

Easy fabrication of a new type of mouthguard incorporating a hard insert and space and offering improved shock absorption ability

SHORT COMMUNICATION

Tomotaka Takeda, Keiichi Ishigami, Osamu Mishima, Kensuke Karasawa, Katsuhide Kurokawa, Takaki Kajima, Kazunori Nakajima

Department of Sports Dentistry, Tokyo Dental College, Chiba, Japan

Correspondence to: Tomotaka Takeda, Department of Sports Dentistry, Tokyo Dental College, 1-2-2 Masago, Mihama-ku, Chiba 261-8502, Japan
Tel.: +81 43 270 3605
Fax: +81 43 270 3609
e-mail: ttakeda@tdc.ac.jp

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Abstract – The positive effects of wearing a mouthguard have been indicated in various epidemiological surveys and experiments, and their usage appears to be increasing in many sports. However, many preventable sports-related dental injuries still occur even with the use of a conventional mouthguard. We have developed a mouthguard (the Hard & Space mouthguard) with sufficient injury prevention ability (more than 95% shock absorption ability against impact with a steel ball carrying $15.2 \text{ kg m}^2 \text{ S}^{-2}$ potential energy) and ease of clinical application. This mouthguard consists of an outer and an inner EVA layer and a middle layer of acrylic resin (hard insert), with a space to prevent contact between the inner surface of the mouthguard and the buccal surfaces of the maxillary front teeth or teeth already weakened through prior damage or treatment. The purpose of this article is to describe the method by which the Hard & Space mouthguard may easily be fabricated. We believe that this new type of mouthguard has the potential to reduce sports-related dental injuries.

The positive effects of wearing a mouthguard have been indicated in various epidemiological surveys and experiments (1–5), and their usage appears to be increasing in many sports. However, many preventable sports-related dental injuries still occur despite the use of a conventional mouthguard. For example, in a study of NCAA basketball teams, although athletes wearing custom-made mouthguards sustained significantly fewer oral injuries than those who did not, injuries did still occur (1.16 injuries per 1000 athletic exposures versus 3.00 injuries per 1000 athletic exposures, respectively) (6).

It is clear that when the impact force far exceeds the protective capability of the mouthguard, injury will occur. This is particularly true in cases where the wearer has restored (7–9) or endodontically treated (10) teeth as the strength and resiliency of a treated tooth never return to normal levels. Furthermore, if a dental implant (11) is used, the periodontal tissues become susceptible to secondary injury owing to a high elasticity modulus. However, the ordinal impact power in sports is estimated to be smaller than that found in traffic accidents (12). Therefore, most sports-related dental injuries not only in sound teeth but also in treated teeth are assumed to be preventable by use of an appropriate mouthguard with high shock absorption ability.

Many studies have investigated new methods for improving the shock absorption capabilities of mouthguards. These have included the use of air cells (13), Sorbothane (14), a metal wire (15), a sponge (16), and a hard material (17–19). Most of these studies showed that

these materials or fabrication methods were effective. However, the results of these studies have not been clinically applied.

The ability of a mouthguard to protect against frequent injuries, often caused by a direct blow to the teeth, is believed to depend on the following three factors: (i) its ability to absorb and dissipate the force of impact throughout the mouthguard material itself, which covers the buccal surface of the maxillary incisors; (ii) its ability to provide reinforcement at the lingual surface of the maxillary incisors; and (iii) its ability to gain support from the mandibular dentition reinforcing the maxillary dentition and alveolar bone. This third effect can be achieved only if the mouthguard allows the wearer to achieve fully balanced occlusion while clenching as a risk avoidance maneuver (20).

In earlier studies (21, 22), we attempted to develop a mouthguard with sufficient injury prevention ability and ease of clinical application. This mouthguard consisted of an outer and an inner EVA layer and a middle layer of acrylic resin (hard insert), with a space to prevent contact between the inner surface of the mouthguard and the buccal surfaces of the maxillary anterior teeth, which often receive direct horizontal impact in sports and in more than 80% of sports-related tooth injuries (23–27), or teeth already weakened through prior damage or treatment (7–10). These mouthguards showed more than 95% shock absorption ability in terms of tooth distortion against impact with a steel ball carrying $15.2 \text{ kg m}^2 \text{ S}^{-2}$ potential energy (21, 22).

