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Mouthguards for contact sports: current state of use

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MOUTHGUARDS FOR CONTACT SPORTS: CURRENT STATE OF USE

by

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B.A., Boston University, 2010

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MOUTHGUARDS FOR CONTACT SPORTS: CURRENT STATE OF USE

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ABSTRACT

Traumatic dental injury (TDI) is a public health problem that affects millions of individuals each year. Contact sports and sports-related activities such as boxing, basketball, and bicycling are the number one cause for TDI's. The most common TDI's resulting from sporting accidents are soft tissue laceration, tooth fracture, luxation and avulsion. Some individuals are more at risk than others in sustaining a TDI due to various predisposing factors. Individuals are at greater risk of dental trauma if they have protruding teeth, insufficient lip closure, and/or teeth that have received restorative dental treatment. Adolescents and teenagers are known to be most affected by TDI's because they are the subset of the population most involved in contact sports and other physical activities. Mouthguards were developed to prevent the occurrence and severity of these dental injuries. There are three different types of mouthguards currently in use. They are the stock, mouth-formed, and custom-made mouthguards. Stock and mouth-formed mouthguards are the least recommended by dental professionals,
yet in combination are worn the most because of their affordability and ease of use. Custom-made mouthguards are the most accepted mouthguards by the dental community because they are the most adapted to the particular individual, and are associated with the lowest number of TDI’s out of the three types of mouthguards.

Users of mouthguards are nearly three times less likely to sustain a TDI while participating in a sport, compared to non-users. Unfortunately, many active individuals do not utilize mouthguards. Non-users of mouthguards associate wearing of mouthguards with undesirable effects, such as breathing difficulties and speech impairment. The side-effects of mouthguards can be so prevalent that they can potentially cause impairment in ones playing ability. In hopes of increasing the number of mouthguard users, researchers and manufactures have continually found new ways to eliminate the negative side-effects of mouthguards, while enhancing their protective function.

Researchers have found mouthguards made from ethylene vinyl acetate (EVA) to have the lowest report of wearer opposition. EVA materials are soft and durable, but more importantly, can be tailored to satisfy the needs of the individual. Also, certain materials and designs can be incorporated into the EVA material to better the mouthguards protective function. For instance, past experiments have shown the placement of compliant materials, such as Sorbothane, in between two sheets of EVA material will significantly enhance the mouthguards protective capability. However, the joining of multiple materials
may result in thicker and less comfortable mouthguards. More recent mouthguard trials have focused on limiting the thickness of mouthguards, while achieving the same level of protection seen in mouthguards made from multiple materials. Researchers have found the insertion of air cells within the EVA material to be useful technique in minimizing the overall thickness of mouthguards, while preserving the mouthguards protective function. In continuing to meet the high demands of athletes and active individuals, researchers and manufactures must develop newer mouthguards by exploring the effectiveness of other materials, as well as finding alternative methods in which mouthguards can be made.
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<td>--------------</td>
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</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
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</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
<td></td>
</tr>
<tr>
<td>EVA</td>
<td>Ethylene Vinyl Acetate</td>
<td></td>
</tr>
<tr>
<td>NCAA</td>
<td>National Collegiate Athletic Association</td>
<td></td>
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<tr>
<td>PDL</td>
<td>Periodontal Ligament</td>
<td></td>
</tr>
<tr>
<td>RCT</td>
<td>Root Canal Therapy</td>
<td></td>
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<tr>
<td>SR</td>
<td>Sports-Related</td>
<td></td>
</tr>
<tr>
<td>TDI</td>
<td>Traumatic Dental Injury</td>
<td></td>
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<tr>
<td>TMJ</td>
<td>Temporomandibular Joint</td>
<td></td>
</tr>
<tr>
<td>UNIRA</td>
<td>Universal Neuromuscular Immediate Relaxing Appliance</td>
<td></td>
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<tr>
<td>WHO</td>
<td>World Health Organization</td>
<td></td>
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</table>
I. Introduction

Contact Sports

There was once a time when distinguishing contact sports from non-contact sports was as easy as making a lay-up or kicking an extra point. However, in today’s society, the same cannot be said with such ease. According to one study, a contact sport is one where players physically interact with each other, trying to inhibit the competitor from winning (Newsome et al., 2001). Alternatively, another study defines a contact sport as one that “presents the risk of blows or falls” (Ferrari and De Medeiros, 2002). The literature’s inability to clearly define a contact sport allows for a number of different sports to fall under this category. Sports are a great way for an individual to make friends, gain confidence, as well as stay healthy; but accidents do occur. Whether the individual is participating recreationally or competitively, there always remains the risk of physically interacting with another player or falling. Sustaining injuries while playing sports is not uncommon, this includes trauma to the mouth and teeth. Table 1 provides what is to be considered a contact sport or sports related (SR) activity.
Table 1: Contact Sports and Sports Related Activities. Table amended from American Dental Assistants Association and dentalcare.org, 2011.

<table>
<thead>
<tr>
<th>Contact Sports and Sports Related Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Boxing</td>
</tr>
<tr>
<td>2) Wrestling</td>
</tr>
<tr>
<td>3) Hockey</td>
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<tr>
<td>4) Football</td>
</tr>
<tr>
<td>5) Rugby</td>
</tr>
<tr>
<td>6) Soccer</td>
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<tr>
<td>7) Lacrosse</td>
</tr>
<tr>
<td>8) Field Hockey</td>
</tr>
<tr>
<td>9) Basketball</td>
</tr>
<tr>
<td>10) Volleyball</td>
</tr>
<tr>
<td>11) Baseball</td>
</tr>
<tr>
<td>12) Softball</td>
</tr>
<tr>
<td>13) Tennis</td>
</tr>
<tr>
<td>14) Track and Field</td>
</tr>
<tr>
<td>15) Handball</td>
</tr>
<tr>
<td>16) Skiing/Snowboarding</td>
</tr>
<tr>
<td>17) Bicycling</td>
</tr>
<tr>
<td>18) Skateboarding</td>
</tr>
<tr>
<td>19) Rollerblading</td>
</tr>
<tr>
<td>20) Gymnastics</td>
</tr>
</tbody>
</table>

Dental Trauma

Trauma to the mouth and teeth has become a public health problem due to the increasing number and physical size of participants in sports. It is believed
that 13-39% of dental injuries are a result of sports related activities (Ramagoni et al., 2007). Similarly to defining a contact sport, the literature does not provide a clear definition of dental trauma. According to the World Health Organization (WHO), dental injuries are fractures, luxations, and avulsions of the teeth, including the mandible of maxilla (Beachy, 2004). However, others believe the definition should include lacerations or contusions to the gums, cheeks, tongue, and lips (Kvittem et al., 1998). There is consensus among the researchers that particular groups are more susceptible to injury. Among these groups are children and adolescents, middle-aged athletes, and men (Saini, 2011).

