Dental Traumatology

Dental Traumatology 2012; **28**: 263–267; doi: 10.1111/j.1600-9657.2011.01106.x

Influence of different types of mouthguards on strength and performance of collegiate athletes: a controlled-randomized trial

Fergus A. Duddy[1], Jake Weissman[1], Rich A. Lee Sr[2], Avina Paranjpe[1], James D. Johnson[1], Nestor Cohenca[1,3]

[1]Department of Endodontics, University of Washington School of Dentistry, Seattle, WA; [2]Department of Prosthodontics, University of Washington School of Dentistry, Seattle, WA; [3]Department of Pediatric Dentistry, University of Washington School of Dentistry, Seattle, WA, USA

Abstract – *Background*: Prevention of traumatic dental injuries relies on the identification of etiologic factors and the use of protective devices during contact sports. Mouthguards are considered to be an effective and cost-efficient device aimed at buffering the impacts or blows that might otherwise cause moderate to severe dental and maxillofacial injuries. Interestingly, besides their role in preventing injury, some authors claim that mouthguards can enhance athletic performance. Thus, the purpose of this controlled randomized trial was to evaluate and compare the effect of two different types of mouthguards on the athletic performance and strength of collegiate athletes. *Materials and methods*: Eighteen college athletes ranging from 19 to 23 years participated in this study. Devices tested in this study included an over-the-counter boil-and-bite mouthguard (O-Flow™ Max Under Armour®) (UA) and a custom-made mouthguard (CM). Physical tests were carefully selected by the head athletic trainer and aimed at evaluating the strength and performance. The following sequence was carried out on each test day: (i) 3-stroke maximum power ergometer test, (ii) 1-min ergometer test, and (iii) a 1600-m run. A random assignment was developed to test all three experimental groups on each test day. Following the tests, each athlete completed a brief anonymous survey aimed at evaluating the athletes' overall satisfaction with each type of mouthguard. *Results:* Custom-made mouthguards had no detrimental effect on athletic strength and performance and were reported by the athletes as being comfortable and not causing difficulty in breathing. In contrast, boil-and-bite mouthguards did not perform as well and were reported as being uncomfortable and causing breathing difficulties. *Conclusions*: Based on the results of this study, the use of custom-made mouthguards should be encouraged in contact sports as a protective measure, without concern for any negative effect on the athletic performance of the athletes.

Key words: athletes, mouthguard, performance, strength

Correspondence to: Dr. Nestor Cohenca, Department of Endodontics, University of Washington, Box 357448, Seattle, WA 98195-7448, USA
Tel.: 1-206-543-5044
Fax: 1-206-616-9085
e-mail: cohenca@uw.edu

Accepted 27 November, 2011

The mean prevalence of dental and oral injuries reported in the literature ranges between 4% and 33%, depending on the gender and age of the patient (1–3). Previous epidemiologic surveys have reported associations between dental trauma and the gender of the athlete and his or her participation in sports-related activities (4). While only 9% of young adults (18–19 years) involved in a sport will experience a dental injury (5, 6), the incidence is 39% in children (7), with an overall incidence rate of 27–30% (3, 8, 9). Recently, Glendor (10) reported that amateur athletes have been found to suffer from TDIs more often than professional athletes and often associated with serious esthetic, functional, psychological, and economic consequences (9).

With such a high frequency of injuries, prevention becomes the primary goal. A preventive approach relies on the identification of etiologic factors and taking measures aimed at avoiding these factors or, at least, reducing their impact. Mouthguards are considered to be an effective and cost-efficient device, mainly for contact sports, as it aims at buffering the impacts or blows that might otherwise cause moderate to severe dental and maxillofacial injuries. Mouthguards were recommended by the American Dental Association in 1950. While injury to the face and mouth when playing football before 1962 was estimated to affect 50% of players, this incidence decreased dramatically to 1.4% after 1962 as a result of the mandatory use of mouthguards (11). Morrow et al. (12) conducted a prospective study involving women basketball players and found that the use of a mouthguard significantly reduced injury rates from 30.3% for those athletes not wearing a mouthguard to 2.8% for those wearing one. Cohenca et al. (13) studied the incidence and severity of dental trauma in

© 2012 John Wiley & Sons A/S

intercollegiate athletes from 1996 through 2005. The incidence for male basketball players was five times higher than that for football players for whom mouthguard use is mandatory.

