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Review Article

Prevention of Sports Related Dental Injuries-The Mouthguard

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Abstract

Dental trauma caused due to sporting accidents can be time-consuming and expensive ,depending on the severity of the trauma. The athletic mouth guard also referred to as a gum shield or mouth protector, is defined by the American Society for the Testing of Materials (currently known as ASTM international) as a "resilient device or appliance placed inside the mouth to merely reduce oral injuries, particularly to teeth and surrounding structures.The fitting of a mouthguard is best accomplished under the personal supervision of a dentist.The physical properties of mouthguards that have been described include shock-absorbing capability, hardness, stiffness, tear strength, tensile strength and the resistance of a material to deflect by water absorption.The bimaxillary mouthguard is a concept in the effective prevention of orofacial and sports related concussion injuries.It is recommended in contact sports especially by those who are at ultimate risk of sustaining such extensive injuries.The recommended age to start wearing a mouthguard is at about 16 years .The bimaxillary mouthguard costs about twice the price of a standard custom mouthguard, hence proper care should be taken for it to last two to three years and is perfect for orthodontic patients undergoing fixed appliance therapy.

Keywords: Sports; Dentistry; Injuries; Mouthguard; Dental Trauma

Introduction

Dealing with dental trauma because of sporting accidents can be time-consuming and expensive, depending on the severity of the trauma. Though orofacial and sports-related dental injuries are reported to be common, they have also been termed as a "rare sports injury. "Facial protection with helmets and face shields help to a great extent for this, but the most important protective equipment for the budding athletes in today's era is the athletic mouthguard [1,2]. The athletic mouth guard also referred to as a gum shield or mouth protector, is defined by the American Society for the Testing of Materials (currently known as ASTM international) as a "resilient device or appliance placed inside the mouth to merely reduce oral injuries, particularly to teeth and surrounding structures."Despite of the proposed definition, no mouthguard has been the best in design or perfect in the material. In that manner, the appropriate statement of what constitutes an acceptable mouthguard for the athletes has been produced by the Academy for Sports Dentistry (ADA) [3].

The Academy of sports dentistry (ADA) has adopted that the single word "Mouthguard" must be named by the term a "property fitted mouthguard. In contact sports, the mouthguard must protect from both direct and indirect impact. It should stay in position during impact, and completely redistribute the impact's energy. The criteria for the fabrication of a properly fitted mouth protector includes oral health status that considers: Dental Caries, Periodontal Status, Developmental Occlusion, Orthodontic or Prosthodontic Appliances, Congenital/Pathological Conditions, and Jaw Relationships, Demographic Factors and Type of Sport Playing [3]. The fitting of a mouthguard is best accomplished under the personal supervision of a dentist. The athlete or concerned parents should repeatedly be advised of the significant design for

the "properly fitted mouthguard" and the product should have the following properties and considerations: It should be fabricated adequately to cover and provide protection to the teeth and the surrounding tissues.

The mouthguard should be fabricated and properly fitted and worn on precisely the leading arch of the athlete. This is the most protruding arch which is more likely to incur the greatest forces. It should be fabricated on a model of the patient's teeth made from an impression of the athlete. Adequate thickness in all protected areas to provide for the marked reduction of impact forces. Approximately minimum 3mm thickness in the occlusal/labial area. It should have a seated equilibrated occlusion that is properly balanced for even occlusal contact. This helps to adequately provide for the ideal absorption of impact energy. A precise fit that is retentive and not dislodged on direct impact. Speech considerations equal to the practical demands of the playing status of the athlete. It should be fabricated using FDA approved materials [2]. The properly fitted custom mouthguard should be routinely and professionally examined for proper fit and function. Specific frequency of routine inspection is dependent on prime factors such as the athlete's age, the demand of the organized sport that the athlete is engaged in, and the apparent willingness for the athlete to properly care for the necessary appliance. The specific frequency of the comprehensive inspection should be correctly determined by the dental professional for each respective individual situation and athlete [2]. The history of the appliance, the technicalities, the functions and the effectiveness of them, and the different types of mouthguards all should be basic knowledge for sports dentists. However, dentists should know how an effective mouthguard is fabricated.

