Preventive and Protective Role of Sports Occlusal Splints

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PREVENTIVE AND PROTECTIVE ROLE OF SPORTS OCCLUSAL SPLINTS

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Dedication

“Read! In the Name of your Lord, who has created all that exists.
Has created man from a piece of thick coagulated blood.
Read! And your Lord is the Most Generous, who hast taught by the pen.
Has Taught man that which he knew not.“ Quran (96:1-5-)

Without the invaluable help, guidance, and support of my esteemed Professor Pelivan, it would have been impossible for me to complete this work. I sincerely thank you for everything!

I would like to extend my gratitude to all my professors who have guided me throughout my academic journey. Each one of you has provided me with a piece of the puzzle, which I hope will never be completed, as we all strive for excellence in our profession.

I am grateful to my parents and siblings for their unwavering support throughout my academic journey. Without their help and unshakable faith in me, I would not have been able to make the moves I did. I would also like to extend my thanks to my friends who started out as colleagues and ended up being lifelong friends: Mohsen, Pia, Sanja, and Sara. Each of you played a significant role in this journey, and I will always treasure the memories we shared.

Thanks to my Amcas who never made me feel absent since 2017.
Last but not least, thanks to Naz!

Preventive and protective role of sports occlusal splints

Summary

The utilization and application of mouthguards have become an indispensable tool in sports in recent years. The primary objective of mouthguards is to safeguard the orofacial region, particularly the hard and soft tissues of the mouth. The purpose of mouthguards is to shield athletes from jaw and teeth fractures.

Several studies have investigated the significant cushioning role of mouthguards and their capacity to reduce the incidence of teeth and jaw fractures. The preventive and protective properties of mouthguards have been the focus of extensive research in recent years.

The use of digital technologies in the manufacturing of mouthguards is another crucial factor to consider. Traditional mouthguards involved several steps, such as taking impressions with alginate. However, with the advent of intraoral scanners, these steps can now be bypassed to achieve a precise and optimal fit for the athlete. This customized fitting and optimal retention lead to better usage of the mouthguards by athletes.

The following thesis aims to analyse the various types of mouthguards, the different fabrication methods, and their protective and preventive role against injuries to gain a better understanding of the current research on mouthguards.

Keywords: Mouthguards; scanner; protection; occlusal splints

Preventivna i zaštitna uloga sportskih štitnika za zube

Sažetak

Korištenje i primjena štitnika za zube posljednjih je godina postalo nezaobilazno sredstvo u sportu. Primarni cilj štitnika za zube je zaštita orofacijalne regije, posebno tvrdih i mekih tkiva usta. Svrha štitnika za zube je zaštititi sportaše od loma čeljusti i zuba.

Nekoliko je studija istraživalo značajnu ulogu amortizacijskih svojstava štitnika za zube i njihovu sposobnost da smanje učestalost prijeloma zuba i čeljusti. Preventivna i zaštitna svojstva štitnika za zube bila su u središtu opsežnih istraživanja posljednjih godina.

Upotreba digitalnih tehnologija u proizvodnji štitnika za zube još je jedan ključni čimbenik koji treba uzeti u obzir. Tradicionalni štitnici za zube uključivali su nekoliko koraka, poput uzimanja otisaka alginatom. Međutim, s pojavom intraoralnih skenera, ti se koraci sada mogu zaobići kako bi se postiglo precizno i optimalno pristajanje za sportaše. Ova individualna preciznost dosjeda i optimalna retencija dovode do boljeg korištenja štitnika za zube od strane sportaša.

Ovaj diplomski rad ima za cilj analizirati različite vrste štitnika za zube, različite metode izrade te njihovu zaštitnu i preventivnu ulogu kod ozljeda kako bi se bolje razumjelo trenutna istraživanja štitnika za usta.

Ključne riječi: štitnici za zube; skener, zaštita; okluzijske udlage; udlage

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ADA – American Dental Association

EVA – Ethylene vinyl acetate

CAD – Computer-aided design

CAM – Computer-assisted manufacturing

SMP – Shape memory polymer

SME – Shape memory effect

STL – Standard Tessellation Language

1. INTRODUCTION

Mouthguards have long been recognized as a protective and preventive measure in sports, particularly in contact sports. Recently, there has been a surge of interest in using mouthguards due to their proven benefits, including the reduction of oral injuries such as fractured teeth and jaw fractures. Advancements in materials and design have led to more comfortable and effective mouthguards. Mouthguards can also protect against soft tissue injuries such as lacerations and bruises, which are common in contact sports. Furthermore, mouthguards can prevent knocking-out of teeth, which is a common occurrence in contact sports.