Different types of mouthguards are available with the most popular being self-adapted 'boil-and-bite' and custom-made mouthguards. Custom-made mouthguards have been shown to provide the greatest protection from dental injuries and should therefore be recommended for those who participate in contact sports (14). Interestingly, besides their role in preventing injury, some authors claim that mouthguards can enhance athletic performance (15, 16). Garner & Miskimin (17) claimed that mouthpieces positively affected visual and auditory reaction time, which is a vital aspect to optimal sport and exercise performance.

Teeth clench in response to elevated stress levels. This clenching mechanism completes a circuit and signals the brain to begin a complex series of responses in the hypothalamic–pituitary–adrenal (HPA) axis. As a result, the adrenal glands release adrenaline, noradrenaline, and cortisol, all enabling the body's stress response. Adrenaline increases blood pressure, reaction time, and heart rate and sends blood to the muscles. Cortisol releases glucose, to supply the brain and muscles with immediate energy. However, at excessively high levels and particularly for long periods, the endocrine system is affected negatively. High cortisol levels limit peripheral vision, decrease metabolism, cause fatigue, reduce muscle-building, and suppress the immune system. Therefore, when stress becomes excessive, both performance and health are adversely affected. A properly designed oral appliance which prevents the teeth from occluding prevents the completion of the clenching mechanism (18).

Despite their role in preventing injury and possibly enhancing athletic performance, there is a lack of willingness among athletes to use mouthguards routinely. Athletes commonly cite discomfort, breathing and speech difficulties, and interference in athletic performance as reasons for rejection (19, 20). Delaney & Montgomery (21) examined the effect of a non-custom bimolar mouthguard on ventilation in female varsity ice hockey players and concluded that they may reduce ventilation and oxygen uptake at maximal efforts. In contrast, Francis & Brasher (22) concluded that although mouthguards may be perceived as uncomfortable and restrict forced expiratory air flow, they appear to be beneficial in prolonging exercise by improving ventilation and economy. Researchers reported that custom-made mouthguards have no detrimental effects on aerobic and anaerobic performance capacity of the athletes (23–25). However, actual enhancement of power and performance while using custom-made or boil-and-bite mouthguards has yet to be determined using a controlled randomized trial. Our null hypothesis was that custom-made mouthguards and 'boil-and-bite' mouthguards have no effect on athletic strength and performance. Thus, the purpose of this controlled randomized trial was to evaluate and compare the effect of these two different types of mouthguards on the athletic performance and strength of collegiate athletes.

Materials and methods

Eighteen members of the University of Washington Men's Varsity Crew (Rowing) participated in this study, which was approved by the University of Washington Institutional Review Board. Athletes' age ranged from 19 to 23 years and represented five different countries. This group of world-class athletes was selected as they were relatively equal athletically and performed both aerobic and anaerobic exercises as part of their routine training schedule. Statistical power analysis revealed that a sample size of 18 athletes provided 80% power, to detect an effect size of 0.7 when comparing physical performance under two different test conditions, based on a two-sided paired *t*-test and assuming a significance level (alpha) of 0.05. All participants consented prior to taking part in the study and reported being healthy and having no previous history of mouthguard use.

Mouthguards tested in this study included an over-the-counter boil-and-bite mouthguard (O-Flow™ Max Under Armour®, Minneapolis, MN, USA) (UA), and a custom-made mouthguard (CM). A descriptive flow chart of the methodology is presented in Fig. 1.

