Customized mandibular orthotics in the prevention of concussion / mild traumatic brain injury in football players: A preliminary study.

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Abstract

Background! Aim: It is accepted that sports mouthguards decrease the incidence of dental injuries in athletes, but the value of oral orthotics in the prevention of concussion/mild traumatic brain injuries in footballers remains contentious. However, previous investigations have primarily studied non-customized mouthguards without dental/temporo-mandibular joint examinations of the subjects. Therefore, the aim of this study is to determine whether the use of a customized mandibular orthotic after temporo-mandibular joint assessment reduces the incidence of concussion/mild traumatic brain injuries in high-school football players. Sample and Methods: Using a longitudinal, retrospective design, data were collected from a cohort of football players (n = 28) over three seasons using a questionnaire. The mean age of the sample prior to the use of the customized mandibular orthotic was 17.3 years ± 1.9. Prior to deployment, dental records and temporo-mandibular joint evaluations were undertaken, as well as neurocognitive assessment, including history of concussion/mild traumatic brain injuries. After establishing optimal jaw position, a customized mandibular orthotic was fabricated to the new spatial relations. Results: The mean age of the sample after three seasons Was 19.7 years ± 2.0. Prior to the use of the customized mandibular orthotic, the mean self-reported incidence of concussion/ mild traumatic brain injuries was 2.1 ± 1.4 concussive events. After the deployment of the customized mandibular orthotic the number of concussive events fell to 0.11 ± 0.3 with an odds ratio of 38.33 (95% CI 8.2-178.6), $P < 0.05$. Conclusion: The preliminary results of this study suggest that a customized mandibular orthotic may decrease the incidence of concussion/mild traumatic brain injuries in high school football athletes, but a comprehensive study is required to confirm these initial findings. Furthermore, additional research is necessary to indicate the possible mode(s) of action of a customized mandibular orthotic in the prevention of concussion/ mild traumatic brain injuries.

Introduction

Concussion or mild traumatic brain injury (MTBI) may be caused by a direct blow to the head, face, neck or elsewhere on the body [1]. Typically, this trauma results in the rapid onset of a short-lived impairment of neurological function that resolves spontaneously. However, concussion/MTBI can also result in a graded set of clinical syndromes that may or may not

involve loss of consciousness. Commonly-described neurologic alterations associated with concussion / MTBI include: anterograde and/or retrograde amnesia; loss of orientation with respect to time, place and person; gait or postural instability; vertigo, and dysarthria. But, the occurrence of MTBI / concussion during participation in sporting events may lead to more than temporary alterations in mental status. For example, it is thought that concussion/MTBI is associated with: increased recurrence rates for subsequent concussion ("second impact syndrome" or post-concussion syndrome)2; an associated loss of time from participation in contact sports activities, as well as an increased risk of cognitive impairment in later life. In a two-year prospective study involving high-school football , it was reported that the relative risk of concussion /MTBI is approximately six times greater for individuals with a prior history of concussion as compared to those with no prior history.

In contrast, when acute recovery from concussion / MTBI was assessed in professional footballers and high school football players, the professional athletes demonstrated a rapid neuropsychological recovery (2-7 days) after injury, while the high school athletes demonstrated a slower recovery with more prolonged neuropsychological effects of concussion/MTBI". These results suggest that other factors such as age and weight *inter alia* may influence the out-come of head injuries. Indeed, simulation studies suggest that a stronger neck musculature reduces head acceleration and displacement, which might explain the increased concussion risk in youths and women when compared to male football . Interestingly, other research indicates that skeletal muscle strength might be enhanced while wearing a customized mouth- .