In addition to protecting against oral injuries, mouthguards can also prevent concussions, which makes them a vital piece of safety gear for athletes participating in high-impact sports. There are various types of mouthguards available, such as boil-and-bite and digital custom-made mouthguards, which allow athletes to protect their teeth and mouth in a more effective and personalized manner than ever before. These advancements in mouthguard technology have resulted in more comfortable and effective mouthguards, making them an essential piece of equipment for athletes participating in contact sports.

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This thesis constitutes a comprehensive examination of the current scientific understanding and pertinent data regarding the manufacture, deployment, and benefits of mouthguards. It aims to elucidate the preventive and protective properties of mouthguards and their application, thereby enabling the uninformed reader to gain a grasp of the pertinent information.

2. MOUTHGUARDS

Mouthguards were first developed over a hundred years ago. Given the growing popularity of various sports, such as boxing, mixed martial arts, American football, and rugby, it is crucial to gain a deeper comprehension of mouthguards as a safeguarding concept. In many sports, such as the ones mentioned, it is nowadays mandatory for athletes to wear mouthguards (1).

Participating in contact sports increases the likelihood of sustaining traumatic injuries, with an estimated range of 10-39% of all dental injuries in children (2). This includes accidents such as road and home accidents, as well as fights. Contact sports involve physical interaction between athletes or teams for the purpose of winning, and athletes in these sports are at a higher risk for orofacial injuries, with dental injuries being the leading cause (2).

Nowadays the American Dental Association (ADA) directs that mouthguards have to be properly fitted for maximum effectiveness (1).

The design of mouthguards has evolved significantly with the advancement of materials technology and research over the past century. The aim is to achieve optimal protection for both soft and hard tissues of the mouth. An effective mouthguard design provides protection against impacts from large external objects, such as martial arts gloves, as well as smaller and harder objects like baseballs (1).

A mouthguard operates by absorbing energy and distributing the impact stress across the entire orofacial complex, thereby minimizing the impact on hard and soft tissues. For instance, if a particular tooth is struck by an impact, it would cause the crown to bend with the palatal enamel under tension and the buccal enamel compressed. With a mouthguard, however, this dangerous situation of fracture can be prevented (1).

Throughout the last century it was mostly believed that mouthguards could reduce concussions. By reduction of impact on the skull, with the help of bite opening and separation of condylar head and glenoid fossa, mouthguards were thought to help. In the last years however, it has been researched and concluded that there is at the moment no science-based evidence for a statement saying mouthguards could prevent concussions (2).

Mouthguards are commonly constructed with thermoplastic material, most notably ethylene vinyl acetate (EVA), due to its malleability and elasticity during the production process. Although some individuals may experience allergic reactions to EVA, like any other material used in the mouth, no adverse reactions have been reported thus far (2).

2.1. Types of mouthguards

Nowadays we distinguish between three main types of mouthguards (2):

1. Pre-fabricated mouthguards

2. Mouth-formed mouthguards

3. Custom-made mouthguards

2.1.1. Pre-fabricated mouthguards

Pre-fabricated mouthguards are manufactured commercially and are not custom-fitted for individual use. They are produced in a variety of shapes and sizes, allowing patients to select the most appropriate one for their needs. Typically, they are the least expensive option of mouthguards and can be purchased online or over the counter at sports stores (2).

Majority of pre-fabricated mouthguards are made from polyvinyl acetate polyethylene copolymer, being in this case also as mentioned the cheapest option (1).

Many athletes and novices in contact sports opt for pre-made mouthguards due to their accessibility. However, these mouthguards may not provide optimal protection for the orofacial complex (1).

Pre-fabricated items possess the capability to interact with an individual's breathing and speech capacities. Unfortunately, these items often lack sufficient retentive properties, which may result in their becoming lodged within the airway (1).

We can also divide pre-fabricated mouthguards into three types:

- Single jaw
- Bimaxillary
- Orthoguard (2).

Single jaw mouthguards are typically crafted for either the upper or lower jaw, with the upper

jaw being the more common choice, as the teeth in the upper jaw are more prone to sustaining trauma (2).

