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and severity of sports-related oral injuries**
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Using mouthguards to reduce the incidence and severity of sports-related oral injuries

ADA COUNCIL ON ACCESS, PREVENTION AND INTERPROFESSIONAL RELATIONS;
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For decades, the athletic mouthguard, or mouth protector, has been considered the primary appliance for minimizing oral injuries sustained in sporting activities.¹⁻⁶ Mouthguards typically are composed of a thermoplastic copolymer (usually ethylene vinyl acetate [EVA])⁷ and designed to fit over occlusal surfaces of the maxillary teeth and gingivae.⁸ Class III occlusions may require mouthguard placement on the mandibular arch.⁹

By providing a resilient, protective surface to distribute and dissipate transmitted forces on impact, mouthguards can minimize the risks of sustaining trauma to the hard or soft tissues (such as chipped, luxated or avulsed teeth; maxillary or mandibular fractures; lip lacerations and other injuries to the gingivae, tongue or mucosa) or minimize the severity of that trauma.^{3,10,11} Such injuries are common not only to high-risk contact sports such as boxing, hockey, rugby and lacrosse, but also to other, less obviously hazardous sports (for instance, basketball and baseball) and noncontact activities (for instance, gymnastics and in-line skating).

ABSTRACT



Background. This report reviews the available literature on the types and properties of athletic mouthguards, current fabrication methods and the role of mouth protectors in reducing the incidence and severity of sports-related oral injuries.

Overview. For more than 50 years, the American Dental Association has promoted the protective value of wearing properly fitted mouthguards while participating in athletic or recreational activities that carry a risk of dental injury. Safety is essential to maintaining oral health, and a properly fitted mouthguard can minimize the risks of sustaining oral injuries during participation in sports.

Conclusions. The dental literature supports the use and protective value of mouthguards in reducing sports-related injuries to the teeth and soft tissues. Dentists are encouraged to educate patients regarding the risks of oral injury in sports, fabricate properly fitted mouthguards, and provide appropriate guidance on mouthguard types and their protective properties, costs and benefits. Further studies addressing the effectiveness of currently available mouthguard types and population-based interventions for reducing oral injuries are recommended.

Clinical Implications. Participants in sporting and recreational activities are often susceptible to oral injury. To reduce the incidence and severity of sports-related oral trauma, the use of a properly fitted mouthguard is recommended in any athletic or recreational activity that carries a risk of injury.

Key Words. Mouthguard; mouth protector; sports dentistry; injury prevention; preventive dentistry.

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Address reprint requests to the ADA Council on Access, Prevention and Interprofessional Relations, 211 E. Chicago Ave., Chicago, Ill. 60611.

Unlike some other injuries, a single traumatic injury to the dentition may never heal completely, and it can create a lifetime of expensive, long-term problems for the affected athlete.¹²⁻¹⁶ To minimize the risks of intraoral trauma, mouthguards offer protection by separating the cheeks and lips from the teeth, making users less susceptible to soft-tissue laceration and preventing opposing arches from traumatic contact.

Although sports-related oral injuries cannot be eliminated entirely, many can be reduced in severity or prevented with use of a properly fitted mouth protector.^{17,18} This report reviews the available literature on the types and properties of athletic mouthguards, current fabrication methods and the role of mouthguards in reducing the incidence of oral injury in sports.

SPORTS-RELATED ORAL INJURIES

In virtually all sporting and recreational activities, accidents happen and traumatic oral injuries are possible. The U.S. surgeon general's report on oral health identified sporting activities as one of the "principal causes of craniofacial injuries."¹⁷ Studies have linked sporting activities to nearly one-third of all dental injuries,^{13,17,19} and approximately one in six sports-related injuries is to the craniofacial area.²⁰

Mouthguards first came into general use in the sport of boxing in the 1920s,²¹ but their application in other sports did not follow until the 1960s. As mouthguard research emerged in the 1950s, the American Dental Association (ADA) began promoting mouth protection to the general public. Before the development of orofacial protectors—such as helmets, face shields and mouthguards—the ADA estimated that one-half of the injuries sustained by high-school football players who were not wearing face or mouth protection occurred in or around the mouth, and that most of those injuries could have been prevented by the use of orofacial protectors during play.²² Given those findings, the ADA urged all agencies involved with interscholastic athletics to require mouthguards for members of football teams and other body-contact athletic activities.²³ By 1962, all American high-school football players were required to wear mouthguards during games,²⁴ and in 1973, a similar rule was adopted by the National Collegiate Athletic Association (NCAA) for college football.²⁵

Studies have linked sporting activities to nearly one-third of all dental injuries.

