

CDHA Position Paper on Sports Mouthguards

Putting More Bite into Injury Prevention

by the Canadian Dental Hygienists Association

CDHA POSITION STATEMENT ON SPORTS MOUTHGUARDS

Research shows that orofacial injury in sport is prevalent and carries significant medical, financial, cognitive, psychological and social costs. Research also confirms that mouthguards can prevent orofacial injuries. The CDHA therefore strongly recommends that dental hygienists play an integral role in the prevention of orofacial injury in sports and promote properly fitted mouthguards as an essential piece of protective equipment, in sports that present a risk of orofacial injury at the recreational and competitive level, in both practices and games.

INTRODUCTION

PARTICIPATION IN SPORTS MAKES A POSITIVE AND POWERFUL contribution to social, personal, and physical development. It helps promote the adoption of a healthy lifestyle and prevention of diseases and illness. Despite these benefits, there are some risks involved with sport participation, including a risk of orofacial injury. This risk exists in contact sports such as rugby, and hockey, but also in sports with less contact, such as basketball, soccer and baseball. Estimates of the number of dental injuries attributable to sports related accidents range from 13 to 39%^{1,2} of all dental injuries. Every individual involved in contact sport has at least a 10% chance each season of sustaining an orofacial injury.^{3,4}

These injuries can occur during organized competitive sports as well as unorganized recreational activities. Orofacial injuries may be caused by a sudden fall; an elbow to the jaw in basketball; a ball to the teeth in softball; and high-sticking, cross-checking, and slashing in hockey. Hockey pucks, 6-ounce pieces of solid rubber, can hit a hockey player's mouth at approximately 120 mph and hit their teeth with an impact force of 1,250 lb.¹ The main instances of orofacial injury in non-contact sport results from projectiles such as baseballs, tennis balls, or bats hitting the face. Injuries to the teeth include crown fractures which occur due to high-velocity trauma from an object such as a baseball; root fractures; and displacements (luxations), which occur due to low-velocity trauma from an elbow or entanglement in a basketball net.

The majority of orofacial injuries affect the upper jaw, with maxillary incisor injuries accounting for 80% of all cases.⁵ Early trauma to the mouth may result in damaged teeth that may exfoliate abnormally; permanent teeth that fail to erupt; colour changes in teeth; infections in which painful abscesses develop; injury to underlying permanent teeth, such as localized enamel hypoplasia⁶ on the surface of the crown; and tooth loss that leaves unwanted open spaces.

Most orofacial injuries occurring from sports activities can be painlessly avoided by using a mouthguard. Mouthguards are removable appliances that protect intra-



Mouthguards are removable appliances that protect intra-oral soft tissue...from lacerations and bruising.

oral soft tissue—such as lips, cheeks, and gums—from lacerations and bruising. They prevent chipping, luxations, avulsions; fractured teeth, roots, and bones; mandibular/maxillary fractures; and temporomandibular dysfunction. (See Appendix B for tooth injury definitions and Appendix C for categories of orofacial injuries.)

In 1892, the first mouthguard was made by Woolf Krause. There was no mention of mouthguards again until 1915 when a professional boxer named Ted “Kid” Lewis used a mouthguard during a championship bout. This mouthguard, or “gum shield” as it was referred to at that time, was fabricated by Jacob “Jack” Marks of London, England and consisted of a custom-fitted rubber strip that fit under the lips and over the outer surfaces of the teeth and gingival.^{7,8}

The total health service costs in Ontario... were estimated to be between US\$22 million and US\$25 million.

Between 1950 and 1965, extensive field studies and material testing took place in the United States.⁹ In 1962, the U.S. National Alliance Football Rules Committee adopted a mandatory mouthguard rule for high school and junior college football, and recommended that an impression of the mouth be used in fabricating the mouthguard. In 1973, the National Collegiate Athletic Association (NCAA) made mouthguards mandatory football equipment.¹⁰ After mouthguards and facemasks became mandatory for amateur football, the incidence of facial and dental injuries fell from 2.26 per 100 players to 0.30.¹¹ Then in 1975, USA Hockey, the national governing body for hockey adopted a mandatory mouthguard rule. In 1974, NCAA made the use of mouthguards mandatory for ice hockey, field hockey and lacrosse.⁷

The requirement to use mouthguards varies by sport and the position on the team. Requirements also vary from one city and province to the next in Canada. Boxing is the only professional sport that requires mouthguards. Mouthguards are required in four states for soccer, in three states for basketball; and in two states for wrestling.¹² Currently in Canada, mouthguards are required in the following amateur sports: football, rugby, lacrosse, field hockey, and boxing.^{11,13-15} Hockey Canada, the governing body for amateur hockey in Canada, has no mandatory mouthguard rule, but it recommends mouthguard use for contact hockey. Local hockey governing bodies at the league or provincial branch level across Canada have begun to implement mandatory mouthguards within their jurisdictions. For example, the Canadian Hockey League, which is the major junior league, has made mandatory the use of mouthguards for girls and boys. Orofacial injury prevention is still lagging behind in baseball, basketball, soccer, field hockey, softball, wrestling, volleyball and gymnastics, and in most of the professional sports.

PSYCHOLOGICAL, SOCIAL AND ECONOMIC COSTS

The smile and the aesthetics of the anterior dentition play an important psychosocial role in human relationships. Sports injuries that cause orofacial disfigurement or negatively affect the appearance and position of anterior teeth may have a negative psychosocial impact. A study using the Oral Impact on Daily Performance Index was carried out in 2002 comparing the quality of life of 189 children with and without traumatic dental injuries. Results showed that children with injured but untreated anterior teeth were 20 times (95% CI CI=2.2-45.6) more likely to report a negative impact on quality of life.¹⁶ The children with untreated fractured teeth reported embarrassment; emotional problems; and avoidance of social contact, eating, and enjoying contact with people. They

were also more likely to be teased about their teeth. These findings point to the possibility that children with unrepaired orofacial injuries may be at risk of long-term psychological and social distress.

Mandibular fractures, dentoalveolar fractures, and temporomandibular joint injuries can also occur in sports and may require long-term care. Extended health problems may result in reduced participation in sport and exercise. This in turn may contribute to a decrease in health, increased medical, economic and societal costs, which may include work or school absenteeism.

Although there are few studies examining dental injury costs, Locker and Maggias calculated two types of costs associated with traumatic dental injuries that were caused by a broad array of factors, including sports injuries.¹⁷ The direct treatment costs in Ontario are estimated at between \$3.2 million and \$4.98 million per year. Using data derived from international cost estimates, the total health service costs in Ontario, including direct and indirect costs, were estimated to be between US\$22 million and US\$25 million. Another study estimated the total costs for repairing one avulsed tooth at more than 20 times the cost of a custom-fabricated mouthguard and the lifetime costs associated with this one tooth may exceed \$15,000.¹ The cost of a mouthguard appears to be well worth the expense, since it can prevent costly treatment of injuries.

POSITION STATEMENTS of VARIOUS HEALTH ORGANIZATIONS

A number of associations and organizations consider orofacial injury to be an important public health issue and have adopted position statements on injury prevention and the use of mouthguards. Notable in the following list is the paucity of Canadian organizations with position statements on mouthguards.

- The Canadian Academy of Sport Medicine has a position statement on head injuries and concussions in soccer in which they call for mouthguards to be worn during participation in soccer, due to the dental protection and the possible role in concussion prevention.¹⁸
- The Canadian Dental Association has a position statement that encourages dentists to counsel clients about orofacial protection and encourages organized activities to develop safety protocols to minimize the risk of orofacial injury.¹⁹
- Several professional health organizations have recommended the use of mouthguards in a variety of contact sports at all levels of competition, both organized and unorganized. These organizations include the American Medical Association and the American Academy of Pediatrics.²⁰
- The American Academy for Sports Dentistry recommends the use of properly fitted mouthguards and supports mandates for their use in all collision and contact sports for practices and games.²¹
- The Academy of General Dentistry in the United States recommends "that players participating in basketball, softball, wrestling, soccer, lacrosse, rugby, in-line-skat-

ing and martial arts, whether for an athletic competition or leisure activity, wear mouthguards.”¹⁵

- The American Academy of Pediatric Dentistry recommends¹³ the continuation of preventive practices in youth high school and college football, lacrosse and ice hockey, and call for mandating mouthguards in other organized sporting activities with risk of orofacial injury.
- The American Public Health Association “recommends to schools and other sponsoring organizations that all participants in contact sports be required to wear quality fitted protective mouthguards.”²²
- The American Dental Association (ADA)²³ recognizes the preventive value of orofacial protectors (such as mouthguards, face shields and helmets) and endorses the use of orofacial protectors by all participants in recreational and sports activities with a significant risk of injury, all levels of competition including practice sessions, physical education and intramural programs.

