SUMMARY

Data from international literature indicate that injuries of children and adolescents in the orofacial region have increased during sport activities in recent years, as more and more children and adolescents participate. The use of mouth guards, nowadays, constitutes essential and necessary equipment in many sports and athletic activities. It is known that there are 3 types of mouth guards, which are fitted or are made to be fitted either on one jaw (the maxilla or the mandible) or on both jaws (bi-maxillary mouth guards).

The aim of this article is to describe the fabrication processes of some types of mouth guards. Firstly, the fabrication process of the bi-maxillary mouth-formed boil and bite mouth guard is described. These types of mouth guards are available commercially, but they need further modification. Secondly, the fabrication process of the custom made mouth guard, which is individually fabricated for each athlete, is described. Additionally, the peculiarities of fabrication of mouth guards for those who are wearing, simultaneously, fixed orthodontics appliances, as well as for athletes with mixed dentitions, are specified. Lastly, particular emphasis is given on fabrication processes of bi-maxillary custom made mouth guards and 3 methods are described.

Keywords: Mouth Guards; fabrication.

Introduction

It is a fact that the sports-related injuries have increased during the last years, due to the popularity of sports and athletic activities in children and adolescents. As a result, orofacial injuries have also increased1-3. The orofacial injuries are very common injuries among children and adolescences participating in various sports1,4-8.

The use of mouth guards by athletes has been shown to provide effective protection against injuries1,4-6,9,10. The general or specialist dentist has 3 types of mouth guards at his disposal and in proportion with each situation, namely each athlete’s needs, can propose the adequate mouthguard5,6,11-18.

The first type (type I) of mouth guards are stock mouth guards, which are available in sporting stores and ready to use, and there are in different sizes. They offer the least protection and adaptation, and the great interference with speaking and breathing activities. As this type of mouth guards is available commercially, it won’t be described6,14,15,18.

The second type (type II) of mouth guards is known as mouth-formed boil and bite mouth guards. This type of mouth guards is also available commercially, but they need further modification by the dentist, before the athlete wears it in the mouth. They offer better protection and adaptation than the type I, but less than the third type. They offer, also, less interference with speaking and breathing than type I mouth guards. They are made from thermoplastic material5,12,16,18.

The third type (type III) of mouth guards are custom made mouth guards, which are individually fabricated for each athlete after they have been ordered. They are made in a dental practice or in a dental technician laboratory on a cast of the athlete’s mouth according to the dentist’s
Fabrication of Type III Mouth Guards

The basic stages for the fabrication of type III mouth guard are 6-12:

a) The impression of the dental arches;
b) The fabrication of the casts;
c) The record of the relationship of the mandible to the maxilla that mouth guard will provide;
d) The fabrication of the mouth guard;

Among these materials the most common used material is the EVA 5,6,12,23-32.
e) The trimming and the polishing of the mouth guard;
f) The placement and the equilibration of the occlusion through the mouth guard.

The receiving stage of the impression must be done very carefully, especially when the athlete is undergone an orthodontic treatment with fixed appliances (braces) in order not to distort the appliances during the removal of the impression. The more exact the impression is, the better adaptation the mouth guard will have. After receiving the impression, it is poured-in with a high-strength stone and the cast is fabricated.

The type III mouth guard can be fabricated with 2 methods in proportion to the 2 types of machine that will be used\textsuperscript{12,14,15,17}. The former is based on a respectively high temperature and vacuum (approximately 1 atm), whereas the latter is based on very high temperature and high positive pressure (approximately 10 atm)\textsuperscript{5,12,14,15,17,26,34}. The internal adaptation that the mouth guard will have after fabrication is directly dependent on the level of temperature and the amount of pressure of each machine. The new pressure machines, which operate with positive pressure, have significant differences from the conventional machines, which operate only with vacuum. The most important advantage of the pressure machines, due to the higher temperature and higher pressure which they provide, is the better internal adaptation of the material over the cast and, consequently, better adaptation of the mouth guard in the mouth. As a result, the mouth guard offers better protection and is more convenient for the athlete\textsuperscript{12,14,15,17}.