**Mouthguards**

An athletic mouthguard is the primary prevention tool used during sporting activities to diminish the occurrence of dental injuries. The Journal of the American Dental Association (2006) states that a mouthguard protects the oral cavity from injury by “providing a resilient, protective surface to distribute and dissipate transmitted forces on impact to the hard and soft tissues. Several types of mouthguards are available for active individuals who are looking for ways to prevent traumatic injuries while involved in their activity. Although the literature clearly supports the beneficial use of mouthguards, there still remain a large percentage of individuals who do not wear a mouthguard while participating in sport related activities.
**Risk Factors**

Certain individuals are more likely to experience orofacial trauma while participating in sports related activities due to certain conditions of their oral health. A study performed by Brin et al. (2000) suggests that “increased overjet and inadequate lip coverage” of the upper front teeth are major risk factors, as well as individuals receiving orthodontic treatment. An additional study performed by Bhalla et al. (2012) identified individuals who have misaligned teeth to be more at risk of injury than teeth with normal occlusion. Lastly, people who have received restorative dental treatment will be at higher risk because their teeth never regain a similar strength following treatment. All participants in contact sports, especially the ones who are at a higher risk of injury, should utilize the protection of a mouthguard.

**Goals**

There have been numerous studies performed measuring the use of mouthguards in limiting the occurrence and severity of injury to the oral cavity during a traumatic event. The purpose of this study is to educate the reader by providing valuable information one must consider when participating in a sport related activity. Primary prevention practices are safe, practical, and economical. Nevertheless, some do not know of these practices, or simply decide not to use them based on their own beliefs. The goal is that once reading this review, one will understand the varying types of injuries one may sustain to their mouth and
teeth while participating in sport activities. One will truly appreciate the significance of mouthguards through understanding the mouthguard fabrication process. Also, by presenting numerous statistical studies defending the impact mouthguards have on maintaining sound oral health, one will become a user and advocate of mouthguards. Lastly, the necessity for further advances on mouthguard design will be discussed.
II. Review of Dental Injuries In Contact Sports

Soft Tissue Injuries

Contusions, abrasions, and lacerations all fall under the definition of a soft tissue injury. Contusions are commonly known as bruises, and have been given the nickname “Charlie horse”. Either a blunt force or significant penetrating trauma to oral soft tissues (lips, cheek, tongue) may result in a contusion (Demertzis and Rubin, 2012). Hemorrhaging under the soft tissue results following trauma to the particular area, and is characterized by a change in normal appearance (Gelfman and Thomson, 2008). Studies, including one performed by Hubbard and Denegar (2004), advocate the brief application of ice to the site of injury immediately following the traumatic event to reduce the hemorrhaging, along with lowering any pain being experienced.

Abrasions often “overlie prominent facial features”, and are classified as disruptions of the epidermis (outer layer of the skin), that may breach into deeper layers of the skin (Gelfman and Thomson, 2008). If multiple layers of the skin are penetrated following a facial injury, it becomes increasingly difficult to classify the injury as an abrasion rather than a laceration. Simple and mild abrasions that affect only the outermost layer of the skin should be cleaned using a mild soap and rinsed with a saline solution (Gelfman and Thomson, 2008). To decrease the likelihood of infection, one should apply antibiotic ointment over the abrasion
and cover with a bandage after properly cleaning the affected area (Stevens et al., 2005).

Laceration is a broad medical term to define a cut or tear of the skin. Lacerations are to be considered more serious in nature than abrasions because lacerations pose the risk of affecting other soft tissues such as blood vessels and can lead to serious infection if left untreated (Hollander and Singer, 1999). Small lacerations (i.e. paper cut) do not require immediate medical attention, and should follow a protocol similar to a moderate abrasion. However, more severe cuts (i.e. deep tongue laceration) will require immediate medical attention, and will most likely need to be sutured using advanced management techniques (Brown et al., 2007).

**TMJ Injury**

The temporomandibular joint (TMJ) is a synovial joint that contains articular disks, which allows one to chew, swallow, and speak (Buescher, 2007). A study by Muhtarogullari et al. (2004) suggests sporting injuries of the TMJ are not felt right away, and may take up to a couple of days for one to start experiencing discomfort. Trauma to the TMJ will lead one to experience intense jaw pain caused by the dysfunction of the jaw joint and muscles (Sharma et al., 2011). It is strongly recommended that individuals seek medical attention after experiencing jaw pain resulting from a traumatic injury to the jaw or mouth. Table 2 contains questions one suffering from TMJ pain will receive during a medical
center visit following a traumatic injury. An examination will be given on the masticatory system, testing the maximal range of jaw movements, joint sounds, and pain tolerance (Muhtarogullari et al., 2004). Treatment for a traumatized TMJ greatly depends on the degree of discomfort being experienced by the person. For less severe and moderate cases, a splint or even a new aid, like the Universal Neuromuscular Immediate Relaxing appliance (UNIRA) will be administered to help alleviate the pain (Rampello et al., 2010). However, if the TMJ does not respond well to non-invasive therapy, or the traumatic injury is so severe (i.e. displacement of the articular disc), surgery will be required (Sanders, 1986).

Table 2: Questionnaire given to patients suffering from TMJ discomfort. Table amended from Sharma et al., 2011.

<table>
<thead>
<tr>
<th>Examination Protocol</th>
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<tr>
<td>Is it difficult or painful to open the mouth? (e.g., yawning)</td>
</tr>
<tr>
<td>Does the jaw get stuck, locked or go out?</td>
</tr>
<tr>
<td>Is it difficult or painful to chew and talk?</td>
</tr>
<tr>
<td>Do the jaw joints make sounds?</td>
</tr>
<tr>
<td>Do the jaws often feel stiffness and muscular tiredness?</td>
</tr>
<tr>
<td>Are headaches, neck aches or toothaches frequent?</td>
</tr>
<tr>
<td>Have there been any recent changes in bite? (orthodontic or prosthodontic treatment)</td>
</tr>
<tr>
<td>Has there been previous treatment for any unexplained facial pain or a jaw joint problem?</td>
</tr>
<tr>
<td>Is there any history of trauma?</td>
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</table>
**Avulsion**

Tooth avulsion is a very serious dental injury that requires immediate attention and care. As defined by Ozer et al. (2012), avulsion is when “one or more teeth are completely knocked out of their alveolar sockets.” A traumatic event that leads to the displacement of a tooth may also cause damage to the supporting tissues and roots of remaining teeth. When diagnosing the severity of an avulsed tooth, one must take account of the individual’s age.

Avulsion of primary teeth (baby teeth) can often time lead to complications due to the possibility of damaging the “permanent successor”. There is very little room separating the root of the baby tooth from the tissue layer of the permanent tooth. “Tooth malformation, impacted teeth, and eruption disturbances” are only a few concerns that may result after having a tooth knocked out (Malmgren et al., 2012). It is strongly recommended that a child with an avulsed tooth seek medical attention immediately. A comprehensive exam must be performed by a health professional to diagnose and treat the injured area. Replantation of avulsed primary teeth is not recommended (Malmgren et al., 2012).