- Mouthguard use is encouraged in the U.S. document Health People 2010, which outlines goals and objectives for improving oral health. One of the objectives calls for the following: “Increase the proportion of public and private schools that require use of appropriate head, face, eye, and mouth protection for students participating in school-sponsored physical activities.”²⁴ The rationale for appealing to schools is that healthy habits are formed early in life, and by the time athletes reach young adulthood they will be familiar with the hazards inherent in sports and be more familiar and comfortable with mouthguard use.

TYPES OF MOUTHGUARDS

The American Society for Testing and Materials identifies three categories of athletic mouthguards including the stock, mouth formed and custom made. These three different types of mouthguards score differently on each of the following mouthguard qualities. **Fit** is critical, since the

Déclaration sur les protège-dents dans les sports

RÉSUMÉ

Les recherches démontrent que les blessures orofaciales dans les sports sont fréquentes et coûteuses sur le plan des frais médicaux mais aussi sur les plans financier, cognitif, psychologique et social. Elles confirment également que les protège-dents peuvent prévenir les blessures orofaciales. L'ACHD recommande donc fortement que les hygiénistes dentaires jouent un rôle complet dans la prévention des blessures orofaciales dans les sports et qu'ils fassent la promotion du protège-dents ajusté correctement comme pièce essentielle de l'équipement de protection dans les sports qui présentent un risque de blessure orofaciale, qu'ils soient pratiqués dans un contexte récréatif ou compétitif.

Relativement peu d'organismes canadiens prônent l'utilisation du protège-dents en comparaison avec les organismes américains. L'appui inconditionnel de l'Association canadienne des hygiénistes dentaires en faveur de l'utilisation du protège-dents comme moyen de prévention de base contre les blessures orofaciales fait de l'ACHD un chef de file dans ce domaine, au Canada. Les hygiénistes dentaires ont une bonne occasion de protéger la santé et la sécurité des enfants et des adultes dans les sports en appuyant l'utilisation du protège-dents et en en faisant la promotion. Ce ne sont pas seulement les sports les plus rapides et les plus rudes, comme le football, le rugby et le hockey, qui causent des blessures orofaciales. Les sports qu'on estime moins dangereux, comme le soccer, le baseball, le hockey sur gazon et le basketball, sont également susceptibles de causer des blessures orofaciales.

Il existe des preuves convaincantes selon lesquelles le protège-dents peut rendre le sport plus sécuritaire en protégeant contre les blessures orofaciales. Les preuves du rôle du protège-dents dans la prévention ou dans la réduction de la gravité des commotions sont très ténues; aussi faut-il faire d'autres recherches dans ce domaine. Le protège-dents fait sur mesure, celui de type laminé en particulier, semble fournir certains avantages par rapport aux autres protège-dents : on peut en ajuster l'épaisseur en fonction du sport; on peut le prolonger jusqu'à la deuxième molaire; on peut l'articuler autour du modèle mandibulaire.

Un certain progrès a été fait en matière de prévention des blessures orofaciales depuis les années 1960 et 1970, époque où les protège-dents sont devenus obligatoires pour la première fois. Cependant, il reste encore beaucoup de chemin à parcourir dans le développement d'attitudes plus positives et dans l'augmentation de l'utilisation du protège-dents. Premièrement, il faut faire la promotion de l'utilisation généralisée du protège-dents dans tous les sports de contact. Le coût d'un protège-dents fabriqué par des professionnels de la santé bucco-dentaire est très peu élevé par comparaison avec celui des conséquences pour la santé et des conséquences financières, cognitives, psychologiques et sociales associées à une blessure orofaciale. Deuxièmement, il faut adopter une approche multidisciplinaire pour augmenter le nombre de joueurs qui portent un protège-dents. L'entraîneur, les officiels, les parents, les hygiénistes dentaires, les autres professionnels de la santé bucco-dentaire, ainsi que les professionnels de la santé de façon générale, ont tous un rôle à jouer. Ils peuvent aider la population à adopter une attitude positive envers l'utilisation du protège-dents, influencer les comportements et aider au respect des règles dans les sports où le port du protège-dents est obligatoire. Troisièmement, il faut élaborer une approche favorisant la généralisation des règles sur le port du protège-dents dans les sports.

Malheureusement, les statistiques canadiennes sur la fréquence des blessures orofaciales dans les sports sont limitées et il se peut qu'elles soient incomplètes faute de système national de surveillance. Il serait possible de combler ce fossé dans la connaissance grâce à la création d'un centre canadien de prévention des blessures. Un centre de ce genre aurait les moyens de coordonner la surveillance et de maintenir une base de données à partir des signalements de blessures orofaciales. Cette information pourrait servir à étudier l'efficacité des protège-dents; elle pourrait contribuer à l'amélioration de la conception des protège-dents et favoriser une sensibilisation accrue de la population.

RECOMMANDATIONS

L'hygiéniste dentaire peut

- collaborer avec d'autres professionnels de la santé pour effectuer des campagnes de sensibilisation en matière de santé, de prévention des blessures et de promotion du port du protège-dents soit sur une base individuelle, soit devant des groupes de clients, de parents, d'athlètes, d'équipes sportives, d'entraîneurs, d'officiels et d'enseignants en éducation physique;
- servir d'agent de changement pour influencer sur une culture dans les sports qui accepte le port du protège-dents comme élément de l'équipement de base du sport;
- fabriquer des protège-dents et prodiguer des conseils sur l'utilisation et l'entretien de protège-dents adaptés;
- effectuer des recherches sur la promotion du protège-dents en santé bucco-dentaire et sur la prévention des blessures.

Les organismes de réglementation des sports, les centres de prévention des blessures et les commissions ou conseils scolaires peuvent

- rendre obligatoire l'utilisation du protège-dents pendant les entraînements dans tous les sports présentant un risque de blessure orofaciale, y compris dans des sports comme le basketball, le baseball, et le soccer;
- élaborer un plan pour veiller au port du protège-dents dans les sports où il est obligatoire;
- accentuer la promotion de la santé et la sensibilisation auprès des entraîneurs d'athlètes, des entraîneurs d'équipes sportives, des officiels, des organisateurs, des administrateurs, des athlètes et des parents.

Les organismes professionnels en hygiène dentaire et les établissements d'enseignement peuvent

- collaborer avec les organismes sportifs nationaux et les organismes scolaires pour élaborer une approche visant à accroître la réglementation sur le protège-dents dans les sports et pour veiller à son application dans les sports qui disposent d'une réglementation sur le port du protège-dents;
- fournir régulièrement, pendant la formation collégiale, universitaire ou permanente, des occasions d'acquérir des connaissances et de l'expérience sur les questions relatives au protège-dents.

Les gouvernements peuvent

- financer des programmes de promotion de la santé et de prévention des blessures qui font appel au protège-dents;
- collaborer avec les centres régionaux et provinciaux de prévention des blessures en vue de mettre sur pied un centre canadien de prévention des blessures (CCPB); celui-ci serait chargé de gérer un système de surveillance des blessures, de surveiller l'exposition aux blessures et leur fréquence, et d'évaluer les tendances des blessures dans les activités, par suite de l'introduction d'une nouvelle pièce d'équipement ou d'une nouvelle règle;
- établir un fonds de recherche et de démonstration sur les blessures pour tester et évaluer les méthodes de prévention et de limitation des blessures.

