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Mouthguards and Concussion Prevention

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It has been known for years that mouthguards provide great protection from orofacial injuries that occur in many contact sports. They are crucial for reducing the risk of contusions, lip lacerations and fractured teeth and jaws. A controversial topic today in sports medicine and biomechanics is whether or not mouthguards provide any protection against concussions. This paper will examine the issue by first looking at whether or not research supports the idea of mouthguards reducing the incidence of concussions and then examining the different types of mouthguards to see if one has been shown to be more effective than the others.

There are three basic types of mouthguards. Stock mouthguards can be purchased at most sporting goods stores and come in limited sizes, usually small to large. They are the cheapest, but often don't fit properly so they are the least protective and often athletes find them painful to wear (Sports Dentistry, 2006). Most research excludes this type of mouthguard since it is advised in most dental literature to avoid wearing them because of their lack of protection. Boil and Bite mouthguards are the most commonly used. They are immersed into boiling water and then molded to the athletes mouth themselves. If not formed to the mouth properly, i.e. not coving all of the posterior teeth, they will be less effective (Sports Dentistry, 2006). Lastly are the custom made mouthguards. They are made by dentists who create a mold of the athletes mouth and then can properly fit an individualized mouthguard to the athlete. Often they are made of the same materials as the boil and bite, however they are recommended for their better fit, which also means they typically don't become deformed as quickly (Sports Dentistry, 2006).

Early studies on the prevention of concussions by wearing a mouthguard really took off in the 1960s. One of the first studies, by Stenger et al, followed the Notre Dame University football team for an entire season. They took stats on every player during all games and practices and noted when each athlete wore a mouthguard and all injuries that occurred. It was noticed that

those that wore a mouthguard had fewer concussions and also missed less playing time due to concussions than those who didn't wear a mouthguard. The possible explanation for this was that a mouthguard alters the position of the mandible so that the condyles aren't in full articulation with the base of the skull, as they normally are without a mouthguard in place. The authors suggest that forces from mandible impact would be attenuated from the gap and result in fewer injuries (Stenger et al, 1964). This study was a good starting point to see a correlation between mouthguards and concussions, however no causal evidence can be concluded from this.

Following this study, Hickey et al, performed a controlled laboratory study where they used a cadaver model and showed that a mouthguard could attenuate forces applied to the head when a blow to the tip of the chin occurred. They used an intracranial pressure transducer, which showed a 50% decrease in the amplitude of intracranial pressure after impact when a mouthguard was used. This was an interesting first start but it was criticized on its methodology for using a cadaver to simulate a live skull, which doesn't have any of the soft tissue and most likely has different skull compliance (Hickey et al, 1967). These early studies showed that a mouthguard could have a beneficial effect against concussions and triggered lots of research that has occurred since then looking at this issue.

An interesting study was done in 2005 by Lim et al, which looked at how the impact response, stiffness and damping, of the jaw and neck are affected by wearing a mouthguard. It is believed that the soft tissues around the teeth and jaw act naturally to reduce system stiffness and absorb energy from blows to the chin. It was hypothesized that a mouthguard would add to this by further absorbing more energy, reducing the total force that gets to the cranium. The study was conducted where subjects sat a table with their chin on a platform that had a tenson/compression load cell under it. An excitation weight 1.2 kg, 1.7kg, or 2.1 kg, was place

on the subjects head and then released once signal tracing had stabilized. The load cell along with an analog-to-digital converter could detect vertical force changes during each of the conditions, with a mouthguard or not. It was found that wearing a mouthguard did result in more force absorption than not wearing one. The material used for the mouthguard was polyethylene. They also tested different thicknesses of mouthguards, 3mm vs. 5mm, and found that the thicker mouthguards absorbed the greatest amount of force. The thicker the mouthguard, the greater the reduction in stiffness. All mouthguards in this study were boil and bites (Lim et al, 2005). The problem with thick mouthguards is that athletes are more resistant to wear them because of lack of comfort, impaired breathing, or impaired speech.