Powell and Barber- report that approx. 4-7% of high school and college athletes sustain a concussion/MTBI each year. Many of these athletes will continue to play despite these increased risks, and feel protected by such appliances. But, a study of the incidence of concussions in college basketball players showed no statistical difference between mouthguard-wearers and non- .Wisniewski et al.[11] also found no positive affect for a custom-made mouthguard compared to a "boil and bite" type appliance for the prevention of orofacial injuries or concussions in a study on football players. Similarly, a dual arch appliance recommended by the American Boxing Association to prevent concussion, was found to provide no greater protection when compared to a non-custom mouthpiece in a randomized .These studies perhaps explain why many experts in Sports Medicine discount the potential effects of blows to the jaw in the etiology of concussion/MTBI. In

contrast, an investigation of hockey players wearing full vs. half face-shields suggested that forces directed against the mandible can act as contributing factors to the incidence of concussions [13]. Moreover, it was found that the increased potential for concussion in those players wearing half face-shields could be reduced significantly if they wore a mouth guard. Furthermore, in a laboratory study using lateral blows to the jaw on a skull , it was found that wearing a mouth guard decreased distortion of the mandibular bone and acceleration of the head significantly compared with not wearing a mouthguard. Therefore, this 'mouthguard' issue remains unresolved .

In studies of incidence during athletic participation, concussion/MTBI occurred most frequently in association with . Based on these initial reports, this preliminary study was undertaken on a group of high school football players. The aim of this study is to determine whether the use of a custom-made mandibular orthotic (CMO) reduces the incidence of concussion/MTBI in high school football players after correction for TMJ/jaw relations. The null hypothesis to be tested in this study is that there is no difference in the incidence of concussion/MTBI in footballers even after wearing the CMO. Rejection of the null hypothesis could lead to translational research that would focus on the provision of CMOs to football players and other sports athletes at increased risk of concussion / MTBI during contact sports.

Subjects and methods

Potential study subjects were provided with a letter of informed consent for review and signing by their parents or legal guardian. After receiving informed consent, the subjects received a questionnaire regarding their previous symptoms, and an examination of their dentition, occlusion and TMJ, which was carried out by one clinician (GJM). For this study, 28 consecutive high school football players with a mean age of 17.3 years ± 1.9 prior to deployment of the CMO were identified. AU of the subjects had been cleared to play by their family physicians.

Clinical protocol

Clinical examination started with history-taking; specifically, any prior history of concussions/MTBI or orthodontic treatments. If an affirmative response was elicited, then

the subject's class of occlusion prior to and after orthodontic treatment was determined. As well, a cervical spine evaluation was undertaken to assess the cranio-cervical relationship prior to a cranio-mandibular' examination.

Next, a thorough temporo-mandibular joint (TMJ) evaluation was undertaken. In this step, the TMJ was palpated. bilaterally to determine whether it was symmetrical and if asymmetry was detected, whether this was pronounced. In addition, the clinician (GJM) looked for acceleration of the condyle on closure, and whether the slope of the articular eminence was steep or shallow. ,The, position of the condyles was assessed to determine if they were located posteriorly on closure, as well as any lateral movement on closure. The TMJ was also palpated to determine whether it was tender and whether there was any reciprocal disc clicking: Other signs of TMJ function such as eccentric movements on opening or closure were assessed, as well as listening for joint sounds (crepitus) using a stethoscope. For the intra-articular disc, evidence of dislocation was assessed to determine any anterior disc displacement with 01' without reduction.

In the next step, a dental evaluation was undertaken to determine what occlusal (Angle) class presented in the cuspid and molar regions bilaterally. Specific features noted included: anterior or posterior crossbites; wear facets; increased or decreased overbite (vertical overlap), including anterior open bite; third molar development (degree of eruption); missing teeth (congenital or early loss), and any retained deciduous teeth.

Once the patient examination had been completed, upper and lower alginate impressions were taken. The impressions included details of all frenae and the mucobuccal fold (similar to a denture impression), making sure the impression tray did not impinge on the mandibular lingual alveolar ridge, but ensuring that the impression extended deeply into lingual flange region. Critically, the bite registration was finished to an occlusal vertical dimension that recaptured the intra-articular disc, if it was found to be displaced on initial examination. This spatial relation was verified by digital palpation, auscultation, or visual confirmation.

