WOJDA, Martyna and WIELGOSZ, Aleksandra. Dental Injuries in Sports: Analysis, Prevention, and Protection. Quality in Sport. 2024;20:53986. eISSN 2450-3118.
https://dx.doi.org/10.12775/QS.2024.20.53986
https://apcz.umk.pl/QS/article/view/53986

The journal has been 20 points in the Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553.
Has a Journal's Unique Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 r. Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398.
Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 01.08.2024. Revised: 20.08.2024. Accepted: 21.08.2024. Published: 22.08.2024.

Dental Injuries in Sports: Analysis, Prevention, and Protection

lek. dent. Martyna Wojda
Non-public Health Care of the Catholic University of Lublin,
Racławickie 14 avenue, 20-950 Lublin, Poland
https://orcid.org/0009-0008-9256-9275
martyna.wojda.praca@gmail.com

lek. dent. Aleksandra Wielgosz
Masovian Dental Center in Warsaw,
Nowy Zjazd 1, 00-301 Warsaw, Poland
https://orcid.org/0009-0001-1157-0821
aleksandra.wielgosz26@gmail.com

Abstract

Introduction and purpose: Participating in sports plays a vital role in maintaining both physical and mental health. However, as the popularity of physical activity increases, so does the incidence of dental injuries. The aim of this scientific paper is to evaluate the effectiveness of various types of mouthguards in preventing sports-related dental injuries and to demonstrate their positive impact on athletes' overall health.

State of knowledge: Dental injuries are prevalent in sports, comprising 31% of all maxillofacial injuries. The most common types of injuries are crown fractures, dislocations, and soft tissue damage.
Preventive measures, particularly the use of mouthguards, are the most effective means of reducing these injuries, lowering their incidence by 82-93%. Custom-made mouthguards provide the best protection and comfort, and their use can improve physical endurance.

Summary: Mouthguards are an essential component of injury prevention in sports, providing effective protection for the oral cavity and significantly reducing the risk of serious injuries. The use of mouthguards, particularly custom-made, should be a standard practice in contact sports. In addition to protecting the teeth, mouthguards offer additional benefits, such as improving physical endurance and releasing protective substances like chlorhexidine and fluoride, which contribute to oral health. Increasing awareness and enacting legal regulations mandating the use of mouthguards can significantly improve the oral health of athletes.

Keywords: sports dentistry, contact sports, sports injury, dental trauma, mouthguards

Introduction

Engagement in sports is crucial for physical and mental health. In recent years, there has been an exponential increase in the number of athletes worldwide, and dental injuries have emerged as a significant concern in oral health. [1] Although the oral cavity comprises only 1% of the human body, injuries in this area account for as much as 5% of all injuries of the body across all age groups. [2] Sports-related injuries constitute up to one-third (31%) of all maxillofacial injuries. The incidence of sports-related dental injuries varies among individuals. Most scientific studies indicate that men are more prone to dental injuries than women, with a ratio of 2.5:1. [3][4] Certain malocclusions are significant predisposing factors for dental injuries. These include class II malocclusion, increased overjet with protruded upper incisors, and inadequate lip closure. Typically, dental injuries affect the anterior sextants, particularly the maxillary central incisors, while the maxillary lateral incisors and mandibular central incisors are less frequently involved. [3] Dental injuries sustained during sports can include crown or root fractures, dislocations, subluxations, soft tissue damage, and jawbone fractures. Crown avulsions and fractures are the most common injuries. [5] Some injuries may require athletes to withdraw from competitions, incur significant treatment costs, and lose training time. [6] Therefore, athletes should use appropriate mouthguards to minimize the risk of serious injuries, such as concussions and maxillofacial trauma. [1] Despite expert recommendations for the widespread use of mouthguards in high-risk sports and recreational activities (Tab.1), many athletes remain reluctant to use them.