Although dental and soft-tissue injuries typically are associated with collision and contact sports such as football or ice hockey, oral trauma is just as common, if not more so, in basketball, soccer, baseball, bicycling, in-line skating, gymnastics and other sports.²⁶⁻³¹ Through the years, the use of orofacial protectors (face shields, helmets and mouthguards) in football has reduced the prevalence of oral trauma from 50 percent of all injuries to approximately 1 percent.^{2,3,32,33} Yet, in limited-contact sports such as basketball that do not mandate mouthguards or other orofacial protectors, 14 to 34 percent of reported injuries are to the orofacial area.^{17,33-37} Another survey of practicing dentists found the highest incidence of oral injury in baseball and biking, two popular noncontact sports.³⁸

Oral trauma data generally have appeared in the literature as surveillance-based studies, with wide variations in research design (for instance, prospective surveys and retrospective surveillance), study populations (for instance, athletes, athletic trainers, parents and coaches) and injury definitions (oral, dental, orofacial, craniofacial and others).^{5,34,39,40,41} To date, a national dental-injury surveillance system has not been established, and reported incidences of sports-related oral injury vary widely based on the sport played, level of competition, the participant's age and sex, and other factors.^{14,17,41,42} Thousands of schoolchildren play at least one organized sport¹⁰ and are most susceptible to sports-related oral injury between the ages of 7 and 11 years.^{15,26,43,44} In addition, children and youths can be at an increased risk of experiencing orofacial injuries as a result of behavioral risk factors, such as hyperactivity⁴⁵ and an increase in risk-taking behavior.⁴⁶ For injured children and their families, the consequences of orofacial trauma are substantial because of its potential for pain, psychological effects and economic implications.^{5,15,17,32}

With hundreds of oral injuries occurring in youth baseball each year,⁴⁷ and even more injuries to basketball players involving the teeth or oral cavity,^{33,41} mouthguards can offer significant protection to athletes participating in these and other noncontact sports. The properly fitted mouthguard is especially important because approximately 80 percent of traumatic dental injuries occur to the maxillary incisors.^{15,48,49}

While male athletes generally are more susceptible to oral trauma,^{44,50-52} considerable oral-injury risks have been identified for male and female participants in baseball, softball, bicycling, soccer, volleyball, alpine skiing, karate and other sports.⁴¹ Since the adoption of Title IX of the Education Amendments of 1972, which barred sex discrimination in U.S. educational settings, more women are participating in athletic competition and experiencing more oral injuries as a result.^{10,39,52} Oral injuries sustained in athletic and recreational activities are a significant problem worldwide as well.^{19,37,44,53,54}

MOUTHGUARD TYPES

The American Society for Testing and Materials⁹ designated three categories for athletic mouthguards:

- the ready-made, or stock, mouthguard;
- the mouth-formed, “boil-and-bite” protector;
- the custom-made model, either vacuum-formed or pressure-laminated by a dentist or a dental laboratory (based on the dentist’s instructions).

The role of the athletic mouthguard is to offer effective protection against oral injury, with variation in materials, comfort, cost and adaptation to the teeth. The properties of these common mouthguard types are presented below.

Stock mouthguard. The stock mouthguard is a preformed thermoplastic tray that fits loosely over the teeth. This mouthguard type is fabricated in an inexpensive, ready-for-wear model and is sold in limited sizes (ranging from small to large), with little-to-no retention or adaptability to hard and soft tissues. To be held in place, the stock mouthguard requires the wearer’s mouth to be closed to provide any protective benefit, which can interfere with breathing and speaking. For these reasons, the stock mouthguard is considered by many to be less protective.^{15,55-57}

Mouth-formed mouthguard. Mouth-formed protectors are sold in two varieties: the shell-liner mouthguard and the thermoplastic, boil-and-bite model. The shell-liner mouthguard consists of a polyvinyl chloride outer shell that fits loosely over the dentition and includes an inner lining of plasticized acrylic gel or silicone rubber.^{2,56,57} This appliance is less commonly available and usually bulkier than a boil-and-bite mouthguard.

