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Mouthguard Materials and Design Types: Narrative Review of Their Effectiveness in Sport-Related Dental Trauma Prevention

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ABSTRACT

Dental and/or orofacial trauma is a common problem in the lives of athletes, especially in contact sports. The purpose of this review is to compare and present different materials and types of mouthguards, focusing on their effectiveness in dental trauma prevention. A significant percentage of kids, teenagers, and adults suffer from various injuries. Mouthguards are equipment that can reduce the risk of orofacial injuries by 1.6–1.9 times. The review focused on three main types of mouthguard: stock, mouth-formed (boil-and-bite), and custom-made, as well as materials such as EVA and thermoplastic polyurethanes. Traditional thermoformed EVA remains one of the most commonly used materials thanks to its availability and satisfactory properties, although it does have its limitations. 3D printing offers an alternative to traditional manufacturing. Custom 3D-printed mouthguards demonstrate slightly better parameters discussed later in the article. Custom-made mouthguards provide the best level of protection and comfort, and additive manufacturing provides new possibilities for performance, individual fit, and cost-effectiveness.

Keywords: mouthguard, sports injury prevention, ethylene vinyl acetate, additive manufacturing, custom-made mouthguard, boil and bite mouthguard, thermoplastic elastomer.

1. INTRODUCTION

Dental and/or orofacial trauma is a common issue in athletes' lives. Orofacial trauma includes soft and hard tissues of the orofacial tissues such as teeth, bones, upper and lower lip, and mucosa lining the oral cavity (Fine, 2026). A report by the United States Surgeon General on oral health identified sports as one of the primary contributors to oral and craniofacial injuries. It says that these injuries lead to up to one-third of all sports-related injuries (Knapik et al., 2019). A distinction can be made between safer non-contact and contact sports, with the prevalence of dental trauma being 5.25% and 11.38% respectively (De Lima et al., 2024). The general rate of oro-facial injuries in sport is also described as "unacceptably high" (Fine, 2026).

The highest rate of dental injuries was observed in football (40%), followed by basketball (30%), hockey (15%), and other sports including gymnastics and swimming (15%) (Pandey et al., 2025). Retrospective reviews show that oral injuries caused by sports may affect up to 52% of children aged 11–13 years (Zaleckienė et al., 2020) and, in general, the most susceptible to sport-related dental injuries are kids between 7 and 11 years of age (Mojarad et al., 2020). Studies estimate that between 20% and 30% of all 18-year-olds have experienced injury to their teeth, and potentially one third of those could be severe enough to lead to permanent harm (Sigurdsson, 2013). At least one orofacial injury has been reported by up to 70% of athletes (Roberts, 2023). There is a connection between the incidence of dental injuries and use of a mouthguard (Fernandes et al., 2019).

Using protective mouthguards is recommended in a variety of sports as a precautionary measure to decrease the prevalence and acuteness of orofacial injuries. Studies show that when athletes do not wear any protective mouthguard, they are 1.6-1.9 times more prone to injury (Agarwal et al., 2025; Cao et al., 2023; Mojarad et al., 2020). Wearing a mouthguard can also create a separation between the base of the skull and the condylar head, which helps prevent forces of impact from the mandible from being transmitted to the base of the skull (Cao et al., 2023).

At present, the American Dental Association (ADA) advises wearing mouthguards in 29 various sports disciplines (De Queiroz et al., 2023; Knapik et al., 2007). Wearing mouthguards also has an influence on other parts of athletes' performance, such as breathing (Nasrollahzadeh et al., 2024), communication, and users' comfort (Agarwal et al., 2025). For instance, research has shown that forcefully clenching the jaw on a mouthguard can generate an ergogenic benefit, improving vertical jump ability. During vertical jump, deliberate contraction of the jaw muscles may help enhance the CAP of lower limb muscle power (Cao et al., 2023).

