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Influência da utilização de protetores bucais na capacidade aeróbia de atletas portadores de aparelho ortodôntico fixo

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Influence of mouthguards on aerobic capacity of athletes using fixed orthodontic appliances

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Abbreviations List

MG: Mouthguard

EVA: Polyvinyl acetate-polyethylene copolymer

U-18: Under-18 years

VAS: Visual Analogue Scale

VO_2 max: Maximum Oxygen Uptake

Abstract

Introduction: Sporting activities are frequently associated with the occurrence of orofacial trauma. Currently, the improvement of mouthguards as devices designed to prevent this public health problem especially in high impact sports has been noticed. Studies have been made in order to infer if mouthguards' usage interferes with functional aspects during competition. Focus on the awareness of athletes and community about risks, prevention and recommendations of these devices in each sport is needed to reduce this type of injuries.

Aim: The aim of this study was to evaluate the influence of mouthguards on aerobic performance capacity of under-18 athletes undergoing orthodontic treatment with custom-made mouthguard using the *Luc-Léger* test; a secondary aim was also to evaluate athletes' knowledge about mouthguards and functional differences experienced by them while its usage.

Materials and Methods: Out of a total of one hundred thirty-nine convoked athletes, seventy three had interest in participating in this study. The final sample was constituted by sixty players from local rugby and basketball team clubs. Athlete's knowledge regarding mouthguards usage and protection during sport activities were assessed through an initial questionnaire. Subjects were divided into two groups, experimental and control group. Difference between groups is related to having or not fixed orthodontic appliances. The aerobic capacity was compared with the values of maximum oxygen uptake using the *Luc-Léger* test twice, with and without wearing a custom-made mouthguard. A second questionnaire assessing athlete's satisfaction and difficulties during the exercise with mouthguard was delivered in the end of the 20-meter shuttle-run tests using a visual analogue scale. Standard descriptive techniques and also statistical tests such as student-t test were employed to evaluate differences between groups.

Results: Wearing custom-made mouthguards does not influence the aerobic capacity of athletes undergoing orthodontic treatment nor athletes without using fixed orthodontic appliances. Only 23.3% referred to use this devices during training and competition, being boil-and-bite type mentioned as the preference. Of the eight parameters measured in the visual analogue scale questionnaire the highest mean value scored was stability. Speaking was the functional aspect presenting lowest acceptance with the use of mouthguard.

Conclusion: There are no differences in aerobic capacity of under-18 athletes without intra-oral appliances with those undergoing orthodontic treatment during custom-made mouthguards' usage. Strategies should be created to raise awareness among players, coaches, parents and community about risks involving oral trauma's high prevalence in contact

sports. Recommendations for enhanced protection should also be given by dentists to decrease the occurrence of this type of injuries.

Keywords: “Mouthguards”, “Orthodontics”, “Aerobic Capacity”, “Sports”, “Dental Trauma”.

Resumo

Introdução: A prática desportiva está frequentemente associada à ocorrência de trauma oro-facial. Recentemente, o desenvolvimento de protetores bucais como dispositivos desenhados para prevenir este problema de saúde pública têm-se verificado, sobretudo para a utilização em desportos considerados de elevado risco. Têm sido desenvolvidos vários estudos com o objetivo de avaliar possíveis interferências dos protetores com aspetos funcionais durante a atividade física. É cada vez mais necessário promover o conhecimento de atletas e da comunidade relativamente a riscos, prevenção e recomendações para estes dispositivos em cada desporto, de forma a reduzir o número de lesões deste tipo.

Objetivos: O objetivo principal deste trabalho foi avaliar a influência dos protetores bucais na capacidade aeróbia de atletas Sub-18 portadores de aparelho ortodôntico fixo utilizando o teste de *Luc-Léger*. Como objetivos secundários, pretendeu-se avaliar o conhecimento dos atletas sobre estes dispositivos e perceber possíveis dificuldades durante a sua utilização.

Materiais e Métodos: De um total de cento e trinta e nove atletas convocados para o estudo, apenas setenta e três se demonstraram interessados. Dentro desta amostra, participaram na totalidade deste estudo sessenta atletas pertencentes a clubes de rugby e basquetebol locais. Avaliou-se o conhecimento dos atletas sobre o uso de protetores bucais no desporto através de um questionário inicial. Os atletas foram distribuídos em dois grupos, grupo experimental e controlo, consoante apresentassem ou não aparelho ortodôntico fixo, respetivamente. A análise respetiva à capacidade aeróbia foi executada através da comparação entre os valores de consumo máximo de oxigénio resultantes da realização do teste de Luc-Léger duas vezes, com e sem protetor bucal em boca. Foi realizado um segundo questionário utilizando a escala analógica visual para avaliar a aceitação e possíveis dificuldades sentidas com a utilização do protetor por parte dos atletas durante o exercício de corrida de 20 metros. Foram utilizadas técnicas descritivas e testes estatísticos, como o teste t de student, para avaliação das possíveis diferenças entre grupos.

Resultados: A utilização de protetores bucais individualizados não influencia a capacidade aeróbia de atletas com ou sem aparelho ortodôntico fixo. Apenas 23.3% referem utilizar protetores durante a atividade física, como treino e/ou competição, sendo o tipo “boil and bite” mencionado como preferido. Dos oito parâmetros avaliados através do segundo questionário distribuído o valor atribuído ao protetor como mais aceitável foi o correspondente à estabilidade. A interferência do protetor com a comunicação foi a mais referida pelos atletas, apresentando o menor valor de atribuição na escala.

Conclusão: Não existem diferenças na capacidade aeróbia de atletas sub-18 com e sem aparelho ortodôntico fixo durante o uso de protetores bucais individualizados. Devem desenvolver-se estratégias para consciencializar jogadores, treinadores, pais e a restante comunidade para riscos que envolvem a elevada prevalência de trauma oral em desportos de contacto. Os médicos dentistas deverão igualmente promover recomendações sobre o melhor tipo de proteção a usar de forma a diminuir a ocorrência de lesões deste tipo.