L'industrie de l'assurance-santé peut envisager d'assurer le coût des protège-dents adaptés dans le cadre des régimes de soins de santé et de faire la promotion de l'utilisation du protège-dents fabriqué sur mesure.

Les chercheurs peuvent effectuer des recherches de haute qualité sur le protège-dents ainsi que des essais comparatifs aléatoires sur des sujets comme :

- l'efficacité de différents types de protège-dents dans la prévention des blessures et commotions orofaciales;
- la rentabilité du protège-dents;
- l'efficacité des interventions populaires et de la réglementation dans les sports visant l'accroissement du port du protège-dents – par exemple celle de l'augmentation de la sévérité des punitions pour contravention aux règles sur le port du protège-dents;
- la consultation des hygiénistes dentaires et d'autres professionnels de la santé bucco-dentaire pour établir le niveau de connaissance générale et d'expérience en ce qui a trait au port du protège-dents et déterminer les attitudes des hygiénistes dentaires en ce qui concerne la promotion du port du protège-dents;
- l'amélioration de la conception d'un protège-dents efficace et confortable qui favoriserait le respect général des règles.

mouthguard must be properly positioned at the time of impact. **Comfort** is important, since individuals will be more likely to wear mouthguards if they fit properly. **Durability** is important, since the public expects some degree of longevity with their purchase. **Ability to breathe** is important, since a good flow of oxygen means better performance and less muscle fatigue. **Ability to speak** is important, since some players must communicate verbally with team members.

Stock

Stock mouthguards are commercially available in stores and are worn without any modifications. They are easy to use but have a number of limitations, including poor fit that may lead to discomfort and low user compliance. They may also restrict breathing and speech. Since they generally do not have a high degree of conformity with the teeth, the wearer has to clench the teeth to hold the mouthguard in place. A mouthguard that shifts and allows gaps between the teeth and the guard offers reduced protection. Also, they may not last as long as a custom-fabricated mouthguard.²¹ They are generally considered inferior to the other types of mouthguards, particularly the custom-fabricated mouthguard, in terms of retention, protection, and comfort.^{25,26}

Mouth-formed

The mouth-formed mouthguards—also referred to as boil-and-bite mouthguards—are the most commonly used type of mouthguard. Some of the advantages include a low price (compared with custom-fabricated mouthguards) and a removable strap that allows them to be attached to a helmet. They also are less bulky than stock mouthguards and offer a fair potential for proper fit. This mouthguard may be good for growing children, since it can be remoulded over time.

Mouth-formed mouthguards are the most commonly used type of mouthguard.

There is a new generation of anatomically designed mouth-formed mouthguards, more expensive than the earlier version, that may provide a better fit. Retention, protection, and comfort are improved over the earlier versions; however, they may require an adjustment by an oral health professional.²⁷

The positive aspects of the mouth-formed mouthguard are overshadowed by several significant drawbacks, including inadequate coverage of teeth, loose fit, and decreased air flow. In addition, there is an inability to control the degree of pressure that is used in biting down on the softened material during the formation process. One study found that the mouth-formed mouthguards do not properly cover all posterior teeth in 85% of athletes tested.²⁸ In a 1994 study by DeYoung et al.,²⁹ 42% of athletes

indicated that both the stock and mouth-formed mouthguards had a loose fit compared with the custom-made type. As with the stock mouthguards, this loose fit may force the wearer to hold the mouthguard in place by clenching the teeth. Bemelmans and Pfeiffer conducted a biomechanical study in 2001 to test the shock absorption capacities of mouthguards in a laboratory and found that the boil-and-bite type of mouthguard was inferior to the other types.³⁰

Delaney and Montgomery³¹ conducted a prospective crossover study in 2005 using a skating treadmill to simulate the intensity of a hockey game. They found that 12 hockey players who wore a non-custom bimolar mouthguard experienced significantly lower expired ventilation (VE) (108.5 l/min) ($P < 0.05$) and significantly lower oxygen uptake (VO₂) (48.8 mL) ($P < 0.05$), at maximal effort, compared with the athletes not wearing a mouthguard. Although these results are limited due to the small number of subjects, this preliminary research indicates a need for a larger study comparing non-custom with custom-fabricated mouthguards.

Custom-fabricated

The custom-fabricated mouthguards are created using a mould or impression of the dentition using an alginate material. They can be fabricated from the cast in-house by a dental hygienist, or the cast can be sent out to a laboratory. Once the mouthguard is formed, it is trimmed and polished to allow for proper tooth and gum adaptation. The mouthguard may be coloured to increase the ease of retrieval should it be dislodged during a practice or game, and the date and clients' name can be embedded in the mouthguard. For example, in a sport like water polo, it is difficult to find a blue or clear mouthguard.

Custom-fabricated mouthguards are considered to provide superior comfort, retention and protection compared with the other mouthguard types.²⁷ Newsome et al. conducted a review in 2001 of four studies⁵ comparing custom made and mouth-formed mouthguards. It shows that custom-fabricated mouthguards consistently provide better fit, allow the athlete to breathe and speak more easily, and are more comfortable than mouth-formed mouthguards. DeYoung et al.²⁹ conducted a study in 1994 with 20 female and 16 male high school students, comparing custom-



made and mouth-formed mouthguards. The participants scored the custom-made mouthguard higher on a number of comfort and wearability factors, including mouth irritation, tightness or looseness, bulkiness, difficulty speaking, difficulties breathing. Overall, 86.1% of the participants preferred the custom mouthguard.

One of the reasons that the custom-fabricated mouthguard is considered more comfortable is that it provides an optimal fit. It maintains its position in the mouth without the need for the wearer to bite down on the mouthguard. This may translate into better acceptance, and compliance. The custom-made mouthguard also has a longer life span than the other mouthguards, which may be more likely to harden or tear over time.³²

More importantly, custom-made mouthguards are reported to provide better protection than the other types of mouthguards.³² Echlin et al. in 2005 reviewed the literature on this topic and found that four studies conclude the custom-fabricated mouthguards provide superior protection to the stock and mouth-formed type.³³ There is one minor drawback to the custom-formed mouthguard: it costs more than other types of mouthguards.

Custom-made mouthguards can be fabricated using a vacuum or a pressure lamination machine. Although there is much debate about which technique is best, and the studies presented below attempt to answer this question, there is a need for a larger number of studies, including randomized controlled trials.

Vacuum-formed mouthguards

The vacuum-formed mouthguards are fabricated using a single layer of thermoplastic material that is adapted over the mould with a vacuum machine. Vacuum-forming machines are simpler and less expensive than pressure-forming machines. Vacuum-forming the mouthguard using a wet model may create difficulty with the fit, so some researchers recommend using a dry model cast³⁴ with its surface temperature elevated³⁵ in order to obtain a better fit. Park et al.³⁶ note some deficiencies with vacuum-formed mouthguards: the incisal edges can become thin,

and the occlusal, labial, and lingual aspects of the mouthguard can shrink.

Pressure-laminated mouthguards

Some studies indicate that the pressure-laminated mouthguard may have superior fit, comfort, and protection, with negligible deformation when worn for a period of time compared with other mouthguards. The pressure-lamination process provides some advantages over the single-layer vacuum-formed design. It allows layering of material to a specific thickness to suit the specific sport and can provide added protection to certain vulnerable areas in the mouth, as required. In a study of 60 mouthguards by Waked et al. in 2002 that simulated the effects of aging on mouthguard type, the pressure-laminated mouthguards, constructed from two 3-mm sheets, showed the best stability compared with the vacuum-formed mouthguards and the least number of changes in mouthguard shape over time.³⁷ Newsome et al.⁵ in 2001 conducted a review of the efficacy of different types of mouthguards and concluded that the pressure-laminated variety provided the most protection.