Bimaxillary mouthguards, which cover both the upper and the lower jaws and are connected as a single appliance, differ from single jaw mouthguards. These mouthguards serve as a connector between the two jaws and protect both the upper and the lower teeth. However, their size can make them more cumbersome, and athletes may find them challenging to wear. Additionally, the mouthguards' bulk could impact an athlete's speaking abilities (2).

In recent years, Orthoguards have been developed as mouthguards specifically designed to protect the jaws of athletes undergoing orthodontic treatments. Athletes with fixed orthodontic appliances have traditionally faced difficulties with mouthguards, necessitating the development of Orthoguards. It is important to note that Orthoguards require regular monitoring and replacement in accordance with the treatment plans devised by orthodontists (2).

2.1.2. Mouth-formed mouthguards

Mouth-formed mouthguards are also referred to as "boil and bite" mouthguards. These are made from thermoplastic material, which becomes soft and easily mouldable when heated. To use, the mouthguard is placed in hot water according to the manufacturer's guidelines until it becomes soft and mouldable. It is then placed under cold water for five seconds to prevent burning, and then placed in the athlete's mouth to form the teeth, occlusion, and soft tissues. By applying pressure on the mouthguard, the retention becomes better. Finally, it is placed in cold water for over a minute to become firm (2).

2.1.3. Custom-made mouthguards

Custom-made mouthguards are a considerably more intricate process than either pre-fabricated mouthguards or mouth-formed mouthguards, which have been discussed previously (2).

Due to a better protection, retention and comfort for the athlete, custom-made mouthguards are considered to be the gold standard in mouthguards (1). Research indicates that the dimensions, comfort, and size of mouthguards have a direct impact on athletic performance. Oversized mouthguards that impede respiratory function can negatively affect performance (3).

These mouthguards are highly recommended for individuals with impacted canines, as they are at a high risk of trauma from tooth impaction. By wearing custom-made mouthguards, the increased compressive stress on the cortical bones caused by the impaction can be alleviated (1).

Patients who have received dental implants must also be provided with custom-fabricated mouthguards in order to minimize the likelihood of bone fractures. A traumatic impact following the osseointegration of the implant could lead to severe fractures (1).

Table 1. Comparison of advantages and disadvantages of mouthguards (1)

Mouthguard Type	**Advantages**	**Disadvantages**
Pre-formed	Cheap Easy to purchase	Athlete must bite always Can be irritating for TMJ Poor fitting Irritations regarding speech and respiratory tract Not the best thickness for athletes needs
Mouth-formed (Boil and bite)	Easy to purchase Easy to use Good entry level	Not perfect fitting Thickness cannot be adjusted to the needs Can lack in protection due to not optimal fitting
Custom-made	Best fitting Best protection Less irritating Less breathing problems Can be optimally adjusted to the athletes' needs	Price In the traditional way needs impression, which can cause irritation due to gagging Not the quickest option for a novice who wants to start the same day

2.2. Fabrication of mouthguards

Two main methods for constructing custom-made mouthguards exist, varying based on the dental professional involved. Dental literature typically discusses variations of the vacuum forming and heat-pressure techniques for creating mouthguards (4).

Due to the existence of various techniques with their unique benefits, there is currently no clinical evidence that demonstrates the superiority of one method over another. While mouthguards are manufactured and produced differently in each approach, no in vivo advantages have been proven (4).

In contemporary times, there has been a significant evolution in the establishment and implementation of digital systems in the field of dentistry. It is evident that this trend will continue to influence the fabrication of mouthguards. We will also examine these developments in our analysis (5).

2.2.1. Vacuum-formed mouthguard technique

The vacuum-formed mouthguard method involves utilizing a vacuum forming machine to heat a sheet of EVA material and subsequently drawing it over a stonecast model of the athlete's teeth (4). The material is subsequently reduced to the required dimensions to fashion the appropriate borders for the mouthguard (4).

The following steps are necessary for the production of a mouthguard in the vacuum-formed technique:

1. Dental cast: The first step is to take an impression of the teeth. We can rate this as the most important step in the production of our mouthguard. Impression is typically obtained from the upper arch, unless the patient is diagnosed with a prognathic malocclusion that warrants a different approach. In case of protruded mandibular incisors, a lower jaw impression would also be taken. The use of alginate is commonly employed for obtaining impressions as we can see in Figure 1. It is crucial that the stone utilized for the cast is sufficiently strong to withstand the process of formation. The

stonecast is reduced to a border which allows the operator to easily remove the material. No modifications are made to the area of the palate during the production process, as this ensures a more durable cast for our mouthguards. In instances where the palate remains, it is essential to create a hole for precise vacuum forming. The facial surface of the incisor ought to be roughly 90 degrees to the platform, followed by the application of a separator medium to facilitate the simple extraction of the mouthguard material (4).