Palavras-Chave: “Protetores Bucais”, “Ortodontia”, “Capacidade Aeróbia”, “Desporto”, “Trauma Dentário”.

Introduction

Sports dentistry is already an unexplored field to general dentists. It comprises essentially prevention and management of injuries related to oral, facial and dental trauma during sports activities.[1]

The most common type of orofacial trauma is dental injury especially due to participation in contact sports.[1, 2] Emerich *et al.*[3] pointed out that the most frequently reported dental injury related to sports were crown fractures (40.6%) and avulsions (21.9%) whereas Correa *et al.*[4] also indicated that dental fractures (74.1%) and avulsions (59.3%) were the most common type of dental trauma during this activity. Therefore, crown fracture is indicated as the most common dental sports trauma, with more prevalence in males.[5]

The World Dental Federation (FDI) indicated two sport categories based on risks of traumatic dental injuries: high-risk (rugby, martial arts, hockey, lacrosse, American football, skateboarding, inline skating and mountain biking) and medium-risk sports (soccer, basketball, diving, squash, water polo, gymnastics, parachuting and team handball).[6, 7]

As dental trauma is associated with some particular conditions, Fields *et al.* [8] reported that there is a relation between the existence of protrusive maxillary anterior teeth, angle class II malocclusion, increased overjet (exceeding 4 mm), incompetent lips and mouth breathing and a major risk of trauma to the patient. Specifically, this risk may double because of increased overjet and inadequate lip coverage.

The teeth which are more predisposed to trauma are the central incisors and then the lateral incisors due to their position in the dental arch and their anatomy. Some other risk factors related to trauma are: age (under 15 years), male gender, professional competition level, the direction and the magnitude of the impact forces, player in an offensive position during competition and wearing fixed orthodontic appliances.[5, 9]

In order to prevent sports trauma, mouthguards have been described in the literature as the best option to prevent dentoalveolar injuries.[10-13] A mouthguard (MG) is a removable protective appliance used by athletes for oral protection during training and competition. Although its utilization should be well known, especially among contact sports athletes, its usage is still far from being widespread. According to some authors, this situation is related to the lack of information, discomfort while using MG, difficulties in functional aspects such as breathing, speaking, nausea and also aesthetic issues.[14-17] Fakhruddin *et al.*[18] carried out a study in which over 50% of the schoolchildren aged 12 to 14 year old who participated reported that they had never been encouraged by their parents and/or coaches to wear a MG, and 40.7% of them assumed that they did not need to wear this device during sport exercises.

As a crucial appliance for protection, some of the main functions of MG are: maintaining soft tissues separated from teeth (lips, tongue, cheeks); absorb direct impact forces to anterior teeth, distributing those forces among the whole dental arch; avoid cusps and posterior restorations injuries; prevent temporomandibular joint disorders, cerebral concussion and other intracranial lesions; protect the athlete from clenching; prevent jaw fracture.[14, 19]

In the 1890s, Woolf Krause tested the first MG putting together strips of gutta-percha and attaching them on the maxillary teeth of an athlete, in order to give protection from boxing activity.[12] Although this was the first reference to MG in the literature, the development of materials and forms of confection has continued since then. Through the decades of 1960s and 1970s, the use of MG became mandatory in sports such as football, boxing, ice hockey, lacrosse and field hockey.[19]

There are types of sports in which federations suggest the use of these devices. In Portugal, the Rugby Portuguese Federation recommended in June 2004 the use of “teeth protection” during competition.[20]

According to the literature reviewed, there are three basic types of MG: Stock prefabricated MG; Boil-and-bite or self-adapted MG; Custom-made MG.[12, 21, 22]

Stock prefabricated MG has a universal fit, can be purchased in sportswear stores and is low-priced; besides this conditions, this type of MG constitute a standard protection, without any sort of preparation to fit in the mouth of the individuals, providing poor fit and the least protection of all available types. It is used in most cases due to economic factors and the facilities in the access to the purchase; however, it is well documented the difficulties in breathing, speaking, drinking and the discomfort related to its usage.[12, 22]

The second type cited above, boil-and-bite MG, is commonly constructed from a preformed thermoplastic material of polyvinyl acetate-polyethylene copolymer which is softened in warm water and then adapted in the mouth of the athlete after biting. As well as the first type, it can be found in sportswear stores. This MG has numerous advantages over the stock MG, as it gives closer fit and the retention in mouth is also improved; therefore, it can affect breathing, speech, and may easily lose adaptation and fit.[12, 20]

Custom-made MG is individually made with dental professional support, being the most effective and expensive type. The fabrication of this MG involves taking alginate impressions and obtain working models from individuals, providing the best adaptation and comfort to their mouth.[20] Still, this procedure can be performed by a vacuum-forming process or a pressure-forming process. It has been suggested that vacuum-formed MG results in a product with an irregular and reduced thickness when compared with the MG fabricated by pressure-forming

machines.[23, 24] According to Farrington *et al.*[25], pressure forming machines are the most widely used and indicated to fabricate MG, albeit being more expensive to purchase.

Duarte-Pereira *et al.*[22] stated that comparing custom-made MG with the "boil-and-bite" type, the first interferes less with breath, oral dryness and speech. These authors demonstrated that custom-made MG is the most effective and recommendable to prevent injuries due to sport activity also from the standpoint of retention and comfort. Hersberger *et al.*[26] also concluded that as athletes indicate a higher level of comfort and an enhanced fit than with standardized MG, custom-made MG are expected to become the first choice in teeth protection.

In 1981, the American Standards of Testing of Materials (ASTM) F697-80 standard examined the types of mouthguards available and indicated that the first choice should be custom-made devices formfitting and effectively prepared by dentists according to particular fabrication guidelines.[27] Since the decade of 1890 different materials such as natural rubber, vinyl resins, acrylic resins and polyurethane have been used to manufactured MG. Though, polyvinyl acetate-polyethylene copolymer (EVA) has been described in the literature as being the most commonly used.[27-29] Santiago *et al.*[20] reported that the best MG should be fabricated with EVA because of its properties: non-toxic material; easily produced; effectively resilient and elastic. Besides this, Coto *et al.*[27] also indicated that beyond its low cost, this material is in conform with the international standards responsible for the regulation of the MG fabrication and it has shown suitable results under compressive and shear forces. In a study referent to the mechanical properties of commercialized MG materials Gould *et al.*[30] recommended that organizations such as the American National Standards Institute (ANSI) and the Standards Australia International (SAI) should promote a standard impact test protocol for MG materials.