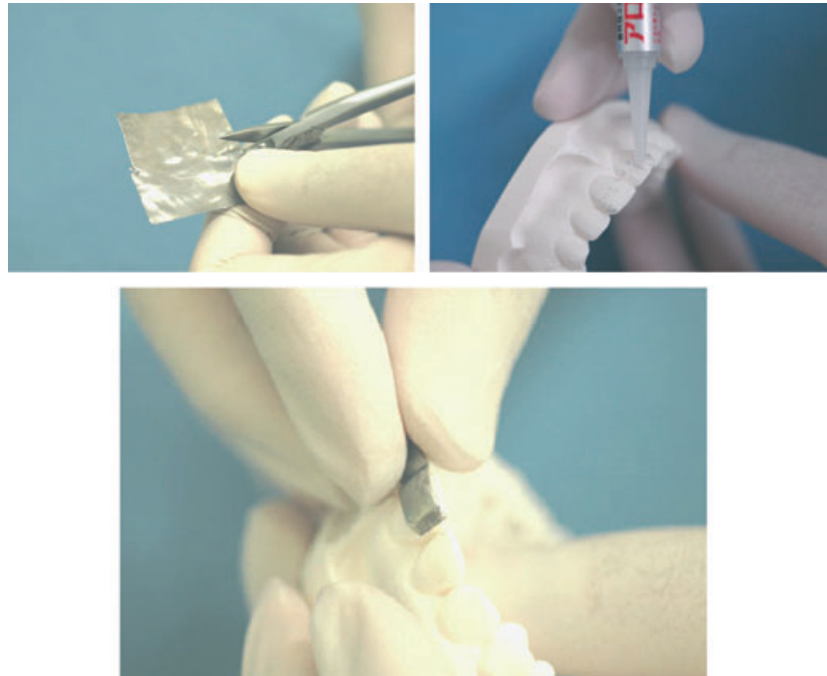


Fig. 1. Metal spacer material affixed to buccal surface of maxillary anterior teeth to establish air space chamber of finished mouthguard.

However, this method still left room for improvement, and we were concerned that delamination might occur at the laminated surface. Moreover, the production method was rather complex. Therefore, to resolve these issues, we modified the method of fabrication. We have designated this new type of mouthguard the 'Hard & Space mouthguard'. It should be noted that in addition to the advantages demonstrated that, here, this mouthguard complies with the general standards required for mouthguards worldwide. Namely, it has an appropriate thickness of approximately 3 mm, even in the buccal hard and space area. Furthermore, appropriate adaptability has been achieved using an air pressure machine, and there is no toxicity or pungency of the materials, all of which are used in conventional mouthguards and splints.

This article describes the fabrication method of this new and improved type of mouthguard.

Procedure

Our newly designed Hard & Space mouthguard has three major characteristics: (i) a relief chamber metal (Toyokagaku Kenkyusho Co., Ltd, Hyogo, Japan) affixed to the buccal surface of the teeth for easy establishment of a space; (ii) sufficient lamination; and (iii) a hard material insert of the desired thickness to reduce impact force transmitted to the teeth. In selecting teeth, range, and thicknesses of the desired space, we need to consider the needs of the athlete with respect to age, type of sport, level of competition, history of past injuries, and oral conditions (presence or absence of fractured or repaired teeth, teeth with veneer metal crowns, porcelain facing crowns, implant prosthetics, fixed partial denture, etc.).

