J. Gifu Dent. Soc.
Vol.48, No.3, 143 ～ 151
February, 2022

CASE REPORTS

Custom-made Mouthguard Fabrication by Using Gothic Arch Tracing for a Jaw Deformity

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To fabricate a custom-made mouthguard (CMG) for a patient with a jaw deformity, we examined his mandibular position by using a Gothic arch tracer.

A 19 year old man presented with malocclusion and temporomandibular joint dysfunction. He was a competitive volleyball player and needed a custom-made mouthguard (CMG) to prevent injury during his activity. At the first visit, the extraoral examination revealed that the mentum deviated to the left. The intraoral examination revealed Angle class III malocclusion, left posterior crossbite, left deviation of the lower middle line in the intercuspal position, and anterior deep overbite (overjet: -3.1 mm, overbite: 1.4 mm). He also had pains in the left temporomandibular joint and masseter muscle, but no abnormal bone morphology was found in the temporomandibular joint. Therefore, the patient was diagnosed with skeletal mandibular protrusion and type II temporomandibular disorders.

To treat this malocclusion, orthodontic surgery was required; however, the patient did not want to have any aggressive treatment as long as he was an active athlete. Therefore, we decided to fabricate a CMG for preventing injury and stabilizing the jaw position.

We used a Gothic Arch tracer to record the mandibular movement and positions and found that the tracing showed asymmetric movement to the right, indicating that the movement of the left mandibular condyle was inhibited. Assuming that Gothic arch apex position is pressureless mandibular retraction position (reference position), we fabricated a CMG in the reference position to stabilize the mandibular while the CMG was being worn.

We took bite registrations in the Gothic Arch apex and centric occlusal positions to fabricate CMGs in both positions. We then examined the occlusal contacts, grip strength, and fit state when each CMG was worn.

The results showed that the occlusal contact points were distributed more evenly when CMG in the Gothic Arch apex position was used than that in the centric occlusal position was used. The grip strengths of both hands were greater in the Gothic Arch apex position than in the centric occlusal position. The right and total grip strengths were significantly greater than the other measurement values ($p < 0.05$). The patient had a slight discomfort wearing the CMGs because these were his first CMGs, although he felt that the CMG in the Gothic arch apex position was more stable in his mouth than that in the centric occlusal position.

Key words : jaw deformity, skeletal mandibular protrusion, Gothic Arch tracing, custom-made mouthguard

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(*Accepted January 7, 2022*)

INTRODUCTION

Mouthguards (MGs) are recommended to be worn during sports activity to protect athletes from injury of the oral and maxillofacial regions.[1] The rate of MG use has been increasing as various sports associations require or recommend athletes for wearing MGs.[2] There are two types of MGs: commercial and custom-made types. The former includes stock type, which is preformed mouth pieces, and formed type, which end-users can customize. The commercial types are affordable, but their fits may be poorer and less effective in protecting athletes from injury than custom-made mouthguards (CMGs). A CMG is designed by a specialist adequately considering injury prevention and proper jaw position, depending on the athletes' conditions and the sports they are involved in.[3-5] Many researchers have reported their methods for CMG fabrication;[6-8] however, no report was found for fabricating CMGs in a mandibular position recorded by Gothic Arch tracing.

Here, we used a Gothic Arch tracer to record the mandibular movement and positions in a jaw deformity patient with temporomandibular dysfunction to fabricate a CMG effective for injury prevention and occlusal stability.

We obtained consent from the patient for this publication.

CASE SUMMARY

A 19 year old college student presented to our hospital with malocclusion, trismus, and temporomandibular joint pain. He was a competitive volleyball player and needed a CMG to prevent orofacial injury during his sporting activity. At the first visit, the extraoral examination revealed that the mentum deviated to the left. The intraoral examination revealed Angle Class III, left posterior crossbite, and anterior deep overbite (overjet: −3.1 mm, overbite: 1.4 mm). The lower midline deviated to the left in the intercuspal position, implying that the movement of the mandibular condyle was inhibited. He also had pains in the left mandibular joint and masseter muscle, but no abnormal bone morphology was found in the temporomandibular joint. Due to his severe jaw deformity, we asked an orthodontist to analyze his dentofacial morphology. Posteroanterior cephalometric analysis showed that the mentum deviated 4 mm to the left from the facial midline, and lateral cephalometric analysis showed an ANB angle of 5.6°, indicating skeletal mandibular protrusion (Figs. 1, 2, 3, and 4 and Table 1). As a result, we diagnosed the patient as having high-angle skeletal Class III with left deviation of the mandibular and type II temporomandibular disorder. To treat this malocclusion, orthodontic surgery was required; however, the patient did not want to have any aggressive treatment as long as he was an active athlete because the treatment might have affected his performance. Therefore, we decided to fabricate a CMG for preventing injury and stabilizing the jaw position.