The boil-and-bite mouthguards (UA) were fitted by the investigation team, according to the manufacturer's instructions. This involved placing the mouthguard in boiling water for 10 s followed by cooling in a cup of water for 1 s before quickly inserting the mouthguard over the upper teeth and asking the wearer to gently bite down. Using finger pressure, the mouthguard was then pushed tightly against the upper teeth to ensure that it was flat against the front teeth. The lower jaw was then brought forward and up into the posterior pads with the molars in alignment with the upper teeth. Pressure was then applied upward against the teeth using the thumbs and the wearer asked to bite down gently. While biting down, the finger pressure was then applied firmly against the lips and cheeks for 20 s to continue to form the mouthguard. Finally, the mouthguard was removed and cooled under tap water for 30 s before replacing into the mouth and testing for a good firm fit.

Custom-made (CM) mouthguards were also fabricated by the investigation team. Alginate impressions were made of the maxillary arch and models poured immediately. Each mouthguard was comprised of a double 3-mm lamination made of thermoformable ethyl vinyl acetate (Great Lakes Orthodontics, Tonawanda, NY, USA). A pressure-molding machine (BIOSTAR®; Scheu-Dental, Iserlohn, Germany) was used for 90 s at 427° Fahrenheit under 4.9 bar of pressure. The cooling phase lasted 120 s. Mouthguards were then contoured and trimmed, especially on the palatal surface, allowing maximum breathing. Finally, all mouthguards were polished and measured to confirm a 4-mm thickness as recommended by Westerman et al. (26). Delivery of UA and CM mouthguards took place 1 week before the tests were carried out. Each mouthguard was individually tested for comfort and fit, and adjusted as necessary.

Physical tests were performed on three consecutive Monday mornings. No major event or training was scheduled 24 h prior to these tests, and there was a 1 week interval between each test day. Athletes were