One main property related to this material is the ideal thickness. Presently, there is lack of information already published accessible to the public that allows an informed decision associated with the correct thickness of MG that should be used for each sport in particular.[25] Nevertheless, some studies suggest a predetermined range of values between 3 and 6 mm, being the range between 3 and 4 mm currently the most recommended one.[24, 25, 31] This property influences the shock absorption and the protection ability of the MG and it also has effects in the comfort, speaking facility and in the MG compliance. [23] The capacity to absorb energy impacts of the MG has also been linked to the finish post-production thickness. As a result, the greater the thickness the greater the ability of the MG to dissipate any impact force.[25] Despite of this fact, thickness should not exceed 5 mm due to discomfort associated, alterations induced in the oral soft tissues during its usage and difficulties reported in breathing

and speaking.[20] Verissimo *et al.*[31] demonstrated that the existence of a balance between MG thickness and its comfort is crucial for athletic performance and wearing compliance.

Investigations by Bemelmanns *et al.*[32] in 2001 and Westerman *et al.*[33] in 2002 pointed out that inclusion of air cells in EVA sheets used in fabrication of MG may improve the reduction of impact forces transmitted. A reduction of 32% in the maximum transmitted forces through 4 mm sections of EVA can be noticed by air inclusions with controlled air cell volume and wall thickness. The impact effects of the presence of second impulse forces on EVA MG material are also reduced or eliminated as a result of air inclusions.

Besides the requirements mentioned above, during MG usage by athletes they should be aware of a proper hygiene related to the device as MG may carry a wide range of microorganisms.[34] D'Ercole *et al.*[35] demonstrated that after one year of using custom-made MG, changes in ecological factors of the oral cavity were reported, with the reduction of buffering capacity and salivary pH. According to this, there are basic preservation considerations which should be taken into account: wash the MG with toothpaste or soap and water with a non-abrasive toothbrush; save the device wet in a box, letting it dry without directly inducing that; do not bend while saving; put the MG wet in the mouth before its usage.[20]

Regarding the influence of MG in the aerobic capacity of athletes, several studies has been published concerning performance conditions. A research made during the decades of 1970 and 1980 demonstrated that wearing MG could enhance performance during strength and endurance exercise. The interpretation of results obtained in this period were difficult owing to a subjective methodology used.[36]

In 1991 Francis *et al.*[37] concluded that wearing MG may produce an effective breathing pattern through short-term periods of heavy exercise and that this situation could enhance tissue oxygenation and lower metabolic cost. Amis *et al.*[21] studied the influence of wearing two different types of custom-made MG on the airflow dynamics of oral breathing and demonstrated that different individuals respond differently to the presence of a MG in their mouths; they also indicated that wearing maxillary MG is unlikely to provoke interferences with breathing capacity at high ventilatory rates.

The lower compliance of the athletes with MG usage is due to the conviction that this device would negatively interfere with their exercise performance.[38] Results from a study carried out by Keçeci *et al.*[39] suggested that wearing custom-made MG do not notably affect aerobic performance capacity in a group of elite taekwondo athletes during a test using maximal field just before they reached VO_2 max. In a following study, Cetin *et al.*[40] investigated possible negative effects of the use of MG on the performance of athletes from the same sport cited above and also concluded that wearing a custom-made MG does not interfere with main

aerobic performance parameters and that this type of athletes can use this device without negative effects on their strength and anaerobic performance.

Comparing the influence in the athletic strength and performance of custom-made MG and the boil-and-bite type, a study from 2012 reported the first type had no negative impact on these parameters whereas self-adapted boil-and-bite MG had a slight negative effect on athletic performance being this condition directly associated with breathing difficulties and the discomfort during the usage of this kind of device.[41] Moreover, in 2013 Queiroz *et al.*[42] examined the influence of different MG in the physical performance of female soccer players, concluding that taking into account the three types of MG mentioned previously, custom-made MG was the one that presented the best results concerning the evaluation of the physical performance of athletes including physical tests performed without the use of MG. Also, there were no reports of interference with attention during training and competition, presence of nausea nor difficulties in speaking.

Regarding to orthodontics, only few attention has been given to the use of MG in patients undergoing orthodontic treatment. Athletes submitted to this sort of dental treatment may be at higher risk of oral-facial injuries as it may origin further damage to soft tissues and even lead to accidental traumatic face lesions. It has been shown that the presence of short upper lip and overjet mainly predispose to dental trauma.[2, 11]

Fabrication of MG for athletes during orthodontic treatment, as well as control adjustments have to be made by dentists due to special considerations: maximized retention, creation of space around appliances inside the MG concerning orthodontic tooth movements, minimized extension of the device and requirement of regular adjustments.[43, 44]

Several materials have been described to create a space inside MG for orthodontic appliances since tooth movements during therapy can occur at such a rate that the device can become unfitted throughout a period of two weeks. Putty material, tissue conditioner and catheter tubes are characterized.[2, 43, 44]

Until this moment, there is no evidence nor studies which demonstrate possible interference of these devices in the presence of fixed intraoral orthodontic appliances with athlete's capacity during exercise, comparing with the use of MG in athletes without this applications.

The main purpose of this study was to evaluate the influence of custom-made MG on aerobic performance capacity of under-18 athletes with fixed orthodontic appliances using the *Luc-Léger* test and compare it with the influence of these devices on aerobic capacity of athletes without wearing any intraoral appliances.

As secondary aims: this study also intended to evaluate athletes' knowledge about protection and types of MG; moreover, the aim was to analyse possible discomfort associated with functional aspects while its usage.