Adults who experience traumatic tooth avulsion must also be wary of serious complications. Avulsion of a permanent tooth requires immediate emergency care. Time is not in the favor of the individual experiencing this type of injury. A protocol should be followed to maximize any hope of retaining the lost tooth. According to Andersson et al. (2012), the displaced tooth should be handled by its crown to avoid any further damage to the periodontal ligament
PDL. PDL cells remain viable only one hour after a tooth is displaced from the mouth. If possible, the individual should try to reposition the tooth in the alveolar socket and bite down on a piece of cloth to keep it in place (Andersson et al., 2012). However, there remains the possibility that the individual is experiencing too great of pain to reposition the tooth, or is simply unable to hold the tooth in place (unconscious). In such events, the tooth should be transported in a container of milk or saliva with the individual to the emergency room. If the PDL of the traumatized tooth is no longer viable, one must seek extensive dental treatment to restore health the affected area. It is with great emphasis that any person experiencing traumatic tooth avulsion seeks immediate health care to improve their present and future oral health.

**Luxation**

Tooth luxation is a common traumatic dental injury that refers to the repositioning of a tooth while still maintained within the alveolar bone (DiAngelis et al., 2012). Luxations are defined by the direction in which the tooth has moved from its original position. Extrusive luxation is an injury that separates the PDL from the tooth; causing the tooth to loosen or move in the axial direction (Hermann et al., 2012). A tooth experiencing this type of injury will appear elongated and will be overly mobile. Once again, age of the individual will determine the best possible therapy. It is recommended that extruded primary teeth be repositioned in the tooth socket, and held in place by a splint for a
couple weeks to allow proper healing. The same therapy is applied to extruded permanent teeth if the PDL is not affected. However, if the PDL of extruded permanent teeth is adversely affected, root canal therapy (RCT) is necessary (DiAngelis et al., 2012).

Lateral luxation is characterized by a fracture to the supporting bone of traumatized teeth, causing displacement of the tooth in any direction but axial (Hermann et al., 2012). As mentioned in DiAngelis et al. 2012, the tooth will be immobile and the PDL space is noticeably wider in lateral luxation cases. Treatment for intrusive luxation is identical to extrusive luxation, although a splint may be needed for a longer period of time to heal the alveolar fracture.

Intrusive luxation, unlike the other luxations discussed, is displaced axially into the alveolar bone (DiAngelis et al., 2012). Similar to lateral luxation, the traumatized tooth will be immobile; however the PDL space may be completely missing. Therapy for a tooth with a developing root calls for the tooth to erupt naturally without any intervention. After a couple of weeks, if the tooth still remains in the displaced position, orthodontic treatment is required. Treatment of a mature tooth that experiences intrusive luxation depends on how far impacted the tooth has become. If the tooth has moved three millimeters or less, the handling is identical to that of a tooth with a developing root. Treatment for a tooth that has been moved seven millimeters or greater will require surgery. Most likely any tooth experiencing intrusive luxation will require RCT due to the disappearance of the PDL space. Splints must be used for a longer period of
time than the other forms of luxation, it is recommended to have the splint stabilize the affected area from four to eight weeks (DiAngelis et al., 2012).

Less severe luxations such as concussion and subluxation do exist. These injuries carry a much less risk of healing complications because the tooth has not been displaced. The main clinical finding of concussion and subluxation is tooth sensitivity. No treatment is provided in these cases other than a routine checkup to re-evaluate the traumatized area (DiAngelis et al., 2012).

**Fractures**

Seven varieties of tooth fracture are documented in the literature. Tooth fractures alone or in combination with luxation could inflict serious impairment to one’s oral health (Lauridsen et al., 2012). Children who experience minor fractures of their primary teeth will have breaks in their enamel, dentin or both. If the pulp of the tooth is not exposed then treatment consists of using glass ionomer for small fractures and composite for larger fractures (Malmgren et al., 2012). However, if the pulp of the tooth is exposed more extensive treatment is needed. It is recommended that a health professional do what is needed to salvage the primary tooth. In such a case, a “partial pulpotomy” or “pulp capping” will be performed to maintain the integrity of the tooth. Partial pulpotomy is an effective technique that uses calcium hydroxide-based materials which allows the rebuilding of dentin by its ability to eliminate infection, along with accelerating the wound healing process (Karabucak et al., 2005). Once the pulp has been
repaired, one can expect to receive similar treatments performed on minor fractures to repair the crown of the tooth. A partial pulpotomy or pulp capping will be performed on permanent teeth experiencing a similar injury, if treatment is unsuccessful then RCT is needed (Lauridsen et al., 2012).

More complicated tooth fractures such as crown-root fracture, crown-root fracture with pulp exposure, and alveolar fracture demand a greater amount of attention. An individual who experiences one of these types of fractures to their permanent dentition will have sustained significant damage to different parts of the tooth.

Crown-root fracture is a painful injury that affects the tooth’s’ enamel, dentin, and cementum. Additionally, one may also experience loss of tooth structure. Clinical findings show a fracture of the tooth below the gum line that extends to the crown of the tooth (DiAngelis et al., 2012). To address the health of the tooth’s root, an x-ray must be taken to determine whether or not the tooth’s pulp has been affected. In the case of crown-root fracture with no pulp exposure, treatment is determined by the severity of the fracture. Extraction is necessary for severe vertical fractures; however a fracture that does not spread the majority of the tooth can be salvaged (Garcia-Godoy and Murray, 2012). First, a gingivectomy must be performed on the tooth. According to Ganji et al (2012), gingivectomy is a procedure done on teeth that have experienced a “deep subgingival pathology”. A gingivectomy focuses on exposing additional tooth structure to assist restorative procedures. Highlighted earlier, crown-root
fractures extend below the gum line; this requires a health professional to perform the gingivectomy to visualize the length of the fracture. Once additional tooth structure is exposed, restorative work will be done to return the tooth to a healthy state. Small fragments from the fracture will be removed, but if a larger fragment is retained, it may be used in the restorative process (DiAngelis et al., 2012).

Crown-root fracture with pulp exposure demands more medical attention then crown-root fracture with no pulp exposure. DiAngelis et al. (2012), recommends preserving and maintaining the pulp vitality by performing partial pulpotomy or RCT. If the traumatized pulp does not receive immediate attention, the individual will experience varying levels of discomfort, as well as several poor physiological outcomes. Most likely, the pulp will suffer from inflammation, and quickly become necrotic, also known as tissue death (Garcia-Godoy and Murray, 2012). This unfavorable outcome may cause harm to surrounding hard tissues, further complicating one’s recovery. It is in the best interest of the individual experiencing this type of trauma to receive immediate treatment to prevent ongoing disorder. A crown-root fracture with pulp exposure will also have a gingivectomy before any restorative work is done (DiAngelis et al., 2012).

Alveolar fracture is another form of traumatic injury one may suffer when playing contact sports. The fracture may be located anywhere from the bone margin of the gums to the root of the tooth. More than one tooth could be out of position, and most times the individual will have difficulty biting down. The best
treatment for alveolar fractures is to “stabilize the displaced segment with a splint for four weeks, as well as and suturing any gingival laceration” (DiAngelis et al., 2012). If treatment is unsuccessful, endodontic therapy is the next best option. Table 3 provides classification of the injuries discussed by severity level.

Table 3: Oral traumas by severity. Table amended from Cohenca et al., 2007.