**Vacuum Formed (Single-Layered) Mouth Guard**

According to the first fabrication method, the cast is placed on the platform of the machine (Fig. 5a), while a single sheet of specific thermoplastic material is placed a little higher, in a specific case, with size 12.7 x 12.7 cm\textsuperscript{2} and thickness 5 mm (Fig. 5b). The thermoplastic material should have approximately 5 mm thickness and, consequently, the mouth guard will have a 3 mm thickness after fabrication, taking into account a shrinkage between 25%-50% of the thermoplastic material during fabrication\textsuperscript{5,6,12,17,25}.

Before the placement of the cast over the platform of the machine, the vestibular borders at the bottom of the gingivo-buccal and gingivo-labial sulcus are marked with a pencil on the casts. Then, the cast is trimmed and the excesses of the stone are removed up to the marked borders. In this way the mouth guard will obtain better retention because of the increasing surface contact. Also, the protection at the alveolar bone will be greater. The margins must extend to the previously marked extensions, whereas the mouth guard lingually must extend 1 mm from the teeth and distally must extend to the second molar or at least to the first molar\textsuperscript{17}.

The next step is the trial of the mouth guard in the athlete's mouth. Usually, an equilibration between the occlusal surface of the mouth guard and the teeth of the opposing arch is necessary. The equilibration, generally, is done on an articulator, otherwise the equilibration is achieved by heating gently the occlusal posterior surface (out of the mouth) of the mouth guard with a flame, the immediate placement in the mouth and the careful biting down so that all the posterior teeth of the opposite arch come simultaneously to contact with the mouth guard on the other jaw\textsuperscript{12}. This stage of the procedure is very essential because the athlete must not bite down excessively and maintain the requisite thickness 3 mm of the occlusal surface of the mouth guard so that the absorption of the undesired injuring impact forces can be done. After that the mouth guard is ready for use by the athlete (Fig. 5i).

![](image327x98 to 515x286)

**Figure 5. Fabrication process of type III mouth guard**
According to this way of fabrication, the mouth guard is composed of 1 layer, namely it is a single-layered mouthguard\textsuperscript{6,12,17}. This type of mouth guard is recommended for sports, in which athletes are not at risk to afflict each other\textsuperscript{17}. A lot of scientists suggest that the proper thickness of the material of the mouth guard is not provided in all parts according to the first way of fabrication, without meaning that they reject this way of fabrication. These deficiencies can be faced by fabricating a multi-layered mouthguard\textsuperscript{5,12,26}.

**Pressure Laminated (Multi-Layered) Mouth Guard**

Therefore, many dentists use the second method to make a type III mouth guard that is based on a very high temperature and high positive pressure; these mouth guards are multi-layered (Fig. 2). A pressure-lamination machine is used for this method.

2 or 3 sheets of material in size 12.7 x 12.7 mm\textsuperscript{2} and thickness 3 - 4 mm each are usually chosen for placement\textsuperscript{6,9,17}. Mostly, the internal material is soft and resilient, whereas the external material is rigid and tough\textsuperscript{18}. Moreover, each layer can be from different material, which is laminated under high pressure (approximately 10 atm) and temperature\textsuperscript{12}. The placement of the layers is done one-by-one. The first layer is placed at the beginning, which is slimmer and there is the potential of better adaptation, then it is trimmed, polished at the margins and finished according to the above procedure. Afterwards, the same procedure for the next layer is done, namely the cast with the mouth guard is placed on the platform of a pressure-lamination machine, as well as a second sheet of thermoplastic material in the specific case, which is thicker and together with the other layer will provide better mouth guard and proper thickness in order to absorb any impact forces\textsuperscript{5,12,15,17,26}. It is highlighted that this stage must be done carefully because the material must be warmed enough to achieve the lamination, otherwise the lamination won’t be done sufficiently and in due time the layers will separate. The second layer is left under pressure to cool on the cast for 15 minutes\textsuperscript{17}. Then, the under fabrication mouth guard is modified, trimmed and the margins are polished again in accordance with the first method of fabrication. It is noteworthy to refer that all layers of a multi-layered mouth guard must be done with the same machine.

Lastly, the equilibration of the occlusion between the mouth guard and the dental arch of the opposite jaw is necessary, with 1 of the 2 preferred ways. According to this method of fabrication, type III mouth guard is ensured better thickness (4.5 mm) of the material, owing to the fact that shrinkage 25\% - 50\% is occurred\textsuperscript{5,6,12,15,17,25}. Furthermore, this method allows the record of some athlete’s data, as well as the placement of some decorative figures on the first layer before the lamination of the second sheet of the material.