Material and Methods

This interventional study included a sample of 73 athletes of a total convoked of 139 competition athletes from two different group modalities corresponding to local teams: 33 from Rugby and 40 from Basketball. All participants were males aged 13-17 years who trained approximately 8 hours per week. The majority of tests were performed at the clubs' installations. All participants and also their parents were informed about the purposes of this study in accordance with Helsinki Declaration. A written consent was obtained from parents allowing their children to participate. Considering medical evaluation conditions, from the final sample of 73 athletes, only 60 (26 from rugby and 34 from basketball) were able to complete the whole protocol of this study: 8 athletes were excluded from the 20-meter shuttle-run test because of respiratory conditions, such as presence of asthma and respiratory allergies; 5 athletes presented muscle injuries and were not able to finish all tests. The inclusion criteria for participation in this study were: male competition contact sports' athletes, aged between 13 and 17 years, whose parents accepted the conditions mentioned in the informed consent. On the other hand, the exclusion criteria of this study were: upper respiratory disorders, with or without medication intake, muscle injuries which unable the athletes' condition.

This study evaluated each player with two questionnaires. The first, involving the beginning of this protocol, comprised a total of seven questions concerning athlete's knowledge about using protection during sport activities (adequate to each modality) and also about MG and the importance of its usage. The second questionnaire were delivered at the end of the protocol, using a visual analogue scale (VAS). Each player rated the MG by drawing a line on a 100-mm-long scale corresponding to eight items, being 0 associated with a very bad condition of the MG for that specific item and 100 meaning 'excellent', equivalent to a score for the MG previously fabricated for each of the players. This data was calculated by measuring (in mm) each scale using the distance between 0 and the line drawn. The importance of this second analysis were to evaluate, immediately after training, possible causes of discomfort associated with the usage of custom-made MG.

The final sample (60 athletes) was divided into two groups:

Group 1: experimental group, composed by 12 athletes undergoing orthodontic treatment (using fixed orthodontic appliances).

Group 2: control group, composed by 48 athletes without any appliances in their mouth.

The main outcomes consisted of the results of the *Luc-Léger* test made twice for each participant, the first time without the custom-made MG and the second time with the MG in the mouth, in order to obtain a prediction of the maximum rate of oxygen consumption measured during incremental exercise. This physiologic variable reflected the aerobic capacity of the participants. The *Luc-Léger* test involved running back and forward around a course of 20-meter line using a sound signal emitted from a pre-recorded tape to mark the pace at which athletes should run. The frequency of the signal (beep sound) was increased by 0.5 km h^{-1} each minute taking into consideration the initial speed of 8.5 km h^{-1}. Players continued the exercise until they were not able to reach the cones before the beep sounded for two consecutive times, which means that they had to reach the cones always before the beep, waiting in the cone for a new indication (beep sound) to come back and proceed. The number of stages completed is used as a final measure of the test in which higher stages correspond to better performances. The results of the test were measured using the equation below, concerning the maximum oxygen uptake (**VO_2 max**, ml kg^{-1} min^{-1}) equivalent to the aerobic capacity, the running speed at the moment each athlete left the test (**speed**, km h^{-1}) and the age of each athlete (**age**, years):

VO_2 max = 31.025 + 3.238 x (**speed**) – 3.248 x (**age**) + 0.1536 x (**speed**) x (**age**)

Figure 1: *Luc-Léger* test performed by a group of seven athletes starting in the mark behind the cones.

Maxillary impressions of the selected athletes were taken using irreversible hydrocolloid alginate impression material (*Schmidt Line, reference 048914*) and were poured with dental stone (*Schmidt Line, reference 048470*) to obtain working models. EVA sheets with 4.0 mm of thickness (*Proform,* Dental Resources, reference 006426) were used and placed in a pressure thermal forming machine (*MiniSTAR,* Scheu-Dental, Germany).

Figure 2: Thermal forming machine used to fabricate custom-made MG (*MiniSTAR,* Scheu-Dental, Germany*).*

The orthodontic appliances (brackets, arch wires) presented in the working models of athletes undergoing orthodontic treatment were covered with a catheter tube material (*PMH - Produtos Médico Hospitalares, S.A*., Portugal) in order to create a space during the machine procedure for the appliances (figure 3). This material was applied to the surface of brackets by inducing a cut and was fixed with a ciano-acrylate adhesive.

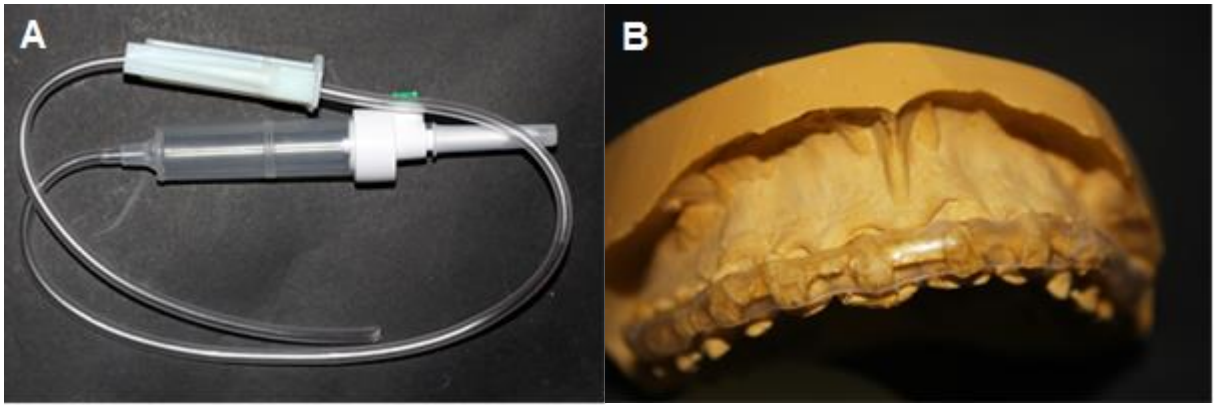

Figure 3: (A) Catheter tube material. (B) Application of the tube in the position of the brackets and wires.