Dental casts were made and the custom~ mandibular orthotic (CMO) was fabricated in a dental laboratory. Once received, the CMO was checked for goodness of fit, tightness and smoothness. It was adjusted according to patient feedback. Next, the occlusion was checked with horseshoe, dual-colored articulating paper (Ardent, Whip Mix Corp., Louisville, KY) to

determine whether it was even and whether any 'slides' occurred. (A slide is an occlusal line instead of a specific spot of occlusion.) If good occlusion was close to being achieved, spot grinding was carried out and all slides were eliminated. If good occlusion was found only on one side (6 to 8 contacts, Fig. 1??), the opposite side was relined with self-cure acrylic. If an anterior open bite was found with contact only on the second molars, both sides were relined (Fig. 2??). If the CMO was found to rock, its fitting surface was relined with self-cure acrylic, and burnished to eliminate locking into undercuts. Thus, equilibration was carried out until even contact was achieved with no occlusal interference and no premature contacts (Fig. 3??).

Next, the subject's condyles were palpated and observed on opening and closing to ensure the subject was still on the intra-articular disc. The positioning of the mandibular condyles during occlusion is critical to prevent the subject from being overclosed. Finally, all subjects were instructed in the proper use and cleaning of the CMO. All subjects were reviewed within a week and once properly habituated all subjects were instructed to utilize the CMO during all football-related activities. The investigators did not interact with the subjects during the subjects' sports involvement. No individual subject identifiers, including the subject's name were used in the analysis.

Results

Figures 4 and 5? show 3-D reconstructions from cone-beam scans with and without the CMO *in situ*. Following the completion of three competitive seasons the total number of athlete exposures was documented. The mean age of the sample after three seasons was 19.4 years ± 1.8. Prior to the use of the CMO the mean self-reported incidence of concussion / MTBI was 2.1 ± 1.4 concussive events. Between them, they had suffered a total of 59 grade I or II concussions in the preceding two seasons (Table 1). However, there were only three reported concussions / MTBI in the study subjects after three seasons (Table 1). Thus, after the deployment of the CMO the number of concussive events fell to 0.11 ± 0.31 with an odds ratio of 38.33 (95% CI 8.2-178.6), $P < 0.05$. These results are summarized in Table 1.

Discussion

The usefulness of mouthguards as a protective device for participants in sporting events has been debated extensively. There appears to be a growing consensus that mouthguards are important in the prevention of sports-related injuries to the dentition and oral soft tissues, as reflected by the policy on prevention of sports-related orofacial injuries distributed by the American Academy of Pediatric Dentistry (2006)16. However, the usefulness of a customized mandibular orthotic (CMO) in the prevention of MTB/concussion has not been tested, even though there is a plethora of manufacturers that claim athletic mouthguards will reduce the incidence of sports-related concussions. Indeed, McCrory17 suggests that one of the most commonly-held myths in sports rnedicine is the premise that wearing a mouthguard will prevent concussion/ MTBIl.

Note, however, that clear distinctions need to be made on the classification of oral appliances, which have variously been described as: mouthpieces; mouthguards; oral splints and oral orthotics. In this study, we consider a mouthpiece to be a commercial, over-the counter, product that is available without prescription. We regard a mouthguard to be a customized, laboratory-fabricated appliance, specifically designed for the prevention of orodental trauma. Similarly, we regard an oral splint to be a laboratory-fabricated appliances for the treatment of.temporo-mandibular dysfunction (TMD), following the prescription of a dental professional. Finally, we define an oral orthotic to be a customized, laboratory-fabricated appliance for alignment of the upper and lower jaws, prescribed by a dental professional. This latter CMO (Fig. 1) that provided spatial correction of the TMJ was the device under investigation in this study.

Stenger et al. 18 first reported a dramatic decrease in injuries to the head and neck, including concussion-associated neurological symptoms, in a group of football players who used a particular type of mouthguard. In a more recent study, Wisniewski et al.[19] report that there is no advantage in wearing a mouthguard to reduce the incidence of cerebral concussions in collegiate football players. Nevertheless, while mouthguards are custom-made to fit the dentition, customization in terms jaw relations has never been documented. Thus, we suspect that there may be an association between derangements of the TMJ and susceptibility to concussive injury in contact sports, such as the infamous 'glass jaw' in boxing.

