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Design, Use, and Contemporary Technological Approaches of Mouthguards in Pediatric Athletes

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Abstract

Orofacial trauma is a common concern among pediatric athletes, particularly those participating in contact and high-impact sports. Due to their developing dentofacial structures, children are more vulnerable to injuries. Mouthguards are intraoral devices designed to absorb and disperse impact forces, playing a critical role in injury prevention. This review outlines the classification of mouthguards, fabrication techniques, and the process of personalized design. It also examines usage trends in children and highlights how awareness among parents and coaches influences adherence. Recent advancements in digital dentistry—especially CAD/CAM systems and 3D printing technologies—have enabled the production of custom-made mouthguards that provide superior fit, comfort, and protection. Studies suggest that individualized mouthguards improve compliance among pediatric athletes and significantly reduce the risk of orofacial trauma. Therefore, technological innovations, combined with increased stakeholder awareness, are believed to enhance the adoption and clinical success of effective protective mouthguards in pediatric sports dentistry.

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Introduction

Sports play an essential role in the physical, mental, and social development of children. However, contact sports, in particular, carry an increased risk of health complications, including orofacial injuries. These injuries are especially common in pediatric populations, whose craniofacial structures are still developing, making them more vulnerable to trauma. This highlights the significance of preventive approaches in pediatric dentistry (1).

Traumatic dental injuries affect nearly one billion individuals worldwide, representing a significant global public health concern (2). Orofacial injuries related to sports account for nearly one-third of all dental traumas, with studies reporting that approximately 52% of children aged 11–13 have experienced at least one oral injury during athletic activities (3,4). Such injuries may not only cause immediate dental damage but also lead to long-term complications, such as pulp necrosis and root resorption (5).

Mouthguards are intraoral appliances designed to absorb and distribute impact forces, thereby protecting the teeth, alveolar bone, soft tissues, and temporomandibular joint (6,7). They are also effective in reducing the risk of more severe outcomes, including mandibular fractures and concussions (8). The World Dental Federation (FDI) recommends the use of dentist-supervised, custom-fabricated mouthguards in all contact sports across all age groups (9).

Mouthguards are classified into three main categories based on fabrication techniques: stock, boil-and-bite, and custom-made models (10). Stock guards offer minimal retention and fit, while boil-and-bite guards can adapt better to individual dentition but are prone to user errors during molding (11). The highest level of protection is achieved with custom-made mouthguards, fabricated through either conventional impressions or digital intraoral scans (12).

Recent advancements in digital dentistry have revolutionized the fabrication of mouthguards.

CAD/CAM technologies and 3D printing now enable the rapid and precise production of custom mouthguards using biocompatible materials (13). These innovations are especially advantageous for children undergoing dentition changes, as they allow for easy adaptation and repeated fabrication over time.

This review aims to evaluate the classification, usage patterns, personalized design features, and current technological approaches related to mouthguard use in child athletes, in light of contemporary scientific literature.

Definition and Classification of Mouthguards

Mouthguards are flexible intraoral appliances designed to protect oral structures against traumatic injuries sustained during sports activities. Their role is particularly critical in pediatric athletes, whose maxillofacial and dental structures are not yet fully developed, rendering them more susceptible to orofacial trauma. By absorbing and dissipating impact forces, mouthguards help minimize damage to the teeth, alveolar bone, lips, and jaws, while also reducing the risk of severe complications such as mandibular fractures and concussions (13,14).

In the literature, mouthguards are generally categorized into three main types based on their fabrication technique, degree of customization, and fit: stock, boil-and-bite, and custom-made (15,16).

Stock mouthguards are industrially manufactured in standard sizes and require no individual fitting. Due to their poor retention and minimal adaptability, they are often uncomfortable, may hinder breathing and speech, and are typically not preferred by pediatric users (17).

Boil-and-bite mouthguards, on the other hand, are made from thermoplastic materials that soften when immersed in hot water. These devices are then adapted intraorally by the user to achieve a semi-personalized fit. Although more comfortable and retentive than stock models, improper molding during fitting can cause deformation and a reduction in protective efficiency (18,19).

The highest level of protection is offered by custom-made mouthguards, which are fabricated by dental professionals using traditional impressions or digital intraoral scanning techniques. With the advent of CAD/CAM technology and 3D printing, these mouthguards can now be produced with increased precision and speed. These modern methods also facilitate repeat fabrication and adjustment, which is particularly beneficial for pediatric patients undergoing active dental development (15,17,18).

