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Incidence of cerebral concussions associated with type of mouthguard used in college football

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Abstract – Controversy exists among sports dentists as to whether or not a 'custom made' mouthguard is more effective in reducing the incidence of cerebral concussion than the boil-and-bite 'non-custom made' mouthguard. While members on each side remain steadfast in their opinion, not a single epidemiological study has been conducted to investigate the effect of type of mouthguard worn on the incidence of cerebral concussion. The aim of this study was to determine if there was a difference between the type of mouthguard worn and the incidence of cerebral concussions among National Collegiate Athletic Association (NCAA) Division I-A football players. During the 15-week 2001 college football season, trainers entered, via an interactive web site, weekly data for each game and practice sessions for the preceding week. Eighty-seven (76%) out of a possible 114 Division I teams participated. A total of 506 297 athletic exposures were recorded; 369 brain concussions were reported. The incidence of cerebral concussions per 1000 exposures was 0.73. Utilizing a risk ratio with a 95% confidence interval, no statistical difference occurred in the incidence of cerebral concussions between football players wearing custom made versus non-custom made mouthguards (0.990,1.750). In this study, there was no advantage of wearing a custom made mouthguard over a boil-and-bite mouthguard to reduce the risk of cerebral concussion in football players.

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Heated controversy exists among sports dentists as to whether the use of mouthguards can reduce the incidence of cerebral concussions. Literature regarding this topic is limited and divided (1–5). Those who advocate this concept, frequently cite one article published by the team dentist for Notre Dame, Dr John Stenger, in 1964 (2). In the article, five case reports, involving Notre Dame football players who had a history of head and/or neck injuries, were discussed (2). Three players gave a history of 'being concussion prone' and one had previous neck injuries. The fifth athlete experienced definite pain with crepitation on the left side when the temporomandibular joint was palpitated, and cervical pain extending halfway down his shoulder. Each athlete wore a custom-fitted mouthguard when playing football in conjunction with daily interocclusal acrylic splint therapy. Each player's symptoms were either eliminated or diminished. The author concluded that the custom-fitted mouthguard provided protection and relief for patients (2). In another paper, an *in vitro* study investigated a series of impact blows on a single cadaver (3). The authors of that study concluded that 'there was a decided reduction in the amplitude of the intracranial pressure wave when the mouth protector was in place. Bone deformation was also decreased moderately when the mouth protectors were in place (3). However, the correlation between these factors and cerebral concussion is not clear at all.

A project involving South African rugby players investigated the association between the incidence of cerebral concussion and mouthguard usage (4). A sample of 321 university students participating on 555 player occasions was examined in this cross-sectional study. Six cerebral concussions occurred in 194 athletic exposures when a mouthguard was worn versus nine concussions in 361 athletic exposures when a mouthguard was not worn. No statistically significant differences were found between wearers and non-wearers with respect to cerebral concussions (4). Another study, which evaluated male National Collegiate Athletic Association (NCAA) Division I college basketball players, has recently been published (5). It involved the trainers reporting data on a weekly basis utilizing an interactive web site. In this study, 71 324 athletic exposures were documented. Results of this study indicated that there was no significant difference between mouthguard users and non-users for rates of cerebral concussions. This study concluded that wearing mouthguards by this group of basketball players has no effect on reducing the risk of cerebral concussions (5). It is noteworthy that almost all athletes in the study were wearing custom made mouthguards.

There are three broad categories of athletic mouthguards: stock, mouth-formed (shell-liner or boil-and-bite), and custom made (6, 7). The stock mouthguard is a pre-formed rubber, vinyl, or dense foam tray that fits loosely over the teeth. Clenching of the teeth holds this particular type of protective device in place. However, in doing so, the athlete experiences limitations in speech and breathing. The mouth-formed mouthguards can be further classified into two subtypes: shell-liner and boil-and-bite. The shell-liner is a stock mouthguard, which is then lined with a chemically cured resilient mouth-fitted material for an improved fit. The second subtype of mouthguard under mouth-formed is the boil-and-bite mouthguard. This particular mouthguard comprises 90–95% of all mouthguards worn (8). These appliances, which are composed of a thermoplastic material, are softened in boiling water and adapted to fit over the teeth as the material cools. A custom made mouthguard is made by a dentist. Typically, two appointments are required. During the first, the dentist takes an impression of the upper dental arch. Prior to the second appointment, he/she then creates a stone model of the teeth and fabricates a custom made mouthguard by adapting a thermoplastic material to the cast. A second visit is required to insert, verify the fit, and adjust the mouthguard to the mouth. Recently, three different subtypes of custom made mouthguards have been introduced: injection molded, vacuum formed, and pressure laminated. Injection-molded mouthguards are laboratory fabricated using the lost wax injection molding techniques. Most commonly, a urethane or rubber is used for this type of mouthguard. Vacuum-formed mouthguards are constructed of ethylene vinyl acetate. A sheet of ethylene vinyl acetate is heated, and under negative vacuum pressure, is adapted to the stone model. Pressure-laminated mouthguards are fabricated from sheets of ethylene vinyl acetate. These sheets are adapted over a stone model with specialized machines that apply heat and pressure. Utilizing such a device allows for building up multiple layers of vinyl material to be fused together on the cast.

