Role of mouthguards in reducing mild traumatic brain injury/concussion incidence in high school football athletes

Jackson Winters, DDS ▪ Richard DeMont, PhD, CAT(C), ATC

There is continued speculation on the value of mouthguards (MGs) in preventing mild traumatic brain injury (MTBI)/concussion injuries. The purpose of this randomized prospective study was to compare the impact of pressure-laminated (LM), custom-made, properly fitted MGs to over-the-counter (OTC) MGs on the MTBI/concussion incidence in high school football athletes over a season of play. Four hundred twelve players from 6 high school football teams were included in the study. Twenty-four MTBI/concussion injuries (5.8%) were recorded. When examining the MTBI/concussion injury rate by MG type, there was a significant difference ($P = 0.0423$) with incidence rates of 3.6% and 8.3% in the LM MG and OTC MG groups, respectively.

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Mouthguards (MGs) have been included in the National Federation of State High School Associations (NFHS) mandatory equipment rules for football since 1962.[1,2] The National Collegiate Athletic Association (NCAA) adopted this rule in 1973.[1,2] The 2005 NFHS football rule on Mandatory Equipment (Rule 1-5-1-I) as written states:

1. A tooth and mouth protector (intraoral), which shall include an occlusal (protecting biting surfaces) and a labial (protecting the supporting structures) portion and covers the posterior teeth with adequate thickness. It is recommended the protector be properly fitted and:
   a. Constructed from a model made from an impression of the individual's teeth.
   b. Constructed and fitted to the individual by impressing the teeth into the tooth and mouth protector itself.[3]

Mild traumatic brain injury (MTBI)/concussion injury has been defined as a "traumatically induced alteration in mental status that results in post-injury cognitive and or symptom impairment."[4] The relationship between MGs and injuries has been studied sparingly over the years. One of the first articles appeared in 1964 by Stenger et al; Hickey et al, Chapman, and Ommaya followed with additional publications on MGs and their relationship to concussion injury.[5-8]

An important consideration in the article by Stenger et al was a comparison of cephalometric X-rays of football players either wearing a thick MG or not wearing one at all.[5] Overlaying the 2 cephalometric tracings (Fig. 1), the authors proposed a theory that the force to the skull is mediated through a decrease of acceleration when a thicker MG is in place as the head of the condyle approaches the glenoid fossa (Fig. 2).[5] This likely occurs when an external force is delivered to the mandible. The cephalometric tracings also showed a change in the cervical vertebrae and position of the hyoid bone. In their study, the critical thickness of the MG in place at the time the blow was received was 3-4 mm.[5] Stenger et al also stated that there was growing dissatisfaction among coaches and training staff with commercially available MGs, and recommended that criteria should be set up for the appropriate spacing of the occlusal area.[5] This concept was reintroduced in a 2001 *Journal of Athletic Training* commentary calling for new investigations into a link between MTBI/concussion injuries and MGs.[9]

In a 2000 survey of MG usage from 17 NCAA Division III football teams, 1 team (65 players) reported 11 concussions, 10 of which were suffered by players wearing "cut off" MGs that had no posterior occlusal support over the teeth.[10]

Articles by Chapman and McCrory raised questions about the relationship between MGs and the prevention of MTBI/concussion injury issues, but both articles indicated the need for more research on the subject.[7,11] Labella et al found no

Fig. 1. Overlaying cephalometric tracings showing the changes in head position (upon impact) with and without a 3-4 mm posterior occlusal thickness mouthguard (MG) in position. Note the changes in the head of the condyle, cervical vertebrae, and hyoid bone when an adequate thickness MG was in place (dotted lines) vs normal occlusion (solid lines). (*Stenger JM, Lawson EA, Wright JM, Ricketts J.* Mouthguards: protection against shock to the head, neck and teeth. *J Am Dent Assoc.* 1964;69(9):273-281. *Copyright © 1964 American Dental Association. All rights reserved. Reproduced with permission.)*