The classification of mouthguards based on production methods reflects key differences in terms of comfort, adaptability, and overall protective capacity. The distinguishing features of each category are summarized below.

Table 1. Classification of Mouthguard Types (16-18)

Type of Mouthguard	Definition	Usage	Fabrication Method	User Adaptability
Stock	Pre-molded, non-customized devices with poor fit	Low-contact sports, temporary use	Mass industrial production	Low
Boil-and-Bite	Thermoplastic device molded intraorally by the user after heating	Recreational/amateur users	Thermoplastic, self-molded	Moderate
Custom-Made	Fully individualized design from impressions or scans	High-contact sports, orthodontic patients	CAD/CAM or lab-based production	High

Use of Mouthguards in Pediatric Athletes

The effectiveness of mouthguards in pediatric athletes depends not only on their technical design but also on behavioral and environmental factors (20). Although these appliances are highly efficient in preventing orofacial trauma, regular use among children remains limited (20, 21). This issue is particularly evident in non-contact sports, where the absence of mandatory regulations leads to negligence and significantly increases the risk of injury. In contrast, higher compliance is observed in contact sports such as boxing, taekwondo, hockey, and regionally prevalent sports like wrestling, where mouthguard use is often mandated by federations or coaching staff (22, 23).

The most commonly cited reasons for low compliance include discomfort, difficulty in breathing or speaking, and the perception of the mouthguard as a foreign object. These concerns are especially prominent in stock and boil-and-bite models due to their poor fit and adaptation. Custom-made mouthguards, fabricated using conventional impressions or digital scans, provide superior comfort and retention, encouraging voluntary and continuous use. However, in children with primary or mixed dentition, periodic remanufacturing may be necessary due to the ongoing development of their dentoalveolar structures (24,25).

Another key factor influencing mouthguard compliance is the level of awareness among parents and coaches. Literature indicates that many parents are unaware of the

protective benefits of mouthguards, and in some cases, are not even familiar with the concept itself (26). On the other hand, coach-led interventions significantly increase compliance, particularly in structured sports schools and clubs, where protective equipment use is actively promoted (26,27). Educational efforts directed at both caregivers and trainers—such as informational leaflets, workshops, and in-school programs—are crucial for promoting widespread and consistent usage.

Moreover, socio-environmental factors such as parental awareness and coach advocacy play a vital role in mouthguard usage among children. Several studies have shown that many parents are unaware of the protective benefits of mouthguards, and some are even unfamiliar with their existence (25). Conversely, structured educational efforts directed at parents have been effective in improving usage rates (26). Coaches, particularly in professional or semi-professional youth sports settings, also have a significant influence on reinforcing positive behavior regarding mouthguard compliance (27). Implementing awareness campaigns, distributing informational leaflets, or integrating mouthguard education into school-based health programs may foster long-term behavioral change. These community-based interventions are crucial to ensuring that children understand the importance of orofacial protection and that their caregivers support consistent usage (27,28).

In conclusion, the successful implementation of mouthguard use in pediatric sports is not solely a matter of technical adequacy. Sustainable compliance requires support through school-based programs, active involvement of dental professionals, and alignment with national oral health promotion policies (28).

The Design Process of Custom-Made Mouthguards in Pediatric Athletes

The effectiveness of a mouthguard largely depends on its ability to fit precisely to the individual's oral structures. This is particularly crucial in pediatric athletes, whose craniofacial anatomy continues to develop during growth. Anatomical variability and dynamic dentition necessitate the use of personalized protective devices to ensure both safety and comfort. As a result, custom-made mouthguards are considered the most effective option in terms of both protection and ergonomic adaptation in children (29).

There are generally two primary fabrication methods for custom-made mouthguards: traditional impression techniques using physical molds and digital workflows that incorporate intraoral scanning. In the conventional approach, a physical impression is taken from the child's dentition and cast into a stone model. Thermoplastic sheets are then formed over this model in the dental laboratory. While effective, this method can be uncomfortable and technically demanding in pediatric patients due to limited cooperation and anatomical sensitivity (30).

With the evolution of digital dentistry, intraoral scanners have provided a more efficient and comfortable alternative. These scanners allow for rapid, accurate acquisition of dental arch data, eliminating the discomfort of conventional impressions. CAD/CAM systems are used to design mouthguards digitally, which are then manufactured through milling or 3D printing techniques. One of the major advantages of digital production is the ability to store patient data for future fabrication, enabling reusability and time-efficiency in rapidly changing pediatric dentitions (13,14,18).