Apart from this method of adhesion of the layers, namely adhesion by heating, there are, adhesion using a solvent, which melts the surface of the sheets of the material that are bound to come in contact with, and adhesion using a bond-retentive agent between the layers\textsuperscript{9}.

This type of mouth guard is suggested for contact sports\textsuperscript{15}.

**Fabrication of Type III Mouth Guards in Patients Undergoing Orthodontic Therapy**

It is important to refer that type III mouth guards are the best choice for patients who have already commenced orthodontic therapy with fixed appliances, or in children with mixed dentition\textsuperscript{1,5,11,12,35-41}. Nevertheless, some special management must be done for fabrication the type III mouth guards (either single-layered or multi-layered) in athletes with fixed orthodontic appliances.

Firstly, utility wax (like string) is placed on the braces, compressing gently. Therefore the penetration of the alginate impressing material in the braces is averted by far and consequently, it is averted the tearing of the impression when the impression is removed from the mouth.

Secondly, a Mortite Weatherstrip and Caulking Cord is placed on the athlete’s cast, which must cover the braces that are sticking out and wires, as well as must pouring the regions where the eruption of tooth or prospective tooth movements are going to be done. The using material must be resistant to high temperature during the heating of fabrication process so as not to change during the adaptation of the thermoplastic material of the mouth guard. It is separated from the thermoplastic material with a separating medium, such as vaseline. So, there is no problem from the prospective tooth movements during the orthodontic treatment and the continually eruption of permanent tooth, which would otherwise occur and, as a result, the initial impression, as well as the mouth guard, soon won’t adapt to the dentition. The same is happened in mixed dentition due to growth of jaws. When a multi-layered mouth guard is suggested in athletes with fixed orthodontic appliances, the technique is the same as the conventional type III multilayered mouthguards\textsuperscript{37,41}.

**Fabrication of Bi-Maxillary Mouth Guards**

The fabrication of bi-maxillary mouth guards can be done, mainly, with 3 methods.
First Method

This method is described by Chapman (1986)\textsuperscript{20}. The procedure is begun with the articulation of the athlete’s casts, using wax or silicone for the record of the “heavy breathing position”. This record involves the athlete to breathe adequately, even under extreme exertion.

The record is done in accordance with the following procedure\textsuperscript{20}: at the beginning, the mandibular opening is determined by placing the patient to sit upright on the ground and to look straight forward. Afterwards, a nose-clip is placed on the nose of the patient to close the nasal cavity and consequently to stop the nasal breathing so that the patient will breath only from the mouth. The patient is asked to start taking slow full breaths, making sure that each face inhalation-exhalation lasts approximately 5 seconds and the mouth should be closed after every exhalation. The breath should be held for 10 seconds after the first 2 exhalations, 15 seconds after the next 2 exhalations and 20 seconds after the next 2 exhalations. The process is repeated after 2 minutes, with the nose-clip on the nose. The mandible now should come to the prospective position, while the patient intermittently is breathing out all the air. In this point maxilla abstains from mandible. The opening between the upper and lower incisors of the jaws at the midline is measured with a Willis gauge or with another similar instrument. With this instrument the opening is recorded. Usually, the opening is fluctuated between 7 - 10 mm. This distance is not stable and varies in each person, recorded. Usually, the opening is fluctuated between 7 - 10 mm. This distance is not stable and varies in each person.

The opening of each of the mouth guard should have incisally 3 mm thickness over the anterior teeth. If bigger thickness is required, 1 or 2 more sheets of the material are added. The thickness of each mouth guard, apart from the previous region, should have at least 2 mm thickness. Moreover, each mouth guard should extend backwards until the middle of each second molar, whereas buccally, labially and lingually should extend beyond gingivo-buccal, gingivo-labial and gingivo-lingual sulcus, and cover up to 2-3 mm soft tissues. Finally, palatally, it should extend and cover from the gingival margin from 10 mm to 15 mm.

Additionally, the thickness of each mouth guard is reduced occlusally from 3 mm, as it is made, to 1.5 mm approximately, namely it is decreased by 1.5 mm.