<table>
<thead>
<tr>
<th>Type of Injury</th>
<th>Severity Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concussion</td>
<td>Mild</td>
</tr>
<tr>
<td>Subluxation</td>
<td>Mild</td>
</tr>
<tr>
<td>Uncomplicated Crown Fracture</td>
<td>Mild</td>
</tr>
<tr>
<td>Soft-tissue Laceration</td>
<td>Mild-Moderate</td>
</tr>
<tr>
<td>Complicated Crown Fracture</td>
<td>Moderate</td>
</tr>
<tr>
<td>TMJ</td>
<td>Moderate-Severe</td>
</tr>
<tr>
<td>Crown Root Fracture</td>
<td>Severe</td>
</tr>
<tr>
<td>Root Fracture</td>
<td>Severe</td>
</tr>
<tr>
<td>Luxation</td>
<td>Severe</td>
</tr>
<tr>
<td>Avulsion</td>
<td>Severe</td>
</tr>
</tbody>
</table>
III. History of Mouthguards

Mouthguards have been utilized by athletes for nearly the past 100 years, and most recently by armed forces in combat (Zadik and Levin, 2008). From the time they were introduced in sports, and throughout ensuing generations, mouthguards have significantly lowered the number of orofacial injuries sustained by athletes (Beachy, 2004). The effectiveness of mouthguards in preventing injuries in a sports setting has led to the enforcement of mouthguards in a number of sports. In the 1960’s, athletic committees from varying competition levels (i.e. colligate, professional) began mandating the use of mouthguards in sports like boxing, American football, and ice hockey to better protect their athletes from traumatic dental injuries (Daneshvar et al., 2011).

Boxing

The history of mouthguard use has been well documented in the literature. Prior to being allowed to wear mouthguards, boxers had to develop their own methods to protect themselves. Described by Knapik et al. (2007), boxers would try to reduce the amount of force delivered to their teeth by clenching on “mouthguard-like devices from cotton, tape, sponge or small pieces of wood”. Records dating back to the 1920’s suggest mouthguards were first fabricated to address the countless number of injuries boxers suffered to their mouth and teeth during boxing matches.
American Football

Soon after mouthguards were introduced to boxers, many American football players began using the mouth protectors. In 1962, it became mandatory for all United States high school football players to wear a mouthguard, and by 1974 the same was done collegiately (Newsome et al., 2001).

Collegiate American Hockey

One year after mandating the use of mouthguards in college football, the NCAA (National Collegiate Athletic Association) required all student athletes participating in collegiate hockey to do the same in 1975. The mouthguard must cover all the teeth of one jaw, usually the upper, and should not be altered from the manufactures design without the consent of medical personnel (Hawn et al., 2002).

High School Sports

Nearly two decades later in 1993, Minnesota became the first state in the United States to require both boys and girls participating in soccer, basketball, and wrestling at the high school level to always wear a mouthguard. For game officials to enforce the wearing of mouthguards, a rule was put in place ordering students to wear a mouthguard of distinctive color (i.e. yellow), making it easier for the officials to determine whether or not the student was using a mouthguard (Kvittem et al., 1998).
**Mouthguard Materials**

The first mouthguard was made from natural rubber, offered very little protection, and in some cases caused harm to the wearer (i.e. choking) (Patrick et al., 2005). Soon after the first mouthguard was introduced, people were interested in ways to improve it by making new mouthguards from different materials. In the past natural rubbers, vinyl resins, acrylic resins, polyurethane, and ethylene vinyl acetate (EVA) copolymer were used to make mouthguards (Westerman et al., 1997). However, these days nearly all mouthguards are made from EVA materials.

**Ethylene Vinyl Acetate (EVA)**

Ethylene vinyl acetate materials are superior to other mouthguard materials for several reasons. To start, EVA materials have widespread usage resulting from its many mechanical properties and are rather easy to obtain due to its commercial abundance (Gould et al., 2009). Since EVA materials have many mechanical properties, manufacturers rely on them to make an array of different mouthguards with ranging physical properties. In the laboratory, researchers have found ways to easily manipulate EVA materials, causing changes in its properties (Going et al., 1974). One manipulation is by fluctuating the ratio of its parts, vinyl acetate and ethylene (Westerman et al., 1997). As one increases the vinyl acetate percentage, the EVA material becomes “more flexible, stretchable, softer, and tougher” (Park et al., 1994). This is important
because EVA materials will be able to achieve similar physical properties as other mouthguard materials without the association of health risks. For instance, a mouthguard made with 10-15% vinyl acetate will achieve a flexibility similar to mouthguards made from polyurethane, but does not pose the same health risks seen in polyurethane mouthguards (i.e. respiratory complications) (Gould et al., 2009).
IV. Classification of Mouthguards

There are three commercially available mouthguards on the market. They are the stock mouthguard, the mouth-formed or boil-and-bite mouthguard, and the custom-made mouthguard. The three mouthguard types vary in a number of ways. First, they differ in the materials used to build the mouthguard. Second, there are different techniques in which the mouthguards are constructed (i.e., number of layers of EVA materials). Third, they differ in the processes in which the mouthguards are molded to the individual’s mouth (i.e., mouth-formed or dental cast). Fourth, each mouthguard offers a different level of protection and comfort to the wearer. Last but not least, the final costs of the three mouthguards are variable.

Stock Mouthguards

Stock mouthguards are the simplest mouthguard available. They can be purchased over the counter at many pharmacies and sporting goods stores. Stock mouthguards are unfitted, inexpensive, and come in a variety of sizes. These mouthguards are made from rubber and vinyl acetate (Powers et al., 1984). They come ready-made and are simply placed over the upper teeth (Duarte-Pereira et al., 2008). Since they come ready-made, there is no ability to adjust the mouthguard to the exact morphological features of an individual's mouth.
(Maeda et al., 2009). Universally, stock mouthguards are not recommended by dentists because they lack retention to one’s teeth, and must be clenched to remain in the wearers mouth, causing disruptions with the wearers breathing and speaking (Ranalli, 2002). Even though these mouthguards are made from a thin single layer of material, and cause discomfort to the wearer, they do provide significant protection to one’s mouth when compared to not using a mouthguard (De Wet et al., 1999).

**Mouth-formed (“Boil-and-Bite”) Mouthguards**

These mouthguards are made from thermoplastic materials (EVA), and are formed in the mouth using one’s fingers, tongue, and biting pressure (Ranalli, 1991). Prior to being formed in the mouth, the mouthguard is placed in boiling water for 10 seconds and then put in cold water for an additional 2 seconds (Park et al., 1994). Mouth-formed mouthguards are the most used mouthguards by people participating in various sports because they are cheap and are easily available (Takeda et al., 2006). In addition, it is believed that the “ease of use” of the mouthguard is to account for its popularity (Del Rossi and Leyte-Vidal, 2007). Wisniewski et al. (2004), found that up to 90-95% of mouthguard wearers rely on the mouth-formed mouthguards. Mouth-formed mouthguards do offer better protection and comfort than stock mouthguards; however, they are not the ideal mouthguard. During the course of their “service time”, mouthguards tend to deform through prolonged wearing, unnecessary chewing, and extreme biting
pressure (Miura et al., 2007). As a result, the thickness in material on the biting surface of these mouthguards decreases 70-90% (Park et al., 1994). The thickness of the mouthguard material is proportional to the mouthguards' protective ability; thus thinning of the mouth-formed mouthguard material will lead to inadequate protection of one's oral health. Other concerns of mouth-formed mouthguards are interference with pronunciation while speaking, breathing difficulties, and oral dryness; all of which may affect one's performance while participating in contact sports (Duddy et al., 2012).