In designing a custom mouthguard, factors beyond dentition must be considered, including occlusal relationships, temporomandibular joint (TMJ) health, and sport-specific trauma risks. In high-contact sports such as wrestling, rugby, and taekwondo, greater thickness, flexible materials, and vestibular extension are required for optimal protection. This level of personalization maximizes both safety and compliance (18,19).

Ergonomically tailored mouthguards reduce interference with speaking, breathing, and swallowing. Their superior fit promotes voluntary use by children during training and matches. Consequently, custom-made mouthguards not only enhance physical protection but also improve long-term compliance and injury prevention (7).

Clinical Approaches in the Application of Mouthguards in Pediatric Dentistry

The clinical applicability of mouthguards in pediatric patients is influenced not only by their technical performance but also by the child's comfort, adaptation period, and the quality of communication between dentist, child, and parents Children's reactions to mouthguard use may vary significantly depending on the type of guard prescribed and the frequency of its use, necessitating an individualized clinical strategy (31).

Pediatric dentists must consider factors such as the child's age, dentition stage, and the nature of their sports activity when selecting a mouthguard. Especially during the primary or mixed dentition periods, frequent anatomical changes in the dental arch may require periodic remanufacturing of custom-made mouthguards. Clinical observations suggest that when this adaptation process is managed effectively, long-term compliance with mouthguard use improves (30,32).

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Parental involvement also plays a vital role in the clinical success of mouthguard implementation. Studies show that children whose parents are educated about the benefits of mouthguard use are more likely to use them consistently. It is essential that dentists emphasize not only the protective value of the device but also allow trial fittings with the child during appointments to increase familiarity and comfort (32).

The success of clinical adaptation depends significantly on the child's psychological readiness and the clinician's communication skills. At the initial stages, children may perceive the device as uncomfortable or unnecessary. Therefore, it is advisable to introduce the device in a playful and explanatory manner, ensuring that its purpose and benefits are clearly conveyed. The first usage should be brief and positive to support the adaptation phase (33,34).

In conclusion, the clinical implementation of mouthguards in pediatric patients should be addressed through a multidisciplinary and holistic lens. It involves not only the technical specifications of the appliance but also the biological and psychological traits of the child, as well as the educational and motivational support provided by both parents and healthcare professionals (34).

Future Perspectives

The use of mouthguards in pediatric athletes presents an effective, practical, and evidence-based approach to preventing dental trauma. Thanks to evolving manufacturing techniques and material options, mouthguards can now be tailored to different age groups and types of sports. High levels of individual adaptation improve both comfort and protection, but clinical success also relies on user compliance, as well as awareness among parents and coaches (35).

Recent advances in digital dentistry have led to a paradigm shift in the fabrication of mouthguards. With the integration of CAD/CAM systems, 3D printing technology, and biocompatible materials, highly accurate and personalized appliances can now be produced more rapidly. This technological evolution supports easier adaptation by pediatric patients, especially during phases of transitional dentition (36,37).

Emerging technologies such as sensor-embedded "smart mouthguards" offer the potential for real-time monitoring of impact forces and trauma-related metrics. These systems can support post-injury assessment and help guide clinical decision-making processes. Additionally, the incorporation of artificial intelligence into digital planning workflows may lead to adaptive protocols that propose design modifications based on the athlete's age, dental development stage, and the specific risks associated with their sport (38).

While technological progress continues to evolve, a more widespread and structured approach to mouthguard education and promotion is still needed. School-based oral health initiatives, collaborative involvement from dental professionals, and enhanced training for sports educators can collectively foster consistent mouthguard usage. Integrating these practices into broader preventive health strategies remains a key priority for reducing orofacial trauma among young athletes (39,40).

Conclusion

Mouthguards are an effective method for preventing dental trauma in child athletes. Among the three main types (stock, boil-and-bite, and custom-made) custom designs are preferred for their superior fit and protection. Clinical decisions should consider the child's age, dental stage, and readiness, with support from parents and coaches. The integration of technological innovations with increased awareness among parents and coaches plays a crucial role in ensuring the successful and widespread adoption of mouthguard use. These factors together support mouthguards as an essential part of preventive care in pediatric sports dentistry.

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