While the designs of protective helmets and facemasks provide measurable safeguards against a number of injuries to the dentition, face and head, the transmission of forces to the brain

from blows either directly or indirectly through the mandible is still an area of major concern. Previous studies have demonstrated the association of biomechanical forces on the brain and clinical symptoms of concussion / . Consequently, concussion / MTBI in professional footballers is thought to be primarily related to translational acceleration with considerable head velocity . Furthermore, it is asserted that concussion / MTBI in professional football involves four typical collision , which do not include blows to the chin. For example, about 70% of concussions involve impacts by another player's helmet, but the remaining 30% involve impacts by other body regions or the ground. Nevertheless, when concussive impacts were simulated by finite element , the early strain occurred in one temporal lobe and migrated to the other temporal lobe after head acceleration in 40% of concussive simulations. These early strains in the orbito-frontal cortex and temporal lobe correlate with symptoms of dizziness. Therefore, the prevention of MTBI / concussions may, at least in part, be dependent on full protection of the temporal lobes.

The anatomical structure of the TMJ (Fig. 6) makes it quite apparent that a blow to the mandible could quite readily transmit forces to the temporal bone of the cranial base, and thus to the temporal lobe of the brain. Studies using cadaveric heads measured the biomechanical forces that can be applied to the mandible to subsequently cause cranial base skull fractures. The types of skull fractures that were observed were consistent with clinical experience of this type of mandibular-associated . As well, a retrospective review of the association between the types and number of mandibular fractures and an observed loss of consciousness in patients admitted to a trauma center indicated that dispersal of trauma inducing force through particular types of fractures of the mandible is associated with a decrease in the rate of loss of . Blows to the chin are dangerous as there is no protection from such a blow to prevent direct transmission of the force to the brain, while forces from other directions can be controlled by the player's helmet and facemask. Various studies have examined the benefit of mouthguards to prevent force transmission through the mandible from blows under the . These data indicate that the anatomical and physiologic association of the mandible to the temporal bone during a blow to the jaw may permit the transmission of forces to the brain, resulting in injuries consistent with a concussion / MTBI.

It has been reported that up to 60% or more of the general population has at least one sign of a TMJ disorder, yet only a very small percentage ever seek medical or dental . One common TMJ disorder is internal derangement, where the articular disc no longer localizes to its proper position in the joint. Typically, the disc becomes displaced anteriorly, limiting its functional benefit in relation to the movement of the mandibular condyle . Moreover, in this position it can also no longer serve as an intermediary of force absorption if a blow is directed through the mandible. The absence of this cushioning component would make it more likely that a force to the mandible would transfer more of its energy directly through the glenoid fossae to the temporal bone of the cranial base, and to the temporal lobe

of the brain. On the other hand, the design of the CMO is such that when it is worn, it causes a repositioning of the mandible so that the condylar elements are moved from resting directly against the articular disc or, in the case of patients with internal derangements, the glenoid fossae, onto the articular eminence (Figs. 2-3). This re-positioning changes the contact area and, therefore, might limit the direct transmission of force through the TMJ to the temporal bone and temporal lobe of the brain, by dissipating the forces through the thickest part of the articular eminence *inter alia.*

proposes three explanations for the prevention of concussions with dental appliances i.e. dissipation of forces directed to the jaw; stabilization of neck muscles, and distraction of the condyle from the glenoid fossa. In summary, our preliminary results suggest that the CMO re-positions or aligns the mandible to better absorb, dissipate or reduce potentially-concussive forces. But, it is possible that the benefits of a CMO are limited to a subset of athletes such as those with: TMJ disk displacement; forward head posture; non adult subjects; females, or athletes with a prior history of MTBI. Conceivably, it is possible that, in conjunction with a change in head posture, which involves the muscles of the neck, there may be enhancement of craniofacial homeostasis. Thus, further structural (anatomical) and physiologic analyses need to be undertaken to compare the 2-D and 3-D craniofacial characteristics of players with and without a CMO *in situ.* Clearly further study with a randomized clinical trial to answer these questions is indicated.

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