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SPORTS-RELATED ORO-FACIAL INJURIES: WHICH KIND OF MOUTHGUARD WILL BE THE MOST SUITABLE TO PLAY SAFE?

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The risk of sports-related injuries is constantly present in various sporting activities, like box, rugby, tae-kwon-do, etc. Athletes should be informed of the best characteristics of a custom-made mouthguard in order to prevent oro-facial trauma. Materials used in the manufacture of mouthguards should satisfy a number of physical, mechanical and biological requirements. It is essential to differentiate the intra-oral devices available for the athletes to play safe. There are three main goals that should be taken into account, and that are provided by the authors' modified occlusion mouthguard (MOM): (i) the occlusal stability, by the contacts of the mouthguard with the antagonist teeth, (ii) the equilibrium of the masticatory muscles and (iii) the temporomandibular joint protection from excessive unbalanced forces.

KEY WORDS: mouthguards, oro-facial injuries, temporomandibular joint, sports safety.

INTRODUCTION: A mouthguard is the primary appliance for minimizing orofacial trauma resulting from sporting activities. They have been worn by sportsmen for almost a hundred years and were initially used by boxers (ADA Council, 2006). Usually they are made from a thermoplastic copolymer, ethylene vinyl acetate (EVA), fitting over the occlusal surface of the maxillary teeth, preventing the teeth been chipped, luxated or avulsed, lip lacerations, lesions on the gingivae, tongue and mucosa. The athlete by wearing a properly fitted mouthguard can reduce the risk of injuries to the teeth, soft tissues, or the temporomandibular joints (TMJs). The risk of sports-related injuries is constantly present in various sporting activities, like box, rugby, tae-kwon-do, ice hockey, lacrosse, field hockey, karate, basketball and American football (Biasca et al., 2002; Maeda et al., 2006). The 2006 Women's Rugby World Cup showed that the neck/cervical spine (14.3%) and knee (14.3%) were the most commonly injured regions, followed by the head and face (12.7%) (Takeda et al., 2006a).

Usually, the most common mouthguards used during sports practice are the mouth-formed mouthguard, known as the boil-and-bite model which can be bought in any sports store. The athlete will place the boil-and-bite mouthguard in hot water, briefly cooling it in cold water and then forming it to its mouth after clenching his teeth and shaping the material with his/her fingers (ADA Council, 2006; Biasca et al., 2002). These mouthguards usually have little retention, offering very poor protection and, in addition, may interfere with breathing. Nevertheless these mouthguards are slightly better than the stock mouthguards, which are preformed with a thermoplastic material, and are available in different sizes, these are considered by many to be the less protective (ADA Council, 2006; Biasca et al., 2002; Patrick, 2005). Custom-made mouthguards can be fabricated after getting the maxilla alginate impressions of the maxilla dental cast. These mouthguards are the most highly recommended; due to the fact that they respect quality criteria, such as comfort, fit, retention, ease of speech, resistance to tearing, ease of breathing, as well as, good protection of the teeth, gingiva and lips, essential for successful prevention of orofacial and dental injuries. These mouthguards can be either vacuum-formed or pressure laminated, were some researchers have recommended a material thickness of 4-5 mm for enhanced reduction and absorption of transmitted forces during impact (Biasca et al., 2002; Takeda et al., 2006a; Takeda et al., 2006b).

Mouthguard materials should have an optimal consistency, energy absorption, and strength in order to cushion the traumatic impact. Takeda et al. showed in their study that a mouthguard with a special focus on a hard insertion in between two layers of 3 mm of EVA

had significantly greater buffer capacity than conventional EVA, by itself (Tran et al. 2001). The application of laminated-type mouthguards have higher shock absorption ability as they are fused with another sheet of material, which restrains the entire thickness of the mouthguard, but nevertheless providing an adequate thickness to protect from orofacial injuries (Westerman et al., 2002).
Therefore to evaluate a mouthguard to play safe, it is essential to fill the gap between basic research and clinical results taking into account, what can be provided in the authors modified occlusion mouthguard (MOM): (i) the occlusal stability, by the contacts of the mouthguard with the antagonist teeth, (ii) the equilibrium of the masticatory muscles and (iii) the temporomandibular joint protection from excessive unbalanced forces.