History of Mouthguard

Mouthguard in boxing

Mouth protection in sports came into existence in the late nineteenth century in the sport of boxing. The first use of mouth protector documented was found in the sport of baseball in the United States in the 1870s [4]. Boxing remains the first sport where the development of mouthguard was more clearly described. Boxers mostly fabricated these mouth protectors from cotton, tape, sponge or small pieces of wood. In the year 1890, a London dentist named Woolf Krause uniquely designed the first true gum shield made from strips of gutta percha (a natural rubber like resin) over the maxillary incisors of boxers to protect them from orofacial injuries and lip lacerations. The active participant required to clench his teeth together to carefully hold the effective shield in place. Philip Krause, his son, who was both a dentist and amateur boxer, subsequently refined the design and created a reusable mouthguard from vella rubber. In 1913, a professional boxer named Ted "Kid" Lewis used Phillip's mouthguard during his championship fights. In 1916, the first mouthguard-type device was probably recorded in the United States when Thomas Carlos, a Chicago dentist, manufactured an official mouthpiece for U.S. Olympian Dinnie O'Keefe [4]. Mouthguards became prevalent in 1927 during an elimination tournament boxing match between Mike McTigue and Jack Sharkey. In the tenth round McTigue who was clearly winning the fight; however, a ragged tooth severely cut his lip and forced him to cease the match. Quiet soon, mouthguards became official for boxers by the New York Athletic Commission and also opened the possibilities for mouthguard use to flourish [4]. In 1926, Dr. Clarence Mayer, a prominent dentist by profession and also the boxing inspector for the New York Athletic Commission, wrote about how custom mouthguards might be created from favourable impressions using wax and rubber. He also suggested using steel springs to strengthen the materials [4].

Mouthguard in Football

In 1947, dental injuries were responsible for around 23–54% of all American football injuries. A comprehensive survey conducted in 1950 involving 65 football colleges identified a total of 733 fractured teeth among≈4000 football players. Rodney O. Lilyquist, a dentist from Los Angeles used transparent acrylic resin to promptly form the first acrylic splint. The Journal of American Dental Association used his technique, which led to nationwide recognition for him, and he became known as the father of the modern mouthguard [4]. In 1952, Life magazine prepared a report on Notre Dame football players who lost their incisors during the sport.The article focused a lot of public attention on the likelihood of dental injuries in football and led to the inclusion of mouthguards in other contact sports. In the 1950s, the American Dental Association (ADA) undertook research on the mouthguards and instantly started promoting their benefits to the general public. Before the development of orofacial protectors, ADA estimated that about one half of the injuries sustained by the players could have been minimized and prevented by the protectors such as helmets, face shields and mouthguards. Hence, ADA urged all agencies to involve mouthguards for all athletics of football teams and other contact sports activities. By 1962, all high school football players in the United States were made compulsory to wear mouthguards. The National Collegiate Athletic Association (NCAA) followed the recommendation in 1973 and made mouthguards mandatory in college football. The current NCAA football regulation requires all players to use a colour mouthguard with an FDA approved base material that covers all maxillary teeth [4].

Mouthguard in other sports

On February 24, 1993, Minnesota State High School League (MSHSL) required mouthguards for high school soccer, basketball and wrestling but dismissed the requirement a year later due to lack of scientific data in the selected sports. Besides football, NCAA recommends mouthguards for ice hockey, men lacrosse and women field hockey [4]. Dick Perry, who is a prominent member of UCLA basketball player used the first acrylic mouthguard. He modeled the device at a convention of the Southern California Dental Association. Later, Frankie Albert was the first known professional

non boxing athlete to wear this mouthguard [4]. The American Dental Association (ADA) and the International Academy of Sports Dentistry have recommended that mouthguards should be used in about twenty-nine sport or exercise activities [4]. They are acrobatics, basketball, bicycling, boxing, equestrian events, extreme sports, field events, field hockey, football, gymnastics, handball, ice hockey, inline skating, lacrosse, martial arts, racquetball, rugby, shot putting, skateboarding, skiing, skydiving, soccer, softball, squash, surfing, volleyball, water polo, weightlifting and wrestling.