© 2012 John Wiley & Sons A/S

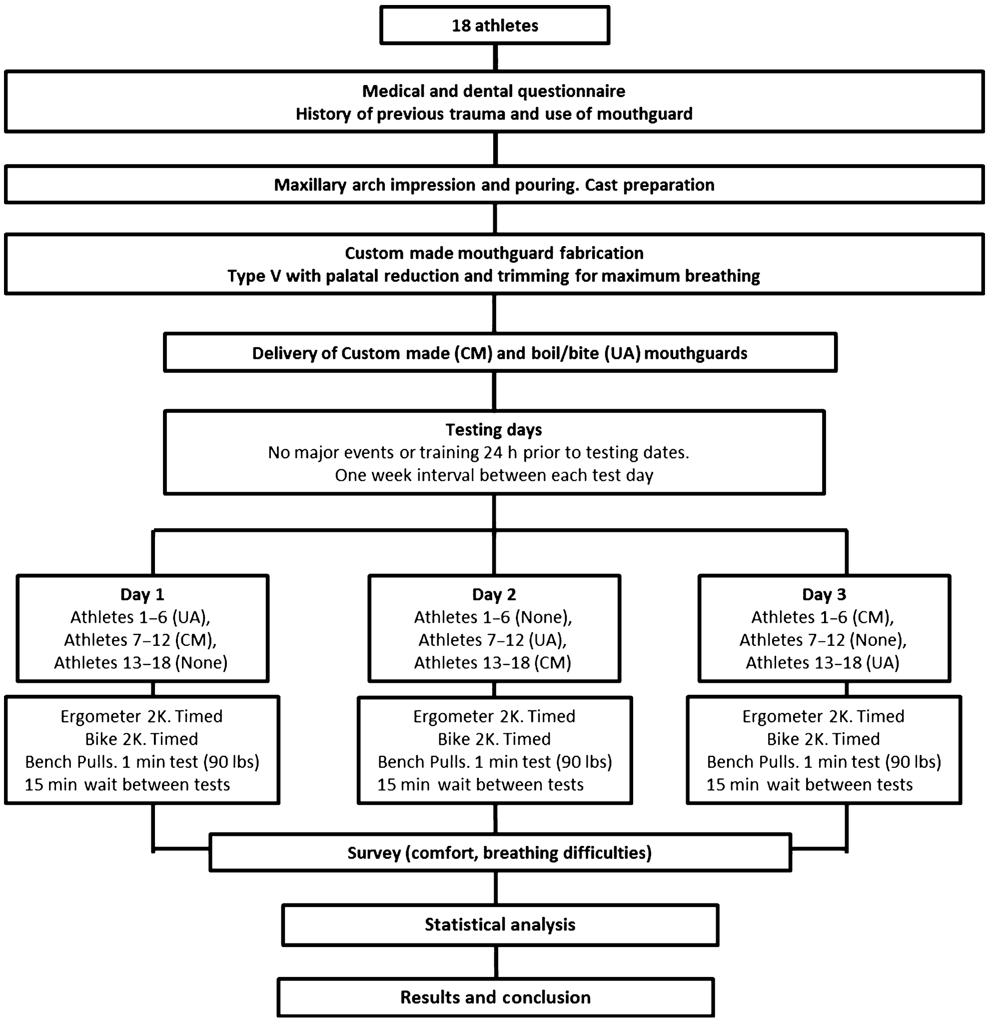

Fig. 1. Flowchart of methodology.

randomly assigned a number from 1 to 18 and placed into one of the three groups (N = 6). Group A comprised athletes numbered 1–6, Group B comprised athletes numbered 7–12, and Group C comprised athletes numbered 13–18. A longitudinal crossover study design was used, in which each group was randomized to a different sequence or ordering in which the mouthguards would be tested. This random assignment was made to test all three experimental groups (mouthguards) on each test day (Fig. 1). All three physical tests were carefully selected by the head athletic trainer and aimed at evaluating the strength and performance. The following sequence was carried out on each test day:

1 3-Stroke maximum power ergometer test (measured in watts) followed by a 15-min recovery period.
2 1-min ergometer test (measured in watts) followed by a 15-min recovery period.
3 1600-m run (measured in seconds) followed by a 15-min recovery period.

An ergometer is an indoor rowing machine used to simulate the action of watercraft rowing. This study used the Concept 2 PM3 ergometer (Concept2 Inc., Morrisville, VT, USA). The 3-stroke maximum power test measured the maximum power output generated by three consecutive strokes on the ergometer and reflected the strength of the athlete. The 1-min ergometer test measured power generated over a period of one minute and reflected the endurance of the athlete. Representative photographs of both types of mouthguard and their use during testing are illustrated in Fig. 2.

Following the tests, each athlete completed a brief anonymous survey aimed at evaluating the athletes' overall satisfaction with each type of mouthguard. The athletes were asked whether they were pleased with each mouthguard. If not pleased, they were asked for a chief complaint (discomfort, breathing difficulty, speech problem, or restriction of athletic performance). The athletes were also asked whether they would continue to wear a mouthguard during training or competition.

Statistical analysis

A repeated measures analysis of variance (ANOVA) was used to test for overall differences by mouthguard type for each of the three performance tests. Pairwise comparisons between each pair of mouthguards for each of

© 2012 John Wiley & Sons A/S

Fig. 2. Representative photographs of both types of mouthguards and their use during testing: (a) UA mouthguard; (b) CM mouthguard; (c) ergometer testing using UA mouthguard; and (d) ergometer testing using CM mouthguard.

the performance tests were analyzed using a paired *t*-test. A *P*-value ≤ 0.05 was considered significant.

Results

Means and standard deviations for each of the three physical performance measures are summarized by mouthguard type in Table 1. Omnibus tests were used to test for overall differences by mouthguard type. We found a statistically significant difference for the 3-stroke maximum power test ($P = 0.03$). No statistically significant difference was found for the 1-min ergometer test ($P = 0.08$) or the 1600-m run ($P = 0.37$). For pairwise comparisons, no statistically significant differences were found between no mouthguard and the CM mouthguard for any of the performance tests. Statistically, the performance was significantly better for the CM mouthguard compared with the UA mouthguard for the 3-stroke maximum power test ($P = 0.01$), while no statistically significant difference was observed for the 1-min ergometer test ($P = 0.09$). Performance was significantly better statistically for no mouthguard compared with the UA mouthguard for the 1-min ergometer test ($P = 0.01$), with no significant difference statistically for the 3-stroke maximum power test ($P = 0.08$).