The reasons for this reluctance include lack of recommendations from coaches, discomfort while speaking, perceived reduction in performance, and the absence of legal requirements for their use. [7]

Table 1.Recommendations by the American Dental Association - sports where it is advised to wear a well-fitted mouthguard. [8]

American Dental Association			
Acrobatics	Field hockey	Racquet ball	Squash
Basketball	Football	Rugby	Surfing
Bicycling	Gymnastics	Shot-putting	Volleyball
Boxing	Handball	Skateboarding	Water polo
Equestrian events	Ice hockey	Skiing	Weight lifting
Extreme sports	Inline skating	Sky diving	Wrestling
Field events	Lacrosse	Soccer	
	Martial arts	Softball	

In 2016, April was designated as National Facial Protection Month in the United States. During this month, five different health organizations - the American Academy of Pediatric Dentistry, the Academy for Sports Dentistry, the American Association of Orthodontists, and the American Association of Oral and Maxillofacial Surgeons - promote oral protection and the use of mouthguards. [9] Evidence has shown that preventive measures are the most effective means of reducing the incidence of maxillofacial injuries. Therefore, mouthguards should be legally mandated to protect athletes' health. [5]

Materials and Methods

Literature Review

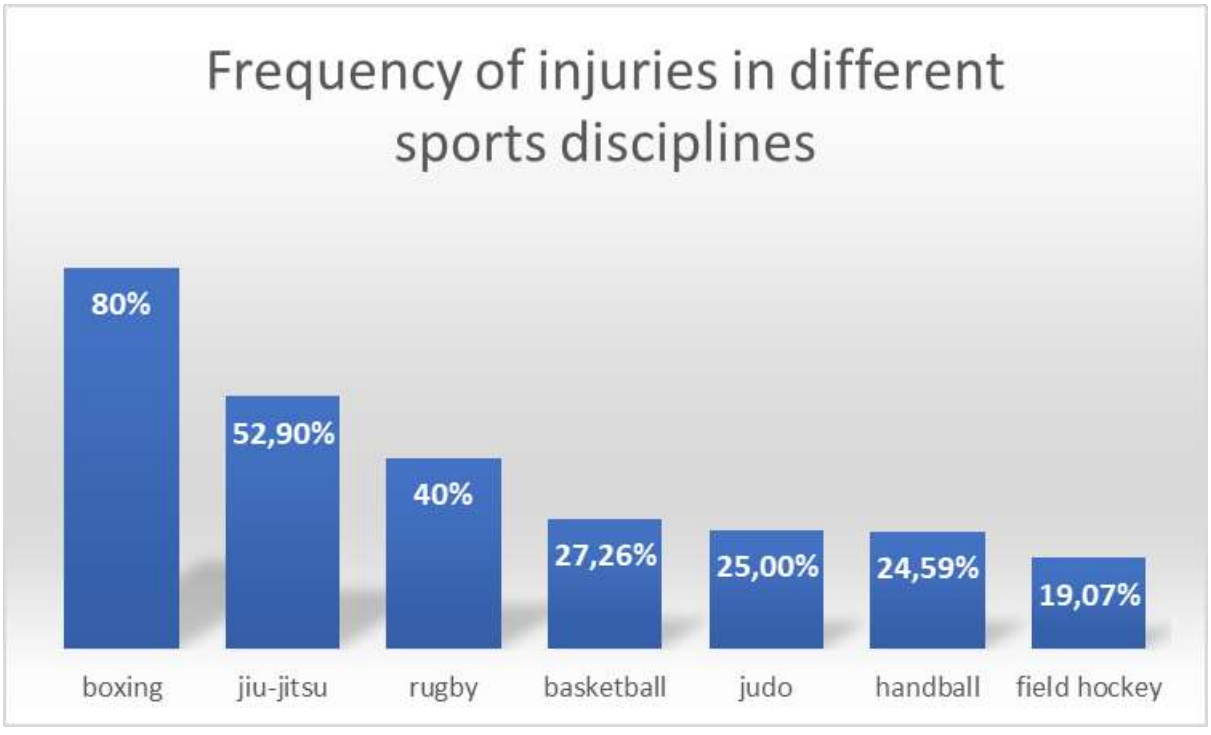
The scientific literature was comprehensively searched using the PubMed database, SpringerLink and additional scientific resources on June 17, 2024, and June 20, 2024. The search aimed to cover a decade, from 2014 to 2024, ensuring a broad scope that captures recent developments in the field. Initially, the keyword "sports dentistry" was used, yielding a total of 1,149 results. However, 532 of these were excluded because they were not readily accessible due to restrictions or paywalls. Beyond accessibility issues, certain articles were disregarded as they did not directly relate to the specific focus of the research, which seeks to explore the intersection of dentistry and sports, particularly in the context of preventing dental injuries. In order to refine the results and gather more targeted insights, further searches were conducted with additional keywords.