TREATMENT

Because the patient's mandibular deviated to the left in the intercuspal position, we used a Gothic Arch tracer to record the mandibular movement and position and found that the tracing showed asymmetric movement to the right, indicating that the movement of the left mandibular condyle was inhibited (Fig. 5). Then, we took bite registration in the Gothic Arch apex position to fabricate an MG in the position (Fig. 6). Also, as a control, we took bite registrations in the centric occlusal position to fabricate another MG in the position. Because of the deep overbite, MGs were fabricated for being placed on the mandibular. An ethylene-vinyl acetate (EVA) mouthguard sheet with a thickness of 3 mm (YAMAHACHI DENTAL MFG, Aichi) was used to fabricate the mouthguards with a pressure molding machine (DRUFOMAT-SQ, Rinkai Inc., Tokyo) to add the same pressure on

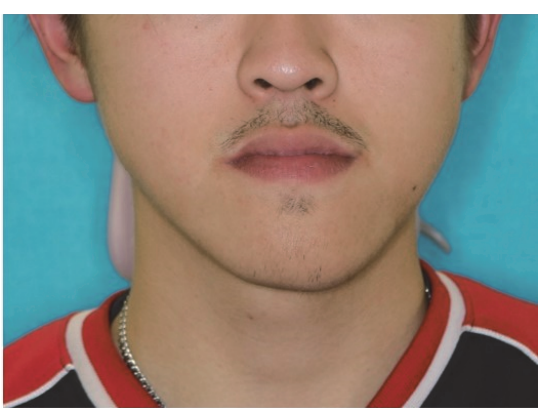


Fig. 1. Frontal facial photo in the centric occlusal position

Fig. 2. Intra-oral photos in the centric occlusal position

