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Improving Injury Prevention in Sports in the Jaw and Maxillary Area: A Comprehensive Overview of Mouthguards and Their Effectiveness

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ABSTRACT

Mouthguards, also referred to as mouth protectors or intraoral protective devices, are designed to safeguard teeth and surrounding soft tissues from injury during sports activities. Typically made from materials such as EVA, acrylics, silicone, and polyurethane, mouthguards play a vital role in preventing dental trauma, including tooth fractures, luxation, soft tissue damage, and jaw injuries. Custom-made variants, particularly those created through digital workflows and 3D printing, offer improved comfort, occlusal fit, and protective efficiency, with ongoing advancements promising further enhancements through biocompatible, rubber-like materials. Proper occlusal adjustment, such as flat grinding, enhances contact and comfort, contributing to better user compliance. Research suggests custom mouthguards not only offer superior protection compared to over-the-counter options but may also positively influence athletic performance, including balance and muscle activation through mechanisms like concurrent activation potentiation. Despite their benefits, cost and accessibility remain barriers to widespread use. Thus, custom-made mouthguards are strongly recommended for athletes engaged in high-impact sports to ensure optimal protection and performance support.

MATERIALS AND METHODS

The article was written using sources from the PubMed and ResearchGate databases. The literature review was conducted based on the following keywords: mouthguards, maxillofacial injuries, dental trauma prevention, 3D printed mouthguards.

KEY WORDS: mouthguards, maxillofacial injuries, dental trauma prevention, 3D printed mouthguards,

INTRODUCTION

Engaging in sports offers numerous health benefits but also carries the risk of injuries, particularly to the orofacial region. In particular, the group of high-risk sports includes boxing, American football, rugby and field hockey. To help prevent such injuries, mouthguards have been implemented. A mouth protector - also known as a mouthguard or intraoral protection -

is a medical device designed to shield the teeth and nearby soft tissues, such as the gums, lips, and jaws, helping to prevent or lessen injuries in these areas (1). Mouthguards have played a crucial role in sports safety since their inception in the late 19th century, with boxing being the first sport to adopt them. Early versions were makeshift, using materials like cotton, tape, and wood to provide basic protection. The 1930s saw significant advancements with the introduction of custom-made mouthguards, improving comfort and shock absorption. Rugby soon followed, and by the 1960s, the American Dental Association (ADA) endorsed mouthguards for contact sports, now recommending them for 30 high-risk activities. Over time, mouthguard materials and designs have evolved, incorporating advanced polymers such as ethylene-vinyl acetate (EVA) and silicone to optimize fit, comfort, and protection. Continuous innovation in mouthguard technology underscores the importance of dental safety in sports and its impact on athletic performance (2).

IMPORTANCE OF PROTECTION

Protecting teeth in certain sports is extremely important. It should not be overlooked, especially when engaging in sports with an increased risk of injury. Losing a tooth can lead to permanent dysfunction of the stomatognathic system and cause significant psychological distress due to aesthetic issues. Young people should be given special attention. Dental trauma in children poses a considerable concern, impacting not only the young individuals but also their parents or guardians. While both boys and girls are susceptible to such injuries, adolescent girls often report a more pronounced decline in oral health-related quality of life. The extent of these injuries significantly affects the emotional and social well-being of the children and their families (3). Unlike other types of injuries, a single traumatic dental injury may never fully heal and can lead to ongoing, costly issues throughout one's life (4). Therefore, prevention is paramount. The table below presents a list of example sports for which the use of mouthguards is recommended. Among athletes involved in various contact sports, the overall occurrence of dentofacial injuries was around 30%, with dental trauma being the most frequently reported type of injury (5).

Tab 1. Sports with the highest incidence of dental injuries.(6).

SPORT	Incidence of Dental Injuries	Importance of Protection	Mouthguards as Preventive Measure
Boxing	Very high;	Constant facial impacts make mouth protection essential.	First sport to use mouthguards; early versions included gutta percha. Modern custom-fitted mouthguards effectively reduce oral injuries.
Football (US)	High - historically 23–54% of all injuries were dental; widespread before mouthguards were mandated.	High collision frequency and intensity make dental injuries common.	Mouthguards mandatory since 1962 in US high schools and 1973 in college. Significantly reduced dental trauma.
Ice Hockey	High; frequent high-speed puck and stick contact with face.	Fast-paced nature and hard projectiles necessitate strong facial protection.	Some organizations mandates mouthguards; shown to reduce incidence of oral trauma, although enforcement is sometimes inconsistent.
Lacrosse	High, especially due to body and stick contact.	Contact with sticks and opponents during aggressive play heightens risk.	Some organizations requires mouthguards.
Field Hockey	High, due to fast-moving ball and	Hard balls and sticks can cause severe oral	Mandated. Mouthguards protect