The phrase "dental injuries in sport" produced 77 results, while "dental injuries in contact sport" returned 17 results, highlighting the niche but critical area of study within more aggressive sports disciplines. Additionally, the search term "mouthguard in contact sports" yielded 5 relevant articles, and "sports mouthguards" resulted in 23 articles. Importantly, all of these articles were freely accessible, allowing for an inclusive and comprehensive review without the barrier of paid access. The selected literature primarily consisted of works in English, ensuring a wide range of high-quality sources. However, the review was not limited to English; a few significant articles in other languages, including German, were also incorporated to provide diverse perspectives and insights. This multilingual approach enriched the understanding of the topic by incorporating research from different regions and contexts. Ultimately, a curated selection of 28 articles formed the foundation of this research work, providing a robust basis for analysis and discussion. This literature review underscores the importance of mouthguards in contact sports, highlighting the role of dental health in athletic performance and injury prevention. Through this research, we aim to contribute valuable knowledge to the field of sports dentistry, emphasizing the significance of preventive measures and the need for increased awareness among athletes and healthcare professionals alike.

Discussion

The overall incidence of dentofacial injuries in contact sports is nearly 30%. [10] The frequency of injuries varies across different sports disciplines. (Diag. 1) The most commonly reported dentofacial injury was a tooth fracture, ranging from 6% to 50%. Other dentofacial injuries frequently included zygomatic bone contusions (0.71–11%) and lip lacerations (11–15%). [11]

Diagram 1. Frequency of injuries in different sports disciplines. [10] [11]



The two main protective measures against traumatic dental injuries (TDIs) are face and mouth guards. Before the mandatory use of face and mouth guards in American football, facial and oral injuries accounted for 50% of all reported injuries.

After the introduction of this protective equipment, the incidence of oral and facial injuries significantly decreased to 3.9%. [3] The use of mouthguards reduces the likelihood of dental injuries by 1.6 to 1.9 times, and for some sports, such as rugby, even up to 5.55 times. [12] Mouthguards are effective in preventing sports-related oral injuries and in reducing their severity. The mechanism of mouthguards involves cushioning, increasing the surface area over which impact forces are distributed, and stabilizing the jaw. [3,13] Mouthguards protect against bruising and cuts of perioral and intraoral tissues, safeguard the teeth from damage, prevent fractures of the jawbones, including the angle and condyle of the mandible and protect against dislocations and injuries to the temporomandibular joint. Additionally, they help minimize the risk of neck and brain injuries. [14] A systematic review has shown that athletes wearing mouthguards are 82% to 93% less likely to experience dental injuries. In fact, the incidence of dental injuries ranged from 7.5% to 7.75% among those wearing mouthguards, compared to 48.31% to 59.98% among those not wearing mouthguards. [5] According to studies, most dental injuries occur during childhood and adolescence. Up to 90% of dental injuries happen before the age of 19, and their frequency decreases with age. [3] Patients undergoing orthodontic treatment are at increased risk of injury while participating in sports. This treatment is most commonly performed during adolescence and as has been said it is a period when dental injuries are more frequent. Additionally, malocclusions such as class II, increased overjet with protruded upper incisors, and incompetent lips may further increase the likelihood of injury. [4] It is crucial for patients undergoing orthodontic treatment to use mouthguards during sports to protect both the oral tissues and the orthodontic appliances. Removable orthodontic appliances should be removed and securely stored during physical activities, and properly fitted mouthguards should be used instead. For fixed orthodontic appliances, it is not possible to remove the appliance each time the patient engages in sports, so they should use mouthguards designed for specific needs. Such mouthguards must be regularly checked by the treating orthodontist to ensure that the appliance continues to function correctly and does not negatively impact the orthodontic treatment process. If misfit occurs, replacing the current mouthguard should be promptly recommended. [15]

Table 2. Global prevalence of traumatic dental injuries in permanent and primary teeth.[2].