DESIGN, CONSTRUCTION, AND MATERIALS ISSUES

Occlusal contact

In 2004, Takeda et al.³⁸ studied different occlusal conditions of a two-layer laminated mouthguard at the occlusal supportive areas, using an artificial skull model and a pendulum impact device. The researchers noted that wearing a mouthguard without good occlusal contact over a large area can potentially cause a bone fracture of the mandible. The appropriate occlusal relationship and incisal guidance can only be achieved if an impression of the opposing arch is made. Only the pressure-laminated mouthguard (not the one-layered vacuum-type mouthguards) permit sufficient occlusal thickness to be created.

Thickness

In 2005, Waked and Caputo³⁹ noted that an interocclusal space at physiologic rest position is 2 to 4 mm from

Study	Basketball	Baseball	Soccer
Kumamoto and Maeda, 2004 ¹⁰	U.S., 11.8% & 12.1%; Finland, 5.8% & 5.2%; Japan, 2.3%; Females 14 to 7.5%; Female Olympic, 1.3%	12.7% to 37%	6 studies: 2.8 to 13.8% 6 studies with small sample size: 9 to 20%
Kvittem et al. 1998 ⁷⁷	30.9%, 1020 athletes		
Ferrari and Medeiros, 2002 ⁵⁹	36.4%		23.1%
Yamada et al., 1998 ⁷⁸			32.3%
U.S. Department of Health and Human Services 2000 ⁷⁹	34% of all injuries are orofacial		

Table 1. Injury rate in sports

tooth contact. They therefore recommend a mouthguard with a thickness greater than 3 mm so the arches are adequately separated. These researchers conducted a study with 10 vacuum-formed and 10 pressure-laminated mouthguards. The pressure-laminated mouthguard produced material thicknesses greater than 3 mm, consistently thicker than the vacuum-formed mouthguard. The results may indicate that the pressure-laminated mouthguard allows the creation of a thicker mouthguard that fits the interocclusal space better.

Design at different angles

In 2004, Patrick et al.³⁴ identified the following criteria for design of the pressure laminated mouthguard:

- The mouthguard should enclose the maxillary teeth to the distal surface of the second molars.
- Thickness should be 3 mm on the labial aspects, 2 mm on the occlusal aspect, and 1 mm on the palatal aspect.
- The palatal flange should extend about 10 mm above the gingival margin.
- The labial flange should extend to within 2 mm of the vestibular reflection.
- The edge of the labial flange should be rounded in cross-section whereas the palatal edge should be tapered.
- When a maxillary guard is constructed, it should be articulated against the matching mandibular model for optimum comfort.

In a 1999 study by McClelland et al., 22 participants reported that the last three features mentioned above created a mouthguard that was more comfortable to the lips, gums, and tongue; felt less bulky; was less likely to keep the teeth apart or to cause pain in the jaw muscles compared with a mouthguard that was under-extended and had an unadjusted occlusion.⁴⁰

A research study examining the length of the distal end of the mouthguard and response to simulated impact shows that a mouthguard should cover at least up to the second molar to ensure efficient absorption and/or disper-

A review of the efficacy of different types of mouthguards concluded that the pressure-laminated variety provided the most protection.

sion of force.⁴¹ Other researchers argue for extending the guard as far back onto the molar areas as the client can tolerate, to maximize the force dissipation.³² In addition, some league rules require full molar coverage; however, care must be taken in fabrication, as many athletes cannot tolerate guards that extend to the third molars.

Rebound and thickness testing

Guevara et al.⁴² conducted a study in 2001 comparing 19 vacuum-formed mouthguards with 10 mouth-formed mouthguards. They found that the vacuum-formed mouthguard did not perform as expected and produced the lowest value on the tests for rebound and thickness in the incisor region. This suggests that caution should be taken in making the vacuum-formed mouthguard to ensure that adequate thickness of material is located over the incisors. The mouth-formed mouthguard had problems with slumping of the facial portion of the mouthguard after boiling. This resulted in thicker material over the occlusal surface but a lack of material over the facial surface of the posterior teeth. The other surprising finding was that none of the mouthguards tested achieved the standard of at least 50% rebound, established as a minimum requirement by ANSI/ADA Specification No. 99. It should be noted that not all custom-made mouthguards have problems with thickness in the incisor region; as Waked et al. point out, the pressure laminate mouthguard gives the best results in the incisor region.³⁷

Westerman et al. conducted two studies of the inclusion of air or gas into the EVA (ethylene vinyl acetate) mouthguard material to determine if it will improve perform-

Hockey	Field hockey	Bicycle	Rugby	Football	Martial arts
11.5% of all reported injuries	Rates are lower than in ice hockey	5.6% of all injuries	Rates are similar to football rates prior to mandating of mouthguards	Prior to mouthguard rules: 54%; Post rule: significantly reduced	
11.5%			56.5%		32.1%

Researcher/participant	Football	Soccer	Basketball	Baseball
U.S. Department of Health and Human Services (U.S. children) ⁷⁹	72%	7%	4%	7%
Woodmansey KF, 1997. ⁷ 557 British children				
Nowjack-Raymer RE, Gift HC, 1996. ⁵² Children	Majority			
Braham RA, Finch CF, Australia RCT., 2003 ⁸⁰ ** mouthguards are not mandatory in Australian football	100% (games) 0% (practices)			
Hawn KL, Visser F, Sexton PJ, 2003. ⁸¹ 104 U.S., certified hockey trainers				
Ferrari CH, Medeiros JMF, 2002. ⁵⁹ 204 professional and semi-professional		1.4%	2.1%	
Yamada T et al., 1998. ⁷⁸ 2670 Japanese males		0.8%		
Comstock et al., 2005. ⁸² 234 females				
Ranalli, 1995. ¹⁴ US college level	33% custom-made; 33% custom-made and mouth-formed; 27% boil and bite			
Bolhuis J, et al. 1987. ⁸³ International players				
Berry et al. 2005. ⁵⁸ 165 Central Collegiate				
Comstock et al. 2005. ⁸² 234 females				

Table 2. Utilization rates

ance. The first study was conducted in 2002,⁴³ using regulated air inclusion in an EVA mouthguard material (Shore A Hardness of 85). The air inclusion was found to reduce the transmitted force by as much as 32% when tested with a pendulum impact.

However, the second study in 2002 did not show the same energy absorbing qualities of air inclusion.⁴⁴ This study examined results of simulated impact on two types of mouthguard materials. The control was an EVA polymer (with Shore A hardness 83) and the test samples were the same EVA polymer injected with a foaming agent to form indiscriminate gas cells throughout the polymer. The researchers found that the foaming agent did not produce statistically significant improvements in the impact performance, measured by improvements in energy absorption, and reductions in transmitted forces of the EVA material.

Types of arch casts

Generally, single-arch mouthguards are fabricated for the maxillary teeth. However, dual-arch mouthguards—also called bimaxillary mouthguards—cover the upper and lower teeth and provide more protection for the jaw joint

and the mandible compared with a single-arch mouthguard.⁴⁵⁻⁴⁷ The lower guard can be help to cushion the lower teeth with orthodontic fixtures or space maintainers fixed on the lower teeth.⁴⁴ However, athlete compliance may be low, due to a lack of comfort. The American Society for Testing and Materials (ASTM) recommends that mouthguards for individuals with a class I or II malocclusion should be constructed using a maxillary arch impression; those with a class III malocclusion should use a mandibular arch impression.²⁷ However, further research in this area may be warranted since most injuries occur in the maxillary incisors and the mandibular arch impression leaves this area unprotected.

Material and comfort

In 2001, Brionnet et al.⁴⁸ conducted a study with 48 male rugby players aged 14–18 who provided feedback on the comfort of acrylic resin and silicone rubber custom-made bimaxillary mouthguards. Overall, players found the mouthguards quite comfortable and reported no difference in responses to the two types of mouthguard materials. The silicone rubber (a softer material than acrylic resin) mouthguards were less stable than the acrylic ones, since the softer material was broken down more quickly by

	Hockey	Martial arts	Handball	Rugby	Field hockey	All sports
						6%
Not routinely worn and not consistently enforced						
	91.3%	13%	4%			
				24.1%		
				90.8%		
					43%	
17.1% - 50% of time						
				66.7% of scrum halves; 80% of other players		

excessive chewing. Thus a reduction in hardness in mouthguards is linked to an improvement in shock absorption but retention increases with the hardness of the material. Therefore, the researchers suggest that further research be conducted to develop a silicone mouthguard with sufficient hardness to allow greater retention and increased stability (i.e. not breaking down as readily) but that still maintains the resiliency needed for shock absorption.