A published commentary has suggested that custom made multilaminated mouthguards could be more effective in preventing cerebral concussion than the traditional custom made mouthguard and far superior to the store-bought 'boil-and-bite' mouthguard (1). While both these dentist-made mouthguards are superior in comfort for the wearer compared to the mouth-formed boil-and-bite mouthguard or the stock mouthguard, as of yet, no controlled clinical trials or epidemiological studies involving large sample sizes have been conducted to investigate the possible effects of type of mouthguard worn on the incident of cerebral concussion.

Physicians are interested in conducting studies which will provied information regarding the incidence of cerebral concussion. High school athletes, college athletes and professional athletes, who participate in a wide variety of sports, are the focus of these studies (9, 10). In a similar manner, the dental profession should be following suite in trying to establish whether there is a relationship between the type of mouthguard used and the incidence of cerebral concussion. The aim of this study was to test the hypothesis that there is a difference between the type of mouthguard worn and the incidence of cerebral concussions among college football players. The investigators determined, via trainers 'real-time' participation in an interactive web site (5), the incidence of cerebral concussions among NCAA Division I football players and type of mouthguard used.

Materials and methods

The project protocol was approved by the University of North Carolina at Chapel Hill School of Dentistry's Committee on Investigation Involving Human Subjects. The population studied was NCAA Division I-A football players during the 2001 football season. The information regarding these athletes was provided by the head football trainer or his/her designated assistant trainer/graduate assistant, and was weekly communicated to the principal investigator via an interactive web site. The athletic trainer recruitment phase of this project involved a letter and a telephone contact. During mid-July, the head football trainers from the 114 schools fielding a Division I-A football team were sent an introductory letter describing the project and soliciting their participation. In compliance with the University of North Carolina at

Chapel Hill School of Dentistry's Committee on Investigations Involving Human Subjects, this document served as the informed consent. Return responses arrived via an e-mail message, either affirming or declining participation in the project. The head athletic trainers were given 2 weeks to respond. In an effort to ensure receipt of the letter of introduction by the head athletic trainers, those athletic trainers who had not responded by August 1, were contacted by telephone to confirm the receipt of the letter. In case of non-receipt, a new letter was sent to the correct contact person.

The participating athletic trainer weekly communicated with the principal investigator via an interactive web site (5). Each week, the athletic trainer reported the number of games and practices his/her team had during the previous week. The reported data also included: (i) the number of athletes participating in each of those events; (ii) the number of athletes wearing a mouthguard; and (iii) the approximate number of players wearing a custom made mouthguard. Within this initial page, the athletic trainers also recorded how many, if any, cerebral concussions their athletes sustained during the week in a game or practice. If the athletic trainer indicated that one or more of his athletes had sustained a concussion during the previous week, the interactive web site asked the athletic trainer additional and more specific questions for each event. Issues covered within this second set of questions included: (i) if the injured player was wearing a mouthguard when the concussion occurred; (ii) what type of mouthguard the player was wearing; (iii) what was the grade level of the reported concussion; (iv) at what position the athlete was playing; and (v) the mechanism of injury (Table 1). If the athletic trainer had not completed his/her survey for the previous week by Tuesday evening, an e-mail reminder to log on to the web site was sent out late the same day. In order to standardize a starting date for all the athletic trainers who had intended to participate, the project was set to commence 1 week prior to the first collegiate football game of the season.

In this study, the occurrence of an injury per 1000 athletic exposures is used. Incidence per 1000 athletic exposures = (number of concussions/total athletic exposures) × 1000. An athletic exposure is defined as one athlete participating in one practice or game where he/she is exposed to the possibility of athletic injury. Specifically in this study, an athletic exposure is a football player playing in a game or practice, whether it was one play, one quarter, one half, or even the entire game. The common denominator in this case was the fact that the athlete was exposed to the risk of injury.