OBJECTIVES: The purpose of this study was to evaluate, clarify the differences and compare the effectiveness of the boil-and-bite mouthguard (BBM), the custom made mouthguard (CMM) with 4 mm (CMM4), with two layers of 4 mm and 3 mm (CMM4+3), with 4 mm and an intermediate hard layer of 1.5 mm and 3 mm (CMM4+1.5+3) and the modified occlusion mouthguard (MOM) in professional boxers, with particular attention to the material selection, construction method, and design of the intra-oral devices.

MATERIALS AND METHODS: Two professional boxers participated in these studies, which already use a commercial BBM. An ethylene vinyl acetate (EVA) thermoformed maxillary mouthguards were made for each boxer, CMM4, CMM4+3, CMM4+1.5+3 and a MOM using the Biostar® pressure machine Fig. 1-A. Maxillary and mandibular alginate impressions, a wax interocclusal record of centric occlusion together with face-bow registrations Fig 1-B, were recorded for the professional boxers, in the fabrication of the MOM that was made with the dental casts mounted in a Kavo® Protar® semi-adjustable articulator. Electromyographical analysis of the masticatory muscles - masseter muscle, and temporalis muscle, with the Bio EMG 2 (Bioresearch Associates Inc.), was made during maximum intercuspidation with maximum muscles force activity (Clench), at rest position (rest. pos.)

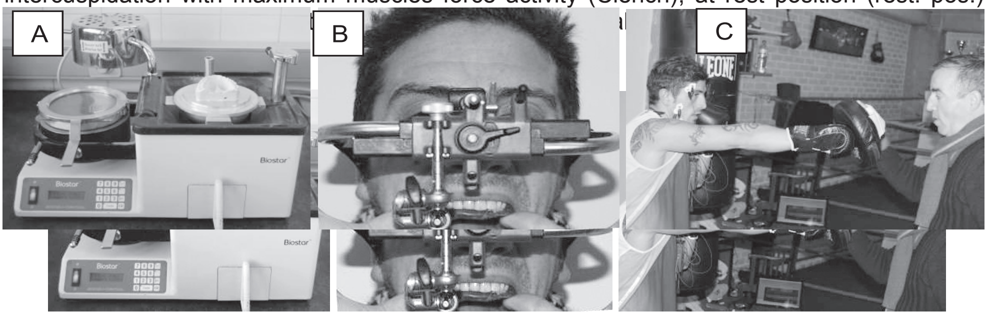

Figure 1: A) The pressure machine, B) MOM Face-bow registration, C) EMG during boxing

A pendulum type impact testing machine with an impact steel cylinder was applied against the dental casts with the different mouthguards having a thermographic evaluation with the thermal camera Flir® A 325, of the impact zone, Fig. 2-A. The acceleration of the pendulum was measured with a MEMS 3D accelerometer through a data acquisition board at a sample rate of 1000Hz. In addition, a piezoelectric sensor was placed between the tooth and the mouthguard therefore intending to measure the impact transferred Fig. 2-B. Regarding the different occlusal contacts of the intra-oral devices, there was an examination that was carried out using the Tekscan's T-Scan® III. This diagnostic instrument uses a thin wafer bite pad to sense, analyze and graphically display the contact forces by imprinting in the sensor the location of the occluding mandibular teeth on the different mouthguards Fig. 2-C.

RESULTS: EMG measurements: The MOM provides a higher EMG value, which increases the masticatory muscle stability obtained during the sports performance. Table 1 presents the voltage recorded from the electromyographic activities of the masseter and anterior

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temporalis, with the MOM, the BBM and the CCM4, during box practice, at rest position and clench.

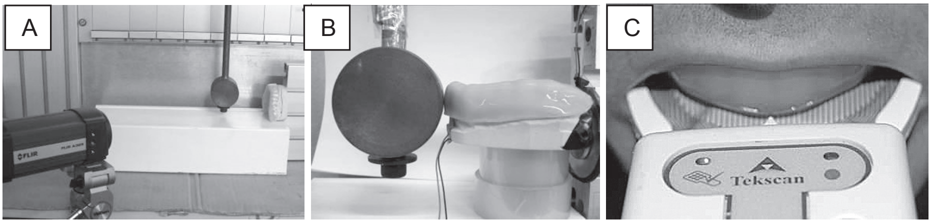

Figure 2: A) Thermal camera, B) Impact pendulum and piezoelectric sensors, C) T-Scan® III

Table 1
Average values of electromyographic activities (μV) of masseter and anterior temporalis at rest position, clench and during box pratice with different mouthguards