Cause	Relevance (%)
Primary and permanent teeth	
Sports	12.5%
Physical activity	19.45%
Permanent teeth	
Sports	12.9%
Physical activity	20.8%
Primary teeth	
Sports	5.8%
Physical activity	11.6%

Available types of mouthguards

American standards for testing materials classify mouthguards into three categories: stock, boil-and-bite, and custom-made. [16] **Stock mouthguards** are standard, pre-fabricated products with a universal fit that are ready to use without any customization. They are the most widely available and affordable. Although they occur in various sizes and shapes, they may not provide an ideal fit for individual tooth and jaw structures. Patients usually select them based on subjective comfort. [17] Discomfort is often experienced during speaking and breathing, and the constant need to maintain occlusion to stabilize the mouthguard in place can lead to muscle strain. There are three types of stock mouthguards: single jaw, bimaxilary, and orthoguard. The latter is designed for patients undergoing orthodontic treatment with fixed braces. They have a cut-out channel along the dental arch on the occlusal surface to accommodate the braces and allow for planned tooth movements. Due to changes in tooth alignment during orthodontic treatment, reshaping the mouthguard may be necessary. [15] Because of poor retention and lack of proper fit, they provide the weakest protection against injuries during sports activities. [18]

Boil-and-bite mouthguards are made from thermoplastic material, which can be softened in hot water and then molded to fit the user's dental arch. This allows for a better fit than stock mouthguards, although the molding process requires certain skills. [16] [17] The recommended fitting method involves starting by immersing the mouthguard in warm water to soften the material, then placing it in the mouth. The user then presses, sucks, and bites the mouthguard using their tongue and fingers to adapt it to their occlusal conditions. The force applied during these actions is crucial, as excessive and uncontrolled pressure can lead to improper fitting and a reduction in material thickness. According to conducted studies, the reduction in thickness can range from 70% to even 99%. Another issue is that the mouthguard may not cover all areas of the dentition due to the limited number of available sizes.

The posterior areas of the dentition are often not covered by the mouthguard plate, which weakens its protective properties and reduces its effectiveness. [18]

Custom-made mouthguards are individually fitted by a dentist based on impressions or scans of the teeth, providing the highest level of protection and comfort due to their precise adaptation to the unique structure of the user's oral cavity. [16] Both stock and boil-and-bite mouthguards do not offer adequate retention and require the user to maintain constant occlusal pressure to keep them in place, which causes discomfort. Custom-made mouthguards are tailor-made to ensure better fit and comfort, as they allow for easier and better breathing and speaking. [19] [20] They also offer superior protective properties. [13] When inserted into the mouth, the mouthguard covers the palate and all occlusal surfaces of the teeth [16]. Studies indicate that only 15% of stock and boil-and-bite mouthguards cover the posterior molars as opposed to custom-made mouthguards. [15] The mouthguard should extend at least to the distal part of the first maxillary molar and have a labial and occlusal thickness of 3 mm, as well as a palatal thickness of 2 mm, to reduce the impact force on the teeth. The occlusion of the mouthguard should be bilateral and balanced. [21] Reducing the palatal extension of mouthguards from 6 to 2 mm improves athlete satisfaction. [22] A custom mouthguard should meet specific criteria, such as being made from a material that is easy to clean and disinfect, durable, and capable of providing proper retention, allowing appropriate occlusal relationships and maximum protection. [3] Additionally, it should be able to absorb and disperse impact energy by covering the maxillary teeth, eliminate any occlusal interferences, enable mouth breathing, and protect soft tissues. In the past, various materials, such as latex rubber, vinyl and acrylic resins, and silicone acrylic resins, were used to produce intraoral guards for individuals engaged in physical activity. [18] However, ethylene vinyl acetate (EVA) has been demonstrated to be the most suitable material for mouthguards. EVA is a copolymer of ethylene and vinyl acetate, known for its flexibility, resilience, and certified biocompatibility. [16] [23] Studies have also been conducted to enhance the effectiveness of mouthguards by incorporating additional reinforcing materials, such as laminated layers, air chambers, acrylic resin, silica mesh, titanium, sponge, fiberglass, and Sorbothane inserts. However, these studies have not provided conclusive results indicating the most effective material. [18] Based on the number of material layers used in the production of mouthguards, custom mouthguards can be classified into single-layer type and laminated type. The first type is made from a single layer, while laminated mouthguards consist of more than one layer of material, which are strongly bonded together. Comparing these two types, laminated mouthguards have advantages such as better stability and appropriate thickness. The improved stability results from reduced stress generated during production. However, a potential drawback of laminated mouthguards is their tendency to delaminate, where the individual layers of material may separate. This can be caused by insufficient temperature during the production process or contamination between the layers, which reduces bonding strength and weakens the structure of the product. [24] There are various methods for producing custom mouthguards. The most commonly used methods include pressure forming, vacuum forming, a combination of these, and 3D printing. Some studies suggest the superiority of the vacuum technique over the pressure technique in terms of less reduction in material thickness. Other studies indicate no difference between vacuum and pressure techniques, noting that the thermoforming process itself can reduce the thickness of the material sheet by as much as 35-60% on the labial surface and 25% on the occlusal surface.