Table 1. Interactive web site pull-down list depicting mechanism of injury

Head-to-head contact
Knee-to-head contact
Foot-to-head contact
Blow to jaw
Blow to side of body
Contact with surrounding equipment
Contact with ground
Other
Unknown

In order to test the hypothesis, a risk ratio statistical analysis was utilized. In this study, concussion rate among custom made mouthguard wearers were compared to non-custom made mouthguard wearers. In our calculations, I_c is the incidence of concussion per 1000 athletic exposures for custom made mouthguards and I_n is the incidence of concussion per 1000 athletic exposures for non-custom made mouthguards; therefore $I = I_c/I_n$ ratio was used as the risk ratio. The two rates were compared by forming a confidence interval about their ratio with $\alpha = 0.05$.

In addition, two subgroups of the whole data were identified. This subgrouping was based upon the type of mouthguard worn. In one subgroup were teams in which all players wore a custom made mouthguard, and the second subgroup had teams in which all the players wore a non-custom made mouthguard. A team was placed into its respective subgroup only if no more than four players were wearing mouthguards that were different from the remaining members of the team. This additional step in the data analysis was carried out to allow teams that exclusively used one type of mouthguard to be compared to teams that used the other kind. The incidence of cerebral concussion was compared between the two subgroups tested utilizing Chi-squared statistics.

Standard frequency analyses were used to describe data related to grade level of concussion, position played when injured, and mechanism of injury.

Results

At the end of the athletic trainer recruitment phase of the project, 94 out of 114 athletic trainers of NCAA Division I-A football team had agreed to participate in the project. The investigation period was the 15-week 2001 college football season. Eighty-seven (76%) out of a possible 114 Division I teams reported some data during the observation period. Seven of those who agreed to participate never entered any data. Seventy athletic trainers (81% of those who reported at least some data) missed only 0–1 week 'reporting in', while three athletic trainers (3%) missed 2–3 weeks. The average number of players per team was 104 (±21) in practices and 58 (±9) in games. Reports were collected on 791 games, 2839 contact, and 1708 no-contact practices. Teams representing all the 12 nation-wide NCAA Division I conferences participated in this study.

Table 2. Concussions and exposures reported by 87 NCAA Division I college football teams for the 2001 season

	Custom made mouthguard	Non-custom made mouthguard
All games and practices		
Total exposures	197958	308339
Concussions	169	200
All games and contact practices		
Total exposures	141165	196332
Concussions	166	199
All games		
Total exposures	21538	24359
Concussions	122	130
Contact practices		
Total exposures	119627	171973
Concussions	44	69
Non-contact practices		
Total exposures	56793	112007
Concussions	3	1

A total of 506 297 athletic exposures and 369 cerebral concussions that were verified by a physician (0.73 per 1000 athlete exposures) were reported for all games and practices (Table 2). A total of 168 800 athletic exposures were reported for non-contact practice sessions. The incidence of concussion per 1000 athlete exposures was calculated for the following: (i) all games and practices; (ii) all games and contact practices; (iii) all games; (iv) contact practices; and (v) non-contact practices (Table 3). As expected, the incidence per 1000 athlete exposures was highest for all games (5.49 per 1000 athlete exposures). Of note, four concussions (0.02 per 1000 athlete exposures) occurred in non-contact practice sessions. Thus, all games and contact practices accounted for 365 concussions (1.08 per 1000 athlete exposures). The concussion risk ratio (custom made mouthguard/non-custom made mouthguard) was calculated for the following: (i) all games and practices; (ii) all games and contact practices; (iii) all games; (iv) contact practices; and (v) non-contact practices (Table 4). The concussion risk ratio for each of the four groups, involving contact athletic exposures, approximated '1.0'. Confidence intervals at 95% were determined (Table 4). There was no statistical difference in the incidence of cerebral concussion when wearing custom made mouthguards versus non-custom made mouthguards in any category (Table 4). Although the concussion risk ratio for non-contact practices was 5.917, this result was also statistically non-significant at the 95% confidence interval (Table 4).

There were 13 teams in each of the two subgroups that were selected based on exclusive use of either custom made or non-custom made mouthguard (maximum of four players wearing a different type of mouthguard than the rest of the team). The data for

Table 3. Incidence of concussion per 1000 athlete exposures among 87 NCAA Division I college football teams for the 2001 season

Criteria	Incidence of concussion (per 1000 athlete)
All games and practices	0.73
All games and contact practices	1.08
All games	5.49
Contact practices	0.39
Non-contact practices	0.02

Table 4. Concussion risk ratio (custom/non-custom) among 87 NCAA Division I college football teams for the 2001 season

Criteria	Concussion risk ratio	CI
All games and practices	1.316	95% CI: (0.990,1.750)*
All games and contact practices	1.160	95% CI: (0.869,1.548)*
All games	1.061	95% CI: (0.808,1.394)*
Contact practices	0.917	95% CI: (0.599,1.402)*
Non-contact practices	5.917	95% CI: (0.627,55.877)*

*Not statistically significant at 95% confidence interval.

these subgroups were separated into three time frames. These time frames included: (i) all games and contact practices; (ii) all games; and (iii) contact practices (Table 5). Chi-squared analysis ($P < 0.05$) showed that there was no statistical difference in the incidence of cerebral concussions between the subgroup of athletes wearing custom made mouthguards and the subgroup of players wearing non-custom made mouthguards within each of the time frames (Table 5).