Fabrication Specifications of Mouthguards

The construction and design of the mouthguard are as follows [4-7].

a) Full coverage to the distal side of the maxillary first permanent molar in low contact sports and to the distal sides of the second molar for high contact sports with a thickness of ~2-3mm on labial aspects ~3mm on occlusal aspects and ~2 mm on the palatal aspect.

b) Occlusion must be bilaterally balanced.

c) The labial flange should extend 2mm above the vestibular margin.

d) The palatal flange should extend 10mm above the gingival margin.

e) The edge of the labial flange and palatal flange should be rounded and tapered respectively.

During the construction of the maxillary guard, articulation should match the mandibular guard for optimum comfort.

Measurement of Physical Properties of Mouthguards

The physical properties of mouthguards that have been examined include shock-absorbing capability, hardness, stiffness, tear strength, tensile strength, and the resistance of a material to deflect by water absorption.

Shock absorption

Shock absorption is defined as the ability of a material or a device to reduce the impact of energy or to transmit the force beneath the mouthguard. Shock absorption measurements are achieved in two ways. One way is to drop a force onto the material by a device or to use a pendulum to swing a force swinging onto the material. The acceleration of the impacting force can be measured by the degree of a rebound. Lesser amount of rebound depicts more shock absorption and vice-versa. Another shock absorption quantification comprises of the force measured on a transducer beneath the mouthguard once a known force which is from a pendulum, dropped weight is applied to the top of the material. The mass of the object and the force transmitted can be calculated. A material having high shock-absorbing capability results in a lower peak force or power (force/time) than a material with low shock-absorbing capability. In some studies the impact mass is constant, acceleration measured and impact force (force=mass*acceleration) is calculated. Another study measured acceleration in which the change in acceleration reflected the change in shock absorption [3,4].

Hardness

Hardness is defined as the "resistance of a material to penetration with a load applied." The measurement is performed with a device called a durometer and for the softer materials used in mouthguards, the American Society for Testing and Materials 'A' scale has been used.It has a shaped intender which applies a specific load to the material The values for hardness are rated from 0 to 100. A measure of 0 means the material penetrated completely, and 100 means there was no penetration of the intender at all [3,4].

Stiffness

"Stiffness represent the relation between hardness and stiffness. Hardness is directly proportional to stiffness, as it increases, stiffness also increases". Most mouthguard materials possess linear elastic properties; once the load is removed the deformation disappears. For materials with linear elastic properties, Young's modulus quantifies stiffness. Young's modulus is the force needed to elongate a material of specified cross-sectional area, expressed in N/m^2. When force is applied, materials with low stiffness deform, which allows a maximum amount of the force to be centered under the impact. Materials with high stiffness distribute forces over a larger area because they undergo less deformation [3,4].

Tear strength

The ability to resist tear forces is termed as tear forces. It is measured as the amount of force required to tear a material divided by the thickness of the material (N/cm). Depending upon the size of the specimen and the rate of pull there is a difference in tear strengths. Many studies didn't report them, so only those comparisons within individual studies should be used [3,4].

Tensile strength

Tensile strength is defined as the pull force required to break a material of known size. Tensile strength is measured in N/cm^2. There in, a notched piece of material is placed between the two arms. At that time the material is pulled with increasing force until it breaks [3,4].

Water absorption

Water absorption is defined as the amount of water taken up by a material. These measurements can be performed by two processes. Firstly, the amount of water taken up after material is submerged can be measured. This is expressed as a proportion of initial weight (%). Secondly by measuring the change in the weight of a material in water after a specific time and temperature which is water absorbed per square centimetre of the material (mg/cm^2)

[3,4]. The potential protectiveness of a mouthguard or material is indicated by shock absorption capability, hardness, and stiffness. The durability of mouthguards is indicated by tear strength, tensile strength, and water absorption. The latter is critical as many athlete's chew or otherwise bite their guards and water absorption is an indication of the ability of a mouthguard to absorb saliva and microorganisms.