Additionally, tooth structures such as the incisal edge or cusp are areas where the thickness of the mouthguard plate decreases. [24] After fabricating the mouthguard and before delivering it to the patient, the thickness and fit are checked on the working model.

Additional advantages of using mouthguards

The main function of a mouthguard is to prevent injuries, but it can also serve as a reservoir for materials aimed at preventing oral diseases, such as chlorhexidine, fluoride, and casein. Moreover, it can be a valuable aid in enhancing athletic performance by providing both psychological and physical advantages. Using a mouthguard improves athletes' physical performance by increasing their respiratory capacity in both aerobic and anaerobic activities. [25] In individuals with reduced respiratory capacity, such as patients with cystic fibrosis, the concentration of 8-iso-PGF2α (a marker of antioxidant deficiency and lipid peroxidation in saliva release among athletes) was significantly higher compared to healthy individuals. [26] Based on these findings, Chiavaroli and colleagues hypothesized that using a mouthguard not only enhances aerobic performance but also reduces the release of 8-iso-PGF2α, leading to a decrease in oxidative stress, which contributes to improved oral and overall health. [27] Due to recent studies, the common belief that mouthguards reduce performance has begun to be challenged. On the contrary, it appears that mouthguards, especially custom-made ones, enhance athletic performance. Custom mouthguards can change the occlusion and improve ventilation efficiency during exercise. [25] To prevent oral damage caused by prolonged use of mouthguards and their contact with pathogenic microorganisms, various strategies can be employed, such as incorporating protective substances into the mouthguard material. Chlorhexidine, as an active ingredient, can be used to prevent and reduce the colonization, growth, and pathogenicity of dental plaque. [28] The positive effects of chlorhexidine in mouthguards were highlighted by D'Ercole et al. in an in vivo study. This study observed that the addition of chlorhexidine during training inhibits the proliferation of microorganisms on the surface and reduces the concentration of *Streptococcus mutans, Candida spp.,* and molds in saliva. Furthermore, its contemporary use increases saliva pH and its buffering capacity. [29] [30] Depending on the individual needs of the patient, different materials can be used, such as fluoride and casein. Fluoride is recommended for patients who require enhanced prophylaxis, as its use (in the form of toothpaste or gel) strengthens enamel and reduces its susceptibility to bacterial action and the development of cavities. [1] Studies on casein have shown that its incorporation into EVA mouthguards (made from ethylene vinyl acetate) effectively prevents plaque adhesion to tooth surfaces. Additionally, casein contributes to increasing pH levels, saliva secretion, the amount of stimulated saliva, and buffering capacity, which positively impacts the oral health of athletes. [31] Hegde and Thakkar indicated the positive effects of casein chewing gums on the reduction of white spots, increased saliva flow, buffering capacity, and improved pH levels. [32] Nagai et al. propose the introduction of a bioactive filler into the structure of EVA material. The new material demonstrated bacteriostatic activity against *Streptococcus mutans* and *Porphyromonas gingivalis* and showed no cytotoxicity towards human gingival cells. [33] Yoshida et al. proved that silver nanoparticles embedded in the EVA matrix possess effective antibacterial properties against *Streptococcus sobrinus*, *Porphyromonas gingivalis*, and *Escherichia coli*, suggesting the potential use of this material in the production of mouthguards. [34]