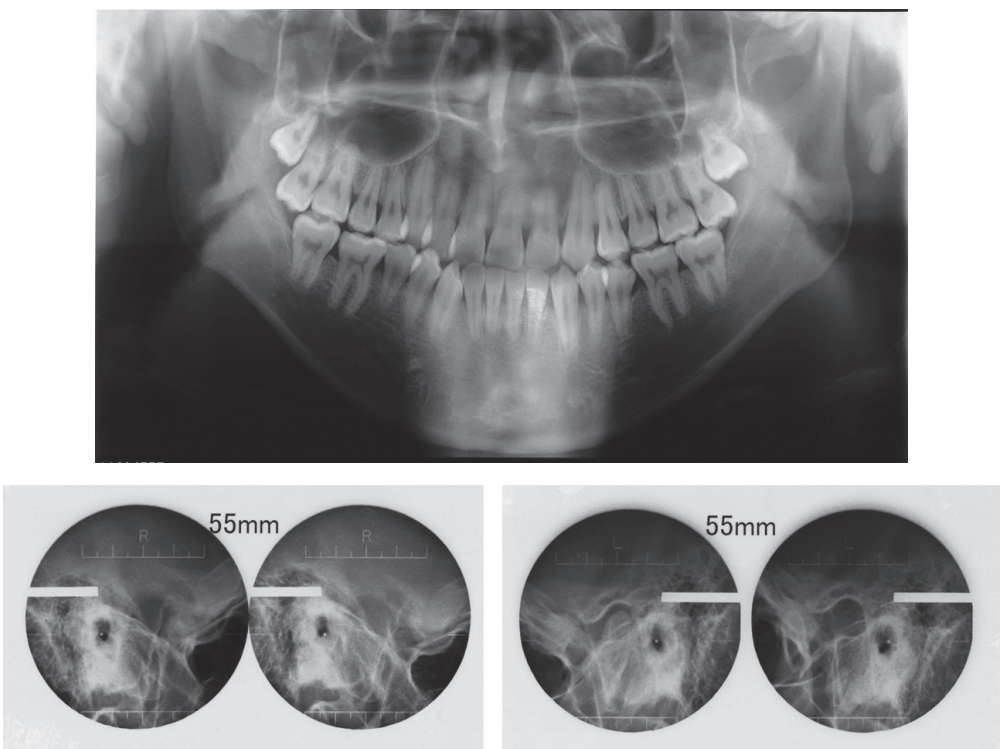


Fig. 3. Orthopantomogram and Schüller projection

each CMG.[2] To examine the stability of the CMGs in the mouth, we marked the occlusal contact points by using Blue Silicone Low Flow (GC, Tokyo) and then visualized them by using Bite Eye BE-I (GC, Tokyo). To assess isometric strength when CMGs were worn, the grip strengths of both hands were measured 3 times in the standing position with each CMG by using GRIP D digital grip dynamometer TKK 5101 (Takei Scientific Instruments, Niigata).[9] For statistical analysis, Student's t-test and Microsoft® Excel® 2016 (Microsoft Corp., Redmond, USA) were used, and $p < 0.05$ was considered statistically significant. We

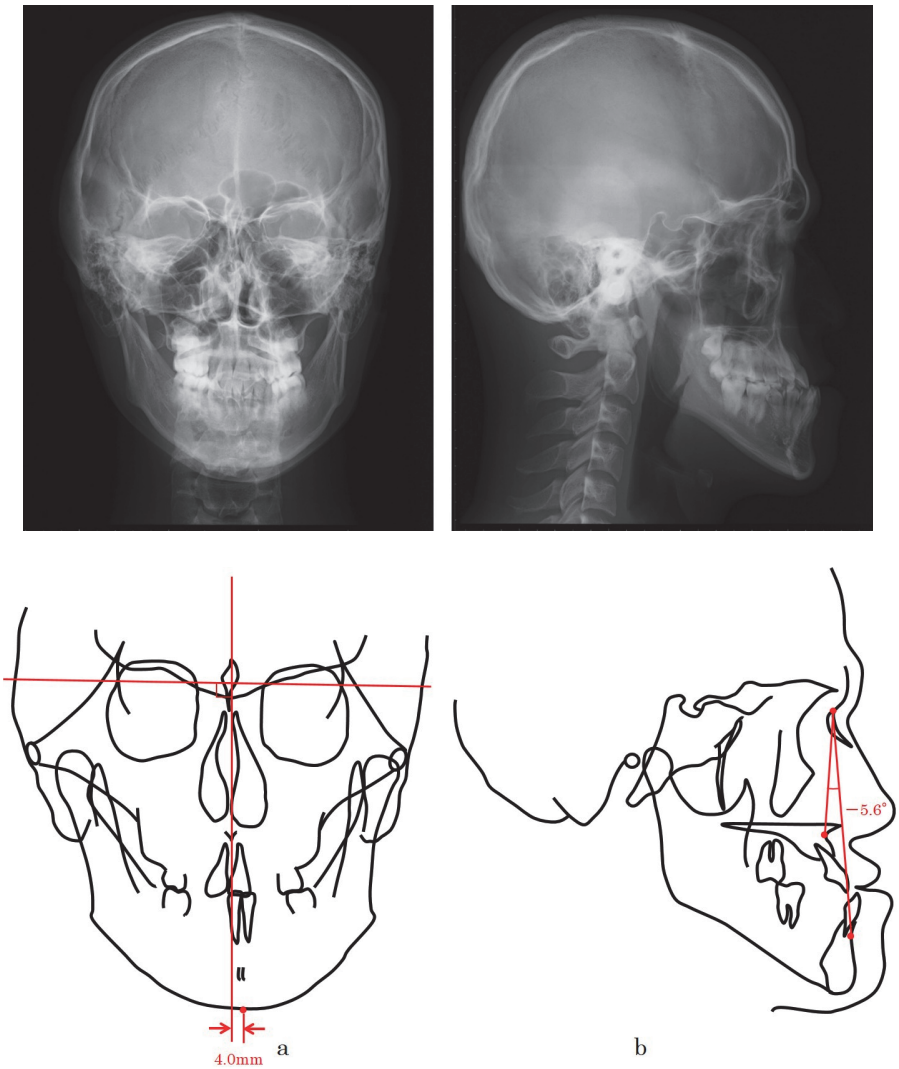


Fig. 4. Cephalograms and cephalometric analysis

a: Midline deviation of the mandibular

b: ANB angle

obtained information on the fit state and the stability of the mandibular position with each CMG from the patient to assess the difference between the CMGs.