Care of the mouthguard

Proper education for the appropriate care and cleanliness of the mouthguard should be correctly given to the athlete. Soapy water can be used for cleanliness in a plastic box or denture cup can be properly used as a container for storage of the mouthguard. This can prevent the mouthguard from staining and deformation. The athlete should be warned about the excessive chewing and bruxism frequently done as an emotional release which can cause grazing and cracking of the mouthguard. The mouthguard should be assessed regularly by the dental officials to check whether its adequate for the specific task. The mouth protector with the lingual insert is of concern because the insert may loosen leading to the breakage of the protector if it is chewed through [8-10]. ASTM designation F697-06 [8-10] has provided the general recommendations with respect to cleaning, storage and shipping. The mouthguard can be disinfected by antimicrobial agents such as Listerine, Scope, or defense sport mouthguard rinse soaked in cold or lukewarm water. during the storage of a thermoformable mouthguard excessive heat should be avoided. The best recommendation for the shipping is to make it fully seat on its dental stone model. Chapman recommended mouthguards to be replaced every 2 years. Kerr and the bureau of health education and audio-visual services have also recommended to store it in a rigid container and to be washed in cool and soapy water and rinsed before use [8].

In an in vitro study by D'Ercole et al [11]. The EVA mouthguards were contaminated with culture of Enterococcus faecalis, Candida albicans and saliva. Enterococcus faecalis is a facultative gram-positive, anaerobic non motile microbe which can even survive in extreme environmental conditions such as acid/alkaline pH, high salts-heavy metal concentrations and low nutrient concentrations. It has a capacity to grow in the range of 10 to 45 °C and is resistant to a temperature of 60 °C for 30 min. It is resistant to a wide range of antibiotics and intra-canal drugs. Candida albicans a yeast is a commensal organism of the oral cavity but can become pathogenic and it is frequently found on dental prostheses. The study showed that there was no ideal methodology for the disinfection of mouthguards. Hydrogen peroxide, 0.5% sodium hypochlorite and the solution Oral Care Foam™ made it possible to achieve optimal disinfection and 0.5% sodium hypochlorite for 5 min determined a significant reduction of Candida albicans. Barton [12] recommends sanitizing daily and soaking the mouthguard in commercially available antimicrobial denture-cleansing solution. Ogawa [13] showed that washing with sterilized water and a ventilated environment is effective for hygienic storage of dental devices made of EVA.

The bimaxillary mouthguard

The bimaxillary mouthguard is a concept in the effective prevention of orofacial and sports related concussion injuries [14]. It is recommended in contact sports especially by those who are at ultimate risk of sustaining such extensive injuries. Chapman in 1983[15] first developed this mouthguard and has been in use since then. The bimaxillary mouthguard was uniquely designed to improve effective protection by covering both arches with the mandible open at a predetermined position. An anterior opening within the mouthguard allows for adequate oral airflow. During non-exertion with a Respiratory Minute Volume (RMV=Tidal volume multiplied by respiratory rate) of, for example, six litres per minute, most or all breathing occurs through the nose. During strenuous physical exertion with the RMV increased upto 90 litres per minute, oral airflow comprises 2-3rd of the RMV. This is termed as position of heavy breathing and the mandible is placed at this opening during the fabrication of the bimaxillary mouthguard [16].

Functions of bimaxillary mouthguard

The bimaxillary mouthguard provides virtually complete protection to both dental and soft tissue because the mandibular teeth are enclosed. It typically prevents mandibular fractures as it is made stable, and because of increased attenuation of impact forces due to enhanced energy absorption qualities [15]. Proper protection against concussion following mandibular impact is increased due to the mandibular opening. The increased separation between the base of the skull and the condyle associated with the bimaxillary mouthguard. This lessens the transmission of force across the mandibular joints after a mandibular impact leading to reduced risk of concussion. There is no decreased level of breathing, even during strenuous physical exertion [16].

In a preliminary report [15] of proper use of bimaxillary mouthguards by Chapman, thirty sportsmen with an average age of 21 years with a range from 14 to 27 years were interviewed approximately for 12 months after they had received their mouthguard. The specific group comprised of nine boxers, two 1984 Australian Olympic contestants and seven professionals, ten Rugby Union players, including six Internationals. The rest eight were Rugby League players, including one International. One was a State representative Australian Rules player. Two were kick-boxers. Two footballers and a boxer were provided with a bimaxillary mouthguard after they sustained a mandibular fracture. The 14-year-old athlete was accurately provided with a bimaxillary mouthguard as he was undergoing fixed appliance therapy and desired to continue playing Rugby Union.