This study shows how mouthguards do have the capability to absorb forces applied to the neck and jaw. This is valuable information for sports, such as boxing and martial arts, where blows to the jaw are more common. Wearing a mouthguard may do more than just protect from dental injuries. It may actually reduce the number and severity of concussions. If less force in transmitted to the brain, then the acceleration of the brain will be decreased resulting in a less severe impact of the brain against the skull.

Many controlled studies have been done looking at mouthguard materials and testing the energy absorption properties of various materials. This provides greater insight into how mouthguards may prevent concussions. The elasticity of the material determines how much impact energy it will absorb, thereby determining the effectiveness of the mouthguard. If elastic limit is exceeded, permanent deformation occurs, making the mouthguard less effective. The most commonly used mouthguard material is EVA (ethylene-vinyl-acetate). This material was shown to have significant absorption properties through testing using a pendulum apparatus. This works by creating a 50mm disc out of EVA that is 4mm thick, the thickness of a typically

mouthguard. The disc is then struck with a pendulum. An accelerometer is placed on the pendulum and the amount of force absorbed by the material is inferred from the change in acceleration before and after the impact (Westerman, 1997).

An improved mouthguard material has recently been created where the same EVA material is used, however the middle layer contains air cells. Pendulum studies have looked at comparing the traditional EVA material and this modified version. It has been found that the air inclusions cells absorb more energy when the impact force is less than 10kN. It is proposed that the air cells allow for greater elastic deformation and enhanced energy absorption. These air cells can be included into any type of mouthguard as well (Westerman, 2002).

So it appears that there in evidence support the hypothesis that mouthguards can act to prevent the incidence and severity of concussions by absorbing impact forces from impacts to the neck and jaw. Looking at the different types of mouthguards will provide greater insight into this issue.

There are three main categories of mouthguards that are worn on the top set of teeth; stock mouthguards, boil and bite mouthguards, and custom mouthguards (Using Mouthguards..., 2006). These different types vary from each other in comfort, fit, cost, and protective benefit (Using Mouthguards..., 2006).

The stock mouthguard is a very inexpensive, ready for wear model (Using Mouthguards..., 2006). It is made of a thermoplastic material that fits loosely over the teeth (Using Mouthguards..., 2006). It does not adapt or retain the indentations made from the teeth and is difficult for the wearer to keep in place (Using Mouthguards..., 2006). The wearer's mouth must be closed around it at all times, which can make it quite challenging to breath and speak while playing sports (Using Mouthguards..., 2006). This is considered to be the least comfortable

and protective of the three, and is not very common among athletes (Using Mouthguards..., 2006). For these reasons, we will be focusing more on the other two types of mouthguards.

The boil and bite mouthguard is the most popular type of mouthguard among athletes (Using Mouthguards..., 2006). It is an inexpensive form of protection that has many more benefits than the stock mouthguard. This type of mouthguard can actually be molded to keep the indentation of the teeth (Using Mouthguards..., 2006). This is done by placing the mouthguard into boiling water, removing it and running under cool water for a couple seconds, then placing it in the mouth for forming. It can be shaped by using the fingers and the tongue to centre the mouthguard and by biting down on it to make the impression of the teeth (Using Mouthguards..., 2006). Having it molded to the shape of your teeth is an advantage because it allows the mouthguard to stay in place while the mouth is open, which allows for easier breathing and speaking (Using Mouthguards..., 2006). Boil and bite mouthguards can also be reshaped after the initial formation to the teeth by using the same process as mentioned above (Using Mouthguards..., 2006).

However, research has shown that there are some problems with the boil and bite mouthguards. One study found that 40% of athletes said their mouthguard had a loose fit and 66% said they were too bulky (Using Mouthguards..., 2006). Another study reported that during the shaping process the mouthguard could become extremely thin in areas (losing up to 70 -99% of thickness). This is obviously a problem that arises when professionals are not involved in the fitting process.