Frequency analysis of concussions ($n = 369$) regarding the 'grade level' revealed: 226 Grade I concussions, 61.3%; 134 Grade II concussions, 36.3%; and 9 Grade III concussions, 2.4%. Chi-squared analysis ($P < 0.05$) demonstrated that there was no significant difference in the association between grade level of concussion and the use of a custom made versus a non-custom made mouthguard by the players in the entire sample of teams. The average grade level of concussion between the custom made subgroup versus

Table 5. Comparison of custom versus non-custom subgroups

Thirteen teams per subgroup	Custom	Non-custom
All games and contact practices ($P = 0.553^*$)		
Athletic exposures	57452	59751
Concussions	57	66
All games ($P = 0.906^*$)		
Athletic exposures	8524	8906
Concussions	42	45
Contact practices ($P = 0.376^*$)		
Athletic exposures	48928	50845
Concussions	15	21

*Not statistically significant – Chi-squared analysis ($P < 0.05$).

Table 6. Association of concussion with position

	Frequency ($N = 369$)	Percentage
Linebackers*	56	15.2
Wide-outs**	43	11.7
Safeties*	33	8.9
Cornerbacks*	30	8.1
Quarterbacks**	29	7.9
Halfbacks**	25	6.8

*Denotes a defensive player position.
**Denotes an offensive player position.

Table 7. Association of concussion with mechanism of injury

	Frequency ($N = 369$)	Percentage
Head-to-head contact	226	61.2
Knee-to-head contact	50	13.6
Contact with ground	41	11.1
Blow to side of body	27	7.3
Blow to jaw	6	1.6
Other	6	1.6
Contact with surrounding equipment	5	1.4
Unknown	5	1.4
Foot-to-head contact	3	0.8

the non-custom made subgroup was also evaluated utilizing Chi-squared statistics ($P < 0.05$). Similarly, the results demonstrated that there was no significant difference in association between average grade level of concussion between the custom made and non-custom made subgroups.

Of individual players, positions linebackers incurred the most number of concussions (15.2%), followed by wide-outs (11.7%) and safeties (8.9%; Table 6). Most common mechanism of injury for concussion was reported to be 'head-to-head' contact (64%), while 2% occurred by 'blow-to-jaw' (Table 7).

Discussion

In reviewing the literature regarding studies concerning mouthguards and the association of the incidence of cerebral concussions, the total of 506 297 reported athletic exposures in this study is an extremely large number and should give increased power for the statistical analysis (Table 2). The total number of athletic exposures is more than seven times the nearest value of 71 324 athletic exposures, which was recently published in the literature. This number of athletic exposures was recorded in a prospective study of NCAA Division I male college basketball players (5). The research design of this football study was similar to that of the basketball study. Both studies were prospective or 'real time' in nature, and data were collected via the athletic trainer's participation in an interactive web site. The results of the basketball study indicated that there was no significant differences for the rate of concussions between mouthguard users and non-users (5). The results of this study similarly indicates that there is no significant association in the incidence of cerebral concussion whether or not NCAA Division I football players are wearing custom made or non-custom made mouthguards.

In a separate part of this project, the data collected in this study, using the internet web site, were compared to the NCAA data which were collected in the traditional pen and paper, 'mail-in' approach (11). In both cases, data were collected for NCAA Division I football players in the 2001 season. The NCAA reported 256 cerebral concussions and 435 292 athletic exposures; this study documented 369 cerebral concussions and 506 297 athletic exposures. Using Chi-squared analysis, there was a statistically significant difference between 369 concussions versus 256 concussions ($P < 0.0001$). This finding suggests an under-reporting of cerebral concussions by the NCAA (11).