On summarizing the results, it was pinpointed that all except one, a Rugby Union Forward, had continued wearing the mouthguard. This player was equally unable to adjust to wearing the bimaxillary mouthguard. Thus, the acceptance rate was 97 per cent. Rest players stated that they adapted to wear the mouthguard quite quickly and wore it soon after they received it. There was a difficulty of speech adaptation among all the footballers. However,

they all rapidly adjusted to this during training sessions. Another minor difficulty was dryness of the mouth during a match among 42 percent of the footballers. It was suggested to prevent this by applying petroleum jelly to the lips before a match and further rinsing the mouth with water at half-time. None of the wearers had sustained any type of orofacial injury or concussion and were strongly convinced of the enhanced protection provided and stated that they would not consider reverting to a standard custom mouthguard [15].

Fabrication of bimaxillary mouthguard

The fabrication of bimaxillary mouth guards can be done, mainly, with 3 methods.

a) First method

This method is described by Chapman (1986) [15,16]. A complete dental examination should be performed. Radiographic assessment of mandibular third molars is typically advised because their presence reduces the strength of the bone by approximately one-third, thus increasing the risk of mandibular fracture during contact sport. Their possible removal, if indicated, should be planned accordingly. Any dentures worn are to be carefully removed before continuing. The mandibular opening is then determined with the patient sitting upright and looking straight forward. A large nose clip is correctly applied to completely prevent nasal breathing. The patient is then asked to commence taking slow full breaths. It should be noted that each inspiratory-expiratory phase must last approximately for 5 seconds with closed mouth. After each of the first two exhalations the breath should be held for 10 seconds, then for 15 seconds and for 20 seconds consecutively. With the nose clip in place, the patient should wait for two minutes before rehearsing the breath holding procedure. The mandible should now acquire the required position. The midline interincisal opening is measured with a Willis gauge and the gauge is fixed at that amount of opening. The nose clip is then removed. Depending on the anterior overbite the opening is usually within the range of 7 mm to 10 mm, which will read between 4 mm and 7 mm on the internal scale of the Willis gauge. The mandibula-maxillary relationship at this opening is then obtained using two blocks made from sheets of heat-softened bite registration (boxing) wax approximately about 40 mm long and 20 mm in height and width. These blocks are placed on each side posteriorly and the patient is asked to slowly close until the anterior teeth touch the blades of the previous set Willis gauge [17].

Accurate maxillary and mandibular casts in dental stone are fabricated. After the impressions are gently poured, mouthguards are vacuum-formed onto each cast using clear polyvinylacetate-polyethylene polymer mouthguard. Each mouthguard should be 3 mm thick over the anterior teeth: if required, additional thickness can be added using heat-softened mouthguard material .The mouthguard should typically extend to sufficiently cover upto half of the second molar and approximately 2 mm towards the buccal, labial and lingual aspects. Palatal coverage should properly extend 10 mm to 15 mm from the gingival margin. The occlusal thickness of each mouthguard is reduced to approximately 1.5 mm and the incisal edges of the lower anterior teeth are then exposed by 1.5 mm on both buccal and lingual aspects. This necessary adjustment improves comfort, increasing the apparent size of the airway. The labial and buccal edges are rounded, the palatal and lingual edges are tapered to prevent unnecessary bulk. This also prevents interference in speech and breathing [17]. Required adjustments to the mouthguards are made before the wax-up. The material is packed in vast amounts at each half of the flask and then closed. The flask is immersed in hot water (70°C) for 15 minutes. The flask is tightened with more pressure, immersed again in hot water (80°C) for other 15 minutes. The process is replicated until the material obtained is fully adapted and the excess material is eliminated. Subsequently, the flask is allowed to cool for 4 hours, and immersed in cool water for 30 minutes. Finally the flask can be opened to take out the bi-maxillary mouth guard. The preceding step is its finishing and polishing with stone burs, polishing discs, and chloroform or trichloro-ethane. The additional adjustment of the mouth guard is necessary and can be done approximately after 7 days from the wearing day [17].