Each sheet used was softened for a heating period of 130 seconds and a cooling time correspondent to the fabricant considerations of 240 seconds. The design of the MG obtained after the thermal forming machine procedure was executed taking into account anatomic limits of each model in particular and also limits established by the literature[20]: labially extended 3 mm above the gingival margin, protecting teeth till the second maxillary molars, in the palatine side extended 10 mm above the gingival margin, contouring also anatomic frenum. In relation

to the finishing phase, a tungsten drill was used in a low-speed handpiece to eliminate irregular margins of the MG.

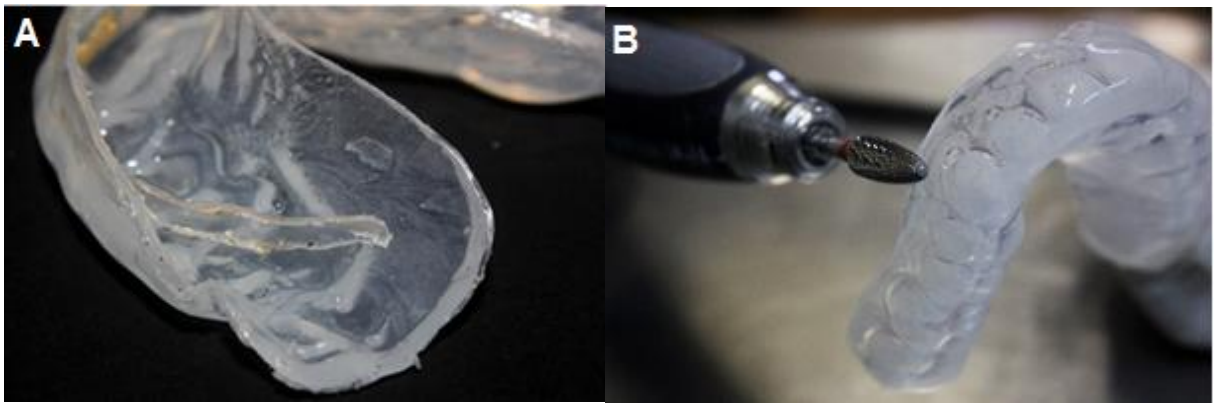

Figure 4: (A) Removing the catheter tube from the inside of the MG for orthodontic appliances. (B) Finishing the MG with a tungsten drill.

After the fabrication procedure of the MG adapted to orthodontic appliances the tube was removed from the inside, to allow the creation of the space needed. Final aspects such as retention, adaptation or stability of the MG were examined when the deliver was made in the athlete's presence. All the MG delivered stayed with each athlete after the conclusion of this study.

Figure 5: Finished custom-made MG fabricated for the control group.

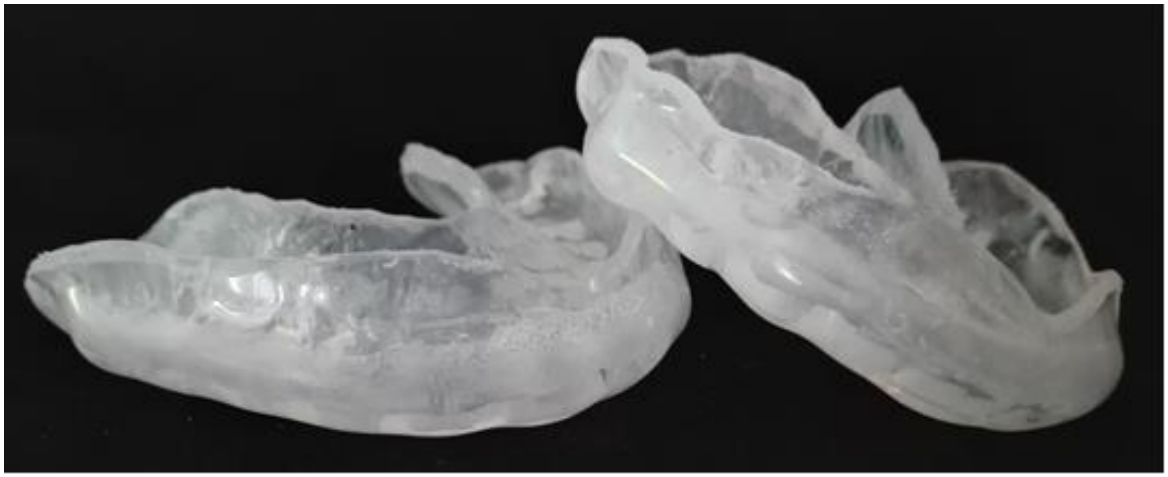

Figure 6: Finished custom-made MG fabricated for the experimental group – space created in the labial side for the orthodontic appliances.

Regarding the statistical analysis, standard descriptive techniques were employed to summarise the results and also statistical tests to evaluate differences between the groups. Notably, after verification of normality using the *Shapiro-Wilk* test, the paired samples student-t test was used to assess the existence of meaningful differences between the values obtained by the *Luc-Léger* test performed in each group. In addition, to analyse the existence of statistical significant difference between the *Luc-Léger* tests comparing the groups (athletes with and without orthodontic appliances), the independent samples student-t test was utilized after verification of normality and homogeneity of variance (*Levene* test) assumptions. For these comparisons, a *P* value less than 0.05 was considered statistically significant.

Results

The first questionnaire regarding the athlete's knowledge about MG and its importance for each modality was delivered in the beginning of the study, including a total of 73 athletes.

Regarding the occurrence of dental trauma, 12.3% of the athletes reported suffered trauma during sport activities. Only 4.1% referred do not know anything about MG. As shown on the figure below (figure 7), Dentists and Parents constitute the principal information providers regarding protection devices. Instead, 8.2% of the subjects mentioned that watching players from professional leagues on the television help them being informed about MG.