**Custom-made Mouthguards**

Custom-made mouthguards are fitted by dentists and are fabricated on a dental cast (stone or plaster) that is made from an impression of one's teeth (Poisson et al., 2009). They are specifically constructed for the individual, and thus they will fit the individuals' mouth better than the stock and mouth-formed mouthguards (Greasley and Karet, 1997). A better fitted mouthguard will have a smaller influence on a player's performance because it is associated with fewer objections as compared to the other mouthguard types (Hoffmann et al., 1999). Figure 1 is an example of a custom-made mouthguard made from a dental cast.
Figure 1: Custom-made mouthguard fitted over dental cast. Figure taken from Miura et al., 2007.

Custom-made mouthguards are the least worn mouthguard of the three types because of their expensive price (Guevara et al., 2001). According to Park et al. (1994), custom-made mouthguards are 10-100 times more costly than the other two mouthguards because they require a significant amount of time and effort to create. Figure 2 displays the results of a questionnaire given to 10 professional Spanish rugby players on the side effects they experienced while
wearing both the mouth-formed mouthguard and custom-made mouthguard. Duarte-Pereira et al. (2008) conducted the survey, and found that custom-made mouthguards interfered less with breathing, oral dryness, speaking, and nausea (P < .05); while significantly (P < .05) having better adaptability, comfort, and drinking ability.

![Bar chart showing adverse effects associated with mouth-formed and custom-made mouthguards. The chart includes bars for Breathing Difficulty, Oral Dryness, Tiredness, More Thirsty, Speech Interference, Bad Taste, Difficult to Drink, Nausea, Adaptability, and Comfort. The x-axis represents different adverse effects, and the y-axis represents the number of respondents (N).]

**Figure 2:** Survey questionnaire (analog scale) on the adverse effects associated with mouth-formed and custom-made mouthguards. Figure amended from (Duarte-Pereira et al., 2008)
Similar to mouth-formed mouthguards, EVA materials are used to make custom-made mouthguards (Keçeci et al., 2005). In contrast, custom-made mouthguards are made in the laboratory via two different methods; vacuum-pressure and the pressure-laminated. The vacuum-pressure method involves the application of low heat and moderate suction to mold a single layer of EVA material over a dental cast (Del Rossi and Leyte-Vidal, 2007). This method is the least accepted by the dental community because the single layer of EVA material significantly decreases in thickness during the heating and cooling process (Bhalla et al., 2012).

The pressure-formed method is the method of choice for several reasons. Custom-made mouthguards that are fabricated via the pressure-formed method require high heat and pressure during the molding process; this will “heighten the level of adaption” of the EVA materials to the dental cast (Del Rossi and Leyte-Vidal, 2007). Using the pressure-formed technique, fabricators are able to regulate the final thickness of the mouthguard by using laminates (Takeda et al., 2006). Lamination is a technique that “fuses” multiple sheets of EVA materials together; ensuring that the mouthguard will maintain its desired thickness throughout the fabrication process (Bhalla et al., 2012).

Multilayered custom-mouthguards are the most ideal mouthguard because they register the greatest shock absorption of all the mouthguards, while offering the best fit (De Wet et al., 1999). In addition, laminated mouthguards experience “less stress accumulation” than single-layered mouthguards during their...
construction; meaning laminated mouthguards will be more stable over time (Miura et al., 2007). As an added benefit, lamination allows the individual to personalize their mouthguard by adding letters or images to the surface of the intermediate layers (Takahashi and Koji, 2005).

Two classification systems have been available on the varying types of mouthguards. They are the American National Standards Institute (ANSI), and the American Society for Testing and Materials (ASTM), the latter being the most common and current classification (Gould et al., 2009). Table 4 provides a comparison of the two classification systems, which are based on the methods used to construct mouthguards. According to the ASTM, their standards are used by researchers to improve the quality of products on the market, while enhancing the safety of the consumer (American Society for Testing and Materials, n.d.).

ASTM provides the research community with set guidelines on how to test specific properties of variable materials. These guidelines, in turn, create a uniform testing protocol that is implemented by researchers performing experiments on similar materials. With respect to mouthguards, the ASTM has specific standards on how to test the varying properties of mouthguard materials. The most important properties of mouthguard materials that are subject to ASTM standards are shock absorption, hardness, tear strength, and water absorption. The next section provides a detailed explanation on how these properties impact the performance of custom-made mouthguards.
Table 4: ASTM and ANSI classification systems. Table amended from Gould et al., 2009.

<table>
<thead>
<tr>
<th><strong>ASTM classification system</strong>¹</th>
<th><strong>ANSI classification system</strong>²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1 - Thermoplastic type</td>
<td>Type 3 - Custom</td>
</tr>
<tr>
<td>Class 1 - Vacuum formed</td>
<td>Class 1 - Vacuum formed</td>
</tr>
<tr>
<td>Class 2 - Pressure formed</td>
<td>Class 2 - Model formed</td>
</tr>
<tr>
<td>Type 2 - Thermosetting type</td>
<td>Type 2 - Mouth formed</td>
</tr>
<tr>
<td></td>
<td>Class 1 - Thermoplastic</td>
</tr>
<tr>
<td></td>
<td>Class 2 - Chemical setting</td>
</tr>
<tr>
<td>Type 3 - Stock type</td>
<td>Type 1 - Stock</td>
</tr>
</tbody>
</table>

² Last updated in 2001.
V. Properties of Custom-Made Mouthguards

A number of properties are associated with custom-made EVA mouthguards. The properties of greatest interest are shock absorption, hardness, tear strength, and water absorption. Whether it is to make the mouthguard increasingly protective or resilient, each property serves a purpose for the mouthguard. With these properties in mind, developers of mouthguards are actively trying to develop mouthguards that can better serve active individuals. Researchers and developers of mouthguards use a number of testing procedures endorsed by the ASTM to measure the effect of these properties on mouthguard function. It is necessary for mouthguard wearers to understand the meaning of each property and the ways in which they are measured.

Shock Absorption

Shock absorbing capability may be the single most important characteristic to consider when selecting the proper mouthguard. Shock absorbance simply refers to the amount of energy that is transferred and dissipated throughout the mouthguard, minimizing any blow to the teeth or mouth. A study done by Hoffmann et al. (1999) found that the thickness of a mouthguard is the “decisive criterion” for an acceptable shock absorption, with a minimum thickness of 3 mm being necessary. Experiments have been done to
test the quality of shock absorbance in mouthguards using a pendulum swing (Westerman et al., 1995). The rebound of the pendulum determines the shock absorbing capability. The smaller the rebound, the greater the material’s shock absorption capability (Knapik et al., 2007).