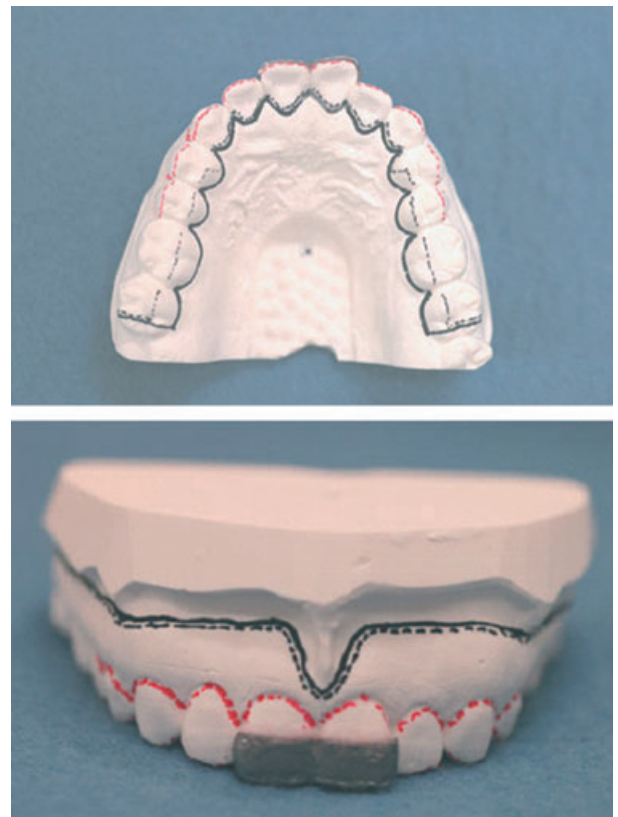


Fig. 2. Border extensions for the completed mouthguard are marked on the master cast prior to mouthguard fabrication. First layer, black-dotted line EVA; second layer, red-dotted line hard layer; third layer, solid black line EVA.

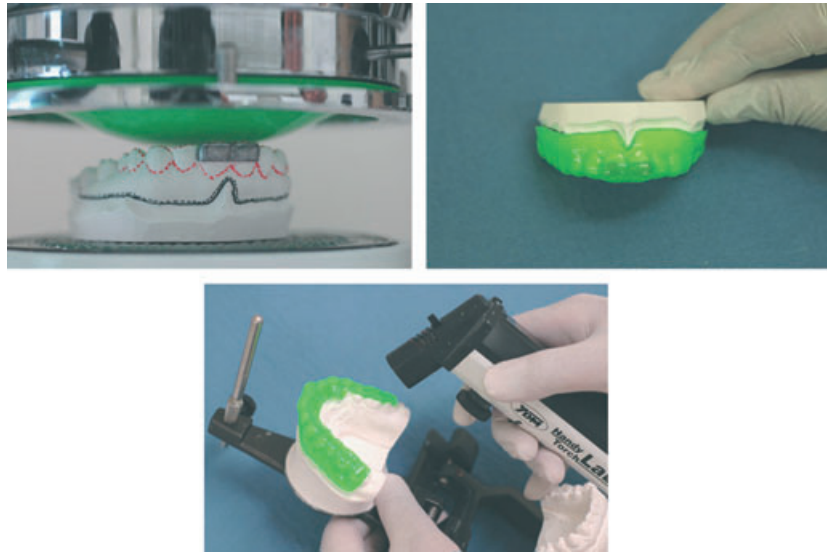


Fig. 3. Occlusion adjusted on first layer.

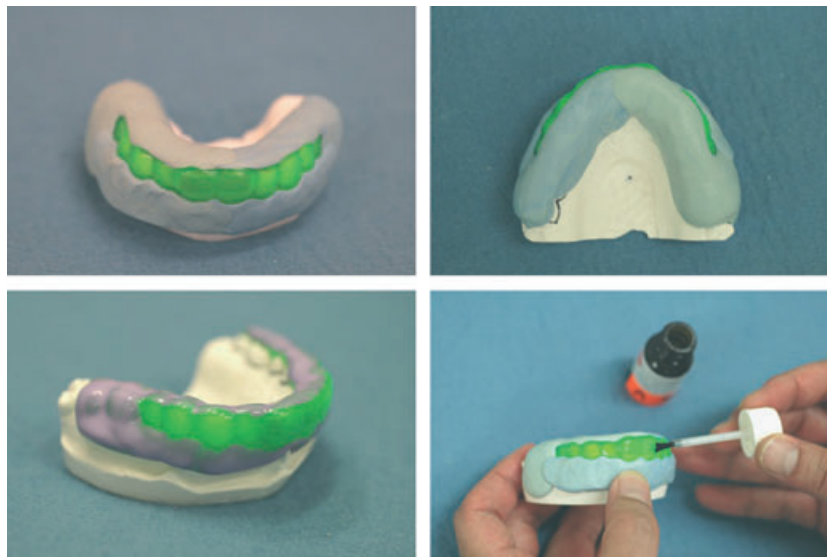


Fig. 4. Silicon putty or Erkoskin is placed over first layer of EVA except buccal tooth surfaces from second premolar to second premolar.

The following gives a step-by-step description of the fabrication process, figure-by-figure.