RESULTS

In analysis of occlusal contact points, 24 points were observed in the centric occlusal position and 36 in the Gothic Arch apex position. The occlusal contact areas were 136.8 mm^2 in the centric occlusal position (97.4 mm^2 on the right occlusion: the observers' left and 39.4 mm^2 on the left occlusion: the observers' right) and 113.9 mm^2 in the Gothic Arch apex position (54.2 mm^2 on the right occlusion and 59.7 mm^2 on the left occlusion). The contact areas were distributed mostly on the right occlusion in the centric occlusal position and were evenly distributed on the left and right in the Gothic Arch apex position. Bite Eye BE-I automatically described the occlusal contact balance on a 5-point scale (A = symmetry and E = asymmetry). The balances in the centric occlusal position and Gothic Arch apex positions were categorized as E and A, respectively (Fig. 7).

With CMG in the centric occlusal position, the means of the grip strength were 46.3 kg for the right and 43.4 kg for the left, and the total grip strength was 89.7 kg. With CMG in the Gothic Arch apex

Table 1. Lateral cephalometric analysis

Measurements		
SNA(deg.)	89.4	**
SNB(deg.)	95.0	***
ANB(deg.)	-5.6	###
Mp-SN(deg.)	31.3	
Mp-FH(deg.)	30.6	
Go.A. (deg.)	137.8	**
Occ.Plane-SN(deg.)	4.8	##
U1-SN(deg.)	125.1	**
U1-FH(deg.)	125.9	*
L1-FH(deg.)	75.2	**
L1-Mp(deg.)	74.2	###
Inter incisal angle(deg.)	129.3	
PTM-A/PP(mm)	53	
Ar-Go(mm)	56.3	
Go-Me(mm)	91.6	***
Ar-Me(mm)	137.2	***
OJ(mm)	-4.8	###
OB(mm)	2.0	

*	1S.D. Large
**	2S.D. Large
***	3S.D. Large
#	1S.D. Small
##	2S.D. Small
###	3S.D. Small