Table 1. Physical performance measures by mouthguard type

	No mouthguard	Boil and bite	Custom	Overall*
	Mean (SD)	Mean (SD)	Mean (SD)	*P*-value
Run (seconds)	356 (24)	361 (23)	358 (23)	0.37
3 stroke (watts)	809 (113)	767 (111)	811 (89)	0.03
Ergometer (watts)	571 (48)	547 (69)	571 (84)	0.08

*Omnibus *F*-test from the repeated measures ANOVA analysis.

The results of the survey revealed that 94% (17/18) of the athletes were pleased with the CM mouthguard and 61% (11/18) stated that they would continue to use it, particularly for weight training. When questioned about the UA mouthguard, all athletes (18/18) unanimously expressed dissatisfaction with it. When asked for a chief reason, 44.5% (8/18) cited discomfort, 44.5% (8/18) cited breathing difficulty, and 11% (2/18) stated that it restricted their athletic performance.

Discussion

Mouthguards are essential for the prevention of dental and maxillofacial injuries while participating in contact sports. However, their use by athletes is not widespread owing to the perception that they are uncomfortable, cause breathing difficulty, impair speech, and negatively affect athletic performance (19, 20). This is despite claims by commercial companies (http://www.mouthguardscience.com/ and http://www.bitetech.com) that the performance is actually enhanced by oral appliances. However, prior to this present study, actual enhancement of power and performance while using either boil-and-bite or custom-made mouthguards had not previously been determined by a controlled randomized trial.

The results of the present study failed to demonstrate improved strength or performance while using either type of mouthguard. This is in complete accordance with previously reported research (23). Cetin et al. reported that no significant differences were found in 20-min sprint time, jumping tests, handgrip strength, isometric leg, or back strength. However, peak power and average power in Wingate anaerobic test and hamstring isokinetic peak torque significantly increased as a result of wearing custom-made mouthguards (24).

© 2012 John Wiley & Sons A/S

The present study demonstrated that custom-made mouthguards had no negative effect on athletic performance and strength. In addition to the protection provided by custom-made mouthguards, the fact that they were reported as being comfortable and not causing breathing difficulty by all but one athlete and did not impair athletic performance is very encouraging. Conversely, self-adapted boil-and-bite mouthguards had a slight negative impact on athletic performance. This might be directly correlated with the breathing difficulty and uncomfortable feeling reported by all athletes while using the O-Flow^{TM} Max Under Armour mouthguard.

Our study was aimed at testing only the strength and performance using a cohort group of athletes. Further studies are warranted to test other athletic conditions such as flexibility, accuracy, and power on professional and amateur populations.

Conclusion

Custom-made mouthguards had no detrimental effect on athletic strength and performance and were reported by the athletes as being comfortable and not causing difficulty in breathing. In contrast, boil-and-bite mouthguards did not perform as well and were reported as being uncomfortable and causing breathing difficulties.

Acknowledgements

The authors would like to thank Dr. Christine A. Riedy for her assistance and critical review of the manuscript.