2. A piece of EVA sheet is inserted into the forming machine with the cast positioned at its centre (4). Implementing EVA sheets in various thicknesses can depend on the intended purpose. Research suggests that there was no significant difference observed in the protective and impact-absorbing properties among mouthguards with thicknesses ranging from 4 to 6 millimetres (3). Beforehand, research indicated that a thicker and more substantial mouthguard could result in a decline in athletic performance capacities, impaired speech, and restricted breathing (6).

3. Following the cooling and temperature reduction process, EVA and cast are trimmed to the ideal borders for the mouthguard as previously marked on the stonecast. The anterior extension should be 2 millimetres of vestibular reflection, with the relieving of frenum attachments. The palatal borders should be positioned 10 millimetres above the gingival margin (4).

4. In this stage, we offer the flexibility to personalize the mouthguard according to the athlete's preferences. This includes incorporating names, logos, and numbers. However, it is essential to restrict any customization to vinyl material and avoid extending it to the final borders of the mouthguard, as the lamination process will not allow that (4).

5. Prior to applying the lamination in the vacuum-formed technique, it is essential to thoroughly examine the surface for any potential sources of air bubbles before the second layer is applied. To accomplish this, a sharp-tipped bur or pin can be utilized to open up any prominent areas (4).

6. The application of the second and final EVA layer is performed in a manner similar to step 2, with the layer being applied on top of the initial layer. Before this step, it is vital to confirm that the initial layer is devoid of any substances, such as oils, Vaseline, or other materials, that may obstruct the lamination process. Additionally, it is helpful to gently roughen the surface to remove any particles (4).

7. Next, set aside the mouthguard to cool and lower its temperature. Subsequently, trim the mouthguard according to the borders identified in step 3. The buccal and facial borders should be rounded, while the palatal borders should have a thin, feathered edge finish (4). The final thickness of the mouthguard is as previously discussed, 3 to 4 mm, and should be placed over the incisal surface of the front teeth and the occlusal surfaces of the posterior teeth (3).

8. The process of refining the edges now involves the utilization of buffing wheels in a handheld tool, followed by the application of gentle flames to achieve a polished and glossy finish of the mouthguard (4).

9. Ultimately, the mouthguard is optimally laminated and endowed with precise internal definition (4).

10. The use of occlusion in the vacuum-formed method can be accomplished either chairside or in the dental lab with the assistance of an opposing jaw model. The mouthguard can be heated and then placed on the athlete's mouth, with the athlete biting to attain proper occlusion. Additionally, the mouthguard can be mounted on an articulator along with the opposing jaw model in the lab to ensure the correct depth of the bite (4).

The vacuum method provides a precise and supportive mouthguard. It is essential to comprehend that in this technique, the accuracy and heat depend significantly on the

implemented machines.

Figure 1. Alginate impression of maxillary teeth and soft tissue
Courtesy of: Associate professor Tomislav Škrinjarić, PhD, DMD

2.2.2. Heat-pressure lamination technique

The heat-pressure lamination method involves employing specialized equipment designed to apply pressure rather than pull a heated sheet of mouthguard material over the athlete's cast (4).

Different varieties of pressure machines are available on the market, each one exhibiting subtle distinction yet adhering to a similar process. The production of a custom-fitted and tailored mouthguard involves numerous layers of chosen material that are bonded together (4).

Although there are slight differences in the machines, the steps for performing the task are generally consistent and can be summarized as follows:

1. In the vacuum-forming process, creating an impression is the initial step. While precision and accuracy of the impression are vital in the vacuum-forming technique, it is not as critical in the heat-pressure method as the material is uniformly pressed onto the cast. Moreover, the cast is aided with a separating medium for easier removal (4).

2. The EVA sheets are enclosed within the pressure unit and covered by a hanging heating element. Modern devices can often be programmed with specific materials, thicknesses, and colours for precise manufacturing. The process of heating can be initiated by scanning the bar code on the box containing the EVA sheet (4). Different colours can be utilized effectively in mouthguards. According to research conducted by Del Rossi et al., the fit of the mouthguard is influenced by the colour of the sheet. Dark-coloured sheets have been shown to result in a superior fit compared to clear or light-coloured materials. Additionally, it was found that the force required to remove clear mouthguards was significantly lower than the force required for blue, green, and black mouthguards. This suggests that the use of clear materials may lead to an inferior fitting of the mouthguards (7).