Afterwards, the mouth guard of the mandible is trimmed, only at the occlusal surface in the region of the incisors, so that the edges of labial and buccal surfaces of the incisors are uncovered approximately by 1.5 mm. This last step is done not only for the maximum comfort of the athlete but also for the airway to become bigger, which facilitates athlete’s ventilation. Possible adjustments of each mouth guard are done before the wax-up and the flasking because the cast is destroyed during the deflasking.

According to the “heavy breathing position” of the athlete which recorded, the casts of the upper and lower jaws are articulated on an average value or semi-adjustable articulator, based on the wax records. The mouth guards are then placed on the casts and they are joined together with a modelling wax at each side. The material of each joining is extended, occlusally, from the distal margin of the mouth guard to the cusp or the distal surface of each canine, avoiding excess thickness where is not necessary and giving the material slightly concave shape on the other 4 surfaces.

Then, the bi-maxillary mouth guard, namely after joining the 2 mouth guards together with the wax, is removed from the articulator together with the casts and it is invested with the casts into the flask in order to remove the wax. The casts are trimmed back before flaking. The wax is removed with a spatula and the removal of possible remains of the wax on the surfaces of the mouth guards is cleaned with a cloth soaked in chloroform.

2 clean sheets of material (EVA) are carefully softened with heat in a metal chaffing dish, without overheating, over a flame until they become pliable and easily formed. The material is packed in big amounts at each half of the flask and then the flask is closed. For better adaptation a clamp is used and the flask together with the clamp is immersed in hot water (70°C) for 15 minutes. After that the flask is tightened with more pressure, it is immersed again in hot water (80°C) for other 15 minutes. This process is repeated until full adaptation of the material is obtained so that the flask is closed completely and the excess material is removed. Afterwards, the flask is left to cool at least for 4 hours, then it is immersed in cool water for 30 minutes, and
finally the flask can be opened to take out the bi-maxillary mouth guard.

The last step of the Chapman’s method, prior to the use of the bi-maxillary mouth guard is its finishing and polishing with stone burs, polishing discs, and chloroform or trichloro-ethane. Nevertheless, sometimes additional adjustment of the mouth guard is necessary and it should be done approximately after 7 days from the wearing day.

**Second Method**

Another method of a bi-maxillary mouth guard fabrication is described by Jagger and Milward. According to them, the impressions of the upper and the lower jaw of the athlete are firstly taken, poured with stone and the casts are made. Then, the extension on each cast is marked, which the bi-maxillary mouth guard will have after the fabrication. The bi-maxillary mouth guard should extend distally up to the middle of the second molars, whereas the labial, buccal and lingual margins should extend beyond gingivo-buccal, gingivo-labial and gingivo-lingual sulcus, and cover up to 2-3 mm the soft tissues. Furthermore, palatally should extend and cover 10-15 mm from the gingival margin.

Afterwards, the casts are articulated on an average value, or semi-adjustable articulator in centric occlusion, and the required vertical dimension is determined, from which the opening of the bi-maxillary mouth guard will depend. Usually, a 7-10 mm opening is made in the anterior region between the incisal edges of the upper and lower anterior teeth. Another technique for determination of the opening of the bi-maxillary mouth guard, namely the distance between the incisal edges of the upper and lower anterior teeth, can be done according to the Chapman’s record of the “heavy breathing position” of the athlete, as it is described above.

Then, sheets of thermoplastic material (usually EVA) of required thickness are chosen, so that the mouth guards have approximately a 4 mm thickness and they are shaped on the cast of each jaw. Mouth guards which are under fabrication are shaped at the predefined dimensions. Before the next step, it is essential to remove material 1-2 mm approximately from the anterior teeth, labially and lingually, from the mandibular mouth guard in order to facilitate the athlete’s ventilation.

To continue, the maxillary and mandibular mouth guards are joined together with extra material (EVA) between the occlusal surfaces. To achieve the conjunction between the occlusal surfaces of the 2 mouth guards and the extra material glue is used, which firstly is heated and then is placed. One long piece of the extra thermoplastic material is placed in each side occlusally of the mouth guards, which is shaped with heating. Usually each piece is extended from the distal margins of the 2 mouth guards to the distal surface or the cusp of each canine of the jaws.