Custom mouthguards are considered to be the best type because of a far superior fit compared to stock and boil and bit mouthguards (Using Mouthguards..., 2006). However, they are also the most expensive type of mouthguard for this reason (Using Mouthguards..., 2006).

Custom mouthguards are usually made by dentists who take the impression of the athlete's teeth, and then make a stone model of the teeth (Using Mouthguards..., 2006). The thermoplastic material is then formed on to the model, and the excess is trimmed away (Using Mouthguards..., 2006). Because of the individuality and care that goes into making this mouthguard, it has the best fit, and therefore interferes the least with speech and breathing (Using Mouthguards..., 2006).

Custom mouthguards have been shown to be superior when it comes to fit and preference, but which type is best when it comes to preventing concussions? One theory as to why custom mouthguards are better comes back to their superior fit. Research has shown that a properly fitting (custom) mouthguard creates a space between the head of the condyle of the mandible and the base of the skull (Winters, 2001). It is thought that this space acts to dissipate forces that would be transferred up to the brain, and therefore reduce injury (Winters, 2001). Poorly fitting mouthguards lack this space and have more articulation at this joint (Winters, 2001). This is thought to increase the transmission of force up to the brain and therefore cause greater injury (Winters, 2001).

A study conducted over the 2001 NCAA Division 1 football season compared boil and bite mouthguards to custom mouthguards (Wisniewski, 2004). A total of 87 teams participated over the 15 week season, with team trainers reporting data on a weekly basis (Wisniewski, 2004). There were a total of 506,297 athletic exposures; defined as either one game or one practice where the athlete was exposed to risk of injury (Wisniewski, 2004). There were a total of 369 concussions reported, with an incidence rate of 0.73 concussions per 1000 exposures (Wisniewski, 2004). They found that there was no significant difference between the two types of mouthguards and the risk of concussion (Wisniewski, 2004).

Another study was done on a community football league in Australia (Finch, 2005). It consisted of 23 teams, and 301 players (Finch, 2005). The teams were randomly assigned to wear custom made mouthguards or as controls (they continued their normal mouthguard habits which may have included wearing a mouthguard) (Finch, 2005). It was noted as unlikely that any of the controls were wearing a custom mouthguard though (Finch, 2005). An important point is that this study looked at head/orofacial injuries and not concussions specifically. Their results showed that wearing a custom mouthguard had a significant preventive effect against head/orofacial injuries, which includes much more than just concussions (Finch, 2005).

Currently, there has not been enough research done on the effectiveness of mouthguards at preventing concussions. Dr. Robert Cantu, an expert on head and neck injury and creator of the Cantu guidelines for grading concussions argues that there has not been a study that has proven that mouthguards prevent concussions, but recommends they be worn because of their effectiveness at preventing dental injuries (Kuipers, 2009). When it comes to different types of mouthguards, his opinion is as follows: "There are no statistics to suggest that custom-fit mouth guards are better than boil and bite mouth guards. There is a higher level of comfort with custom-fit but not more protection" (Kuipers, 2009). Clearly, much more research must be conducted in order to determine if mouthguards do have a preventive effect against concussions. Currently new research is being done to develop a new mouthguard design in hopes for greater concussion protection. On of the leading developments is a bimolar style of mouthguard.

Bimolar mouthguards are a promising new technology in which the upper and lower teeth are covered by the mouthguard. It is suggested that this design allows for increased protection from concussion due to blows to the

Figure : Brain-Pad® mouth guard (from www.brainpad.com)

mandible (lower jaw). A blow to the lower jaw causes it to impact the base of the skull at the temporomandibular joint, leading to a disruption of brain activity known as a concussion (Gusenbauer, 2002).