EPIDEMIOLOGY

A 2003 literature review by Kumamoto and Maeda,¹⁰ which included 104 articles published on international sports-related orofacial trauma during the last 20 years, indicates that the injury rates varied depending on the age of the athletes, the sport, and the geographical location of the sample groups. The results are shown in table 1. Caution should be taken when comparing the numbers in this chart since the definition of injury varies from one reporting body to the next. For example in the National Collegiate Athletic Association players must miss a game or a practice in order for the incident to be counted as an injury and in the International Ice Hockey Federation any dental injury or laceration is recorded as an injury.

With this limitation in mind, there are still some interesting findings from the injury data. Injury rates in basketball are higher than in football and ice hockey where mouthguards are mandatory.^{10,49} For example, a pilot study on this topic indicates that a soccer player is more likely to sustain an orofacial injury than a football player and a basketball player is twice as likely.⁴ Injury rates are lower in countries where sports are less popular and higher in countries where they are very popular. Although there are mixed results when comparing female and male rates, the burden of the evidence shows that males have higher rates than females.^{10,50} In basketball and soccer, older athletes tend to have fewer dental injuries than younger players. Similar results were found in a study with children aged 7 to 13 years who showed increased risk, possibly due to adolescent growth spurts that may cause difficulty adjusting to new body proportions.¹⁰ The high incidence of dental injuries during practice sessions indicates that mouthguards should be worn not only in competitive games but also during practices.³²

It is clear from the research that participation in a number of sports carries considerable risk of orofacial injury. This risk exists in contact sports such as rugby and hockey but also in sports with less contact such as basketball and

Researcher/participants	Football	Basketball
U.S. Department of Health and Human Services, 2000 ⁷⁹	Mouthguard and facemask: <1% risk of injury	30% reduced risk
Labella, Smith, & Sigurdsson, 2002. ⁸⁴ Prospective study with 37 athletic trainers		# of injuries per 1,000 athlete exposures - Custom fabricated vs. no protection: (0.12 vs 0.67; P < 0.05)
Jolly, Messer, & Manton, 1996. ⁸⁵ Retrospective study	Half as many orodental fractures and tooth avulsions as players who didn't wear a mouthguard	
Ranalli, 1991 ⁸⁶	Incidence pre-mouthguard rule: 2.26; post-mouthguard rule: 0.30 per 100 players.	
Flanders & BHAT, 1995. ⁴⁹ Pilot with 820 football and 120 basketball players	1.4 per 10,000 athletic exposures; ⁸⁷ with mandatory mouthguard practice	18.3 injuries per 10,000 athletic exposures; no mandatory mouthguard rule
Marshall SW, Loomis DP, Waller AE, Chalmers DJ, Bird YN, Quarrie KL, Feehan, 2005. ⁶⁵ 240 male and 87 females; adjusted data for covariates such as level of competition, playing position, and injury history		

Table 3. Mouthguard efficacy in preventing orofacial injury

soccer. It is also clear that there is a lack of information in Canada. This gap is addressed in the recent draft of the Pan Canadian Injury Prevention Strategy⁵¹ by SmartRisk. This Strategy identifies the need for the Public Health Agency of Canada to create an Injury Prevention Centre. Such a centre could play a coordinating role in setting national injury prevention targets and could coordinate surveillance, research and programming.

UTILIZATION RATES and BEHAVIOURAL ASPECTS OF MOUTHGUARD WEARING

The utilization rate for mouthguard use varies by sport and although they are mandated in some sports, table 2 shows their use remains very low.^{10,20,52,53} Although approximately 40 years of research shows the benefits of mouthguards, the athletic community has not fully incorporated their use. There is therefore a need to address compliance issues in sports that already make the use of mouthguards mandatory. The table also shows that statistical data are lacking in some sports such as cycling, gymnastics, or skateboarding.²⁰

The utilization rate and behavioural aspects of mouthguards are influenced by the attitudes of players, officials, coaches, and parents. For mouthguards to be effective, they must be well accepted and adopted by athletes. It is clear by the statistics in football, where mouthguards are mandatory, that factors other than the risk of a penalty are influencing a player's decision to wear a mouthguard. For example, a survey of 102 rugby players taken during the second rugby world cup in 1991⁵⁴ shows that although all

the players believed that mouthguards provided protection, approximately one in five did not wear one. This gap between players' beliefs and their behaviour is also reported in a study by Cornwell et al.⁵⁵ Similar findings emerge: even though players realized the benefits of mouthguard use, they frequently did not wear one.

Athletes do not wear a mouthguard for a number of reasons. Lack of mandatory requirements in sports, lack of knowledge about the protective qualities of mouthguards, their cost and the negative effect on their appearance all play a role. Attitudes towards mouthguard use may also be partly influenced by professional sport practices. For example, two of the most visible contact professional sports, hockey and football, do not require mouthguard use.

Players' attitudes towards mouthguards depend on esthetics and the perceived image that they create; comfort, since some mouthguards may cause a headache; and how difficult the mouthguards make talking, and breathing. In a study of male high school basketball players, some of the reasons that players gave for not wearing a mouthguard include discomfort, difficulty with breathing, and difficulty with speaking.⁵⁶ This may be because most players were wearing stock or mouth-formed mouthguards. It is expected that players' difficulty would decrease if they were fitted with custom-fabricated mouthguards.

Rules do not guarantee compliance. Even with mandatory rules for mouthguards, many athletes are still not wearing mouthguards.⁵⁰ This may be due partly to a lack of appreciation by the players of the benefits of wearing

Baseball	Handball
30% reduced risk	
	Mouthguard use lowered risk; rate ratio (RR) = 0.56, 95% confidence interval (CI): 0.07 - 4.63

Coaches have the most influence on players' attitudes about mouthguards.

was presented to athletes, there was little use of mouthguards.

It appears that a previous injury has a considerable impact on an athlete's decision to wear a mouthguard compared with passively reading prevention material. Further research is needed in the area of developing prevention material that would somehow allow players to experience a virtual injury to better influence decision making.

Officials are expected to follow the National Collegiate Athletic Association (NCAA) rules that state a time-out is to be charged when a player is not wearing a mouthguard. They can also give a 5-yard penalty to a team if the limit for time-outs has been exhausted. Although there are rules in place, officials' attitudes towards mouthguard use affect enforcement. In 1993, Lancaster and Ranalli^{60,61} surveyed 109 college football officials and found that officials were unlikely to charge a time-out or to enforce penalties for mouthguard violations, even though they indicated that not all players were in compliance. Officials also reported that coaches should be responsible for player compliance. Officials believed that coaches have more influence on whether or not players wear mouthguards.

Coaches' attitudes towards mouthguard use are also an important factor in influencing players' compliance. Unlike officials, coaches are present with the players during practices and games, so would have a longer period of time during which to influence their behaviour. Coaches are also assisting players to develop consistent patterns of behaviour that should be carried forward into competition.