Mouthguards made from EVA materials can be manipulated to increase shock absorption without having to increase the overall thickness of the mouthguard. Patrick et al. (2005) found that by adding a compliant material in between two sheets of EVA, one can considerably lessen the force being delivered to one’s mouth and teeth. Likewise to EVA, the compliant material will absorb a share of the force, forming a greater shock absorption system as a whole. Figure 3 illustrates the association between shock absorbance and a mouthguard made from EVA materials.

Figure 3: Mouthguards made from EVA materials help distribute an impactful force over a greater area. Figure taken from Patrick et al., 2005.
A laboratory study conducted by Bulsara and Matthew (1998), tested whether having a compliant material in between two layers of EVA really had any effect on shock absorption capability. A visco-elastic polyurethane material (trade name Sorbothane) was used as their compliant material. Bulsara and Matthew (1998) found the addition of Sorbothane was statistically significant in lowering the amount of energy transmitted to an individual’s mouth and teeth; more so than an EVA mouthguard without the compliant material. They calculated that the force experienced by an EVA mouthguard with a compliant region was roughly 30% lower than a mouthguard without the compliant material. Figure 4 shows the mean peak force transmitted thru mouthguards with and without a compliant middle region.
Figure 4: Mean peak forces (kilogram-force, kgf) transmitted through mouthguard with or without Sorbothane layer. Figure taken from Bulsara and Matthew, 1998.

Although, it is shown that having a Sorbothane layer of 2.65mm has the greatest shock absorption ability, manufacturers have to consider the ideal thickness that will allow for optimal protection while still being aware of the
individuals desire for a comfortable mouthguard. Mouthguards with greater thickness are regularly met with wearer opposition because of awkwardness with lip and cheek placement, speech restriction, and respiratory limitations (Westerman et al., 2002). Adding a compliant layer in between two sheets of EVA is not the only way to increase shock absorption. Researchers have found the implementation of air inclusions (cells) to be beneficial as well.

Westerman et al. (1997) successfully fabricated a mouthguard made from EVA materials that contained purposeful air cells. The air cells provide the wearer with additional impact absorption, without presenting any negative side effects. The EVA mouthguards containing air inclusions transmitted 32% less force to the mouth as compared to mouthguards made from the same material but without air cells (Westerman et al., 2002). Figure 5 provides an illustration on the arrangement of air cells within an EVA mouthguard. Whether it be the addition of a compliant inner layer or the insertion of air inclusions to a mouthguard made from EVA materials, both techniques have proved deliver additional shock absorption support to the EVA materials.
Figure 5: Air inclusion placement in mouthguard. Figure taken from Westerman et al., 2002.

**Hardness**

Like shock absorption, hardness is a measure of the mouthguard’s capacity to protect the mouth and the dentition. As defined by Knapik et al. (2007), hardness refers to the resistance a material has to a penetrating object when a certain load is applied. Brionnet et al. (2001) found that insufficient hardness of mouthguard materials will cause the mouthguard to warp and crack, leading to insufficient protection and comfort for the wearer.

Testing for a material’s hardness is rather straightforward, and requires the use of a durometer. Durometers test the hardness of metals and plastics, and are rather exceptional in their ability to record data on a linear scale (Falanga
and Bucalo, 1993). Gould et al. (2009) described the procedure one should follow when testing for a material's hardness. The specific durometer they chose for the experiment is called the Shore device (Model 306L, PTC Instruments, Los Angeles, CA, USA), and they used a specific indentor made from hardened steel, known as the type A indentor. The indentor is attached by a spring mechanism to a scale which is read from 0 to 100. As quickly as possible, the indentor will apply a certain load to the mouthguard material, and will be held in that position for one second. Depending on the scale value, one will be able to determine the hardness of the material.

A value of 0 represents complete penetration of the mouthguard material, while a score of 100 represents no penetration of the indentor (Knapik et al., 2007). Westerman et al. (2002) suggests EVA mouthguards with at least 4mm of thickness to have a Shore “A” hardness of 80 to provide the wearer with optimal protection. In their defense, Tran et al. (2001) found that mouthguards made from the same EVA materials, that only varied in thickness, had no significant difference in their Shore A hardness measurements. Wearers of mouthguards find additional comfort in softer materials, however harder materials have been shown to offer superior protection.
**Water Absorption**

Water absorption by mouthguards materials is measured to determine the mouthguard’s stability in an aqueous environment (Tran et al., 2001). Water absorption simply means how much water is diffused and retained by a certain material. In a study performed by Suzuki et al. (2007), a lower water absorption indicated a greater overall stability of the material used to make the mouthguard. Also, they reported an increase in expansion, pigmentation, and bacterial contamination in the materials with higher water absorption. Similarly, Miura et al. (2007) found that materials with higher water absorption were more likely to undergo an accelerated deformation than materials with a lower water absorption.

One way to test certain materials on their water absorption tendency is by placing the material in a drying agent (i.e. CaSO₄) for 5 days, and once the material is completely free of moisture, it is placed in a 37°C water bath for up to two days (Craig and Godwin, 2002). Once the material is removed from the water bath, it is quickly dried using a soft tissue and weighed to calculate the percent mean weight of water absorbed. According to Craig and Godwin (2002), a material will have an adequate water absorption if the mean weight gained by the absorption of water is in the range of 0.3 - 0.5 percent of the total weight of the material. More importantly, Suzuki et al. (2007) found that the water absorbed by EVA mouthguards contributed only a 0.222 percent increase in the weight of the material, indicating that EVA materials have a more than adequate
water absorption. The study does mention other materials that have lower water absorption (i.e. polyolefin); however these materials were less superior to EVA materials with respect to other physical properties.

**Tear Strength**

Tear strength is not a measure of a mouthguards protective ability, rather is a measure of its durability. Tear strength can be described as the resistance a material has to tearing, and is calculated by the force needed to split the material, in Newton’s (N), divided by the thickness of the material(cm) (Knapik et al., 2007). EVA materials are special. As one increases the thickness of the EVA material, one enhances the material’s tear strength ability, making the material less likely to deform overtime (Tran et al., 2001). Athletes in their respected sport anticipate that their mouthguards will last the entirety of their season and beyond, thus having a mouthguard with adequate tear strength is critical.

Many of the studies testing tear strength of mouthguard materials conducted their experiments with different instruments and units of measurement. However, experiments done by Craig and Godwin (2002) and Gould et al. (2009) tested the materials using a similar contraption (hydraulically controlled materials testing machine) with tear die “C”, along with the same system of measurement (N cm⁻¹). Tear die C refers to the centrally located V-shaped cut (slightly offset) in the material being pulled (Craig and Godwin, 2002). Figure 6 is a representation of EVA sheet material with a tear die “C” cut.
Figure 6: Tear die “C” cut in layered EVA material.