b) Second Method

Jagger and Milward [3-18] proposed a fabrication method for a bi-maxillary mouth guard. According to them, the maxillary and mandibular impressions of the athlete are first taken, poured with dental stone and the casts are carefully made. The direct extension on both casts are properly marked, which the bi-maxillary mouth guard will have after the fabrication. The bi-maxillary mouth guard should extend distally up to the middle of the second should extend beyond gingivo-buccal, gingivo-labial and gingivo-lingual sulcus, and cover up to 2-3 mm the soft tissues. Furthermore, palatally it should extend and cover 10-15 mm from the gingival margin.The casts are articulated on an average value and the required vertical dimension is determined. A 7-10 mm opening is made in the anterior region between the incisal edges of the both arches anteriorly. This can also be performed according to the Chapman's record of the "heavy breathing position" of the athlete, as mentioned earlier [17]. The prepared sheets of EVA of appropriate thickness are carefully chosen. The mouth guards should be 4 mm in thickness. Mouth guards which are under fabrication are shaped at the predefined dimensions. In order to facilitate the athlete's adequate ventilation, 1-2 mm of the suitable material is removed from the mandibular mouth guard labially and lingually. Both the mouth guards are then joined together with extra material (EVA) between the occlusal surfaces. The supplementary thermoplastic material is strategically placed occlusally of the mouth guards on each side, which is shaped with heating.Each piece is extended from the distal margins of the two mouth guards to the distal surface .The bi-maxillary mouthguard is allowed to cool to prevent distortion. Lastly it is polished using stone burs or polishing discs. Jagger and Milward claim that their method of fabrication is quicker and easier when compared to the Chapman's method, which is more sophisticated and long lasting [17].

c) Third Method

In 1995 Milward and Jagger [3-23] described the third prevalent method of fabrication which was heat cured silicone bimaxillary mouthguard. It is almost similar to the first two methods. The difference lies in the investing procedure. Before the procedure, the whole assembly is carefully smoothed and polished carefully with a flame so that the bi-maxillary mouth guard is also smooth after flaking. The lingual and palatal area of the assembly is poured with stone. and is trimmed back when hardened. The assembly is placed vertically deep in the half of a dental flask and the stone is trimmed in order to uncover the maximum amount of wax. A separating medium is employed on the stone and is left to dry. The one half of the flask is placed over the other and is poured with stone. The flask is closed not to entrap air. The flask is placed under a hydraulic press to remove excess material. When the stone is hardened, the flask is boiled to remove the wax and is separated. The space created is packed with silicone concealing it palatially and lingually. The flask is then placed, again, in a hydraulic press in to extract the excesses of the silicone. The flask is closed and is immersed in hot water for 1 hour, according to the manufacturer's guidelines. Then, the flask is left to cool which is followed by deflasking. The excess material is removed, and the bi-maxillary mouth guard is smoothed and polished for use.

The distinct advantage of this effective method of fabrication a bi-maxillary mouth guard is that the material is quite resilient and adaptable by most athletes. In contrast, the bi-maxillary mouth guard from EVA material is stiff and inflexible. However, it is a more time-consuming and costlier than the other methods [17].

d) Storage

Permanent distortion can occur if the mouthguard is subjected to excessive pressure or heat. Therefore, it should be kept in a rigid plastic container typically half-filled with a dilute mouth rinse. The mouth rinse should be instantly changed about every four weeks and after use the mouthguard should be rinsed with water before it is carefully replaced in the container [17].

Conclusion

The recommended age to start wearing a mouthguard is at about 16 years .At this age the ontogeny of the mandible and maxilla is accomplished and the permanent teeth, excepting the third molars, usually have erupted.The bimaxillary mouthguard costs about twice the price of a standard custom mouthguard, hence proper care should be taken for it to last two to three years and is perfect for orthodontic patients undergoing fixed appliance therapy. Remarkably, these patients are advised not to participate in contact sports during their treatment. The only safe choice is to wear two separate mouth guard. However, the lower gets easily dislodged during speech and therefore often thrown-away.

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