To achieve the necessary space between the surface of the teeth and the mouthguard, a relief chamber metal is affixed to the surface of the teeth. In this study, we affixed it to the most frequently damaged teeth, the bilateral upper anterior incisors. It was affixed to the model after cutting to the appropriate size, using quick setting adhesive. To diminish the ridge where the metal meets the model, it may be smoothed out with use of a repairing agent (Tuff Repair, Ruby, Osaka, Japan) or plaster (Fig. 1).

Figure 2 shows the basic outline of the mouthguard. The first layer of EVA material (black dotted line) covers

the buccal and occlusal surfaces, but not the palatal surface. The second, middle layer, a hard sheet (red dotted line), covers the buccal tooth surface between the bilateral second premolars to distribute impact power over a wide area. The third layer of EVA material (black solid line) covers all the buccal, occlusal, and palatal surfaces. Thus, sufficient thickness of the mouthguard is maintained at the buccal and occlusal surfaces to protect the teeth and establish fully balanced occlusion, while it is not so thick as to create discomfort at the palatal surface in the wearer.

After thermoforming the first 2-mm EVA layer (DrufoSoft: Dreve-Dentamid GMBH, Unna, Germany) using air pressure machine (DrufoMat Type SQ, Dreve-



Fig. 5. Adhesive primer applied to first EVA layer and hard layer before thermofusing two layers. Model then embedded in metal beads with buccal surfaces exposed.

Dentamid), the mouthguard material is cut and trimmed along the outline. Then, the occlusion of the mouthguard is adjusted on the articulated model (Fig. 3).

For hard material lamination, the dentition was covered with silicon putty, except for between the buccal

surfaces of the bilateral second premolars. ERKOSKIN (Erkodent, Pfalzgrafenweiler, Germany) may be used instead of silicone putty. DrufoSoft Primer (Dreve-Dentamid GMBH, Unna, Germany) is applied to the rough surfaces of both the first layer of EVA material and the hard insert before pressure forming. This surface treatment will improve the bonding strength of the two laminated materials (28) (Fig. 4).

To achieve precise adaptability, bonding strength, and avoid model fracture, the model is embedded in metal beads with the buccal surface upturned for thermoforming of the second layer of hard material (Biolon, DrufoSoft: Dreve-Dentamid; Erkodur, Erkodent, Pfalzgrafenweiler, Germany, etc.). A cooling-down time of approximately 2–3 min is sufficient after thermoforming of the hard layer (Fig. 5).

The second layer of thermoformed material is then cut according to the outline. At this point, great care must be taken to avoid damaging the EVA material as much as possible. The silicone putty is then removed (Fig. 6).

After surface treatment of the removed surface and application of adhesive, a printed name label, team logo mark, or sticker may be applied. The third sheet also requires surface treatment (Fig. 7).

In thermoformation of the third, 2-mm EVA sheet, a number of factors in addition to those described above need to be taken into consideration in improving layer-to-layer adhesive strength (28). At 30 s of heating, the third EVA layer is turned over, making the heated surface the bonding surface (Fig. 8).

We previously made and reported the 'occlusal spacer', which was developed to secure occlusal consistency (29). It was made from plastic spherules (2- or 3-mm in diameter) placed inside a thin plastic bag. This occlusal spacer is for use at the mounting phase on an articulator, being placed between the upper and lower occlusal surfaces of the teeth (usually used at a first molar). The occlusal spacer is quite easy to use and is effective in obtaining occlusal consistency. Before the