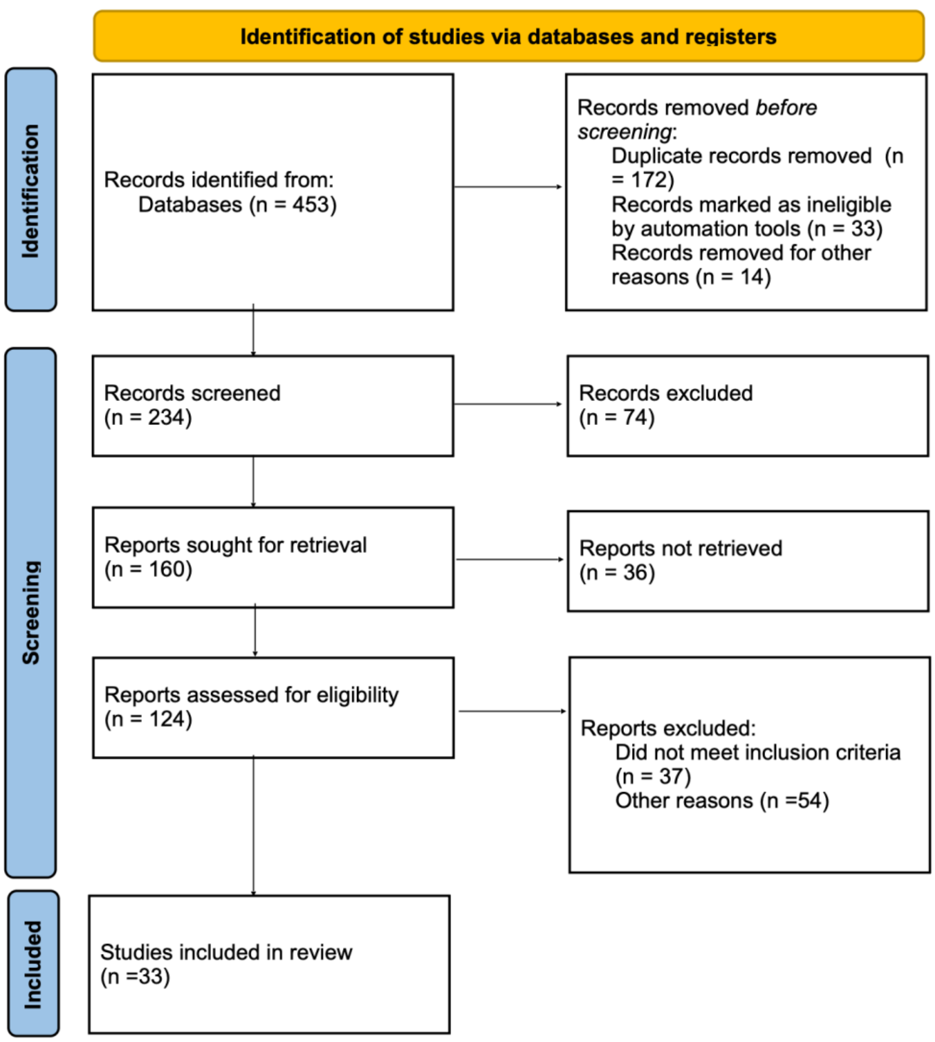

Figure 1. PRISMA 2020 flow diagram of study selection.

2. REVIEW METHODS

The study was carried out as a narrative literature review highlighting differences between materials used in the manufacturing of sports mouthguards. The selection of a narrative review was made because it allows comprehensive and flexible synthesis of existing literature regarding the effectiveness of dental mouthguards. This format is highly suitable for the review's topic due to broadening the literature and protective equipment development. This methodology provides a broader perspective on the topic, allowing the author to highlight practical aspects of dental injury prevention in sports and formulate appropriate recommendations.

A search of the literature started at the beginning of January 2026 and ended in February of the same year. To find articles on the topic, we searched for the following terms and words: mouthguard, sports injury prevention, ethylene vinyl acetate, additive manufacturing, custom-made mouthguard, boil-and-bite mouthguard, thermoplastic elastomer. Manual search included systematic reviews and meta-analyses that were previously identified. The list of articles has been reviewed. The following databases have been used: Scopus, Web of Science, PubMed/Medline, EBSCOhost, Google Scholar. A strict date for chosen publications was not imposed, but we chose the most accurate and up-to-date articles. English-language publications have been used. Exceptionally, only when it provided relevant additional insights, grey literature has been used, mainly regarding information about properties of materials or recent technologies.

Narrative synthesis and comparative approach were used, and results have been presented in the form of text. We have only used materials written in English. In order to be included, the studies had to include: evaluation or analysis of mechanical, physical, or clinical properties of materials used in manufacturing mouthguards; comparison of at least two different materials or structural designs; evaluation of protection provided in dental trauma prevention. Studies, editorials, and materials unrelated to protective qualities or characteristics of materials used in dental mouthguards have been excluded. Studies that we could not access as the full text were excluded. After screening and eligibility assessment, we included 33 studies in the article (Figure 1).