3. The process of heating has been concluded, and the casting has been secured in position. Consequently, the chamber has been sealed. As soon as the chamber is closed, the machine automatically initiates the pressure-inducing process, and specific duration is allotted for the cooling phase. The cooling of the material is crucial for the purpose of trimming and reducing the necessary lines (4).

4. Following the initial layer's cooling, the trimming process is carried out in the same manner as in the vacuum-forming technique. It is essential to remove any dyes or oils and slightly roughen the surface during this step (4).

5. Following the initial customization of the first layer, a second layer of clear EVA is applied over the first one. Similar to the vacuum-forming technique, a sharp instrument can be utilized to eliminate any areas that may cause air bubbles. Additionally, as in step four, there is a need to remove any residual oil or customization material from the layer (4).

6. Once the second layer has cooled down, the mouthguard is reduced and trimmed to the appropriate borders. The facial and buccal borders are shaped to be round, while the palatal borders are made to be feather-edged. Upon completion, the mouthguard is refined using buffing wheels and secured with a butane flame (4).

7. Occlusion is a vital component that must not be overlooked. It can be assessed using an articulator extraorally or intraorally chairside, similar to the vacuum-forming method (4).

Figure 2. Cast of upper jaw

Courtesy of: Associate professor, Tomislav Škrinjarić, PhD, DMD

Figure 3. Dreve Drufomat-Te mouthguard manufacturing device

Courtesy of: Associate professor, Tomislav Škrinjarić, PhD, DMD

2.2.3. Digital techniques

The entire conventional process of creating EVA mouthguards, which includes prior alginate impressions, stonecast models, and various other devices, can now be replaced with a full digital workflow (8). This new approach benefits from the rapid implementation of scanners, computer-aided design/computer-assisted manufacturing (CAD/CAM) systems, and four-dimensional printers, which have opened a vast and still-expanding field for research (9).

The utilization of CAD/CAM technologies has resulted in the efficient and cost-effective fabrication of dental prostheses by minimizing the number of visits and laboratory procedures

required. Employing digital technologies in this manner can yield significantly faster and more affordable outcomes (9).

Numerous clinical cases have been documented where the utilization of 3D-printing techniques has proven unsuccessful due to insufficient hardness of biocompatible materials. According to the reports, the 3D-printed mouthguards have been found to be excessively thin and susceptible to deformation as a result of occlusal forces and impact stress (9). In regard to the 3D printing limitations, I mostly researched new 4D printing solutions and workflows.
The application of 4D printing in dentistry has not been widely embraced. This method of printing adds the dimension of time to traditional 3D printing, resulting in the creation of moulded objects that change and evolve over time (9).
The utilization of the 4D printing method as a digital workflow will incorporate a polyurethane elastomer composite in conjunction with a shape memory polymer (SMP) possessing the shape memory effect (SME) (9).

The SMP is capable of shaping the material by employing a glass transition temperature, which is achieved through a heating impulse. This 4D printing method holds the potential to overcome the limitations of both conventional and 3D-printed mouthguards by delivering a custom-fit that is optimal and protective (9).

The digital workflow of a 4D printed mouthguard would include the following steps:

1. The first step contrast to the preceding techniques with the impression, would involve using an intraoral scanner to capture an image of the athlete's dentition, as seen in Figure 4. Following the scanning process, a bite registration would be conducted (9).

2. The computer-based scan will be developed and applied. One notable aspect of the digital workflow is the efficient time-saving feature for athletes. A professional athlete requiring 6 or 7 custom-made mouthguards per year could be easily accommodated, without the need to visit the office. During the design phase, the operator determines the various layers, including an inner layer with a thickness of 2mm and an outer layer with a thickness of 2mm. Subsequently, both layers will be

individually converted into the Standard Tessellation Language (STL) (9).

3. The STL data of the mouthguard will be send to the printer (9).

4. Following the printing process, the mouthguard undergoes polishing using #1200 grit polishing paper to achieve a smooth and refined finish. The internal and external layers are then bonded together using adhesive to create a seamless and durable product (9).

5. The mouthguard is now placed in hot water, subsequently cooled, and subsequently provided to the patient, similarly to the boil and bite method, to ensure a complete and accurate fit and retention (9).