Brain-Pad® is the leading company manufacturing the bimolar mouthguards. They have developed a dual arch technology that gives the mouthguard wearer a breathing space at the front of the guard. Brain-Pad® has done studies at Wayne State University's biomechanics department to test the quality and protection of their mouthguards. They used the head-form drop test procedure to do these studies. The Brain-Pad® mouth guards create a "safety space" between the mandible and the skull which reduces energy transfer into the skull during a lower jaw impact. This "safety space" is also created with regular boil & bite or custom made mouthguards, however the jaw tends to slide and impact the skull with these styles. Brain-Pad® mouthguards holds the lower jaw forward and down so there is no sliding and the "safety space" is better maintained during an impact. This ability of the Brain-Pad® to preserve the "safety space" is the reasoning around the mouthguard's superior protection

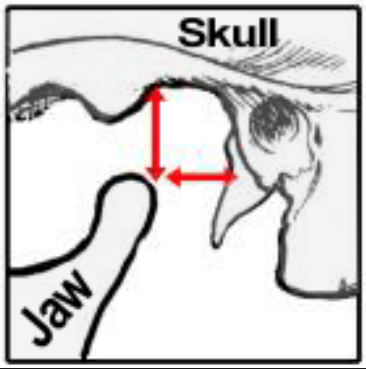


Figure : "Safety Space" (from Gusenbauer, 2002)

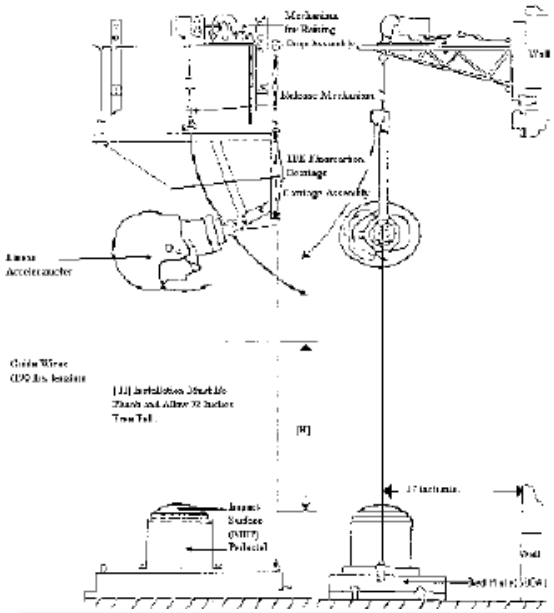


Figure : Head Form Drop Test (from www.brainpad.com)

against concussions. (www.brainpads.com)

Dr. V.R. Hodgson, director of the National Operating Committee on Standards for Athletic Equipment (NOCSAE) and Biomechanics Research Center, Wayne State University were in charge of the studies conducted involving the Brain-Pad® mouthguard. The studies give credit to Brain-Pad® claims of increased concussion prevention. The university conducted the studies using an articulated epoxy head form drop test; the head form was tested to be mechanically similar to a cadaver head. An accelerometer and several force transducers were placed along the mandible, face, and jaw joint. The test was conducted using a 60 inch drop height, a helmet with a chin cup was used to mimic football helmet impacts to the facemask and the forces delivered to the base of the skull. Another test was done without a helmet and from a drop height of 6 inches. It was shown that Brain-Pad® mouthguards disperse the forces more evenly over the surface of the mouth guard to lessen the severity of the impact, and reduces the peak force by half compared to wearing other styles of mouthguards. The total forces transmitted were also reduced by as much as 40% when wearing Brain-Pad® when compared to not wearing it. These studies show that Brain-Pad® mouth guards reduce the severity of the force of impact to the skull during a blow to the chin, demonstrating the superiority of the design in concussion protection. Although Brain-Pad® cannot eliminate concussions, there is evidence that it may prevent the occurrence of a concussion. (www.brainpads.com)