3. RESULTS AND DISCUSSION

To facilitate thorough and structured comparison between different materials used in the production of dental mouthguards, all obtained information was sorted according to the topic. The following data were extracted: material specifics, meaning chemical structure and the polymer it consists of (for example, previously mentioned EVA, polyurethane, thermoplastic elastomers, multilayer composites), what kind of method was used in production, such as custom-made, boil and bite, stock-made, or prefabricated. Other information described material properties derived from thickness, tensile strength, tear resistance, elongation at break, and Shore hardness. Discussed properties also regarded biomechanical performance, meaning force transmission and energy absorption capacity, which can be measured by drop weight tests or finite element analysis (FEA).

Research also involved clinical and functional aspects, which were general effectiveness in dental trauma prevention, comfort, influencing speech, breathing and ventilation, retention in the mouth during sports and stability, whether or not it interfered with occlusion and if it had any influence on general performance in sports. Practical and long-term factors were found such as general durability, wear and tear resistance, degradation over time, absorption, hygienic properties, maintenance and cleaning, and cost-to-effectiveness ratio. Researchers also considered study-specific details such as methods of testing, size of sample, followed standards (for example ISO), reported limitations, and conclusions of authors.

Types of mouthguards, properties comparison

According to the ADA, the types of mouthguards are as follows: Type 1 stock, Type 2 mouth-formed (Class 1 thermoplastic and Class 2 chemical Setting), Type 3 custom (Class 1 vacuum-formed, Class 2 model-formed) (Wang et al., 2025). Type 1 is U-shaped guards with a central groove that covers dentition, but it's not a direct negative of a user's dentition. They are usually over-the-counter, and they do not possess any retaining features; they are held only by force of biting (Roberts, 2023). Therefore, users must keep constant masticatory muscle tension to keep the mouthguard between the dental arches, which leads to muscular fatigue. Users also complain about noticeable discomfort while speaking and breathing (De Queiroz et al., 2023). Their protective properties are worse than custom-made mouthguards due to them being mechanically worse (Tribst et al., 2018). Usually, they are made from polyurethane, polyvinyl chloride, or a copolymer of vinyl acetate and ethylene and are available in standardized sizes as small, medium, or large (De Queiroz et al., 2023).

The Mouthformed type 2 mouthguards are manufactured from thermoplastic material that softens after being heated in hot water and then is formed in the athlete's mouth by pressure to adjust to individuals' dentition (Roberts, 2023). The main drawback of this forming method is its susceptibility to misfit and uneven thickness of the mouthguard caused by different pressure applied by fingers to form the mouthguard in the vestibular area. The thickness of material is closely linked to the user's forming technique, and reduction in thickness can reach 70-99%. Lack of control during the fitting can reduce protective properties. Another flaw is that the mouthguard may not cover all necessary areas due to finite size options, especially in the region of posterior teeth (De Queiroz et al., 2023). Type 3 dentally fitted mouthguards provide specific adaptation to patients' dentition; they cover teeth as well as soft tissues with proper thickness and extension in vestibular areas. They can also be customized to fit patients during orthodontic treatment with fixed orthodontic appliances (Parker et al., 2017). To produce custom-made mouthguards, athletes need to visit a dentist to take impressions of teeth or perform 3D scans and create a plaster or digital (Unkovskiy et al., 2021) model to precisely portray the athlete's intraoral structures, including last teeth in the arch, frenular attachments, palate, and complete vestibular extension. This technique provides a precise and efficient mouthguard that has an ergonomic shape. They are most often made from EVA material (Doğan et al., 2024).

Materials used in fabrication of mouthguards

It is widely known within the dental community that ethylene vinyl acetate (EVA) is the most used material for commercial and custom mouthguard fabrication. The popularity of EVA comes largely from its commercial availability, simple thermoformability, and balanced mechanical properties. EVA is a random copolymer with a high content of vinyl acetate (10–60%), which is produced in the process of radical ethylene polymerization by the high-pressure free process. Structural regularity, and crystallization are inversely related to vinyl acetate content (Petterson et al., 2020). Increasing the vinyl acetate content improves the flexibility of EVA foils, lowers stiffness and hardness (Knapik et al., 2019; Moreira et al., 2021) and causes higher damping capacity and enhances energy absorption (Moreira et al., 2021).