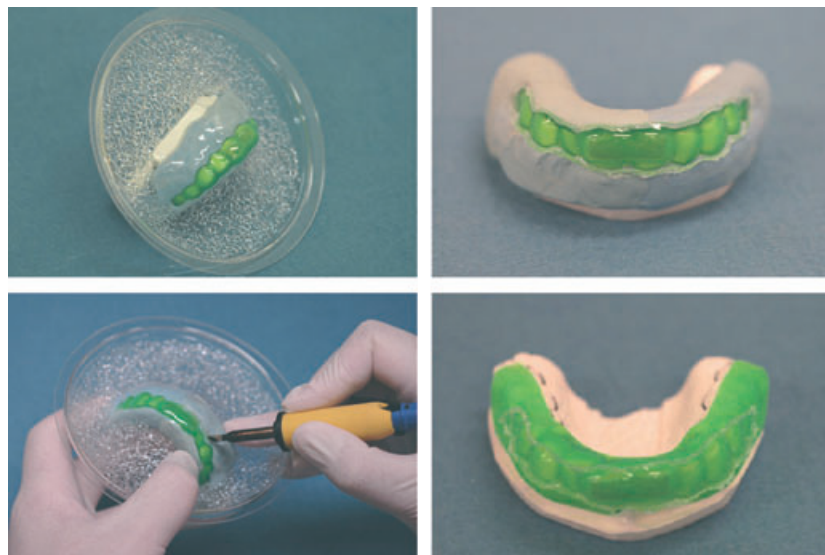


Fig. 6. Excess hard layer material trimmed away from mouthguard and then putty layer removed from mouthguard.

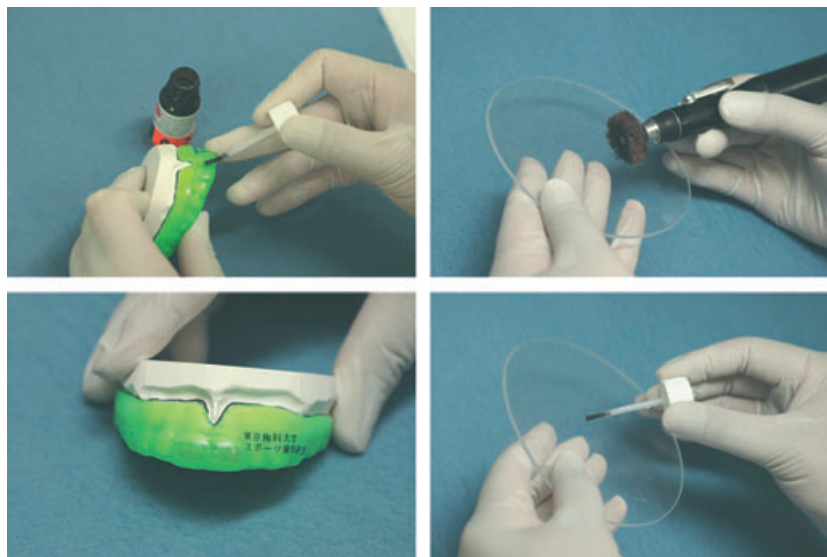


Fig. 7. Primer applied to mouthguard and third layer before thermoforming.

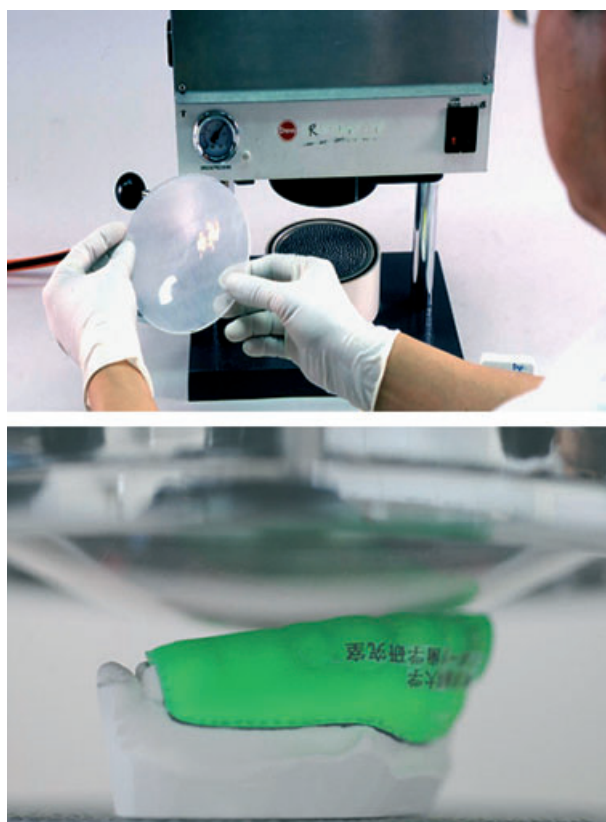


Fig. 8. After 30 s of heating, third layer of material is inverted prior to fusion with mouthguard to improve adhesion between layers.

mouthguard is cut and trimmed completely, occlusion is adjusted on the articulated model to prevent the mouthguard from becoming distorted. This mouthguard

should offer fully balanced occlusion and good protection against direct impact, the most common type of impact, except in sports such as American Football, where damage is more likely to arise from horizontal impact owing to use of a faceguard (30) (Fig. 9).