A number of studies show that coaches have the most influence on players' attitudes about mouthguards.⁵³ In 1995, Ranalli and Lancaster¹⁴ conducted a survey of 98 Division 1-A college head football coaches and found that they viewed themselves, the players, or the trainer as most responsible for players wearing mouthguards, not referees. Two studies on officials' attitudes towards coaches indicate that officials also believe that coaches should be accountable for athletes wearing mouthguards,¹⁴ and they believe that coaches are more influential in convincing players to wear a mouthguard.⁵³

There is some evidence that coaches are not making the best use of their influence in injury prevention. In 1998, Berg et al.⁶² conducted a survey of 508 high school athletic coaches in sports that do not mandate mouthguard use. The researchers found that 31% of coaches reported that they would not encourage mouthguard use, even if provided for free. In addition, only 13.2% of coaches reported that they offered education programs and information on mouthguard use. Somewhat more positive results are reported by Gardiner and Ranalli in 2000.⁵³ This survey of 89 coaches found that 74% of coaches would speak to the player directly if they detected a mouthguard infraction.

mouthguards. Two studies showed that only 50% of athletes thought mouthguards prevented injuries and 82% of soccer players and 26% of rugby players said that mouthguards were unnecessary.⁵⁰

Other factors that increase the athlete's likelihood of wearing a mouthguard include starting to wear a mouthguard at an early age,⁵³ a previous injury, and player position. A study of rugby⁵⁷ and basketball⁵⁵ players indicates that mouthguards were more frequently worn by those who had experienced a previous oral trauma. Some players, such as quarterbacks, may not wear a mouthguard since some find that it interferes with their ability to call signals.⁵³ Similarly, defensive hockey players, who have to talk more than offensive players, report more negative attitudes toward mouthguard use.⁵⁸

Two studies show that promoting injury-prevention material had little impact on whether or not a player wore a mouthguard. In 2003, in Australia, Cornwell et al. conducted a study of 496 basketball players.⁵⁵ They measured mouthguard wearing prior to and following a promotional intervention. Baseline mouthguard use was 62% at games and 25% during training. Although 90% of athletes acknowledged the protective value of mouthguards for basketball, youths after the intervention, did not increase mouthguard use, and adults increased their use by only 14% for training and 10% at games. Players who had previous injuries were 2.76 times more likely to wear mouthguards. In a similar 2002 study, Ferrari and Medeiros surveyed 204 professional and semi-professional athletes⁵⁹ and found that although mouthguard prevention material

Parents' decisions about mouthguard use also affect mouthguard utilization, since they have decision-making power in children's activities. In 1997, Diab and Mourino⁶³ conducted a survey of 1,800 parents with grade school children and found that three fourths of parents had received no information on mouthguards and injury. There was a lack of perceived need for mouthguards in sports such as basketball, baseball, and soccer, even though these are sports with the most frequently reported injuries.

Despite the evidence for the efficacy of mouthguards and the mandatory regulations and positive attitudes about mouthguards in some sports, there is not always compliance amongst athletes. In addition, coaches and referees are not always promoting or enforcing mouthguard use. These barriers to prevention may be addressed with educational information about orofacial injuries and the benefits of mouthguards which targets players, officials, coaches and parents. One of the educational program's goals should be to change athletes'/parents' behaviour, so that it is proactive instead of reactive.

EVIDENCE FOR MOUTHGUARD EFFECTIVENESS

A number of reviews of epidemiological and laboratory studies show that mouthguards reduce orofacial injuries. The first review (eight studies of the years 1968 to 1992⁶⁴) showed mouthguards unequivocally reduce hard and soft oral tissue injuries, jaw fractures, and neck injuries. A second review, which included three other research studies, also documented the substantial impact that mouthguards have on reducing sports-related orofacial trauma.² A third review of four surveillance-based research studies showed that mouthguards are effective in preventing dental injuries.³³

Mouthguards unequivocally reduce hard and soft oral tissue injuries, jaw fractures, and neck injuries.

A fourth review (12 studies) stressed the protective value of mouthguards. Within this review, only 1 of these 12 studies found no protective value. Unfortunately, more than half of these studies were conducted between 1968 and 1986, and only three were conducted more recently, i.e., 10 years ago. The age of the studies calls into question their validity since statistical analysis techniques have changed significantly over the last 15 years. Further efficacy information is presented in table 3, which documents a number of individual studies.

There are some gaps in the existing research, showing a need to conduct randomized controlled mouthguard trials in the field. A recent review of the literature indicates that studies in craniomaxillofacial injury prevention lack high-quality scientific design.³³ The study designs were limited by the small number of studies that included interventions (26%), controls (33%), and randomization (17%).

Marshall et al.⁶⁵ also raise some questions about the quality of studies. They note that, apart from seven cross-sectional studies that provide a weak basis for causal inference, there are only three studies with quasi-experimental or observational designs. Two of the three studies showed that mouthguards have a positive impact and the third shows no impact.

Public awareness of sports concussions has increased recently as the media reports the devastating impact on athletes who are forced into early retirement. Early studies showing the efficacy of mouthguards in preventing concussion took place in 1964 with several case reports⁶⁶ and in 1967⁶⁷ with an *in vitro* study. Heintz in 1979 also found evidence of efficacy for properly fitted mouthguards.⁶⁸ Unfortunately, these studies can be challenged because of the limited numbers of subjects and the lack of a clear correlation⁶⁹ between the factors studied and concussion.

There is still a lack of solid evidence 26 years later that mouthguard use reduces the incidence and severity of concussions. The Canadian Academy of Sport Medicine (CASM) conducted a systematic review of the literature on the topic of mouthguards and concussion and found that the evidence for prevention of concussions is poor. On one hand, they found four studies suggesting a possible benefit; however, on the other hand there are three studies that failed to show any benefit.⁷⁰ A second review of the literature by Echlin et al. in 2005 reaches a similar conclusion. Their review included three different studies, one of which was a very large study with a total of 506,297 athletic exposures. They conclude that the claim that mouthguards prevent mild traumatic brain injury is "controversial and not based on appropriate evidence based studies."⁸³ A third review is conducted by Padilla who found no data to support stock or mouth-formed mouthguards for concussion prevention.³² Other authors, such as Piccininni, have come to a similar conclusion and caution oral health professionals against making an unsubstantiated claim regarding the prevention of concussion with mouthguards.³²

Some evidence calls into question the importance of orofacial trauma in concussion. One study shows that a blow to the jaw is responsible for only 1.6% of concussion;⁶⁹ another study⁷⁰ indicates that the use of the upper extremity or the head, and not a blow to the mandible, was most likely to cause a head or neck injury, including concussion. The literature reviews combined with the etiological evidence indicate that one should be cautious when making a claim that mouthguards prevent concussion.

Although many questions remain in terms of the efficacy of mouthguards in preventing or reducing concussions, some researchers have speculated about the mechanisms for the action of the mouthguard in reducing the incidence or severity of concussion. See Appendix D for three proposed mechanisms of action.

These reviews of mouthguard efficacy suggest a pressing need for further research. The draft Pan-Canadian Injury Prevention Strategy⁵¹ makes three recommendations for increased research and programs. First, it calls for the fed-

eral government to establish a \$30 million annual National Injury Prevention Community Fund to support community-level programs to prevent injuries. Second, it calls for the establishment of a strategic injury research agenda, and a partnership between a newly developed Injury Prevention Centre of Canada and the Canadian Institutes of Health Research (CIHR) to co-fund injury prevention team development grants at \$100,000 annually. Third, it recommends the establishment of a \$4 million annual injury research and demonstration fund to test and evaluate injury prevention and control approaches.

THE ROLE OF THE DENTAL HYGIENIST

Dental hygienists obtain educational information on mouthguards through studies for a university bachelors degree, a college diploma, and continuing education programs. This information includes, but is not limited to, assessing the needs of the client for mouthguard protection, fabrication of the mouthguard, and educating the client on the use of a mouthguard. The 2005 Blueprint for the National Dental Hygiene Certification Board exam includes competencies pertaining to mouthguards—a testament to the importance of this topic in dental hygiene education. Dental hygienists who familiarize themselves with the different types of mouthguards and the advantages and disadvantages of each type are better prepared to reinforce their use with clients.

Dental hygienists are well positioned to help prevent injuries by changing clients' attitudes toward mouthguard use. While providing information on oral disease prevention and oral health promotion, dental hygienists can seize opportunities for simple interventions. They can teach their clients about the risks for dental trauma in sport and about the importance of protecting their teeth with a mouthguard. A conversation about the clients' hobbies and interests can incorporate educational information about the preventive nature of mouthguards. Reducing risk of orofacial injuries in sports is another piece of educational information that should be presented to clients who engage in sports at both the recreational and competitive levels. The "Information Sheet for Dental Hygiene Clients: Mouthguard Use and Care" at the end of the article can help in providing advice on the use and care of properly fitted mouthguards.

