soccer, field hockey and lacrosse
 - football, ice hockey and hurdles
 - football, field hockey, ice hockey and lacrosse
 - football, field hockey, ice hockey, lacrosse and squash
19. Athletes have complained that protective athletic mouthguards _____.
- are uncomfortable to wear
 - are cumbersome
 - contribute to difficulty in breathing
 - all of the above
20. The American Dental Association recommends the use of protective mouthguards for almost _____ sports.
- fifteen
 - twenty
 - twenty-five
 - thirty
21. Symptoms of bruxism can include _____.
- pain and discomfort in the temporomandibular joints
 - excess salivation
 - insomnia
 - all of the above
22. Self-reported bruxism was found in a review of the literature by _____ to be associated with anxiety, stress and other psychosocial factors.
- Tandretti
 - Manfredini
 - Alforetta
 - Houdini
23. Patients with _____ have been found to grind their teeth.
- day bruxism
 - daytime emotional disorder (DED)
 - night bruxism
 - all of the above
24. In their Cochrane review of five trials, Mancedo et al. found that the evidence for any effect of an occlusal splint on sleep was _____.
- unequivocal and influenced tooth wear
 - unequivocal but did not influence tooth wear
 - equivocal but influenced tooth wear
 - equivocal and did not influence tooth wear
25. Over time, bruxism may contribute to _____.
- tooth sensitivity
 - shorter teeth
 - restoration fracture
 - all of the above
26. _____ oral appliances are available for the treatment of TMJ disorders.
- Nonadjustable
 - Nonadjustable and semi-adjustable
 - Nonadjustable and adjustable
 - any of the above
27. Fundamentally, night mouthguards for the treatment of sleep apnea all work by repositioning the mandible _____.
- upward
 - backward
 - forward
 - any of the above
28. Zhao et al. found a minimum velopharynx opening of _____ with an appliance that repositioned the mandible by 8 mm.
- 21 mm²
 - 18 mm²
 - 15 mm²
 - 12 mm²
29. Research on the potential performance effects of mouthguards began with a study by _____.
- Spenger
 - Springer
 - Stenger
 - Stengren
30. Performance mouthguards are also known as _____.
- maxillary orthodontic repositioning appliances
 - mandibular orthodontic repositioning appliances
 - maxillary orthopedic repositioning appliances
 - mandibular orthopedic repositioning appliances
31. _____ in 1984 found no difference in large-muscle group strength with no mouthguard, a placebo mouthguard or a MORA.
- Bates et al.
 - Gates et al.
 - Spates et al.
 - Yates et al.
32. Wang et al. found that use of a MORA resulted in _____.
- greater electrical activity, suggesting increased upper body muscle activity
 - less electrical activity, suggesting increased upper body muscle activity
 - greater electrical activity, suggesting reduced breathing capacity
 - none of the above
33. A small study in 2008 led to the investigators concluding that the perceived negative impact of mouthguards on _____ was objective.
- breathing and speaking
 - concentration
 - athletic performance
 - none of the above
34. The _____ and _____ can be used for power (strength) measurements.
- Winston Anaerobic Test; Hamstring Isometric Peak Torque
 - Wingate Anaerobic Test; Hamstring Isometric Peak Torque
 - Wingate Anaerobic Test; Hamstring Isokinetic Peak Torque
 - none of the above
35. Cortisol _____.
- is released in response to physical exertion
 - results in physiological alterations
 - decreases metabolism and the ability of the immune system to prevent infections
 - all of the above
36. It has been hypothesized that by repositioning the mandible, _____.
- the patency of nerves and arteries in the TMJ is improved
 - blood flow is increased
 - the perfusion of oxygen to the tissues is increased
 - all of the above
37. Francis and Basher found that oxygen consumption in athletes _____ when wearing a mouthguard, and that breathing was _____.
- decreased; less efficient
 - increased; less efficient
 - decreased; more efficient
 - decreased; more efficient
38. A contemporary study on technology used for performance mouthguards and mouthpieces found that grip strength increased in _____.
- 93% of males and 67% of females
 - 83% of females and 67% of males
 - 93% of females and 67% of males
 - none of the above
39. The investigators of recent studies of a performance mouthpiece found that its use resulted in _____.
- improvements in auditory reaction time
 - significantly reduced lactate levels
 - increases in the width of the oropharynx
 - all of the above
40. Stress _____.
- results in clenching of the teeth
 - is involved in the activation of the autonomic nervous system
 - is involved in the activation of the automatic nervous system
 - a and b
41. Cortisol levels were found to be _____ during exercise in more than 50% of study participants using a contemporary oral appliance.
- increased by more than 39%
 - decreased by more than 39%
 - increased by more than 49%
 - decreased by more than 49%
42. It is expected that manufacturing standards for athletic mouthpieces and mouthguards will be proposed through the _____.
- National Orthopedic Committee on Standards for Athletic Mouthguards
 - National Operating Committee on Standards for Athletic Equipment
 - National Operating Council on Standards for Athletic Equipment
 - all of the above
43. Research into the effect of mouthguards on preventing concussion _____.
- has been conclusive
 - has received renewed interest
 - has all but ceased
 - none of the above
44. Mouthguards have evolved into _____ for a number of indications.
- preventive and detractive options
 - treatment and detractive options
 - preventive and treatment options
 - preventive, treatment and detractive options
45. Recent research has investigated mouthguards and mouthpieces for _____.
- orthodontic-enhancing therapy
 - protective therapy
 - performance
 - bruxism

The Genesis and Advancement of Mouthguards and Mouthpieces

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- List and describe the mouthguard variants available over-the-counter and through the dental office.
- List and describe the rationale for protective athletic mouthguards and the recommendations on their use.
- List and describe the rationale and results for the use of oral appliances and mouthguards for the treatment of TMJ and bruxism.
- List and describe the rationale for the use of performance mouthguards and the results that have been obtained using these.

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| 19. (A) (B) (C) (D) | 42. (A) (B) (C) (D) |
| 20. (A) (B) (C) (D) | 43. (A) (B) (C) (D) |
| 21. (A) (B) (C) (D) | 44. (A) (B) (C) (D) |
| 22. (A) (B) (C) (D) | 45. (A) (B) (C) (D) |
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