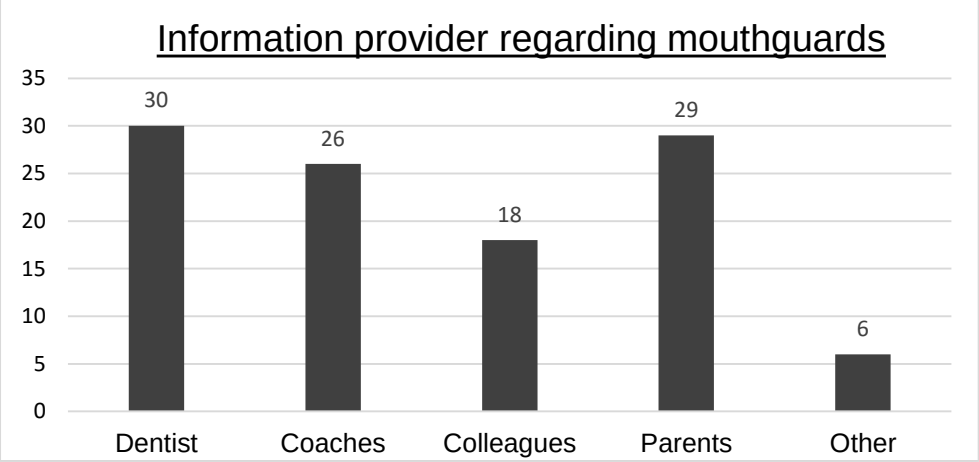

Figure 7: Answers given related to information providers, concerning protection and types of mouthguards.

Evaluating the athlete's knowledge about each type of MG (figure 8), the majority (65.8%) recognised the stock prefabricated MG, 37% knew the boil-and-bite type and 47.9% identified the custom-made MG. Of the 23.3% (17) which use these devices, the majority referred the boil-and-bite type as the preference (13.7%).

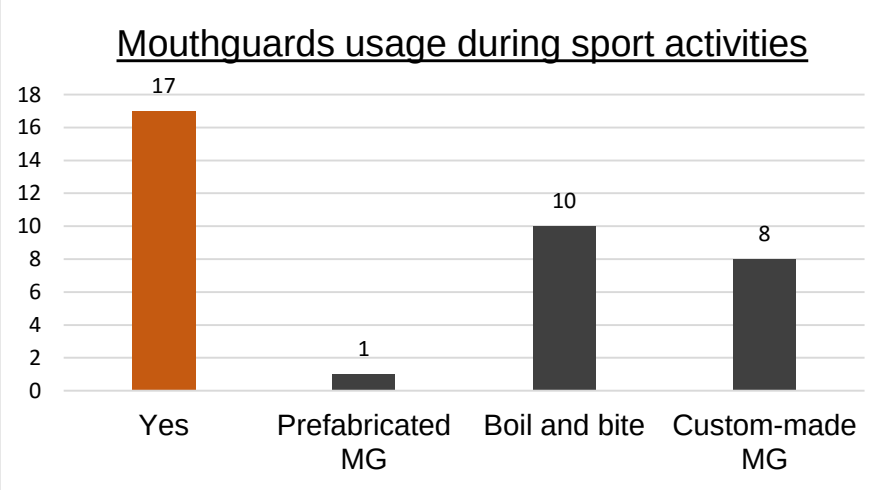

Figure 8: Results related to the use of MG during training and competition.

The functional aspect identified as being more affected during MG usage was speaking (9 of the 11 athletes which referred discomfort), and the second function more affected was breathing (figure 9).

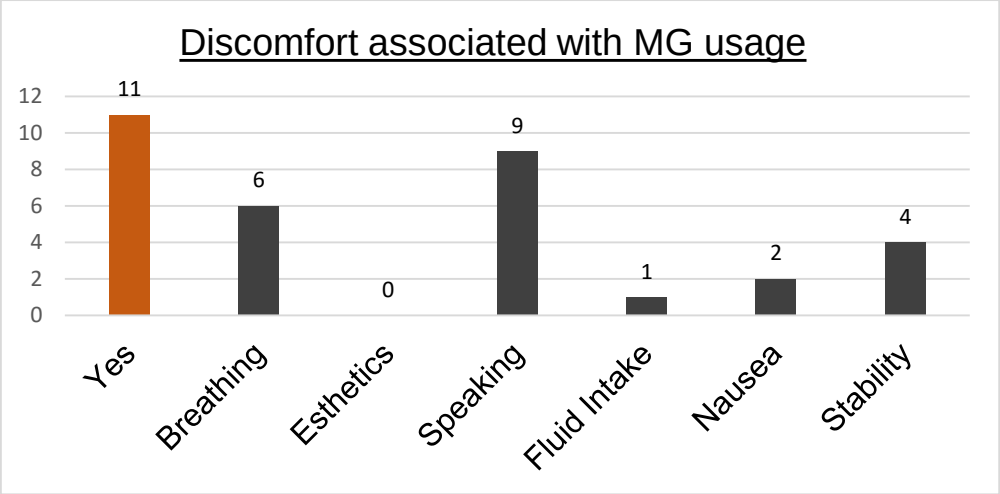

Figure 9: Items concerning functional aspects affected during MG usage.

Only 12.3% of the athletes mentioned that the use of these devices is not necessary. Besides this fact, 65.8% of the total participants indicated that MG should be compulsory for the practise of Rugby and Basketball.

Sixty athletes complete the whole protocol after the first questionnaire in relation to the *Luc-Léger* test. For this kind of physical test, an interval of 1 week between the two tests was adopted. Table I shown below presents the comparison between the two tests (with and without MG in players' mouth), also between the groups 1 and 2 (with and without orthodontic appliances). For both outcomes, there were no statistical differences between these tests.

Table I: Statistics of the VO2 max measured by *Luc-Léger* test made with and without MG in U-18 rugby and basketball players.

	VO_2 max without orthodontic appliances		VO_2 max with orthodontic appliances	
	Without MG	With MG	Without MG	With MG
$\bar{x} \pm std$	50.1 ± 4.6	49.4 ± 5.0	48.5 ± 5.6	46.7 ± 5.4
min/max	40/60	38/60	38/60	39/60

The results of this part can also be analysed in figure 10.