Dental hygienists can promote mouthguards and make them in a number of different settings including independent dental hygiene businesses, mouthguard clinics at schools and at sports arenas, dental clinics, community health centres, and public health. Reaching out to the community through clinics and private businesses helps to make mouthguards more accessible and affordable. The average cost for a mouthguard made in a dental office in Canada is between \$100 and \$135.^{70,71} Studies from the United States show similar costs that range from US\$82.96 to US\$150.^{2,72} Dental hygienists in Ontario and Saskatchewan with private mouthguard businesses make mouthguards for a fee of \$35 to \$50.⁷³

Some examples of dental hygienists who fabricate mouthguards follow. One dental hygienist in Ontario pro-

Dental hygienists are well positioned to help prevent injuries by changing clients' attitudes toward mouthguard use.

vides mouthguard clinics, working mainly with hockey, lacrosse, rugby, baseball, and basketball associations. The clinic involves taking impressions on site at the arena, answering questions, and giving demonstrations. One dental hygienist in Saskatchewan takes the impression in the client's home, fabricates the mouthguard in his home lab, and delivers the mouthguard to the client within one week. This dental hygienist makes mouthguards for a variety of sports, concentrating on hockey and lacrosse, and for disabled children as store-bought mouthguards often do not fit properly. As a public service, this dental hygienist also makes presentations to athletes, coaches, and parents on the different types of mouthguards and the importance of their use. Dental hygienists across Canada who make these types of presentations at team meetings, schools, and clubs such as the Boys and Girls Club are making an important contribution to primary prevention.

Some dental hygienists work with dentists to provide mouthguards to the public. Over the past five years, one Manitoba dental hygienist and dentist run mouthguard clinics with junior hockey team and with the North American Indigenous Games. Some dental hygienists are advocating for legislation changes to remove restrictive supervision by dentists that prevents them from opening up their own mouthguard business. Dental hygienists in Newfoundland and Labrador expect to celebrate success in this area: legislation expanding the scope of practice to allow dental hygienists to construct mouthguards soon will be presented to the Minister of Health. There is more resistance in Quebec where existing legislation prohibits dental hygienists from taking alginate impressions.

Although a greater number of dental hygienists work in independent practices now than in the past, the majority of dental hygienists still work in a team environment with other oral health professionals and general health professionals. Part of this teamwork involves collaborating on service provision, including mouthguard education and fabrication. A study conducted in 1999⁶⁴ examined the attitudes of dentists towards mouthguard protection. This study found that 97% of orthodontists and 67% of general dentists recommended mouthguards for their clients. The two main reasons for not recommending a mouthguard were (1) that a less expensive mouthguard was available over the counter, and (2) the dentist/orthodontist did not receive formal training on fabrication or use of mouthguards.

A similar study conducted in 1998 found that only one third of dentists indicated that dental school taught mouthguard fabrication, 13.8% said they learned in a continuing education course, and almost 40% were self-taught.⁷² In addition, many dentists questioned whether they were the oral health professionals who were responsi-

ble for distributing and fabricating mouthguards. A lack of involvement by oral health professionals is confirmed in a 2004 study by Pribble et al.⁷⁴ who conducted a survey of 120 parents of children participating in competitive soccer. This study found that very few health professionals recommended mouthguards for young athletes. Although some dentists' involvement in injury prevention may be limited, others are strong advocates of mouthguards. For example, the Academy of Sports Dentistry formed in 1983 and now has an international membership of over 800 members who take an active role in promoting mouthguard use.

Dental hygienists also incorporate mouthguard issues into in-service presentations to nursing staff at community health centres. They incorporate injury prevention and mouthguard material into other oral health topics such as fluoride use, oral cancer, and the link between general health and oral health. A U.S. research project substantiates a need for increased work in this area. The study examined primary care nursing centres⁷⁵ and found that, although almost half of nurses examined their clients for gum infections and oral lesions, only 15% educated clients about mouthguards. In addition, the majority do not refer clients to oral health professionals for treatment of dental decay or oral pain.

Public health dental hygienists offer population-based intervention programs to parents, coaches, players, and officials of organized sports. These programs educate the listeners about the risk of injury, the benefits of mouthguards, and encourage the enforcement of rules of play. A systematic review of population-based interventions was conducted in 2002 by Truman et al. to examine increases in the use of mouthguards and decreases in sport-related craniofacial injuries attributable to the intervention.^{20,76} This review examined 17 studies and found that 13 could not be included in the review due to design flaws and 9 of the 13 were also not admissible because of the lack of appropriate effect measure. The remaining 4 studies of fair quality did not provide sufficient evidence to determine the effectiveness of population-based intervention to encourage mouthguard use. Effectiveness could not be determined because of inadequate number, design, or execution of studies.

This does not mean that population-based interventions are ineffective but indicates a need for additional research and evidence to allow a judgment about this intervention.

CONCLUSIONS

Research shows that orofacial injury in sport is prevalent and carries significant medical, financial, cognitive, psychological, and social costs. Research also confirms that mouthguards can prevent orofacial injuries. The CDHA therefore strongly recommends that dental hygienists play an integral role in the prevention of orofacial injury in sports and promote properly fitted mouthguards as an essential piece of protective equipment, in sports that present a risk of orofacial injury at the recreational and competitive level.

Relatively few Canadian organizations take a stand on the use of mouthguards compared with American organizations. The Canadian Dental Hygienists Association's strong stand on the use of mouthguards as primary prevention for orofacial injuries places CDHA as a Canadian leader in this area. There is significant opportunity for dental hygienists to protect the health and safety of children and adults in sport by supporting and promoting mouthguard use. It is not just the fastest and roughest sports such as football, rugby, and ice hockey that result in orofacial injury. Sports that are considered less dangerous such as soccer, baseball, field hockey, and basketball also have the potential to cause orofacial injury.

There is compelling evidence indicating that mouthguards can make sport safer by preventing orofacial injuries. The evidence for the role of mouthguards in preventing or reducing the severity of concussions is very weak and further research is needed in this area. Custom-fabricated mouthguards, particularly the pressure-laminated type, appear to provide a number of benefits over other mouthguards: the thickness can be adjusted for specific sports; it can be extended to the second molar; and the mouthguards can be articulated against the mandibular model.

Some progress has been made in preventing orofacial injuries since the 1960s and 1970s when mouthguards first became mandatory. However, there is still considerable work to be done in developing more positive attitudes and increasing use of mouthguards. First, greater use of mouthguards in all contact sports needs to be promoted. The cost of a mouthguard fabricated by oral health professionals is extremely low compared with the medical, financial, cognitive, psychological, and social consequences associated with orofacial injury. Second, a multidisciplinary approach is needed to increase the number of players who wear mouthguards. The coach, officials, parents, dental hygienists, other oral health professionals, and general health professionals all have a role to play. They can help the public to develop positive attitudes to mouthguard use, influence behaviour, and address compliance issues in sports where mouthguards are mandated. Third, there is a need to develop an approach for expanding regulations regarding mouthguard use in sports.

Unfortunately, Canadian statistics on incidence of orofacial sports injuries are limited and may be underreported due to the lack of a national surveillance system. This gap in knowledge may be addressed by the creation of an Injury Prevention Centre of Canada. Such a centre could coordinate surveillance and maintain a database of orofacial injury reports. This information could be used to study the efficacy of mouthguards, assist in designing better mouthguards, and promote better public education.

RECOMMENDATIONS

Dental hygienists can

- work together with other health professionals to deliver health education, injury prevention, and mouthguard promotion campaigns on either a one-to-one basis or to groups of clients, parents, athletes, athletic teams, sports coaches and officials, and gym teachers;

- act as change agents to influence a culture in sports that accepts mouthguard use as a normal part of dressing for sport;
- fabricate mouthguards and advise on the use and care of properly fitted mouthguards;
- conduct research on the oral health promotion of mouthguards and the prevention of injury.