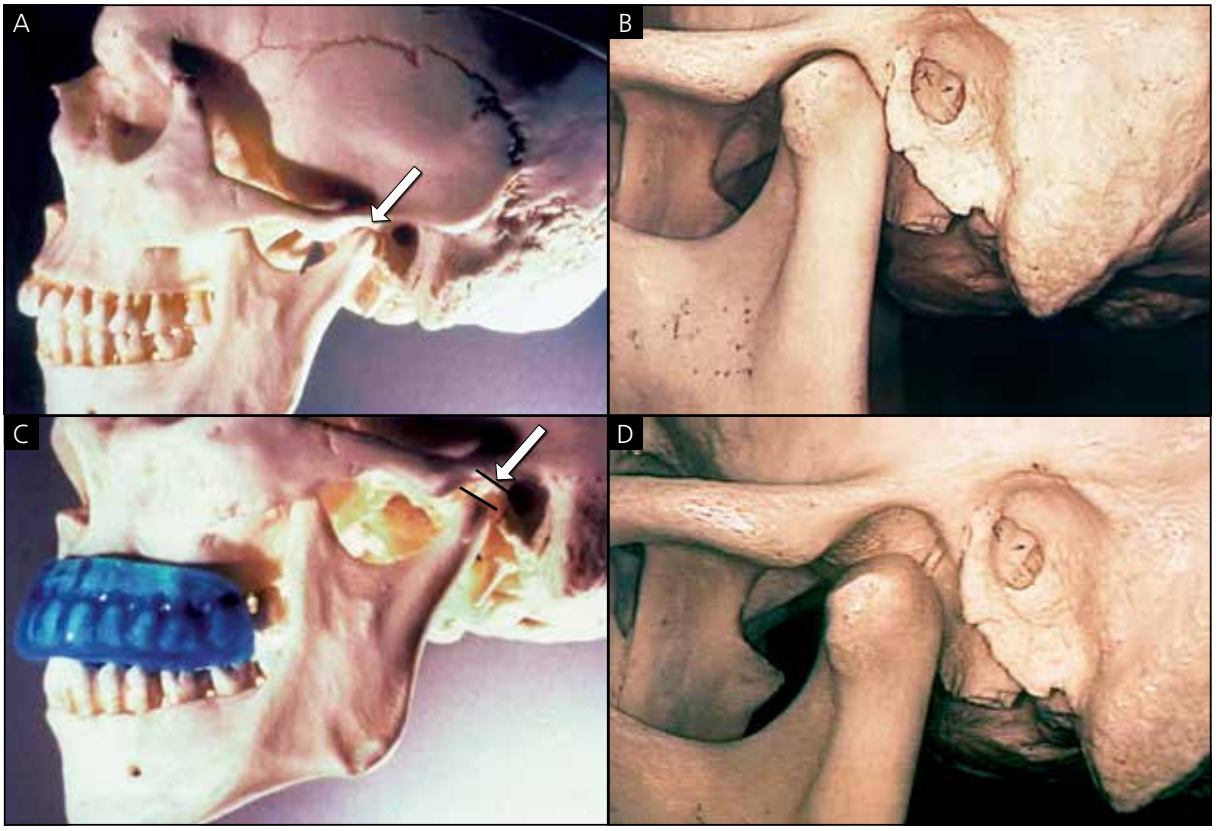

Fig. 2. A. Skull without pressure-laminated LM MG in position. B. Head of condyle position. C. Skull with LM MG in position. D. Head of the condyle position. Note the separation of the condyle. (*Reproduced with permission from the Academy of Sports Dentistry.)*

significant association in the incidence of concussion injury in NCAA basketball players with custom-made MGs compared to noncustom-made MGs.[12] Wisniewski et al found custom MGs did not significantly affect rates of concussion in college football players.[13] Other authors also concluded that custom MG use did not reduce acute clinical neurocognitive performance deficits.[14] However, in these studies, the thickness in the posterior occlusal area of the MGs worn at the time of the MTBI/concussion injury was not measured.

Halstead believed MGs would limit the acceleration of the head in impacts in which the mandible was a primary point of load to the head, thus reducing both linear and rotational forces that resulted from the impact.[15]

Singh et al used customized mandible orthotics (CMOs) in a study of prevention of concussion in football players.[16] Over a 3-year period, the authors followed high school football players with a prior history of concussion injury. The players wore a mandibular acrylic device, and they found the incidence of further concussion injury was reduced. The authors believed that the reduction was due to the CMO repositioning or aligning the mandible to better absorb, dissipate, or reduce potentially concussive forces due to interdigitation of the teeth. They determined that the force delivered through mandibular trauma could contribute significantly to a concussion, especially in the case of poor-fitting or absent MGs.[16] This study supported the theory that the use of a CMO successfully reduces the incidence of concussion; Dr. Maher, one of the 2009 study's authors, advocated for the use of CMOs by NFL players, who are not required by rule to wear an MG. There is a concern in some circles about a CMO qualifying as an MG under the NFHS Mandatory Football Equipment Rule (Rule 1-5-1-I).[3]