The self-adapted, boil-and-bite mouthguard is the most commonly used oral protective device and is widely distributed at department and sporting goods stores. The boil-and-bite mouth-

guard typically is manufactured as a standard tray of thermoplastic material (such as EVA). A dentist or the sports participant can form a boil-and-bite mouthguard by softening it in hot water, briefly cooling it in cold water, placing it in the mouth and shaping the material with fingers, tongue and some biting pressure to form a stable impression.^{15,58,59}

Although the boil-and-bite mouthguard is a low-cost appliance that can be reshaped and refitted after initial formation, some comparative studies have noted limitations in this type of mouthguard. One study found that boil-and-bite mouthguards can become dangerously thin in critical areas during formation, losing between 70 and 99 percent of their occlusal thickness.⁶⁰ Furthermore, laboratory impact tests of boil-and-bite mouth protectors have reported less adequate cushioning, retention and absorption than offered by custom-made mouthguards.^{18,61,62} A 1994 study noted that more than 40 percent of athletes wearing self-adapted mouthguards reported a loose fit, and two of three said they were too bulky.⁶³

Appropriate care should be taken when forming a boil-and-bite mouthguard. A dentist can help ensure proper fit and consistent thickness in the labial and occlusal portions and other critical areas. When properly formed according to the manufacturer’s instructions, a boil-and-bite mouthguard usually can be worn over braces or other orthodontic appliances.

Another variation of the boil-and-bite mouthguard is called the “jaw-joint protector,” a bimaxillary device that positions the mandible forward in an effort to protect the associated basal skull surface from concussion.^{28,64,65} Further study is required to determine the safety and effectiveness of jaw-joint protectors and their ability to reduce brain injury.^{64,66}

Custom-made mouthguard. A custom mouthguard is individually designed and formed in a dental office or made in a professional laboratory, based on the dentist’s instructions. Because of the technique, material and detail that goes into making a custom mouthguard, it is considered by many to be the professionally preferred protective device (Box).^{15,67-69} Although custom mouthguards can be the most expensive option, the literature suggests that they generally provide better retention and comfort, less interference with speech and breathing, and more adaptability to orthodontic appliances.^{15,28,63}

The optimal thickness for custom-made mouthguards has not been determined. Some researchers have recommended a material thickness of 4 to 5 millimeters for enhanced reduction and absorption of transmitted forces during impact.^{60,70,71} Specific material thicknesses for the labial, occlusal and palatal aspects of a custom mouthguard also have been recommended.⁷² Final mouthguard thickness typically is a matter of clinical judgment, patient preferences and the specific needs of the athlete or sport. Dentists also should consider the patient's vertical dimension of occlusion, personal comfort and breathing ability. (Custom mouthguard fabrication involves a number of considerations⁷³⁻⁷⁹; see the sidebar, "Fabricating a Custom-Fitted Mouthguard," for additional information.)

THE ROLE OF MOUTHGUARDS IN REDUCING INJURY INCIDENCE

Studies have long emphasized the protective value of mouthguards in reducing sports-related injuries to the teeth and soft tissues.^{1-6,15,18,22,80} Mouthguards offer protection by absorbing high-impact energy from potentially traumatic blows and dissipating that energy, which otherwise would be transferred directly to the underlying dentition.^{18,60}

Surveillance-based research has supported the protective value of athletic mouthguards. In a study of NCAA basketball teams, athletes wearing custom mouthguards incurred significantly fewer oral injuries (1.16 injuries per 1,000 athletic exposures) than players who did not (3.00 injuries per 1,000 athletic exposures).⁵ The significant protection provided by custom mouthguards also has been supported by one randomized controlled trial.⁸¹ A long-term study of Hawaiian student-athletes reported no intraoral injuries to athletes who wore mouthguards during play.⁵²

Mouthguards also can provide substantial protection to patients receiving orthodontic treatment.⁸²⁻⁸⁴ By moving soft tissue away from teeth and preventing intraoral laceration and bruising, properly fitted mouthguards can assist athletes wearing fixed orthodontic appliances.⁸⁴ Further research has been encouraged to better measure the nature and severity of sports-related oral injuries in orthodontic patients, especially adolescents.¹⁵ In addition, standardization of laboratory tests is required to establish minimal benchmarks for assessing the performance and efficacy

BOX

Ideal Mouthguard Properties.