The position of the V-cut will dictate where the tear will occur (Kim and Reneker, 1999). The test begins by inserting the tear die “C” cut in the material using a hammer, then having a force pull each end of the material 50 cm/min in opposite directions at intra-oral temperatures of 37 °C (Gould et al., 2009). The load at which the material splits will be divided by the thickness of the material to calculate the tear strength. Craig and Godwin (2002) found that materials with a minimum tear strength of 200 N cm⁻¹ to have an adequate “service life”. Furthermore, both studies found that EVA materials, regardless of thickness, had minimum tear strength of 400 N cm⁻¹. When compared to other materials (rubber, acrylic resins), EVA presented no significant difference in tear strength capability (Gould et al., 2009). Since EVA materials tested better in the other properties discussed, it is evident that the most ideal mouthguards are made from EVA materials. Table 5 summarizes the strengths of the various properties of mouthguards.
Table 5. Properties of Mouthguards.

<table>
<thead>
<tr>
<th>Mouthguard Property</th>
<th>Significance</th>
<th>Function</th>
<th>Minimum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shock Absorption</td>
<td>Reduces the amount of energy transferred to the mouth and teeth.</td>
<td>Protective</td>
<td>Material thickness $\geq 3\text{mm}$</td>
</tr>
<tr>
<td>Hardness</td>
<td>Resists the penetration of an object or blow to the mouth and teeth.</td>
<td>Protective</td>
<td>Shore ‘A’ Hardness $\geq 80$</td>
</tr>
<tr>
<td>Water Absorption</td>
<td>Determines the usefulness of the mouthguard in an aqueous environment.</td>
<td>Stability</td>
<td>$\leq 0.3$-$0.5%$ of the total weight of the material</td>
</tr>
<tr>
<td>Tear Strength</td>
<td>Measures the resiliency of the mouthguard material.</td>
<td>Durability</td>
<td>$\geq 200 \text{N cm}^{-1}$</td>
</tr>
</tbody>
</table>
VI. Incidence of Oral Trauma in Sports

All contact sports and sports-related activities pose the risk of injury to the participant(s) mouth and teeth. Bijur (1995) found that orofacial trauma in sports and SR activities accounted for 5.3% of all sporting injuries. Furthermore, Gassner et al. (1999) concluded that 34.6% of all dental injuries are caused by sporting accidents. It is essential that mouthguards be utilized while participating in all physically demanding activities, especially while training and practicing at school. Bijur (1995) calculated that nearly 52% of injuries occur while in school or during a school organized competition. In addition, Beachy (2004) and Emerich and Nadolska-Gazda (2012) found that traumatic injuries are nearly three times more likely to occur while training because of the added exposures to the sport. Nevertheless, some sports and SR activities have a higher incidence of injury than others.

The purpose of many studies has been to determine which sports cause the greatest number of oral traumas. For the studies being discussed, a combination of mouth-formed mouthguards and custom-made mouthguards were worn by the participants of each study. Flanders and Bhat (1995) found that for every 10,000 athletic exposures, basketball had a significantly higher orofacial injury rate than football. Yamada et al. (1998) found rugby players to have a statistically significant (P<.001) greater chance of experiencing dental injury than soccer players, while Ferrari and De Medeiros (2002) found soccer to be the
sport associated with the highest number of dental traumas. Interestingly, a study performed by Newsome et al. (2001) determined that the “two-way collision” sports associated with the most amount of contact, football and hockey, had the lowest incidence of trauma because of the mandatory use of mouthguards in combination with helmets and facemasks. Heintz (1968) calculated that before the mandatory use of mouthguards in football, the injury rate to the mouth was 50%, and after the mandate, the injury rate decreased to 0.05%. In both of the previous studies mentioned, various mouthguard types were used, some offering better protection and comfort than others. Most notably, Schildknecht et al. (2012) found hockey presented the fewest cases of dental trauma compared to other contact sports (martial arts, basketball, handball, soccer) because hockey players are the highest percentage of custom-made mouthguards wearers compared to other sports.

The literature does not provide a clear consensus on which sport presents the highest risk of oral trauma because most of the studies compared different sports and activities. However, sports in which the athlete is exposed to multiple impacts (i.e. head, hands, feet, ball) will have the greatest incidence of oral trauma; these include boxing, wrestling, basketball, soccer, and rugby (Emerich and Nadolska-Gazda, 2012). Since most sports require the use of a ball in order to play, ball sports account for roughly 59% of traumatic dental injuries (Glendor, 2009). Of the non-ball sports, Levin et al. (2003) found cycling accidents caused the third most dental related injuries after basketball and soccer. Due to the
literature’s inability to associate a particular sport with the highest incidence of dental trauma, participants of all contact sports and physical activities should understand that dental traumas are likely to occur in the sport(s) in which they partake. Table 6 groups contact sports based on the incidences of oral trauma in that particular sport.

**Table 6**: Contact sports with the highest and lowest incidence of dental trauma.

<table>
<thead>
<tr>
<th>Highest Incidence</th>
<th>Lowest Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boxing/Wrestling</td>
<td>Football</td>
</tr>
<tr>
<td>Basketball</td>
<td>Hockey</td>
</tr>
<tr>
<td>Soccer</td>
<td></td>
</tr>
<tr>
<td>Rugby</td>
<td></td>
</tr>
<tr>
<td>Bicycling</td>
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</table>

With respect to oral traumas and their occurrences in particular subgroups, there is an agreement in the literature that some subgroups of the population are more affected than others. For instance, both Gassner et al. (1999) and Beachy (2004) found that high school male athletes had a much higher rate of orofacial injury than female athletes playing in the same high school sport. Also, Levin et al. (2003) concluded that the injury rate of
adolescents and teenagers increases as they age because they are more likely to be involved in multiple sports as they get older. In their defense, Conn et al. (2003) determined that 64% of all oral traumas are experienced by age groups 5-14 years old and 15-24 years old. The reason why these particular age groups experience more dental injuries is because they spend an average of 18 hours a week involved in physical activities, more so than any other age group (Glendor, 2009). Dental traumas resulting for sporting accidents can cause irreversible impairment to the athlete; it would be extremely unfortunate for an athlete, especially younger athletes, to suffer physical, emotional, and psychological pain when it can easily been prevented.

When a sporting accident results in an oral trauma, some injuries are experienced more than others. Again, there is consensus in the literature; soft-tissue lacerations are the most common form of sports-induced oral trauma. Yamada et al. (1998), Onyeaso and Adegbesan (2003), and Schildknecht et al. (2012) all state that soft-tissue lacerations were the number one reported oral trauma injury in their respected study. In addition, soft-tissue lacerations were the only injuries suffered by custom-made mouthguard wearers, while users of the other mouthguard types experienced more traumatic injuries. The sports involved in these studies were basketball, soccer, rugby, hockey, and cycling. In addition to these studies, Flanders and Bhat (1995) and Lieger and Von Arx (2006), state that tooth fracture is the second most common oral trauma. As mentioned previously, there are many types of tooth fractures; however they are
all categorized under one general category. Luxations and avulsion are the third most common oral trauma, followed by TMJ injury and severe fractures of the jaw (Lieger & Von Arx, 2006). With regard to which teeth are affected the most in dental traumas, both Glendor, (2009) and Andrade et al. (2010) found that the maxillary anterior incisors (front upper teeth) were the teeth most frequently injured because they are the most exposed structures of the mouth. This is true for all mouthguard types. Table 7 lists the most common dental traumas from highest to lowest.