To ensure that a mouthguard continues to function properly for as long as possible, it should be stored and cleaned appropriately. After use, the mouthguard should be rinsed, ideally with cold water. Cleaning with hot water is prohibited due to the risk of deforming the material, which can result in a loss of fit to the teeth. Similarly, storing the mouthguard in direct sunlight or heat can have the same effect, so it should be kept in a dry, airtight container. The mouthguard should be cleaned with a toothbrush and toothpaste or soap. Regular check-ups with a dentist or orthodontist are also crucial, especially if the patient is undergoing orthodontic treatment, to assess the condition of the mouthguard and recommend replacement if it shows significant wear and no longer serves its original purpose. [15]

Summary

Participating in sports is extremely important for physical and mental health, but it also entails the risk of injuries, both dental and head injuries. Injuries such as jawbone fractures, concussions, and other maxillofacial injuries are common in contact sports and can lead to serious health problems and significant medical costs. Protective gear, such as mouthguards and face guards, provides an effective preventative method by significantly reducing the risk and severity of injuries through impact absorption. Research indicates that regular use of these protectors in high-risk sports significantly lowers the incidence of such injuries. Although some athletes still avoid wearing them due to discomfort or lack of mandatory requirements, widespread implementation of mouthguards could greatly enhance athlete safety worldwide. Properly educating athletes and coaches about the benefits of using protective gear is crucial for minimizing the risk of sports-related injuries.

Disclosures
All authors have read and agreed with the published version of the manuscript.

Conflict of interest:
The authors declare no conflict of interest.

Funding statement:
No external funding was received to perform this review.

Statement of data availability:
not applicable

Statement of institutional review committee:
not applicable

Statement of informed consent:
not applicable

Statement of informed consent:
Permission has been obtained to use photographs from the University Dental Center.

Author's contribution:
conceptualisation: Martyna Wojda;
methodology: Martyna Wojda,
software: Aleksandra Wielgosz
check: Aleksandra Wielgosz
formal analysis: Martyna Wojda,
investigation: Aleksandra Wielgosz;
resources: Martyna Wojda
data curation: Martyna Wojda
writing - rough preparation: Martyna Wojda, Aleksandra Wielgosz
writing-review and editing: Martyna Wojda,
visualisation: Aleksandra Wielgosz,
supervision: Martyna Wojda, Aleksandra Wielgosz;
project administration: Martyna Wojda,
receiving funding: Aleksandra Wielgosz

Corresponding author: Martyna Wojda, **martyna.wojda.praca@gmail.com**

References:

1. Gallagher J., Ashley P., Needlman I. Implementation of a behavioural change intervention to enhance oral health behaviours in elite athletes: A feasibility study. BMJ Open Sport Exerc. Med. 2020 doi: 10.1136/bmjsem-2020-000759.
2. Mordini L, Lee P, Lazaro R, Biagi R, Giannetti L. Sport and dental traumatology: Surgical solutions and prevention. Dent J (Basel). 2021;9(3):33. doi: 10.3390/dj9030033.
3. Andreasen J.O., Andreasen F.M., Andersson L. Textbook and Color. Atlas of Traumatic Injuries to the Teeth. John Wiley & Sons; Hoboken, NJ, USA: 2019.
4. Zaleckiene V., Peciuliene V., Brukiene V., Drukteinis S. Traumatic Dental Injuries: Etiology, Prevalence and Possible Outcomes. Stomatologija. 2014;16:7–14.
5. Fernandes L.M., Neto J.C.L., Lima T.F., Magno M.B., Santiago B.M., Cavalcanti Y.W., de Almeida L.D.F.D. The Use of Mouthguards and Prevalence of Dento-Alveolar Trauma among Athletes: A Systematic Review and Meta-Analysis. Dent. Traumatol. 2019;35:54–72. doi: 10.1111/edt.12441.
6. Ahmed I, Fine P. 'Injury prevention versus performance': has the time come to mandate the use of mouthguards in all contact sports? BMJ Open Sport Exerc Med. 2021;7(1). doi: 10.1136/bmjsem-2020-000828.
7. Collins CL, McKenzie LB, Roberts KJ, et al.. Mouthguard bites (behavior, impulsivity, theory evaluation study): what drives mouthguard use among high school basketball and baseball/softball athletes. J Prim Prev 2015;36:323–34. 10.1007/s10935-015-0402-7
8. Ada.org American Dental Association, 2021. Available:https://www.ada.org/en/member-center/oral-health-topics/mouthguards
9. American Dental Association . Orofacial Protectors. ADA; New York, NY, USA: 2016. p. 181.
10. Oliveira Werlich M., Honnef L.R., Silva Bett J.V., Domingos F.L., Pauletto P., Dulcineia Mendes de Souza B., Duque T.M., Curi Hallal A.L., De Luca Canto G. Prevalence of Dentofacial Injuries in Contact Sports Players: A Systematic Review and Meta-Analysis. Dent. Traumatol. 2020;36:477–488. doi: 10.1111/edt.12556.
11. Polmann H., Melo G., Conti Réus J., Domingos F.L., de Souza B.D.M., Padilha A.C., Duque T.M., Porporatti A.L., Flores-Mir C., De Luca Canto G. Prevalence of Dentofacial Injuries among Combat Sports Practitioners: A Systematic Review and Meta-Analysis. Dent. Traumatol. 2020;36:124–140. doi: 10.1111/edt.12508.
12. Bergman L., Milardović Ortolan S., Žarković D., Viskić J., Jokić D., Mehulić K. Prevalence of Dental Trauma and Use of Mouthguards in Professional Handball Players. Dent. Traumatol. 2017;33:199–204. doi: 10.1111/edt.12323.
13. Guerard S., Barou J.-L., Petit J., Poisson P. Characterization of mouthguards: Impact performance. Dent. Traumatol. 2017;33:281–287. doi: 10.1111/edt.12329.
14. Tuna E.B., Ozel E. Factors Affecting Sports-Related Orofacial Injuries and the Importance of Mouthguards. Sports Med. 2014;44:777–783. doi: 10.1007/s40279-014-0167-9.