To provide adequate protection, the literature suggests that a mouthguard should

- be properly fitted to the wearer's mouth and accurately adapted to his or her oral structures;
- be made of resilient material approved by the U.S. Food and Drug Administration and cover all remaining teeth on one arch, customarily the maxillary;²
- stay in place comfortably and securely;
- be physiologically compatible with the wearer;
- be relatively easy to clean;
- have high-impact energy absorption and reduce transmitted forces upon impact.⁶⁹

For the athlete's safety, the mouth protector should have adequate retention, comfort and fit, without interfering with speech or breathing during play.

Fabricating a custom mouthguard with the above characteristics can be professionally accomplished under the direction or supervision of a dentist. By promoting the use, safety and affordability of properly fitted mouthguards, dentists can increase patient satisfaction and compliance by providing mouthguards of appropriate thickness that do not slip in the wearer's mouth.

of currently available mouthguard types.

By providing cushioning between the maxilla and mandible, mouthguards also may lessen the incidence or severity of condylar-displacement injuries and thereby reduce the potential for concussion.^{76,85} Although some have suggested that properly fitted mouthguards can reduce the incidence and severity of concussions,^{86,87} there is insufficient evidence to determine their effectiveness in mitigating such injuries.^{5,14,40,66,88} The Councils recommend further study regarding the role of mouthguards in reducing the incidence of temporomandibular and concussive injuries.

Although the majority of studies and literature reviews support the protective value of athletic mouthguards, limitations in the available evidence also have been identified, including the limited research data from randomized controlled trials.^{14,15} In addition, a 2001 systematic review by the Centers for Disease Control and Prevention⁸⁹ found insufficient evidence to issue a community-wide recommendation on the effectiveness of mouthguards as a preventive intervention, and identified the need for more "high-quality research on their effectiveness" in preventing sports-related dental injuries.⁹⁰ The formation of a registry for reporting sports-related oral

Fabricating a custom-fitted mouthguard

Formation of a professionally fitted custom mouthguard typically consists of five standard steps:

- making an impression of the patient's arch for which the mouthguard will be made (an impression of the opposing arch and a bite registration are taken only if occlusal adjustments are to be made with an articulated cast);
- pouring a high-strength stone model of the patient's upper teeth;
- forming one or more sheets of thermoplastic material (such as ethylene vinyl acetate, polyvinyl chloride, polyvinyl acetate, natural rubber, soft acrylic resin or other material) on the stone model;⁷³⁻⁷⁵
- seating the mouthguard with proper occlusal balance and equilibration;
- final trimming of excess material from the mouthguard.⁶¹

To begin the fabrication process, the dentist takes an impression of the arch on which the mouthguard will be constructed (typically the maxillary). The impression should include all remaining teeth (except erupting third molars), the gingivae (up to the mucolabial fold), labial frenulum, complete palate, full vestibular extensions and borders.^{61,76} The impression is poured with high-strength stone to produce a model of the dentition and other oral structures, which then is appropriately trimmed and used to form the mouthguard.

Two common fabrication methods for custom mouthguards are vacuum formation, in which a single layer of copolymer material is used, and pressure lamination, which combines heat and high pressure to laminate multiple layers of copolymer material. These techniques are outlined below.

Vacuum formation. To construct a vacuum-formed mouthguard, a conventional vacuum machine is used to apply low heat and vacuum (equivalent to approximately one atmosphere of pressure) to soften a single layer of thermoplastic material and form the mouthguard over the trimmed stone model.^{2,74,77,78} The full-arch model is dampened or an appropriate separating medium is applied (consistent with manufacturer recommendations) to keep the plastic

material from sticking to the model, and then is placed on the platform of the vacuum machine. A single layer of copolymer material is softened by heating until it sags approximately $\frac{3}{4}$ inch to 1 inch. The material is then lowered over the stone model, with the vacuum applied for 30 seconds to one minute, until the thermoplastic material has cooled. To prevent distortion, the appliance should not be handled while warm.