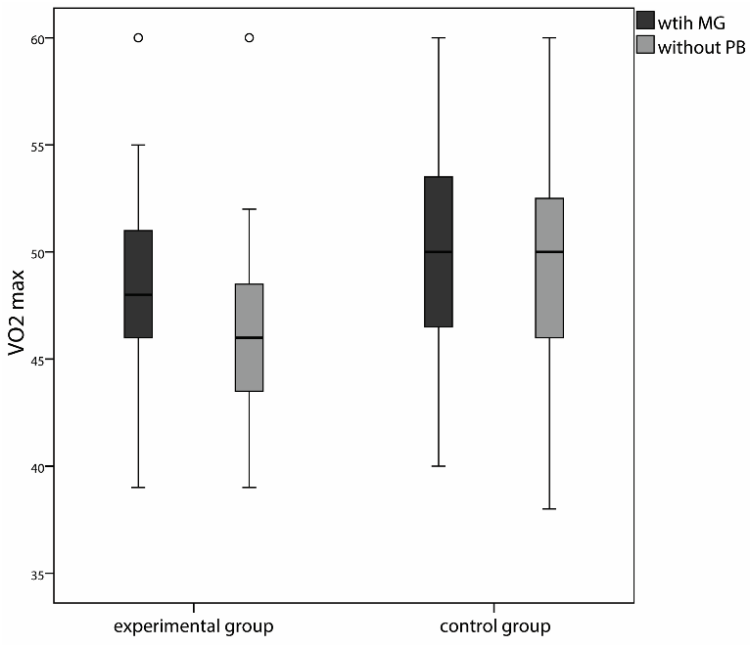

Figure 10: Comparison between tests for the experimental and control group.

The results for the control group did not present significant statistically differences for VO_2 max with and without MG ($t(47) = 1.265, p = 0.212$). For the experimental group the results also shown absence of significant statistically differences for VO_2 max with and without MG ($t(11) = 1.402, p = 0.188$). Comparing the two groups, there were no significant statistically differences in the aerobic capacity (VO_2 max values) using or not the custom-made MG for athletes with and without orthodontic appliances: without MG ($t(58) = -1.040, p = 0.303$) and with MG ($t(15.9) = -1.599, p = 0.129$).

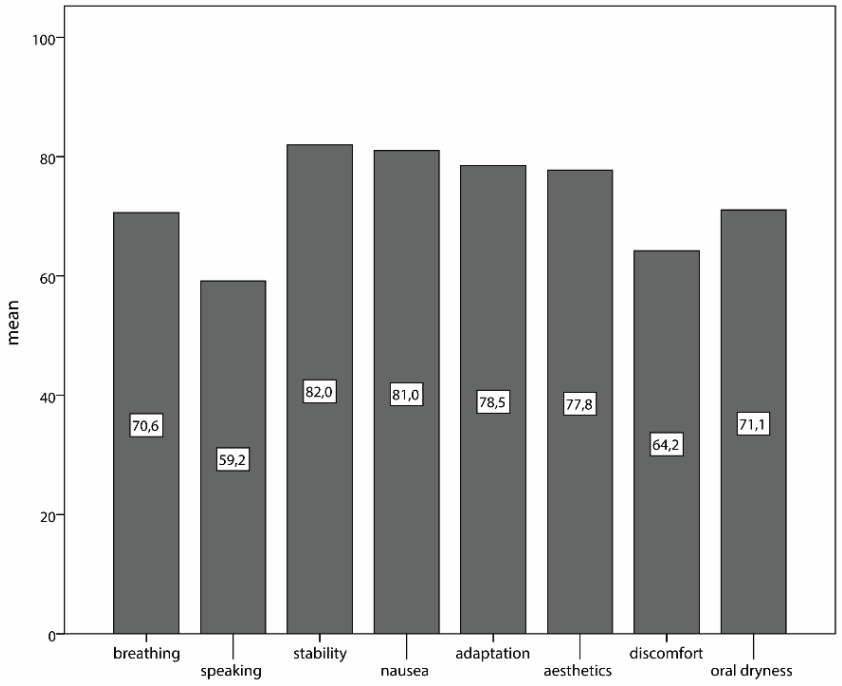

Figure 11: Mean values (mm) of VAS for evaluation after custom-made MG usage.

To complete the study, a second questionnaire using VAS was used to assess the players' approval of MG usage during exercise (figure 11). The eight parameters measured were: breathing, speaking, stability, nausea, adaptation, aesthetics, discomfort and oral dryness. The highest mean value measured as 82.0 mm was stability. On the other hand, the lowest value measured as 59.2 mm was speaking. Breathing capacity during MG usage was an important item to evaluate presenting the third lower value (70.6 mm).

Discussion

The number of the final sample involved in this study (60 athletes) was higher than similar interventional studies presented in the literature, such as the study of Cetin *et al.*[40] in 2009 with 21 voluntary taekwondo athletes, and the study of Collares *et al.*[45] in 2014 with 40 athletes completing the *Luc-Léger* phase tests. Furthermore, the absence of evidence in the literature till this moment comparing aerobic capacity of subjects using fixed intraoral orthodontic appliances during MG usage with athletes without any appliances do not allow to specify the ideal sample number necessary to achieve significant statistical differences.

The difference among sample number between groups may influence the results, despite the fact of this variance illustrates difficulties of having in the same club teams and in the same age range athletes using fixed orthodontic appliances.

Several studies evaluated players' knowledge regarding the use of protection during their sport activities. The occurrence of orofacial lesions associated with training and competition is a common state, especially in contact sports. It was observed that only 4.1% of the participants in this study do not know any type of protection to avoid this kind of injuries, differing from studies of Fakhruddin *et al*.[18] in 2007 and Sizo *et al*.[14] in 2009 which indicated that the majority of the participants do not know MG. This statement may be related to the differences in the sample number inferior of the present study and may also be associated with the type of population and social conditions. In the present study, only 17 of a total of 73 athletes which answered the first questionnaire use MG during training or competition. This result prove the importance of subjects' awareness and preventive measures for information in club teams, schools, dental offices and even at home.