In recently published research, Hasegawa et al found that rugby players wearing a properly fitted MG and clenching their masseter and sternocleidomastoid muscles at the time of physical contact produced a marked decrease in head acceleration.[17]

The 3 subtypes of custom MGs (each modeled from the athlete's dentition) are injection-molded, vacuum-formed, and pressure-laminated (LM). The LM MGs were used in this study. This type of MG more closely complies with the Mandatory Equipment Rule of the NFHS. Over-the-counter (OTC) MGs are categorized as stock, mouth-formed (shell-liner) and boil-and-bite. Instructions are usually included by the manufacturers for the self-fitting of these mouthguards. In the authors' experience, boil-and-bite MGs seem to be the most commonly used. OTC MGs are not constructed from a model made from an impression of the athlete's teeth. Because

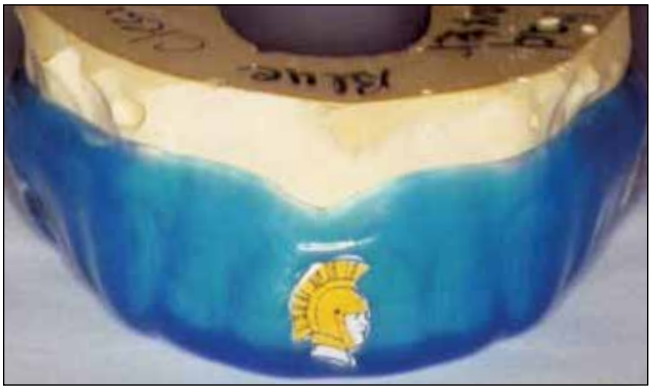

Fig. 3. An example of a custom-made LM MG.

Fig. 4. Collection of OTC MGs found in the course of the study.

the fit is not as comfortable as a custom MG, athletes often chew and abuse them, wedging them in their helmets during down time. This can result in a deterioration in thickness of the posterior occlusal surface over a season of play.

Further controlled studies are indicated to evaluate the relationship between the incidence of MTBI/concussion injuries in athletes and the wearing of MGs. Therefore, the purpose of this randomized prospective study was to investigate the role of custom-made, properly fitted LM MGs compared to OTC MGs, and their effects on MTBI/concussion incidence in high school football athletes.

Fig. 5. Flame-warming the LM MG.

Fig. 6. An example of the caliper used to measure LM MG thickness in the posterior occlusal area at the time of seating.

Materials and methods

High school athletes from 6 football teams in Western Pennsylvania were recruited to participate in this study. Of these, 412 athletes were included in the study. The Institutional Review Board at The University of Pittsburgh Medical Center, Pennsylvania, reviewed and approved the study. Consent was obtained from each player and his parents/guardians. Three teams were randomly assigned to wear the custom LM MG (Fig. 3), and 3 teams wore a standard OTC MG of their individual choosing (Fig. 4). There were a total of 220 and 192 players in each group, respectively. All the players wore the same football helmet (Riddell Revolution, Easton Bell Sports) while in the study. The helmets had been previously provided to the teams for helmet/concussion ImPACT studies.[4]

Certified athletic trainers—members of the National Athletic Trainers Association (NATA)—employed by the high schools were in attendance at all games and practices. Instructions by one of this study's authors (Winters) were given to the players, coaches, and the certified athletic trainers on the proper wearing and care of the LM MGs. Athletes were advised not to chew or wedge the MG in the facemask of their helmet, and not to cut off the posterior occlusal portion of the MG.

To construct the LM MG, a dentist at each of the 3 LM schools took alginate impressions of each athlete's upper dental arch, poured the impression in cast stone, and submitted the models. Under Dr. Winters' supervision, 220 MGs were fabricated following the guidelines of the *Position Statement of a Properly Fitted Mouthguard* from the Academy for Sports Dentistry.[18] The material used was a polyvinyl acetate copolymer, formed using a Drufomat Machine (Dreve Dentamid GmbH). Two 3 mm thick foils were laminated together. The player's name, number, and team logo were placed between the laminations. At the beginning of the season, the LM MGs were individually fitted by Dr. Winters. An occlusal seat was established with the lower dentition by flame-warming the LM MG and having the player close gently into it (Fig. 5). The posterior thickness of the occlusal areas were measured and recorded.

The other 3 teams wore OTC MGs. The athletes selected and self-fitted their own MGs. At the first week of 2-a-day practices, before the start of physical contact practices, all OTC MGs were examined individually in the teams'

locker rooms. The posterior thickness of the occlusal areas were measured and recorded.