With the cooled appliance on the stone model, excess material can be trimmed from the periphery and an alcohol torch may be used to smooth sharp edges. Additional polishing may be accomplished after removing the mouthguard from the stone model using burs, stones or polishing wheels designed for resilient materials. If articulated casts have been constructed, adjustments can be performed to provide even contact between occlusal surfaces and the opposing arch.² This also can be done chair-side (depending on the material characteristics) by gently heating the mouthguard's occlusal portion with a flame and carefully guiding the teeth together until even contact is made. During the vacuum-formation process, the dentist should ensure that the final product has appropriate occlusal thickness, especially in the maxillary incisor region.

Although professionally fitted by a dentist, vacuum-formed mouthguards have been found in some studies to have inadequate material thickness, primarily because of their formation as a single-layered, nonlaminated device.^{15,74} These deficiencies in material thickness can be mitigated by developing a multilayered mouthguard through pressure lamination.

Pressure lamination. Using a pressure-lamination machine, qualified dental laboratories can fabricate a custom-made athletic mouthguard with heat and up to 10 atmospheres of positive pressure.^{77,78} The combination of heat and pressure facilitates proper lamination and precise adaptation of the mouthguard within the specifications of the copolymer material, technique and machinery used.

After preparing a stone model of the selected arch, the operator can adapt a single layer of the same heated thermoplastic material used in

the vacuum-formation technique over the model using a pressure-lamination unit. Additional layers of material then can be permanently laminated onto the original layer to provide customized protection in the anterior or occlusal surfaces, based on the specific needs of the athlete or sport. By laminating copolymer materials to a defined thickness, the pressure-formed protector has minimal elastic memory, thus enabling proper fit and retention over longer periods.¹⁵ More specific techniques for fabricating pressure-laminated mouthguards are available in the dental literature.⁷⁴

Determining which technique is optimal for constructing custom-fitted mouthguards—

vacuum adaptation or pressure lamination—remains a topic of professional interest,^{67,79} and the American Dental Association's Council on Scientific Affairs and Council on Access, Prevention and Interprofessional Relations encourage further research in this area. Mouthguard manufacturers should fulfill the requirements for product characteristics and physical properties, such as biocompatibility, hardness, tear strength, water sorption, and impact absorption and rebound, outlined in American National Standards Institute/American Dental Association Specification No. 99 for Athletic Mouth Protectors and Materials.⁵⁹

injuries could facilitate future epidemiological investigations and assist public health agencies in monitoring injury incidence and developing appropriate recommendations for the general public.

MOUTHGUARD ADVOCACY

For more than 50 years, the ADA has promoted the use of properly fitted mouthguards as the primary means of protecting against oral injury during sporting activities that pose a risk of oral injury, including acrobatics, baseball, basketball, bicycling, boxing, equestrian events, field events, field hockey, football, gymnastics, handball, ice hockey, in-line skating, lacrosse, martial arts, racquetball, rugby, shot-putting, skateboarding, skiing, skydiving, soccer, softball, squash, surfing, volleyball, water polo, weightlifting and wrestling. In 1995, the ADA approved its current policy regarding orofacial protectors, which endorses their use and identifies the preventive value of such protectors by all participants in sports and recreational activities with a significant risk of injury.⁹¹ Today, the ADA continues to promote mouthguard use and collaborate with international and national sports conferences, sanctioning bodies, school federations and other agencies to mandate the use of orofacial protectors.⁹¹

Given the prevalence of oral injury in sports and recreational activities, other dental organizations and health care agencies also have advocated the use of properly fitted mouthguards to reduce oral trauma in the general public. The American Academy of Pediatric Dentistry (AAPD) recommends the use of properly fitted mouthguards in “organized sporting activities with risk

of orofacial injury,”⁹² and the American Academy of Pediatrics encourages youth soccer players to use protective eyewear and mouthguards.⁹³ The AAPD also has teamed with the American Association of Orthodontists and the American Association of Oral and Maxillofacial Surgeons in establishing April as National Facial Protection Month, an annual campaign promoting the use of mouthguards and other orofacial protectors.¹⁷ Recommendations from professional associations and government agencies and programs (such as Healthy People 2010⁹⁴) commonly focus on promoting mouthguard wear to children, parents, athletic coaches and school officials.