Regarding the type of MG preferred for the respondents the boil-and-bite MG was the chosen, similarly according to a study of Leone *et al.* [46] and Emerich *et al.*[3] for boxing practitioners. Custom-made MG type is referenced in the literature as the most effective and recommendable in the prevention of orofacial lesions.[22] Being dentists mentioned as the principal information providers for the participants, this may infer that there is lack of correct information even for professionals.

In addition, the results obtained, comparatively to the most affected functions, while using MG, are in accordance with studies of Duarte-Pereira *et al.*[22] and Boffano *et al.*[17] showing that there occurs interferences with speaking and breathing, in this case using boil-and-bite MG.

In what MG construction concerns, in this study, the use of an alternative method with a catheter tube material to create a space in the working models for the placement of

orthodontic appliances showed good results, specially regarding the feedback given by the athletes in terms of comfort and adaptation when they tried for the first time the devices.[43]

The main purpose of this study was to assess the influence of custom-made MG on the VO_2 max of athletes using fixed orthodontic appliances. The best indicator of aerobic capacity is commonly accepted as the peak of VO_2 max.[47]

Our findings demonstrated that MG usage does not interfere with aerobic capacity during exercise when compared with the same exercise made without MG and also when related to the same tests in individuals which do not have orthodontic appliances in their mouth. These outcomes are in accordance with a previous study of Collares *et al.*[45] in which was compared only the use of custom-made MG in subjects not undergoing any orthodontic treatment. Another study[39] showed that wearing custom-made MG do not significantly affect aerobic performance capacity by evaluating ventilatory gas exchange effects and also indicating VO_2 max values according to *Léger*'s formula. von Arx *et al*.[16] examined the exercise capacity in thirteen athletes of ice-hockey and handball with MG using spiroergometry which constitute another method of evaluation for the VO_2 max parameter. The conclusions were in agreement with this study: custom-made MG does not interfere with maximum exercise performance.

The maximal multistage 20-m shuttle run test used in this study (*Luc-Léger* test) comprehends a valid and reliable method for testing groups which nearly reproduces the speed-incremented treadmill test used in laboratory settings.[47] Athletes were verbally encouraged throughout the exercises to continue running maintaining the rhythm in each stages. Other concerns were taken into consideration regarding the bias' minimization, involving similar conditions at the sports hall, the intensity of training on the day before the exercise and athletes' physical conditions. All of the sixty players from both groups performed the exercise at the sports hall of the participating teams with good acoustic conditions.

A second questionnaire using VAS was utilised in order to assess players' difficulties during the exercise with MG. This type of evaluation is frequently used in health research as well as dentistry due to its good reliability and interpretation facilities.[15, 16, 45] This eight item-scale questionnaire allow the creation of a score of the custom-made MG fabricated for each one of the sixty athletes in the present study. The immediate delivery of the VAS questionnaire after the *Luc-Léger* test in this protocol was a form of certification for precision during the responding period.

Stability was the highest ranked satisfaction parameter (82.0) followed by *nausea* parameter (81.0). This outcome confirms the evidence presented in the literature for custom-made MG, especially when compared with stock prefabricated and boil-and-bite types,

referring the type of MG used in this study as being the most comfortable to use due to its adaptation to the athletes' maxillary arch as well as the special care during the fabrication of MG especially not overlapping the palatal posterior limits to avoid nausea.[15, 41, 42]

Adaptation was another high ranked parameter (78.5) and the use of 4 mm thickness of EVA material may be related to this high score. Some authors stated that 4 mm represent the ideal thickness to provide appropriate comfort and shock absorption as the adequate thickness and proper fit are needed to make MG effective in the prevention of injuries.[24, 31] On the other hand, speaking constitutes the lowest level parameter among the other seven (59.2). Results from a study of von Arx *et al.*[16] showed the same outcome when judging the interference of MG with breathing, speaking, concentration and athletic performance. Moreover, Collares *et al.*[45] stated the same result after using the MG in the *Luc-Léger* test when compared with other parameters such as breathing, oral dryness, stability and overall evaluation.

The use of MG among athletes with fixed orthodontic appliances is essential regarding the higher predisposition of these subjects to oral and soft tissues' trauma, despite the fact of these devices also represent protection to hard tissues as well.[8, 20]

Rugby and basketball, were the team contact sports selected for the study, representing two examples of risk modalities in which there are a possible major sample of subjects wearing and not wearing fixed orthodontic appliances in the same team groups relatively to the social context of the population presented in this study.[6, 7] Regarding other risk group modalities performed in local town, such as hockey and soccer, the possible samples were analysed but they were inferior in size, particularly in what concerns to the athletes wearing fixed orthodontic appliances.

Athletes often are uncertain to wear MG with regularity due to preconceived ideas in relation to discomfort associated or differences in their fitness capacities. Despite this, this study proved, in accordance with conclusions described in several studies, that wearing custom-made MG does not interfere negatively with athletics' performance nor aerobic capacity.[19, 21, 36, 39, 40]

In this study it was also observed the reserved knowledge of athletes, coaches and parents concerning the prevention of oral injuries, the limitations when asked about the most recommendable type of MG and the limited use of these devices during training and competition. These facts suggest that a reinforcement relatively to the information provided by dentists to their patients or even the creation of educational courses in this modalities are needed to promote the importance of wearing protection during sporting activities.

Conclusion

The results of this study indicate that wearing custom-made MG does not interfere with aerobic capacity of athletes using fixed orthodontic appliances during exercise.

Comparing athletes without intra-oral appliances with those undergoing orthodontic treatment, there are no differences in VO_2 max values obtained while wearing these devices.

The majority of U-18 players still do not wear MG during training or competition. Players, coaches and parents regarding this age range do not seem to have enough information about risks related to contact sports and benefits respecting the use of protection.

The functional aspect more affected while using custom-made MG is speaking, despite this device provides very good adaptation to intra-oral tissues.

Strategies should be created to encourage young players to wear MG, especially through information provided by dentists concerning the prevention and management of dental injuries.

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