	sticks.	injuries.	against direct impacts from balls/sticks.
Rugby	High; mandated in New Zealand for all levels.	Physical contact and tackles increase injury potential.	Custom-fitted mouthguards required; studies show significant injury reduction.
Martial Arts	High due to repeated direct facial impacts.	Direct strikes to head and jaw common.	Strongly recommended. Use of laminated mouthguards with varying stiffness improves shock absorption.
Basketball	Moderate to high; often overlooked but facial collisions are frequent.	Although not typically a contact sport, incidental elbow and ball contact can cause injuries.	Not mandatory, but recommended by ADA. Custom-fitted guards reduce injuries while allowing clear speech.
Wrestling	Moderate; potential for contact with mat or opponent.	Falls or direct pressure can cause dental trauma.	Recommended. Custom mouthguards reduce risk, though not mandated in most competitions.
Baseball/Softball	Moderate; mainly from ball impact or collisions.	Risk from line drives or accidental contact.	Not mandated, but ADA recommends use. Custom-fitted mouthguards especially helpful for infielders.

MOUTHGUARDS TYPES AND PRODUCTION METHODS

We can distinguish three types of mouthguards:

- Type I (Stock Mouthguard)
- Type II (Mouth-Formed, Boil-and-Bite)

- Type III (Custom-Made)

Their exact specifications are presented in the table below.

Tab 2. Types of Mouthguards (2)(7).

Type	Description	Comfort	Protection Level	Common Use	Disadvantage	Cost
Type I (Stock Mouthguard)	Pre-formed and ready to wear available in standard sizes.	Poor fit; can be bulky and uncomfortable	Basic protection, may not absorb impact well	Recommended only when other types are not available	Bulky, may not fit well, can impede breathing and speech.	Low
Type II (Mouth-Formed, Boil-and-Bite)	Made of thermoplastic material that softens in hot water and molds to teeth when bitten.	Better fit than stock mouthguards but less precise than custom-made	Moderate protection, depends on fit and thickness	Common among athletes in contact sports	Can be inconsistent in fit, may not provide optimal protection.	Moderate
Type III (Custom-Made)	Made by a dental professional from an impression of the teeth	Best fit and most comfortable	Offers the highest level of protection	Used by professional athletes and individuals requiring precise dental protection	Most expensive option, requires a visit to a dentist	High

There is a wide range of mouthguards currently available, including commercial models, semi-custom options, and fully individualized custom-made devices. The material, shape, and thickness are key factors influencing the shock-absorbing ability of mouthguards (8). The primary materials used include EVA, methyl methacrylate acrylic, acrylic resin, latex, polyurethane, polyvinyl chloride, and silicone. At present, EVA is the most commonly used material in the construction of type II and type III mouthguards (1)(9). In professional sports,

custom-made (Type III) thermoformed mouthguards are preferred due to their superior retention, comfort, and support for the dentoalveolar structures. Although they may not adhere strictly to certain specifications, their effectiveness in providing protection makes them the recommended choice for contact and combat sports. Dentists play a crucial role in the adaptation, retention, and occlusal indentation of these mouthguards, ensuring optimal fit and function. They are also responsible for educating athletes on the importance of mouthguard use and advising on appropriate actions in case of trauma or damage to the mouthguard (1).

However, the semi-custom versions, often made from thermoplastic materials, are shaped in the mouth using the boil-and-bite method and are the most commonly used. Thermoforming is a common method used to produce mouthguards, where thermoplastic materials like poly(vinyl acetate-ethylene) copolymer or polyurethane are heated until pliable, then shaped over a dental cast using vacuum pressure. Laminated thermoplastic - composed of soft inner and hard outer layers - showed least dimensional change in all test areas. It offers the best long-term performance and protection under stress in this group (10). Moreover laminated thermoplastics showed the highest level of durability and effectiveness, maintaining their form more reliably and offering steadier protection. This makes them particularly well-suited for extended use in contact sports, where athlete safety and proper jaw alignment are essential. Thermoforming allows the mouthguard to accurately adapt to the contours of the upper dental arch, ensuring a snug and secure fit. Once molded, the material is cooled to preserve its form, resulting in a mouthguard that offers reliable protection during athletic activities (10). Nevertheless, their fit and protective effectiveness can be unreliable. In contrast, as mentioned earlier, custom-made mouthguards have been shown to offer better shock absorption and a more accurate fit, resulting in greater comfort during use (7). It is proposed that mouthguards made with multiple laminated layers, or those containing a multi-laminated insert, could provide enhanced protection by minimizing the impact forces transferred to the wearer during contact sports (11)(12).

Ongoing research aims to develop a custom multi-material mouthguard using a fully digital workflow, beginning with intraoral scanning. This highlights the necessity for continued advancements in hardware technology. The digital workflow for creating MGs has been found to offer advantages over the traditional method (13). The approach holds significant potential, particularly once a new soft, biocompatible, rubber-like material becomes available for simultaneous multi-material 3D printing (11). So far, evidence supporting the superior shock absorption of 3D-printed mouthguards has only been demonstrated through in vitro experiments (14). More clinical trials are essential to evaluate their protective effectiveness.