Although boxing remains perhaps the only professional sport that formally requires mouthguards, their use has expanded in the United States to football, ice hockey, lacrosse and field hockey at amateur levels of competition (in other words, at collegiate, high school and elementary school levels). Yet in these and other amateur sports, athletes may be required to wear mouthguards only at certain ages or competition levels. In college athletics, the NCAA mandated mouth protectors for college football players in 1973,²³ and extended mouthguard requirements to men's ice hockey in 1975,⁹⁵ men's lacrosse in 1985,⁹⁶ women's field hockey in 1998⁹⁷ and women's ice hockey in 2000.⁹⁸ Mouthguard use also has been strongly endorsed and advocated on an international level.^{71,72,99-104}

EDUCATING PATIENTS

Despite the availability of mouthguards and their role in reducing oral injuries, much more can be done to educate patients about mouthguard use and the risks of dental trauma in sports and

recreational activities. Athletes often are hesitant to wear mouthguards with regularity during play.^{13,15,27} Surveys show that compliance with mouthguard regulations is not universal,¹⁰ and voluntary mouthguard use is substandard at the national and international levels.³⁷ Furthermore, participants in noncontact sports tend to consider mouthguards unnecessary, intrusive, cumbersome, uncomfortable or, in the case of the custom-made mouthguard, too expensive. In many cases, athletes do not wear mouthguards despite being aware of the injury risks.^{15,34} Also, when considering forms of facial and dental protection, many people visit a sporting-goods store, not their dentist.

The underuse of mouthguards is at least partially attributable to the lack of regulations and education provided to athletes by their coaches. According to a 1998 study on the knowledge and attitudes of Arizona high-school coaches, only 13 percent of baseball, softball, basketball and wrestling coaches educated students regarding orofacial injuries and mouthguard use.³⁹ Nearly one in three coaches said they would not encourage mouthguard use to student athletes, and boys were more likely than girls to have received information about injury prevention and mouthguard use.³⁹ Given the strong influence of coaches and peers on young athletes, these attitudes present considerable barriers to patients' compliance and mouthguard use.¹⁵

To counteract these factors, education of athletes, parents and coaches is essential. Increasing mouthguard use among athletes generally is a matter of individual knowledge and willingness. Dentists can begin the process by inquiring, as part of the health history, if each patient participates in sporting or recreational activities that pose a risk of oral injury. On a broader scale, the dental community can play a critical role by advising patients, parents, coaches and school officials on the considerable risks of injury in sporting activities (particularly in the absence of a mouthguard) and the preventive value of properly fitted mouthguards. At the local level, the Councils encourage dentists to become more active and influential in injury-awareness campaigns, which can focus on limited-contact sports that do not mandate mouthguards (among them, basketball, baseball and soccer).⁵⁴ Working with coaches, athletic trainers, teachers and parents, dentists can even develop local initiatives and preventive programs that provide mouthguards in schools, col-

leges, park districts and community centers.¹⁰⁵ Through such efforts, dental practitioners can have a far-reaching role in their communities by actively promoting mouthguards as an appropriate intervention for patients, especially children and adolescents.³⁹

The key educational message is that the best mouthguard is one that is worn. While custom mouthguards are considered by many to be the most protective option, other mouthguards can be effective if worn properly. Dentists, physicians and athletic officials should work to ensure that people wear mouthguards when involved in sporting or recreational activities that might pose a risk of injury.

CONCLUSION

On the basis of the available literature, the Council on Scientific Affairs and the Council on Access, Prevention and Interprofessional Relations 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. Several studies suggest that the custom mouthguard provides patients with the most precise fit and the best retention.

The Councils encourage dentists to educate patients regarding the risks of oral injury in sports, to fabricate properly fitted mouthguards and to provide appropriate guidance on mouthguard types and related properties, costs and benefits. To strengthen the evidence base regarding mouthguards, the Councils recommend further studies addressing the effectiveness of available mouthguard types and intervention programs for reducing the incidence and severity of dental injuries, and the establishment of a multi-site (or even international) injury surveillance system for tracking and analyzing data regarding sports-related oral trauma. ■

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