Manufacturers generally provide EVA sheets in the form of single, double, or multilayer blanks. This enables the use of industrially produced combinations of Shore hardness levels, allowing customization to match the specific risks associated with individual sports or field conditions. Using additional layers results in greater thickness and consequently lowers the overall comfort during wear (Schewe et al., 2022). Suitable physical properties allow absorption of impact and dissipation throughout the mouthguard, therefore lowering stress transmission on nearby anatomical structures. In addition, it is user-friendly, exhibits very low water absorption, and enables embedding of reinforcing layers within the mouthguard (De Queiroz et al., 2023). Few available studies regarding acrylic resins or polyvinyl chloride show that, in comparison with EVA and polyurethane, acrylic materials have higher shock absorption and water absorption, lower hardness, tear strength, and similar tensile strength. When compared with the same two materials, polyvinyl chloride has higher shock absorption and comparable hardness, tensile strength, and water absorption (Knapik et al., 2007).

3D printing

Additive manufacturing has shown significant growth potential that has influenced the creation of intelligent printed materials, called 3D-printed smart materials. These materials can respond and adapt to changing external conditions such as pH, humidity, and temperature through their shape memory effect. This development represents a major step forward in the field and creates new opportunities for further research in this area, paving the way for potential future clinical implementations (Hada et al., 2024). Additive manufacturing provides faster and simplified production (Dias Gonçalves et al., 2024). Ultimately, the digital process offers more precise ways to dampen force. Thanks to multi-material printing, various levels of hardness can be implemented at certain locations within the object. It is possible to integrate air inclusions with additive manufacturing and cross bracing, leading to enhanced structural shock absorption (Schewe et al., 2022).

In vitro research that compared shock absorption of 3D-printed custom mouthguards, thermoformed mouthguards made from EVA, and industrial mouthguards showed that the first mentioned show better shock absorption, are more resilient during repeated mechanical tests, and present the smallest thickness modification (Biqi and Xinyu, 2024). New semi-digital 4D-printed sports mouthguards can be produced by using the inherent Tg of TPU and TPE filament materials. 4D printing technology is simpler in comparison with complex traditional methods of manufacturing. It addresses the limitations of both conventional and 3D-printed mouthguards, for example, reduced fitting accuracy due to deformation, by utilizing shape memory material (Hada et al., 2024).

Compared with other types, a custom-made mouthguard reduces discomfort, allows better cardiopulmonary function, and improves speech capabilities (De Queiroz et al., 2023). Initially, improvement of energy absorption is directly proportional to an increase in thickness of a mouthguard. After reaching a thickness of 4mm, further thickening provides a smaller rise in energy absorption (Maeda et al., 2008). After taking the finite element impact analysis and user comfort into consideration, mouthguard thicknesses of 3–4 mm can be recommended for custom-fitted mouthguards (Verissimo et al., 2016). Studies show that if the only characteristic considered is satisfactory energy absorption, the minimum thickness should be 4mm; however, this is too thick in terms of players' comfort. This shows the need for improvement in impact absorption ability by either reconsidering new designs or developing new materials (Maeda et al., 2008). Thicker mouthguards also hurt athletic performance (Verissimo et al., 2016). Simplified comparison of information about three types of mouthguards is shown in Table 1.

Table 1. Simplified comparison of information about three types of mouthguards.

Type of mouthguard	Stock Mouthguards	Mouth-formed	Custom-made Mouthguards
Level of Protection	Low	Compromised	High
Retention / Adaptation	Low	Moderate	High
Comfort	Low (speech and breathing issues)	Moderate	High
Cost	Low	Low / Medium	High
Manufacturing	Ready-to-use	Self-adapted in hot water	Made by dentist (impressions or 3D scan)
Main Disadvantages	Poor fit, muscular fatigue	Uneven thickness, limited coverage	Higher cost, requires professional visit.