	Rest.Pos.	Clench	BBM	MOM	CMM4
Masseter Right	2.0	243.8	84.5	135.9	76.9
Masseter Left	1.5	238.4	70.5	150.8	100.6
Temporalis Right	1.9	156.9	27.7	68.3	43.9
Temporalis Left	1.4	191.5	31.9	69.0	73.1

Thermographic evaluation with the thermal camera Flir® A 325: The MOM has a higher capacity on absorption of the impact of the pendulum. The thermal images of the MOM show less temperature increasing and small impact area, indicating a better shock dissipation and absorption when comparing to the CMM4.
Impact test: The accelerometer and the piezoelectric sensor on the base serve to measure the impact of the test, Table 2. Relating the signal of the piezo sensor in the tooth zone, the amplitude values refer to the force that is transmitted to the sensor, which means that the MOM receives less force than the others, providing higher shock absorption as well as dissipating and distributing the transmitted forces.

Table 2
Impact tests results (values are dimensionless)

	Acelerometer			Piezo Base			Piezo tooth		
Mouthguard	Max	Min	Amp	Max	Min	Amp	Max	Min	Amp
BBM	3.2714	1.0193	2.2521	8.5329	-1.1402	9.6731	1.3818	-0.9300	2.3118
CMM4	3.1372	1.2026	1.9346	8.4848	-0.6957	9.1805	1.4138	-0.9034	2.3172
CMM4+1.5+3	3.2663	1.0168	2.2496	8.9567	-0.9098	9.8665	0.7645	-1.1660	1.9305
MOM	3.4010	1.0753	2.3257	8.3703	-1.0357	9.4060	0.6177	-0.4963	1.1140

T-Scan® analysis: With the computerized occlusal analysis of the T-Scan® III, it is intended to see the center of force (red spot), where the occlusal forces are located. The MOM, showed a higher occlusal stability, comparing with the others, where the occlusal contacts were 51.3% on the right side and 48.7% on the left side Fig 3-A. The CMM4 has 33.9% of occlusal contacts on the right side and 66.1% on the left side, while the CMM4+3 has 34.8% of occlusal contacts on the right side and 65.2% on the left side. The CMM4+1.5+3 due to the fact of having the insertion of an intermediate hard layer, for more absorption impact, doesn't allow a correct harmony of the occlusion, in this case, only posterior teeth are in contact with the mouthguard. On the other hand the occlusal contacts of the BBM are on the anterior zone Fig 3-B.

There are substantial differences in the manufacturing processes of the different kinds of intra-oral devices, where the MOM intends to respect the correct physiologic jaw relationship, and the correct alignment of the teeth occlusion, Fig 3-C, which is not valid for the BBM, Fig 3-D.

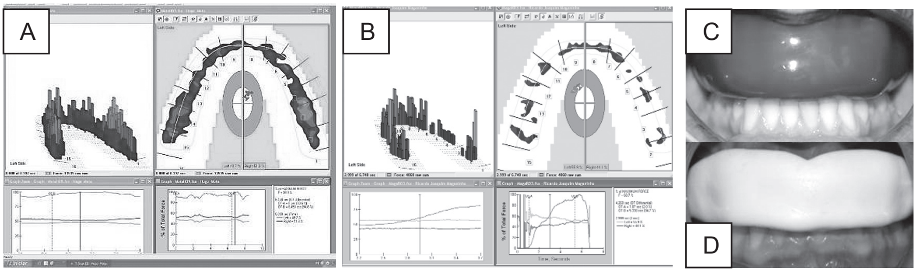

Figure 3: A) T-Scan® data of MOM were we can analyse the centre of foces howing equilibrium of contacts throuhgout the entire mouthguard, B) T-Scan® data BBM, C) MOM, D) BBM

CONCLUSION: Sports-related oro-facial trauma can be reduced or avoided by the use of a properly fitted mouthguard. Dentists play the key role in the prevention and treatment of sports-related dental and oro-facial injuries as well as promoting the research on the preventive procedures with a multidisciplinary team including mechanical engineering.
The manufacturing procedures of the MOM can be more complicated and time consuming, but it will be proportional to its higher level of protection, due to its occlusal stability, muscular stability and protection of the TMJs. The MOM is indispensable in reducing the impact force and may be a further contribute to the establishment of guidelines for safer mouthguards.
Educational programs, like symposiums, seminars with athletes, parents, coaches, medical staff, should be implemented to encourage and educate the sports community regarding the risks of oral injury in sports, and the importance of fabricating properly fitted intra-oral devices, like MOM, regarding their protective properties, costs and benefits.

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