15. Parker, K., Marlow, B., Patel, N. et al. A review of mouthguards: effectiveness, types, characteristics and indications for use. Br Dent J 222, 629–633 (2017).doi:10.1038/sj.bdj.2017.365
16. Spinas E., Aresu M., Giannetti L. Use of mouth guard in basketball: Observational study of a group of teenagers with and without motivational reinforcement. Eur. J. Paediatr. Dent. 2014;15:392–396.
17. Kaur G., Mangat S.S. Attitude toward mouthguard utilization among North Indian school children. J. Int. Soc. Prev. Community Dent. 2016;6:69–74. doi:10.4103/2231-0762.175417.
18. De Queiroz TS, da Cruz BS, Demachkia AMM, Borges ALS, Tribst JPM, Paes Junior TJdA. Ergonomic Sports Mouthguards: A Narrative Literature Review and Future Perspectives. Applied Sciences. 2023; 13(20):11353.doi:10.3390/app132011353
19. Shrestha A., Takahashi T., Kurokawa K., Mitsuyama A., Hayashi K., Ishigami T., Shahrin S., Chowdhury R., Churei H., Ueno T. Effects of Mouthguards on Electromyographic Activity of Masticatory Muscles. Int. J. Sports Dent. 2016;9:27–37.
20. Spinas E., Mameli A., Giannetti L. Traumatic Dental Injuries Resulting from Sports Activities; Immediate Treatment and Five Years Follow-Up: An Observational Study. Open Dent. J. 2018;12:1–10. doi: 10.2174/1874210601812010001.
21. Lloyd J.D., Nakamura W.S., Maeda Y., Takeda T., Leesungbok R., Lazarchik D., Dorney B., Gonda T., Nakajima K., Yasui T., et al. Mouthguards and Their Use in Sports: Report of the 1st International Sports Dentistry Workshop, 2016. Dent. Traumatol. 2017;33:421–426. doi: 10.1111/edt.12375.
22. Gómez-Gimeno À., Zamora-Olave C., Cordobés-Navarro M., Willaert E., Martinez-Gomis J. Satisfaction with shortening the palatal extension of a mouthguard for water polo players: A randomized crossover study. Dent. Traumatol. 2019;35:135–141. doi: 10.1111/edt.12455.
23. D'Ercole S., Martinelli D., Tripodi D. Influence of sport mouthguard on the ecological factor of the children oral cavity. BMC Oral Health. 2014;14:97. doi: 10.1186/1472-6831-14-97.
24. Sousa AM, Pinho AC, Messias A, Piedade AP. Obecny stan w polimerowych ochraniaczach na zęby. Przyszły obszar dla produkcji addytywnej? Polimery . 2020; 12(7):1490. doi:10.3390/polym12071490
25. Schultz Martins R., Girouard P., Elliott E., Mekary S. Physiological responses of a jaw-repositioning custom-made mouthguard on airway and their effects on athletic performance. J. Strength Cond. Res. 2018 doi: 10.1519/JSC.0000000000002679.
26. Spicuzza L., Parisi G.F., Tardino L., Ciancio N., Nenna R., Midulla F., Leonardi S. Exhaled markers of antioxidant activity and oxidative stress in stable cystic fibrosis patients with moderate lung disease. J. Breath Res. 2018;12:026010. doi:10.1088/1752-7163/aa9b39.
27. Chiavaroli A., D'Ercole S., Fulco D., Ferrante C., Orlando G., Recinella L., Tripodi D. The use of customized mouthguards during the training produced protective effects on salivary factors of young athletes. EJPD. 2021 (in press)

28. Mummolo S., D'Ercole S., Marchetti E., Campanella V., Martinelli D., Marzo G., Tripodi D. Oral antiseptic and periodontitis: A clinical and microbiological study. Oral Health Dent. Manag. 2014;13:698–702.
29. D'Ercole S., Tieri M., Fulco D., Martinelli D., Tripodi D. The use of chlorhexidine in mouthguards. J. Biol. Regul. Homeost. Agents. 2017;31:487–493.
30. D'Ercole S., Tieri M., Martinelli D., Ciaravino C., Fulco D., Tripodi D. Microbial contamination and disinfection of sport mouthguard: In vitro study. Curr. Microbiol. 2020;77:246–253. doi: 10.1007/s00284-019-01834-1.
31. Tripodi D., Martinelli D., Ciaravino C., Fulco D., Tieri M., D'Ercole S. The use of casein in sport mouthguards: Microbiological and ecological variations in oral cavity. J. Biol. Regul. Homeost. Agents. 2018;32:1045–1049.
32. Hegde R.J., Thakkar J.B. Comparative evaluation of the effects of casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) and xylitol-containing chewing gum on salivary flow rate, pH and buffering capacity in children: An in vivo study. J. Indian Soc. Pedod. Prev. Dent. 2017;35:332–337. doi:10.4103/JISPPD.JISPPD_147_17.
33. Nagai K., Domon H., Oda M., Shirai T., Ohsumi T., Terao Y., Arai Y. Antimicrobial activity of ethylene-vinyl acetate containing bioactive filler against oral bacteria. Dent. Mater. J. 2017;36:784–790. doi: 10.4012/dmj.2016-321.
34. Yoshida Y., Churei H., Takeuchi Y., Wada T., Uo M., Izumi Y., Ueno T. Novel antibacterial mouthguard material manufactured using silver-nanoparticle-embedded ethylene-vinyl acetate copolymer masterbatch. Dent. Mater. J. 2018;37:437–444. doi: 10.4012/dmj.2017-226.