After reviewing the available literature, it is evident that incorporating new printing technologies in the production of mouthguards is feasible. Specifically, the utilization of 4D printing offers a time-efficient solution that provides an optimal fit for the athlete's dentition (9).

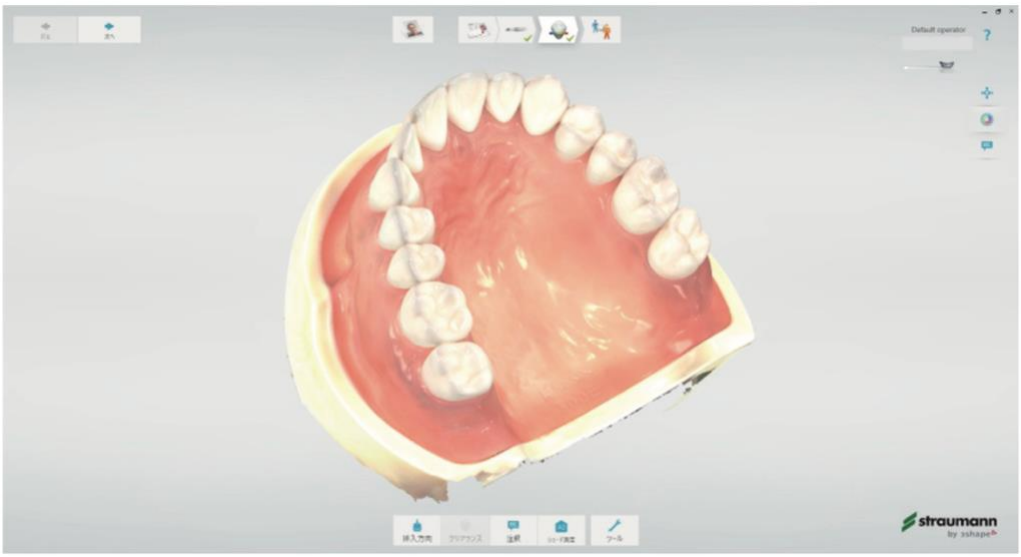

Figure 4. Model scanned by Intraoralscanner
Adapted from (9)

Figure 5. 4D-printed Mouthguard
Adapted from (9)

3. SPORTS AND INJURY PREVALENCE

Mouthguards are a crucial and highly recommended piece of equipment in a variety of sports. The primary objective of wearing mouthguards is to prevent injuries and safeguard the athlete. Sports such as boxing, American football, ice hockey, rugby, and hockey are instances where the risk of orofacial and dental trauma is particularly high.

Dental injuries refer to any disruption in the structure or function of teeth. The prevalence of high-risk sports has led to an increase in sports-related head and facial injuries. Soft tissue injuries and bone fractures in the T-zone, which includes the nose, zygomatic bone, and mandible, are the most common types of injuries sustained in such activities (17).

In boxing and other combat sports such as mixed martial arts and karate, the use of a mouthguard is mandatory. These sports involve direct punches and kicks to the face, which can result in serious injuries if not protected. The mouthguard serves as a protective barrier to absorb the impact of the hit and safeguard the hard and soft tissues (17).

In accordance with the international classification of diseases and causes of death, injuries can be categorized as injuries to the lips and mouth, injuries to the teeth, injuries to hard dental tissue, pulp and alveolar process, and injuries to the supporting structures of the teeth. Among these, the most complex and severe injury with the poorest prognosis is tooth avulsion (18).

In a meta-analysis conducted by Grillo et al., a comprehensive collection of articles and case reports regarding sports injuries was obtained to evaluate and present data on the sports disciplines with the highest injury rates (11).

Grillo et al. utilized two distinct approaches for obtaining data:

1. By identifying the sports that are most commonly associated with maxillofacial injuries.

2. By analysing the incidence of maxillofacial injuries associated with each individual sport identified in the first search (11). The categorization of injury data was based on various levels of risk, with each level corresponding to a specific incidence of risk. Consequently, different sports were classified into low, moderate, or high-risk categories for injuries affecting the maxillofacial structures (11).

High-risk sports that have a potential for maxillofacial injuries include:

1. Karate
2. Rugby
3. Soccer
4. Baseball
5. Skiing
6. Ice hockey
7. Basketball
8. Kickboxing
9. Taekwondo
10. Jiu-jitsu
11. Horseback riding (11).