Table 7: Most common dental traumas.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Soft-tissue laceration (Most)</td>
</tr>
<tr>
<td>2.</td>
<td>Tooth fracture</td>
</tr>
<tr>
<td>3.</td>
<td>Luxation</td>
</tr>
<tr>
<td>4.</td>
<td>Avulsion</td>
</tr>
<tr>
<td>5.</td>
<td>TMJ pain</td>
</tr>
<tr>
<td>6.</td>
<td>Jaw fracture (Least)</td>
</tr>
</tbody>
</table>

The objective of mouthguards is to lower the rate of dental traumas in sports. The literature has profoundly confirmed that wearing a mouthguard while involved in a particular sport/activity will dramatically reduce the number of dental
trauma cases (Beachy, 2004). In an NCAA men’s basketball study, non-users of mouthguards experienced a dental injury in 3 out of 1,000 athletic exposures, while users of mouthguards experienced only 1.16 dental injuries for every 1,000 athletic exposures (Labella et al., 2002). Onyeaso and Adegbesan (2003) reported that non-users of mouthguards are nearly 3 times more likely to experience a dental trauma compared to users of mouthguards. Furthermore, the introduction of mouthguards (combination of mouth-formed and custom-made) to a group of professional rugby players reduced the number of dental traumas from 56% of the athletes, to just 24% of the athletes (Schildknecht et al., 2012). Perhaps the most significant study of all, Andrade et al. (2010) surveyed 409 athletes (225 male, 184 female) who participated in a global sports competition, and found that less than one third of dental traumas were linked to mouthguard users. More importantly, they found custom-made mouthguard users accounted for less than 7% of the total number of dental traumas, which was significantly lower than the 19% for mouth-formed mouthguard users and 69% for non-users of mouthguards. The literature clearly supports the role mouthguards have in preventing dental traumas, however many athletes and active individuals have received little to no education on the significance of mouthguards.
VII. Conclusion

Certainly, it is evident that there are significant benefits in utilizing mouthguards in sports. Wearing a mouthguard during sports or other physical activities can dramatically reduce the risk of experiencing dental traumas by more than 50% (Schildknecht et al., 2012). Yet, every day millions of active individuals are at higher risk of sustaining an oral trauma due to lack of education on the benefits of mouthguards or they simply choose not to use them. Certain subgroups of the population are more susceptible than others, including adolescents, teenagers, individuals with inadequate lip coverage of their teeth, and individuals with orthodontic appliances (Brin et al., 2000). These individuals are at higher risk of suffering injuries consisting of minor soft tissue laceration, moderate tooth fracture, and severe tooth avulsion. The use of any commercially available mouthguard while being active will reduce the occurrence of all these injuries.

Many of those who choose not to wear mouthguards often associate mouthguard wear with discomfort, breathing difficulties, and inability to speak. Yet, they do not know of the advantages custom-made mouthguards have in relationship to stock and mouth-formed mouthguards. Custom-made mouthguards offer greater protection to the individual, while eliminating most, if not all of the side-effects associated with mouthguards. Custom-made mouthguards are specially tailored to the individual’s morphological features by a dental specialist, and can even be personalized to the individual’s needs.
Perhaps the only undesirable feature of custom-made mouthguards is their cost in comparison to the other two mouthguard types. Yet, they are cheaper than emergency room visits and dental procedures. With regard to individuals who experience the most dental traumas (5-14 years old and 15-24 years old), roughly 3.3 – 4.4. million dollars are spent each year to treat dental injuries (Glendor, 2009).

Active individuals enjoy spending their time bettering their health and state of fitness, however if they fall victim to an oral trauma, they will likely be spending a significant amount of their time receiving dental treatments. On average, an individual suffering from an oral trauma will visit his or her dentist 1.9 – 9.1 times per year as a result of their accident (Glendor, 2009). What is more alarming is that only 23% of these individuals will purchase a mouthguard after experiencing their dental trauma (Lieger & Von Arx, 2006). This suggests that the individuals who do not purchase a mouthguard after their first trauma will most likely sustain another injury in the future since restored teeth are more susceptible to injury than healthy, untreated teeth.

Whether it is from receiving treatment, or because they are self-conscious from their altered appearance, dental traumas may lead an individual to experience psychological distress as a result of being away from their friends, teammates, and sport(s) of interest (Hergenroeder, 1998). The best way to prevent any of this from happening is by educating children, but more specifically parents, teachers, trainers, and coaches on the importance of mouthguards.
Dentists should always recommend wearing of mouthguards for active individuals, and should be able to provide information (i.e. statistics, images, models) showing their importance, especially for the custom-made mouthguards. Again, the populations most affected by dental traumas are adolescents and teenagers, however all age groups are affected. It should be mandatory for athletes in all levels of completion to wear mouthguards, this includes school-aged children, as well as athletes playing in high school, college, and professionally. Custom-made mouthguards should be mandatory for athletes with pre-disposing risk factors because these mouthguards will provide additional protection. Since adolescents and teenagers experience the most TDI's, the dental community must do more to educate these age groups on the risks sports have on their health. This can be done by targeting the parents, teachers, coaches, and trainers of these young athletes. Oral health awareness should not be overlooked.

Oral health professionals can present valuable information about the risks sports pose to one’s health in various settings, including classrooms, locker rooms, and parent-teacher organization meetings. In doing so, both age groups may see an increase in the number of mouthguard users. More importantly, as these young individuals age and develop, they will be more familiar and comfortable with mouthguards, leading to lower incidences of trauma in older age groups. Still, other people and organizations can be more involved in trying to
lower the incidence of injury in adolescents and teenagers including professional sports leagues and scientific researchers.

Various professional sports leagues and associations have developed numerous programs that educate younger individuals on making smart decisions when it comes to eating and exercising properly. Professional athletes are role models to many young individuals and can provide very important information to them. By appearing in television commercials and magazine advertisements, professional athletes who have experienced TDI's, as well as ones who support mouthguards during competition, can possibly persuade adolescents and teenagers in wearing mouthguards. Nevertheless, if mouthguards are uncomfortable and effect playing performance, no active individual will be inclined to use them. In the end, researchers must be more involved in trying to develop mouthguard materials that offer better comfort without compromising the other properties of mouthguards. It has been shown that pressure-laminated systems are the best method to use when fabricating mouthguards of multiple layers and materials. Under similar conditions, researchers should experiment using softer materials for mouthguards outer layers, while bolstering the inner compliant material. It would be interesting to see if the adding of another inner compliant layer would be an effective method in strengthening custom-made mouthguards made from softer materials.
REFERENCES


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Medically Relevant Experiences

05/08 to 09/10 Dental Receptionist at Mark C. Beal D.M.D.
• Private Practice
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• Collect payment for procedural work completed, and send claims to
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patients the benefit of their insurance
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12/07 to 5/09 Shadowed Oral Surgeon during procedures
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09/12 - Present

The Forsyth Institute

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Leadership and Activities

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Boston University Pre-Dental Society

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