The advancement of new 3D printing resins may help increase the widespread use of custom-made 3D mouthguards(15). In fact, the low manufacturing costs and ease of design and production support the growth of this protective tool, especially among young individuals who require frequent replacements due to growth. Additional research is necessary to examine the impact of storage conditions and biofilm buildup between uses, as well as their potential effects on mechanical performance over time.

Moreover, it is important for a mouthguard to be properly adjusted to the occlusion. A study was conducted to examine the effect of two types of occlusal accommodation on arch separation in centric and eccentric positions, as well as to assess opposing tooth contacts in professionally made, thermoformed sports mouthguards. The study found that non-accommodated mouthguards increased the vertical occlusal dimension, corresponding to the full thickness of the material used. In contrast, only mouthguards adjusted by grinding maintained high levels of occlusal contact across all tested arch relationships. The flat grinding modification reduced arch separation during eccentric movements and improved opposing tooth contacts, which may enhance comfort, user compliance, and the protective function of custom-made mouthguards, potentially reducing injuries to teeth, arches, and soft tissues (19).

Maintaining proper hygiene and regularly replacing the mouthguard when it shows signs of wear is crucial. Repeated impacts can cause degradation, so athletes should replace mouthguards that are damaged, torn, perforated, cracked, shredded, or locally crushed, as these conditions reduce their protective effectiveness (16)(17).

ROLE AND EFFECTIVENESS OF MOUTHGUARDS

According to the study mouthguards reduce the risk of orofacial sports injury by approximately 39% to 47%. This is derived from the reported 1.6 to 1.9 times higher risk of orofacial injury when a mouthguard is not worn compared to when it is worn (6). It should not be forgotten that in order for the mouthguard to fully fulfil its functions, several requirements must be met. To ensure adequate retention, a mouthguard should be properly fitted to the wearer’s mouth and oral structures, made from FDA - approved resilient material, and cover all remaining teeth on one arch, typically the maxillary. It should remain comfortably and securely in place, be physiologically compatible with the wearer, and be easy to clean (20).

Mouthguards help prevent or reduce the severity of the following injuries: fractured or dislocated teeth, tooth luxation (loosening or displacement), soft tissue injuries (lacerations, bruises to the lips, cheeks, tongue), mandibular fractures (by absorbing and redistributing

shock or stabilizing the jaw), head acceleration and tooth acceleration during impacts (which reduces transmitted force), mandibular deformation, dental injuries may include also pulpal necrosis, intradental resorption (6) While mouthguards significantly lower the risk of dental injuries in sports, their usage - particularly among young athletes - likely depends on the quality of coaching and guidance provided. Given that over one in eight young athletes still experience sports-related dental trauma, it is evident that additional preventive measures are necessary to further reduce the occurrence of these injuries (18).

Additionally, studies have been conducted with rather surprising results. It is well known that, aside from strength, flexibility - which describes the range of motion in an athlete's joints—is particularly important in many disciplines that require significant body extension, such as gymnastics or dance. However, it is no less important in other sports as well. These factors are crucial for athletes to react quickly, maintain stability, and adapt physically in fast-paced competitive settings. Certain studies have examined how customized mouthguards impact body posture and balance in professional basketball players, revealing that such mouthguards can enhance balance performance. (21)(22). Another study results suggest that jaw clenching triggers concurrent activation potentiation during a countermovement jump. Consequently, athletes might use the tactic of forcefully clenching their jaws to enhance performance and gain an ergogenic benefit during the jump. It was observed that athletes using custom-made mouthguards achieved better vertical jump height and a faster rate of force development, possibly due to increased muscle activation linked to the concurrent activation potentiation effect (23)(24). Studies have shown that jaw repositioning methods may enhance athletic performance by improving posture and spinal alignment. However, store-bought jaw repositioning mouthguards did not significantly affect agility, balance, or flexibility in college-aged male athletes (25). It should be noted that the impact of mouthguards on athletic performance depends on how familiar the athlete is with wearing them; the athlete needs time to get used to the mouthguard (21).

CONCLUSION

Dental injuries are a prevalent concern in many sports, particularly those involving direct or indirect contact, such as boxing, rugby, basketball, and soccer. The adoption of mouthguards has been instrumental in mitigating the risk of such injuries. Among the available options, custom-made (Type III) mouthguards have demonstrated superior comfort, fit, and protective capabilities compared to standard (Type I) and mouth-formed (Type II) varieties. Advancements in materials and manufacturing techniques, including the use of ethylene-vinyl acetate (EVA) and 3D printing technologies, have further enhanced the effectiveness of these

protective devices. Studies indicate that custom-made mouthguards provide optimal shock absorption and maintain their structural integrity better under impact conditions. Therefore, it is recommended that athletes, particularly those participating in high-risk sports, utilize custom-made mouthguards to ensure maximum dental protection. In summary, mouthguards not only protect the teeth but also generally support motor abilities. Continuous development and further research are essential to create increasingly better mouthguards that allow athletes to maintain their health and well-being in comfort while training their favourite sport, providing maximum protection against injuries to the facial region.

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The authors used ChatGPT to improve language and readability, after which the content was reviewed and edited. The authors accept full responsibility for the publication's substantive content.

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