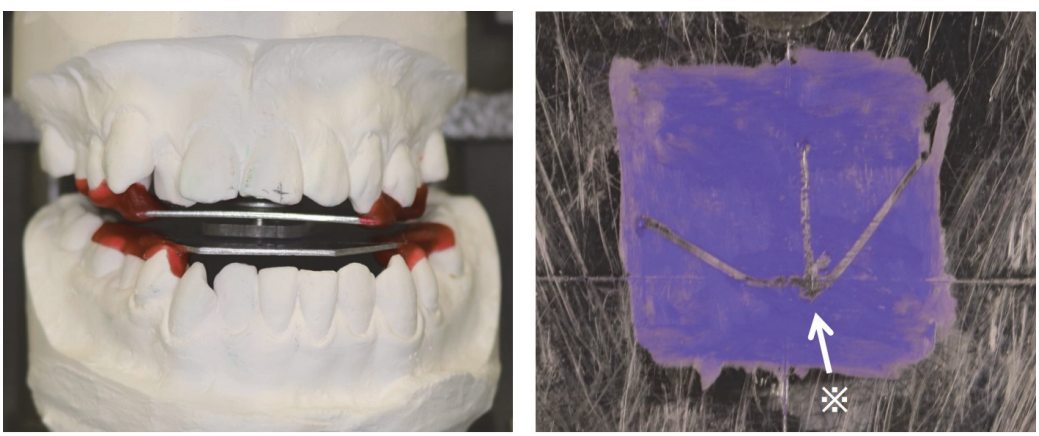


Fig. 5. Gothic Arch Tracing

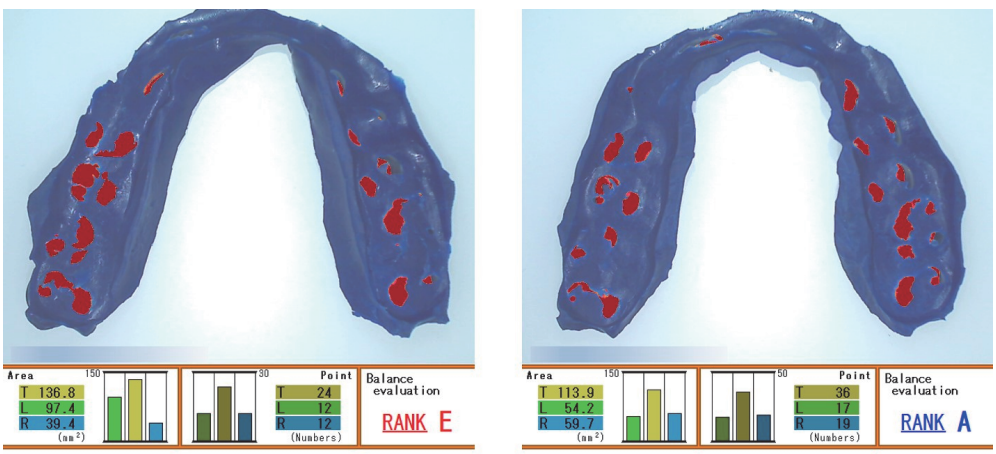
※: Gothic arch apex position

position, the means of the grip strength were 54.2 kg for the right and 48.7 kg for the left, and the total strength was 102.9 kg. All means of the grip strengths with CMG in the Gothic Arch apex position were greater than those with CMG in the centric occlusal position, and the right and total grip strengths were significantly greater than other measurement values (Student's t-test, $p < 0.05$) (Fig. 8).

According to the information from the patient, both CMGs fitted well in his mouth, and no difference was found in breathing difficulties, speaking problems, and discomfort feelings between these CMGs. However, the patient felt better occlusal stability when wearing the CMG in the Gothic Arch apex position. Therefore, we instructed him to use the CMG in the Gothic Arch apex position.

a b

Fig. 6. Intra-oral view with CMGs. This indicates the position of the midline of the maxilla and mandibular dentition.
a: Centric occlusal position
b: Gothic arch apex position



a b

Fig. 7. Analysis of occlusal contact area (red) with Blue Silicone® & BiteEye BE-Ⅰ®.
Visualized occlusal contact area (mm^2) and occlusal contact points (number) were converted into digital data and calculated by the right occlusion (L: the left side), the left occlusion (R: the right side), and their total (T). The occlusal contact balance between the right and left was automatically described on a 5-point scale (A = symmetry and E = asymmetry).
a: Centric occlusal position
b: Gothic arch apex position

DISCUSSION

In recent years, people of all ages, regardless of gender, have begun to participate in sports, showing an increase and diversification of sports injuries. Increased physical strain caused by improved physical ability and sports skills may affect the severity of the injuries.[10] MGs can effectively prevent maxillofacial injuries, so sports dentists recommend for inducing MGs, especially CMGs.[1-5] According to the reports on mouthguard use during sports activity, many athletes wear CMGs following the rules of sports associations, in which appropriate safety measures have been taken.[2, 11] Evidence-based CMG fabrication methods published by the Japanese Academy of Sports Dentistry[12] have been becoming widespread; however,

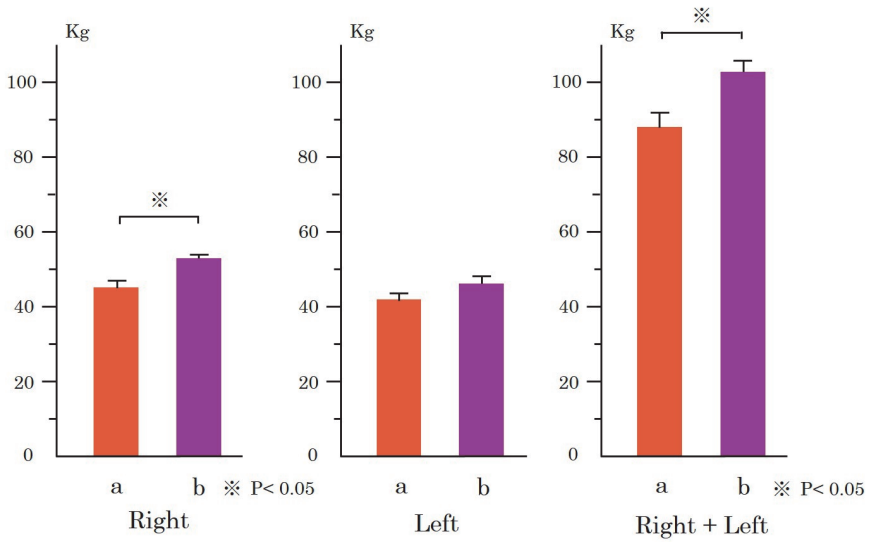


Fig. 8. Measurements of the grip strength with CMGs

a: Centric occlusal position

b: Gothic arch apex position

(Student's t-test, $P < 0.05$)

most of the methods focus on more fabrication techniques than assessments of occlusal correlation and jaw position.[13]