Sports governing bodies, local injury prevention centres, and school districts can

- mandate the use of properly fitted mouthguards during practices and competition in all sports where orofacial injury is a risk, including sports such as basketball, baseball, and soccer;
- develop a plan to address compliance in sports that mandate mouthguards;
- deliver increased health promotion and education of athletic trainers, coaches, sports officials, organizers, administrators, athletes, and parents.

Dental hygiene professional organizations and educational institutions can

- work with national sports and school organizations to develop an approach for expanding mouthguard regulations in sports and for addressing compliance issues in sports that have existing mouthguard rules;
- provide ongoing opportunities during college/university and in continuing education to gain knowledge and experience with mouthguard issues.

Governments can

- fund health promotion and injury prevention programs that include mouthguards;
- work with local or provincial injury prevention centres to establish an Injury Prevention Centre of Canada (IPCC), which would be responsible for an injury surveillance system, monitoring injury exposure and inci-

- dence, and assessing injury trends in activities when new equipment or regulations are introduced;
- establish an injury research and demonstration fund to test and evaluate injury prevention and control approaches.

Health insurance industry can consider covering the cost of properly fitted mouthguards in health plans and promote the use of custom fabricated mouthguards.

Researchers can conduct high-quality mouthguard research, including randomized controlled trials on topics such as:

- efficacy of various types of mouthguards in preventing orofacial injuries and concussion;
- cost-effectiveness of mouthguards and infection control;
- effectiveness of population-based interventions and sports regulations, including an increased penalty severity for mouthguard rule infractions, for increasing mouthguard use;
- survey dental hygienists and other oral health professionals to determine the general knowledge and experience levels with respect to mouthguards and to determine attitudes of dental hygienists with respect to advocating for mouthguard use;
- improved product design of an effective, comfortable mouthguard that would facilitate widespread compliance.

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APPENDIX A METHODOLOGY

The methodological approach in this paper is a comprehensive review of the literature on mouthguards, orofacial injury in sport, mouthguard efficacy in preventing orofacial trauma, and the role of the dental hygienist in promoting injury prevention and preventing orofacial injury. The methodology included the development of specific research questions for each section of the paper. These questions were then used to develop search terms for the literature search.

The researcher conducted a detailed search of relevant international English language literature from 1995 to 2005 using MedLine, CINAHL (Cumulative Index of Nursing and Allied Health Literature), and the Cochrane controlled trials register. In vivo and in vitro studies were included in this review. The keyword search included the terms dental hygienist, mouthguards, mouth guards, mouth protectors, occlusal splint, athletic injuries, sports injuries, orofacial injury, tooth injury, tooth fractures,

brain injury, statistics, incidence, sports, and athletics. The search strategy also used the clinical queries research methodologies search filter, using categories that included systematic reviews, meta-analysis, randomized controlled trials, and review, with a specificity of narrow scope.

The search also included “gray” literature—information not reported in the scientific periodical literature—and web sites known to contain publications on this topic. In addition, references cited in the articles were searched manually as opposed to a computer database search. Recognized experts in the topic area were consulted and asked to comment on the outline and corresponding literature so they could identify relevant articles that might otherwise have not been identified. They were also asked to comment on the draft paper. Members of the Canadian Dental Hygienists Association also provided comment on the draft paper.

APPENDIX B WORLD HEALTH ORGANIZATION TOOTH INJURY DEFINITIONS⁸⁸

Avulsion	A complete displacement of a tooth from its socket
Chipped	A complete fracture and displacement of a portion of the tooth
Concussion	Tooth is sensitive to percussion but not displaced or abnormally mobile
Fracture: crown	Fracture of enamel and dentin; may or may not involve exposure of pulp
Fracture: enamel	Fracture of enamel only and includes chipping, cracking, and incomplete fractures
Fracture: root	Fracture of root only
Luxation: extensive	Tooth is very mobile because of partial displacement out of its socket
Luxation: intrusive	Tooth has been forced down and embedded into bone
Luxation: lateral	Tooth has been displaced and may be very firm
Subluxation	Tooth has increased mobility but has not been displaced

APPENDIX C CATEGORIES OF OROFACIAL INJURIES⁴⁹

Soft tissue injuries

- These include contusions or lacerations to the lips, tongue or gingiva, as well as dislocations or trauma to the temporomandibular joint, bruising to the facial muscles, nerves, fascia, and blood vessels.

Dental injuries

- These include chips or minor, moderate or severe fractures, tooth luxation, avulsions.
- There may also be trauma to the ligaments or trauma/concussion to the tooth where the tooth is not moved out of position.

Bony injuries

- These include minor fractures to the alveolar bone and facial bones.

Other injuries

- These include aspiration of teeth or other dental prostheses, and cerebral concussions.
-

APPENDIX D MECHANISMS FOR THE ACTION OF THE MOUTHGUARD

Researchers propose three mechanisms for the action of the mouthguard in reducing the incidence or severity of concussion. These views, however, are speculative and research is needed to substantiate the theories.⁶⁶

1. Opening the condylar space^{32,49,66}

The mandibular condyle of the jaw fits into the skull at a structure called the trough of the mandibular fossa. The mouthguard opens up the space between the condylar head and the mandibular fossa, of the temporal bone. This space decreases the force delivered to the temporal area of the head by preventing the condyle of the mandible from being driven into the fossa.

2. Dissipation of forces^{2,32,89}

Mouthguards absorb the energy from a blow to the head, chin, and face and dissipate the upward force and remaining energy to the jaw across the entire mouthguard, thereby reducing trauma to the brain and skull. Mouthguards cushion the shock from a blow to the jaw and prevent the transmission of the shock through the temporomandibular joint to the skull.

3. Reduction of rotational forces^{32,49,90}

A blow to the inferior aspect of the mandible is transmitted through the midfacial skeleton, forcing the skull to rotate backwards. The mouthguard allows the user to exert a clenching force with the head and neck muscles, which stabilizes the skull and reduces the jarring of the brain.

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Mouthguard Use & Care



THE CANADIAN DENTAL
HYGIENISTS ASSOCIATION
L'ASSOCIATION CANADIENNE
DES HYGIÉNISTES DENTAIRES

- Mouthguards are for recreational, professional, or competitive athletes and should be worn in practices as well as games.
- Initially wear the mouthguard during training or practices in order to adapt to the new feel of the guard in the mouth.
- Do not chew on or alter the mouthguard as this will affect the fit and possibly damage it or decrease its effectiveness.
- Custom-made mouthguards are made for that particular time when the cast of the dentition is taken.
- It may be easier to find a lost mouthguard on the playing field if it is coloured plastic, rather than clear.
- Rinse the mouthguard with cold water or with a mouthrinse before and after each use. Avoid contact with hot water.
- Since the mouth contains bacteria and plaque, it is important to clean your mouthguard after each use. Clean it with toothpaste and a toothbrush or clean it in cool, soapy water and rinse thoroughly.
- Store and transport the mouthguard in a firm, perforated container to prevent damage and permit air circulation. Do not close the mouthguard container until the freshly washed mouthguard is dry.
- Do not share your mouthguard with others.
- Avoid high temperatures or direct sunlight to minimize distortion.



- Check the condition of the mouthguard occasionally and replace it if it has holes or tears, becomes loose, or irritates the teeth or gums.
- Remove retainers and other removable appliances such as orthodontic retainers, removable bridges, or dentures (complete or partial) before inserting the mouthguard.
- If the mouthguard absorbs a strong blow, it may need to be replaced to maintain a proper fit and protection.
- Due to pressure from the teeth, and alternate wetting and drying that occur between uses and during cleaning, mouthguards wear out over time. The material deteriorates and loses resilience, reducing effectiveness. Therefore, they should be replaced every two to three years. Earlier replacement is recommended if they become cracked, torn, and split, or if fit deteriorates, significant wear appears, or there is unsatisfactory retention.
- Bring the mouthguard to each dental hygiene visit to have it evaluated by the dental hygienist.