According to the findings of Grillo et al., (11) it is strongly recommended that protective devices be utilized in all sports, and it is suggested that authorities make their usage mandatory for athletes. With regard to injuries, contact sports are the most demanding form of physical competition between athletes and teams. Athletes and amateurs are at an elevated risk of sustaining maxillofacial injuries due to high intensity of collisions (12).

Injuries sustained during sports activities are the second most prevalent type of accident, following only domestic accidents. Soft tissue, bone, and dental injuries are the most common types of sports-related injuries. The primary cause of dentofacial injuries are typically falls or collisions with other players or objects on the field.

Not only does orofacial trauma result in physical consequences but also in psychological effects for athletes. In addition to the potential for fractures that may conclude a sports career, it can also lead to everyday difficulties such as speech impairments (13).

According to the available data, approximately 31% of orofacial injuries can be attributed to sports trauma. This represents a significant proportion of all facial injuries, amounting to nearly one third (14). The most prevalent forms of orofacial injuries typically involve:

1. luxation
2. fractures
3. avulsion
4. lacerations
5. soft tissue injuries.

Additionally, facial bone fractures and damage to the temporomandibular joints are frequently observed. Injuries sustained in sports can result in lengthy and costly therapeutic processes, in addition to potential aesthetic and psychological consequences for the athlete involved (14).

4. PREVENTION

Prevention of orofacial injuries is a multifaceted issue that encompasses various approaches aimed at safeguarding the well-being and sporting prowess of both athletes and amateurs participating in sports.

A crucial aspect of protection is the utilization and execution of protective equipment, including mouthguards, specialized training programs, and the instruction of athletes. Gialain et al. documented the effectiveness of a mouthguard in reducing and absorbing the impact of shock to the face in a case report (15). The athlete described in the report was able to prevent severe injury and tooth loss thanks to the protection provided by the mouthguard. Gialain et al. emphasized that a well-fitting mouthguard would not only shield teeth, but also support soft tissues (16).

According to the meta-analysis by Knapik et al., various measurements should be taken to optimize injury prevention:

1. Regular renewing and fitting of the mouthguard: Mouthguards ought to be routinely inspected and replaced if there are indications of wear, damage, poor fit, or excessive use.

2. Education and Training: All individuals involved in athletics, including coaches and support personnel, should be instructed on the proper utilization of mouthguards to ensure maximum protection.

3. Although primarily contact sports employ mouthguards, they ought to be adopted in sports featuring minimal physical contact with opponents or teammates to safeguard teeth and associated tissues (16).

Mouthguards are essential in safeguarding against orofacial injuries. Research demonstrates that the use of mouthguards during intense contact sports lowers the likelihood of orofacial injuries substantially (15). Mouthguards have been manufactured by the British dentist Woolf Krause and utilized since the late 19th century. Since then, the objectives of research and science have been to comprehend and advance to a stage that ensures optimal protection for both professional and recreational athletes participating in contact sports that involve intense physical contact (15).

A study conducted in New Zealand on rugby injuries found that the strict policy of "no mouthguard, no play" led to a reduction of 43% in the incidence of orofacial injuries. This suggests that it is crucial to make the use of mouthguards mandatory for young athletes, particularly those below the age of 16, in order to prevent long-term damage (14).

According to Knapik et al., mouthguards provide significant protection to athletes in terms of injury prevention. Meta-analyses have revealed that the risk of orofacial injuries is halved when athletes wear mouthguards. Knapik et al. reviewed several sports and analysed various protective measures, including mouthguards. The results showed a decrease in the number of orofacial injuries among athletes who wore mouthguards (17).

The available evidence suggests that mouthguards do not have a significant influence in mitigating the occurrence of concussions (17).

The issue of traumatic orofacial injuries prevention in sports is a multidimensional one that requires risk management strategies. Each athlete possesses a distinct set of characteristics that may either increase or decrease their susceptibility to injury, and the relationship between these individual factors and external sports factors can be difficult to decipher. A straightforward approach to mitigating these factors in relation to orofacial injuries would be the use of mouthguards to protect the mouth, as it is the most effective method and not reliant on the aforementioned factors (4). Education, protective gear and rules needs to be always updated and analysed. Changing and revising these factors can elevate the protection of athletes (16).

One key aspect of prevention that cannot be overlooked is the cooperation of both professional and recreational athletes. According to a study conducted by Matalon et al., providing 80 children with free mouthguards and following up with a survey one year later yielded valuable insights. Of the 80 children, 69 participated in the survey along with their parents (19).