References

1. Andreasen JO. Etiology and pathogenesis of traumatic dental injuries. A clinical study of 1,298 cases. Scand J Dent Res 1970;78:329–42.
2. Hunter ML, Hunter B, Kingdon A, Addy M, Dummer PM, Shaw WC. Traumatic injury to maxillary incisor teeth in a group of South Wales school children. Endod Dent Traumatol 1990;6:260–4.
3. Sgan-Cohen HD, Megnagi G, Jacobi Y. Dental trauma and its association with anatomic, behavioral, and social variables among fifth and sixth grade schoolchildren in Jerusalem. Community Dent Oral Epidemiol 2005;33:174–80.
4. McNutt T, Shannon SW Jr, Wright JT, Feinstein RA. Oral trauma in adolescent athletes: a study of mouth protectors. Pediatr Dent 1989;11:209–13.
5. Levin L, Friedlander LD, Geiger SB. Dental and oral trauma and mouthguard use during sport activities in Israel. Dent Traumatol 2003;19:237–42.
6. Delattre JP, Resmond-Richard F, Allanche C, Perrin M, Michel JF, Le Berre A. Dental injuries among schoolchildren aged from 6 to 15, in Rennes (France). Endod Dent Traumatol 1995;11:186–8.
7. Camp JH. Management of sports-related root fractures. Dent Clin North Am 2000;44:95–109, vi–vii.
8. Gutmann JL, Gutmann MS. Cause, incidence, and prevention of trauma to teeth. Dent Clin North Am 1995;39:1–13.
9. Bourguignon C, Sigurdsson A. Preventive strategies for traumatic dental injuries. Dent Clin North Am 2009;53:729–49, vii.
10. Glendor U. Aetiology and risk factors related to traumatic dental injuries – a review of the literature. Dent Traumatol 2009;25:19–31.
11. Sane J. Comparison of maxillofacial and dental injuries in four contact team sports: American football, bandy, basketball, and handball. Am J Sports Med 1988;16:647–51.
12. Morrow RM, Bonci T, Seals RR, Barnwell GM. Oral injuries in Southwest Conference women basketball players. J Natl Athletic Trainers Assoc 1991;26:339–42.
13. Cohenca N, Roges RA, Roges R. The incidence and severity of dental trauma in intercollegiate athletes. J Am Dent Assoc 2007;138:1121–6.
14. Scott J, Burke FJ, Watts DC. A review of dental injuries and the use of mouthguards in contact team sports. Br Dent J 1994;176:310–4.
15. Garner DP, McDivitt E. Effects of mouthpiece use on airway openings and lactate levels in healthy college males. Compend Contin Educ Dent 2009;30 Spec No 2:9–13.
16. Roettger M. Performance enhancement and oral appliances. Compend Contin Educ Dent 2009;30 Spec No 2:4–8.
17. Garner DP, Miskimin J. Effects of mouthpiece use on auditory and visual reaction time in college males and females. Compend Contin Educ Dent 2009;30 Spec No 2:14–7.
18. Balanoff WL. Performance-enhancing mouth wear and craniofacial neurometabolic physiology. Compend Contin Educ Dent 2009;30 Spec No 2:2–3.
19. Zadik Y, Jeffet U, Levin L. Prevention of dental trauma in a high-risk military population: the discrepancy between knowledge and willingness to comply. Mil Med 2010;175:1000–3.
20. Gardiner DM, Ranalli DN. Attitudinal factors influencing mouthguard utilization. Dent Clin North Am 2000;44:53–65.
21. Delaney JS, Montgomery DL. Effect of noncustom bimolar mouthguards on peak ventilation in ice hockey players. Clin J Sport Med 2005;15:154–7.
22. Francis KT, Brasher J. Physiological effects of wearing mouthguards. Br J Sports Med 1991;25:227–31.
23. Kececi AD, Cetin C, Eroglu E, Baydar ML. Do custom-made mouth guards have negative effects on aerobic performance capacity of athletes? Dent Traumatol 2005;21:276–80.
24. Cetin C, Kececi AD, Erdogan A, Baydar ML. Influence of custom-made mouth guards on strength, speed and anaerobic performance of taekwondo athletes. Dent Traumatol 2009;25: 272–6.
25. von Arx T, Flury R, Tschan J, Buergin W, Geiser T. Exercise capacity in athletes with mouthguards. Int J Sports Med 2008;29:435–8.
26. Westerman B, Stringfellow PM, Eccleston JA. EVA mouthguards: how thick should they be? Dent Traumatol 2002;18: 24–7.

© 2012 John Wiley & Sons A/S

This document is a scanned copy of a printed document. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material.