A systematic review showed that custom-made mouthguards caused the least disruption to speech, respiration, and dry mouth sensation compared with various mouthguard types (De Queiroz et al., 2023). Another study conducted by Ferreira et al. found reliable evidence that this type of mouthguard does not have a negative influence on athletes' performance (Ferreira et al., 2019). Some of the newest studies indicate that they can have a potential positive effect on athletic performance parameters (Avgerinos et al., 2025). A study shows that wearing custom-fit mouthguards by soccer players reduced concussion prevalence by 50% compared with soccer players wearing stock mouthguards (Petterson et al., 2020). Single-layered additively manufactured mouthguards are less durable; however, thanks to incorporating hard materials on occlusal surfaces, they provide effective shock absorption. Specific types of double-layer mouthguards exhibited superior retention forces under wet conditions in comparison to the average of all tested mouthguard samples (Li et al., 2024).

As previously said, there are three main categories of mouthguards. Stock mouthguards provide a low level of protection and demonstrate poor retention and adaptation. Pros are that they are the most affordable, but cons are that they can cause discomfort during speech and breathing and muscular fatigue due to the need to keep jaws in contact while wearing them. Mouth-formed offer better, moderate protection, but an uncontrolled fitting process negatively affects their protective capabilities. They are susceptible to misfit and uneven thickness. Custom-made provide the highest level of protection. They also fit the most precisely and are the easiest to adapt to; therefore, they have insignificant side effects. The presence of the aforementioned in the text depends on a proper fabrication process, which is also more expensive (De Queiroz et al., 2023).

Findings showed that inclusion of a less stiff intermediate layer (EVA_SOFT) offers a suitable option for custom mouthguard production, due to its superior displacement capacity. Materials that are thinner and more rigid, for example ERKOLOC, despite exhibiting high levels of elastic energy, were deemed unsuitable due to associated damage (Moreira et al., 2021). The authors conducted a comparison of physio-mechanical properties of filament materials available for additive manufacturing in the context of possible usage in fabrication of custom mouthguards. They evaluated the following: tensile strength, split Hopkinson pressure bar, drop-ball impact, abrasion resistance, absorption, and solubility tests. DSM Arnitel ID 2045 (highly flexible thermoplastic copolyester) turned out to be the best for a single-material custom mouthguard. In the drop-ball test, it transmitted the smallest force among the test materials, at 376.4 N; control samples of EVA transmitted 411.5 N. Despite showing lower abrasion resistance, its absorption and solubility values were statistically comparable to EVA, therefore being suitable for intra-oral use (Trzaskowski et al., 2025). The inclusion of soft damping layers, such as EVA foam in the FMG model, allows for greater deformation. Extending the contact time during impact allows energy to be dissipated over a larger area, which minimizes damage in specific locations (Messias et al., 2021). Material type as well as additive manufacturing parameters have a very big influence on the mechanical performance of a mouthguard (Dias Gonçalves et al., 2024).

Comparison of traditional and 3D-printed mouthguards shows that traditional mouthguards have a tendency to create single occlusal contact on the second molar. In contrast, 3D-printed mouthguards distribute biting forces more evenly and, because of that, provide better comfort and decreased stress concentration (Biqi and Xinyu, 2024). Evaluation based on XP S72-437 showed that custom 3D-printed mouthguards achieved slightly better shock absorption in comparison with thermoformed alternatives. Moreover, they successfully combine the practical benefits of traditional sports mouthguards with better protective performance and lower production costs (Arfi et al., 2024).

4. CONCLUSION

Currently, the best combination of retention, comfort, and protection seems to be offered by custom-made mouthguards, especially those produced using additive manufacturing. Despite their few flaws, traditional thermoformed EVA mouthguards remain the most used thanks to their satisfactory mechanical properties and availability. Newer materials such as selected photopolymer resins may replace or substitute EVA. Constructions that are multi-layered with soft damping layers improve energy dissipation and reduce localized damage. Additive manufacturing allows precise control of thickness and better adaptation for individual anatomy. Further long-term clinical studies need to be conducted in order to confirm the injury prevention effectiveness of 3D-printed mouthguards. Producing high-quality and cost-effective equipment for athletes is a field for further research.

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

Informed consent

Not applicable.

Ethical approval

Not applicable. This article does not contain any studies with human participants or animals performed by any of the authors.

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Conflict of interest

The authors declare that they have no conflicts of interest, competing financial interests or personal relationships that could have influenced the work reported in this paper.

Data and materials availability

All data associated with this study will be available based on the reasonable request to corresponding author.

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