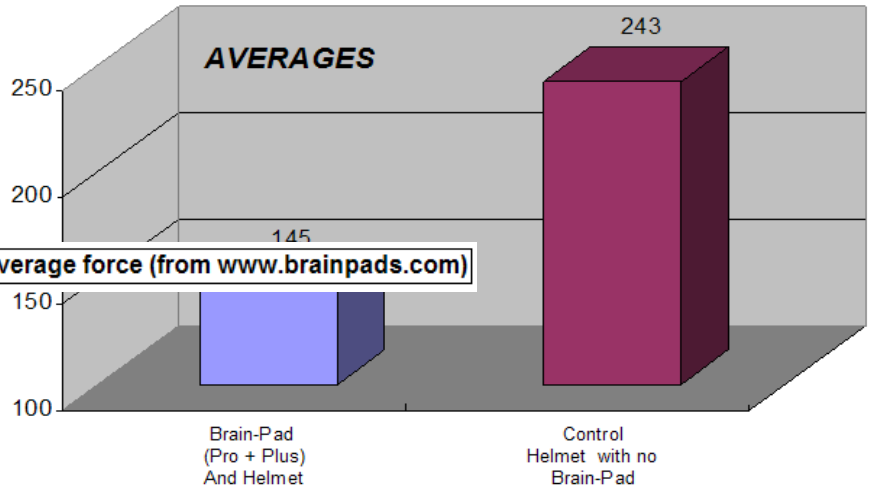
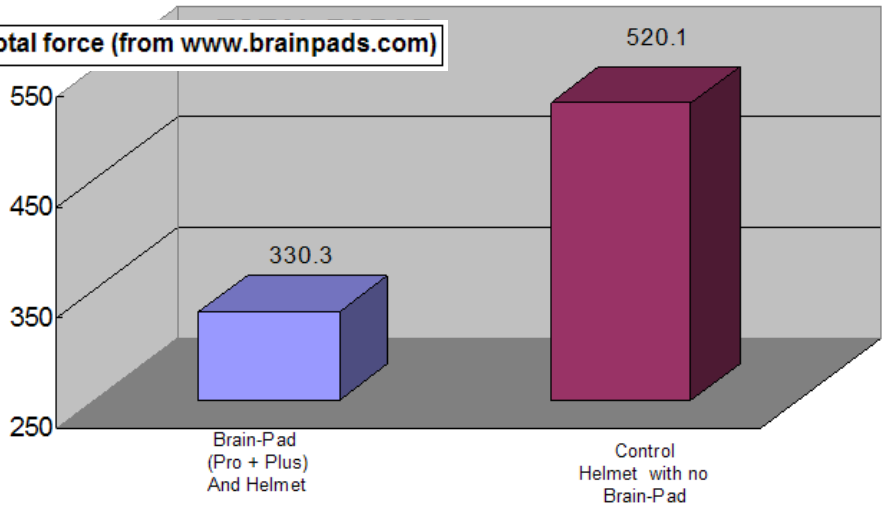


Figure : 60" drop test average force (from www.brainpads.com)

Figure : 60" drop test total force (from www.brainpads.com)



The main issues concerning the Brain-Pad® mouthguards are related to the wearer's breathing. Brain-Pad® potentially may give the athlete the impression that it is harder to breathe using this mouthguard when compared to other designs since it takes up more space in the mouth (Delaney 2005). However, Brain-Pad® claims that with proper fitting the athlete's perception of breathing can be greatly improved (www.brainpads.com).

The Brain-Pad® mouthguard is gaining support from numerous concussion specialists and associations. This type of mouthguard is becoming increasingly popular in contact sports, especially martial arts. Brain-Pad® mouthguards are currently mandated beginning this 2010 year by the International Kickboxing Federation, International Sport Combat Association, International Sport Karate and Kickboxing Association, and Kick International (martial arts)

(www.brainpads.com). There are many more associations that recommend the use of the Brain-Pad® mouthguard.

Even though the effectiveness of mouthguards in preventing concussions currently remains controversial Brain-Pad® shows promising results and may soon lead to a significant advancement in protection technology (Barbic 2005, Maeda 2009). There is still much debate over the protective effect of traditional mouthguards including the boil and bite and custom made mouthguards. However there is no evidence to suggest that wearing any type of mouthguard is detrimental to the athlete and therefore are recommended as a precautionary measure in hopes to prevent injury. Many sport organizations mandate the use of mouthguards and this should continue as research progresses on this topic.

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