Kataoka et al.[14] investigated 1,503 college students aged 18 to 19 years and found that 481 students had malocclusion. Ueno[15] also reported that malocclusion was found in 30% of Olympic athletes at their medical checkups. Given that about a third of people in these population have malocclusion, dentists should assess athletes' occlusion to fabricate CMGs in a proper position of the mandibular. Because of the patient's skeletal condition and the lower midline deviation in the centric occlusion, the left joint overload may cause temporomandibular joint dysfunction, and an impact on the mandibular could cause a fracture of the body and condylar process of the mandibular. Therefore, it was important to correct the jaw position during his sporting activity.

Also, unstable occlusion could increase the sway of the center of gravity, leading to decreased sports performance.[16] We used a Gothic Arch tracer to record functional mandibular movement and, based on the assumption that Gothic arch apex position is pressureless mandibular retraction position (reference position), we attempted to correct the jaw position by placing a CMG at that position.[17, 18] Gothic arch tracing is generally used to accurately record centric relation and functional mandibular movement in complete denture fabrication.[19] Before a treatment for malocclusion, the jaw position is usually assessed by use of a face bow transfer and a semi-adjustable articulator, but the operation is highly specialized. Gothic Arch tracing is considered that general clinical dentists could easily diagnose the jaw position. There are no reports of applying the Gothic Arch tracing to MG fabrication, so this article is the first report using Gothic arch tracing for MG fabrication.

In the occlusion analysis when MGs were applied, the combination of Blue Silicone Low Flow and Bite Eye BE-I system allowed us to assess the occlusal contacts in both positions accurately. Kurokawa et al.[13] reported that this combination was simple and accurately visualized the points. In addition, occlusal contact points were not qualitatively assessed by use of articulation paper or recorded with Dental Prescale and Occluzer if MGs were made from EVA. Thus, the combination of Blue Silicone Low Flow and Bite Eye BE-I system is very useful for analyzing occlusal contacts with MGs.

Takeda et al.[5] conducted a collision experiment using MGs supporting different areas and a skull model to investigate the occlusal condition of MGs on injury prevention. They found that the strain was generated or concentrated in the mandibular

as supporting areas decreased, implying that CMGs in an unstable occlusal position was less effective in preventing injury. Thus, MGs should be fabricated in a position where the mandibular is stable for effectively preventing injury.

In patients with temporomandibular joint dysfunction, using stabilization splints may alleviate their symptoms and improve their physical ability,[20, 21] as well as clenching in the maximal intercuspal position might increase the isometric strength of the limbs.[22] However, Umetani et al.[23] and Inamizu[24] demonstrated that people with mouthguards repositioning the mandibular did not enhance instantaneous power. Our results showed that grip strengths of both hands were greater with a CMG in the Gothic Arch apex position than with that in the centric occlusal position, and the right and total grip strengths were significantly greater than other measurement values. However, evaluating one patient is not enough to draw a conclusion; therefore we need more cases for evaluating assessing isometric strength for better performance.

Schulze et al.[25] showed that the stabilized occlusal condition could fix the center of gravity rather than increase instantaneous muscle exertion, leading to enhanced sports performance.[4, 9] Our results showed that the CMG in the Gothic Arch apex position provides evenly distributed occlusal contact areas, suggesting that the sway of the center of gravity is limited within the proper jaw position.[26]

Takeuchi et al.[27] described that an introduction of MGs may cause poor concentration if athletes had a discomfort feeling, difficulty in speaking and breathing, and a mild vomiting reflex. These conditions may disappear as patients get used to MGs. If not, the design and thickness of the material should be changed. Although the patient has not had any strong discomfort with the CMGs, we should regularly check his CMG and adjust it if needed.

CONCLUSION

We applied a Gothic Arch tracer to record the mandibular position to fabricate the CMG in the proper jaw position. In patients with jaw deformity, mandibular movement should be examined by use of a device, including a Gothic Arch tracer, to fabricate CMGs to effectively stabilize jaw position and prevent injury.

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