During the recruitment phase of the project, athletic trainers had informed the investigators of the variation of mouthguard types within the teams. Because of the extremely large number of teams participating, variations would occur naturally. Compounded with this natural occurrence, athletic trainers indicated that certain players, identified by position, would more likely be using different types of mouthguards than the rest of the team members. Specifically, athletes who need to speak frequently while they are on the field were more likely to be fitted with a custom made mouthguard. These positions typically include: quarterbacks, running backs, and linebackers. In order to take these variations into account, the investigators identified two subgroups from the entire sample of teams. Each subgroup included 13 teams. The first subgroup contained teams in which only up to four of the athletes wore a custom made mouthguard; the second subgroup comprised teams in which less than four of the players wore a non-custom made mouthguard. Chi-squared analysis was applied to the relatively 'clean' data subsets. The results demonstrated that there was no statistical difference in the incidence of cerebral concussions between the subgroup of athletes wearing custom made mouthguards and the subgroup of players wearing non-custom made mouthguards (Table 5), and each of the group had equal but few (two cases in each group) reports of concussion of players wearing mouthguards that were not commonly used by the rest of the team.

As one would anticipate, the results of this study indicated that the incidence of cerebral concussion was highest in games (5.49 cerebral concussions per 1000 athletic exposures) as compared to values associated with various time frames. However, one might not have predicted that a football player is 14 times more likely to sustain a concussion during a game than in a contact practice (0.39 cerebral concussions per 1000 athletic exposures; Table 3). Furthermore, through media attention, the average observer would anticipate that the quarterbacks were most at risk to receive a concussion. This is likely because of the fact that typically, one might predict that it is the athlete who gets 'hit' is the one who usually sustains the concussion as opposed to the player who is doing the 'hitting'. Surprisingly, the results of this study indicated that 'linebackers' (the hitters) received the highest number of brain concussions, 56 out of 369 (15.2%; Table 6). Among these athletes, 27 linebackers were wearing a custom made mouthguard at the time of injury, 27 linebackers were wearing a non-custom made mouthguard, and 3 linebackers were not wearing a mouthguard. In fact, three out of the top four positions which received the highest percentages of concussions were associated with player positions that were 'doing the hitting'. Linebackers, safeties, and cornerbacks ranked first, second, and fourth in 'concussions sustained', while wide-outs occupied the second slot (Table 6). In fact, quarterbacks ranked fifth in this study (Table 6). The fact that a defensive position was associated with the highest incidence of cerebral concussion as opposed to an offensive player position has appeared previously in the literature (12).

The data collected from the 'drop-down' list under 'mechanism of injury' provide documentation regarding the etiology of cerebral concussions among this group of athletes (Table 1). The results of this study demonstrate that 'head-to-head contact' accounted for 61.2% (226 out of 369) of the concussions (Table 7). When isolating a 'head contact' as the related etiological factor, 'head-to-head', 'knee-to-head', and 'foot-to-head' contacts combined for a total of 75.6% (279 out of 369) of the cerebral concussions (Table 7). 'Blow to jaw' caused 1.6% (6 out of 369) of the concussions (Table 7). From the data gathered in this survey, the 'blow-to-jaw' response as the etiological factor of cerebral concussions was insignificant after analyzing the causative mechanisms of concussion. The results of this study do not statistically or scientifically support the statements which are popular and cited as 'accepted truths' in the literature, like 'helmet design can reduce helmet-hit concussions, while padded chin straps and mouthguards reduce chin-hit concussions' (6), and 'one of the functions of a mouthguard is to prevent potential concussions by absorbing the shock of a blow to the mandible' (13). For many years, some experts have speculated that if athletes wear mouthguards in contact sports, many sports-related cerebral concussions might be prevented (1). In this study, the 'blow-to-jaw' mechanism of causing brain concussions was small: 6 out of 369 concussions (1.6%). Popular opinions advocate that the use of mouthguards, especially the 'custom made' over the 'non-custom made' mouthguard, will have a significant impact on reducing the incidence of cerebral concussions, especially the 'blow to jaw'. As a result of the extremely small number of concussions occurring via this manner, yet higher number of non-custom made than the custom made mouthguards, the reduction of concussions by wearing a custom made mouthguard would be minimal, at best, in a case of a 'blow to jaw'.

It should be acknowledged that this study was performed on a group of athletes who already had considerable protection from the helmet used during athletic participation. In fact, the helmet may change the mechanisms of injury such that the mouthguard is irrelevant for concussion prevention. Thus, if the mouthguard is irrelevant in this situation, it can be easily understood that there would not be a difference between the type of mouthguard used. Additional studies with similar numbers of athletic exposures should be carried out to compare sports where helmets are not used to ascertain if firstly, any mouthguard protects against concussions and secondly, if one type of mouthguard is particularly beneficial.

Conclusion

In this study, there was no significant association in the incidence of brain cerebral concussions sustained by NCAA Division I football players with 'custom made' mouthguards compared to 'non-custom made' store-bought mouthguards.

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