The joined and almost finished bi-maxillary mouth guard is left to cool. It is important for to cool it enough in order not to distort, at the next stage, which is its finishing and polishing. Jagger and Milward’s method finishes with the polishing of the bi-maxillary mouth guard, using stone burs or polishing discs.

Jagger and Milward claim that their method of a bi-maxillary mouth guard fabrication is faster and easier in relation to the Chapman’s method, which is more complicated and time-consuming.

**Third Method**

The third method of a bi-maxillary mouth guard fabrication is described by Milward and Jagger in 1995. It has a lot of common data not only with the first method (Chapman) but also with the second (Jagger and Milward). According to this method, as with the other 2 methods, it starts with receiving the impressions of the maxilla and the mandible of the athlete. Then, the impressions are poured in with dental stone and the casts are made.

The margins where bi-maxillary mouth guard will extend are marked on each cast (Fig. 6a). The bi-maxillary mouth guard should extend backward until the middle of the second molars. Furthermore, the labial, buccal and lingual margins should extend beyond gingivo-buccal, gingivo-labial and gingivo-lingual sulcus, and cover up to 2-3 mm the soft tissues. Palatally, as it is referred previously, the mouth guard should extend and cover 10-15 mm from the gingival margins. Then, the casts are mounted in an average value or semi-adjustable articulator, and the required vertical dimension is determined, which corresponds at the opening of the mouth guard after fabrication. Usually, an opening 7-10 mm is made in the anterior region between the incisal edges of the upper and lower anterior teeth. Alternatively, the opening of the bi-maxillary mouth guard can be determined according to the Chapman’s technique record of the “heavy breathing position”.

Afterwards, soft sheets of wax are taken, shaping them on the casts and the mouth guards of each jaw, making sure that each one is extended until the marked margins (Fig. 6, b and c). The required thickness, which the wax should obtain, is approximately 4-5 mm. The mouth guard of the mandible is trimmed only at the occlusal surface in the region of the incisors, so that the edges of labial and buccal surfaces of the incisors will be uncovered approximately 1.5 mm (Fig. 6d). Then, 2 wax models of the maxilla and the mandible are joined together, at the predetermined vertical dimension. The conjunction is done in each side of the mouth guards, adding extra pieces of wax. Each wax conjunction is placed occlusally of the wax models of the mouth guards in the posterior region, and usually extends from the distal margin of the wax model to the distal surface or the cusp of each canine of the jaws (Fig. 6e). The excess
thickness of the added wax is avoided where it is not necessary, and the wax is given a slightly concave shape on the surfaces.

Before the investing procedure, the whole wax assembly is smoothed and polished very well with a flame because as smooth and polished the wax assembly is, so smooth and polished will the bi-maxillary mouth guard be after flasking. Afterwards, the lingual and palatal part of the assembly is poured with stone and when the stone is hardened, it is trimmed back (Fig. 6, f and g).

The flask is placed in a hydraulic press in order to remove the excesses of the stone (Fig. 7e). The minute the stone is hardened, the flask is boiled to remove the wax (Fig. 7f) and then 2 parts of the flask is separated (Fig. 7, g and h). After that, the space that is created (Fig. 8a) is packed with silicone and it should be made sure that the material fills the lingual as well as the palatal part of the assembly (Fig. 8, b and c). The flask is then placed, again, in a hydraulic press in order to remove the excesses of the silicone (Fig. 8d). The flask is closed and it is immersed in hot water. When the water comes up to boiling point, the flask is remained approximately for 1 hour, according to the manufacturer’s guidelines. Then, the flask is left to cool and when it has cooled enough, the deflasking is done (Fig. 8, e and f) and the mouth guard is carefully removed from the casts.

The next step is the removal of the material excesses (Fig. 9a). At the end of the Milward and Jagger’s method, the bi-maxillary mouth guard is smoothed and polished and then it is ready for use (Fig. 9, b-d).
The advantage of this method of fabrication a bi-maxillary mouth guard is that the material is quite resilient and adaptable, which is preferred from the majority of athletes. In contrast, the bi-maxillary mouth guard from EVA material is rigid and inflexible. However, it is a more time-consuming and expensive method than the other methods.22.

References


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