The results were as follows:

1. 29% never wore the mouthguard

2. 32% wore it sometimes

3. 15,9% wore it at the beginning and then stopped

4. 23,2% wore it when it was necessary and needed (19).

Matalon et al. revealed that 45% of children who did not wear mouthguards did so because they forgot, while 42% cited discomfort as the reason.

In addition, the gender factor revealed that girls experienced considerable discomfort and did not wear mouthguards. A noteworthy factor that contributes to the aforementioned educational factor is that even close family members who had sustained dental injuries in recent years were not informed about the option of mouthguards or their protective role for their children (19).

5. DISCUSSION

The primary objective of mouthguards is to minimise the risk of dental injuries. Research has identified discomfort and insufficient knowledge as key challenges in achieving this goal. To address these issues, it is essential to involve and educate all stakeholders, including parents, coaches, dental practitioners, and other clinical and non-clinical staff members, about the shock- and impact-absorbing properties of mouthguards.

In many countries, such as in Germany, it is common for school children to visit the dentist for the first time in primary school, during grades one and two. However, little emphasis is placed on the importance of oral protection, particularly in regard to mouthguards. Although these school events typically focus on topics such as tooth decay and proper brushing techniques, it is essential that dentists also address the need for protection. Hobby and professional athletes start at young ages and it is therefore necessary to educate them and apply a low-level approach and make them understand the importance of wearing mouthguards. The same approach should apply further to parents and coaches.

In a study conducted by Gorseta et al. at the University of Zagreb in 2010, the level of comprehension among professional coaches regarding tooth transplantation and the associated time loss was substantial. According to the research, the majority of coaches had encountered dental injuries, including some who had experienced them personally. Nevertheless, they lacked comprehensive knowledge about the treatment options for replanting avulsed teeth. The study also highlighted insufficient teaching of first aid to schools, parents, and coaches, which can lead to long-term consequences such as psychological, financial, and aesthetic effects on athletes (19).

The objective is to offer athletes the most comfortable, convenient, and efficient mouthguards available. This involves including the entire dental staff at a practice in the custom mouthguard creation process, utilizing the latest research on fabrication and materials for optimal protection and comfort (4). Without comfort, there is no guarantee that the athlete will consistently wear the mouthguard, resulting in an increased risk of injuries due to neglect of protective gear. It is crucial to prioritize comfort to ensure that athletes will be more likely to wear the mouthguard and benefit from its protective properties (3).

Enhancing the comfort and expediency of mouthguard production may stimulate further research into digital workflows, incorporating scanners and four-dimensional printers (9).

A growing number of dental offices presently advertise the elimination of conventional impressions, such as alginate, and boast of impression-free work processes leading to the implementation of scanners. The majority of patients possess a negative disposition towards impressions, which may lead to a lack of regular check-ups for mouthguards and a reluctance

to replace them. The digital method, combined with rapid scanning and saved STL data, allows for the efficient reproduction of a mouthguard with just a single click (9).

6. CONCLUSION

In conclusion, it has been shown that there are different methods of protection in contemporary dentistry. The implementation of mouthguards in sports is fundamental as a protective tool. Studies demonstrate that there is no alternative to mouthguards for safeguarding teeth and surrounding tissues. Additionally, the production of mouthguards for both hobby and professional athletes is critical. A well-fitting mouthguard must be used during training and matches, cleaned, and disinfected regularly. It is recommended to examine the mouthguard every 2 to 3 months, as per the frequency of usage. Failure to do so may result in it becoming ill-fitting, which could lead to further issues for the athlete. Mouthguards can also be combined with other protective equipment, such as helmets, to offer additional protection. It will be intriguing to observe future advancements in digital workflows and the direct printing of mouthguards, which could potentially lead to increased accessibility for sports participants.

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8. CURRICULUM VITAE

Saman Hodjat Shamami, born on June 15, 1987, in Tehran, Iran, relocated with his parents to Germany during the initial Gulf War. He was raised in the city of Cologne. Following his high school graduation, he pursued a degree in Law and Economics. Saman is fluent in German, Farsi, English, Arabic and able to communicate in Spanish, Italian and Croatian.

In addition to his academic pursuits, he established his own company and worked in the entertainment industry. During his university studies in Zagreb, he produced and published books, podcasts, television and online shows. In 2021, he was honoured with the Grimme Award for the show „Die beste Instanz”. Saman was both the screenwriter and actor in a film titled "FISH BOOM BANG," which was co-produced by Greenpeace.