Final adjustment of occlusion to avoid pain and irritation is necessary at the chair side clinically. The completed Hard & Space mouthguard looks very similar to a conventional EVA-type mouthguard with fully balanced occlusion. The ridge where the two mouthguard materials meet is not conspicuous (Fig. 10).

Continual adjustment of the mouthguard through regular appointments with the dentist is necessary, just as with any other conventional dental prosthesis. Furthermore, it should be emphasized that this mouthguard is, at present, only in the developmental stage, and further preclinical and clinical research is required to confirm its efficacy and safety.

Summary

The purpose of this article was to describe how our newly designed Hard & Space mouthguard can be fabricated with ease. We believe that this new type of mouthguard has the potential to reduce sports-related dental injuries.

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Conflict of interest

The authors declare no conflict of interest.

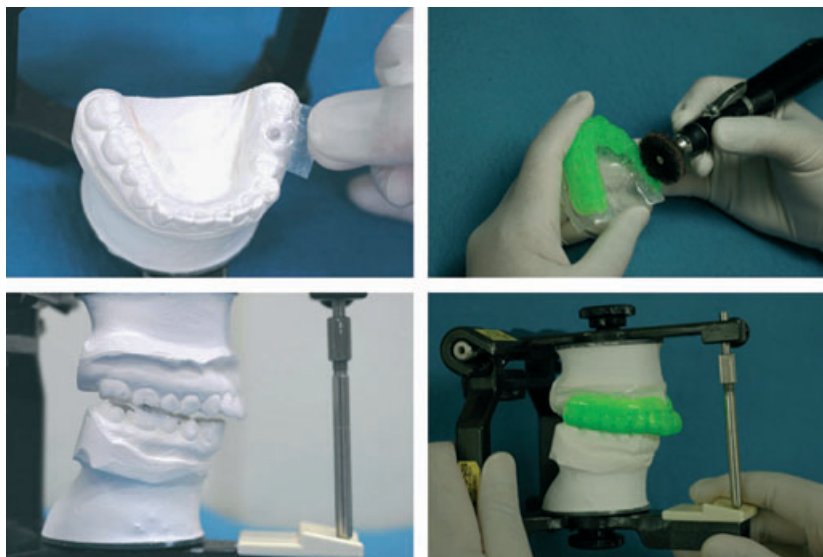


Fig. 9. The 'occlusal spacer' is used to establish the interocclusal distance necessary for a comfortable, 'balanced' mouthguard.

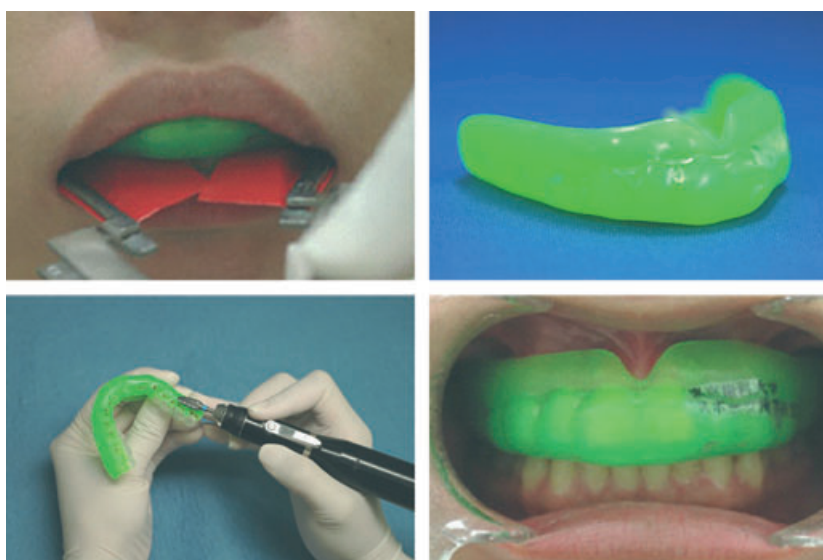


Fig. 10. Final occlusal adjustments should be made to assure comfort. The areas where the layers of mouthguard material fuse are not clinically evident.

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