When an MTBI/concussion injury occurred in any practices or games during the 2005 season, pertinent information regarding the injury was documented by the certified athletic trainer. The MG worn at the time of MTBI/concussion injury was collected and submitted to 2 independent measurers for caliper measurement of the thickness of the MGs in the posterior occlusal area.

ImPACT, a computerized neurocognitive test program, has been shown to be sensitive in measuring the cognitive effects of sports concussions.[19] The athletes in this study previously had received a baseline ImPACT evaluation. Any player with an MTBI/concussion injury was not cleared for a return to play until his test results were within normal limits. These decisions were made by medical personnel knowledgeable in the ImPACT testing program.

The data were analyzed statistically. Differences between the LM MG and OTC MG groups regarding MTBI/concussion injuries were analyzed using a chi-square test. Comparisons were considered significant if $P < 0.05$.

Results

The average age of the males in this study was 16 years (range: 14-18 years). At the beginning of the season, the thickness in the posterior occlusal area of all the LM MGs ranged from 3-4 mm (Fig. 6). The average thickness of the LM MG was 3.50 mm. Four of the 192 OTC MGs (2%) had a thickness of 3 mm in the posterior occlusal area. The average thickness of the OTC MG was 1.65 mm. Of the OTC MGs, 50% were stock (with little or no congruency around the teeth), 40% were boil and bite, and 10% were "cut-off" (with no posterior occlusal coverage). None were custom MGs, that is, made from a model of the player's dentition.

Twenty-three players were identified as having an MTBI/concussion injury during the season. One player had a second injury during the season, bringing the total occurrences to 24 (5.8%). Eight players were wearing an LM MG that had >3 mm thickness in the posterior occlusal area. Thirteen players were wearing an OTC MG with ≤2.5 mm thickness in the posterior occlusal area. The average thickness of the OTC MGs was 1.34 mm. One player was wearing a cut-off OTC MG with no support in the posterior occlusal area, and 2 players were not wearing an MG at the time of their injury; these 3 players were all in the OTC MG group.

There was a 2 to 1 ratio between the 2 groups' incidence of MTBI/concussion injury, which was statistically significant ($P = 0.0423$). The incidence rate within the groups was 8/220 (3.6%) for the LM group and 16/192 (8.3%) for the OTC group.

The certified athletic trainers recorded the incidence of dental injuries for the entire football season, and none were reported.

Discussion

The authors chose to examine football players in this study for several reasons. Football is a collision sport. It is estimated that more MTBI/concussion injuries occur in high school football than in any other organized high school sport.[20] In high school football, it is required by the Mandatory Equipment Rules that all players must wear an MG, with a penalty for noncompliance.[3]

Realizing there are many variables in the mechanisms that can contribute to the MTBI/concussion injury sequela, the LM MG cannot prevent all concussion injuries from occurring. However, all MGs should not be considered equal in the protection they might provide. In this study, the wearing of the custom-made, properly fitted LM MG statistically reduced the incidence of MTBI/concussion injury.

An important control of MTBI/concussion injuries in the current study was that all 412 players in the study wore the same helmet for the entire season. As stated above, these helmets were provided to the teams previously for helmet/concussion ImPACT studies.[4] Previous studies have addressed helmet design and its role in the prevention of MTBI/concussion injuries.[21-23]

Some authors have questioned the benefit of MGs and their relationship to concussion injuries.[12-14] However, the thickness in the posterior occlusal area of the MGs worn at the time of the MTBI/concussion injury were not measured in these studies. The current study measured the occlusal thickness and individually examined the MGs the players were wearing at the time of MTBI/concussion injury and found differences between custom LM MGs and OTC MGs.

As a result of this "on the field of play" study, in a sport where it is required by rule to wear an MG, more in-depth research is necessary. No dental injuries were reported in this study by the certified athletic trainers. Other authors have also found that wearing an MG can significantly reduce the morbidity and expense resulting from dental injuries vs not wearing an MG.[12]

Conclusion

In this study, the authors found that wearing custom-made, properly fitted LM MGs with ≥3 mm thicknesses in the posterior occlusal area statistically reduced the incidence of MTBI/concussion injury when compared to OTC MGs.

Author information

Dr. Winters is a pediatric dentist, Findlay, Ohio. He officiated Division I college football for 20 years and currently is an NFL scout for football officials. Dr. DeMont is an associate professor and program director, Exercise Science, Athletic Concordia University, Montreal, Quebec, Canada.

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Manufacturers

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