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Analysis of micrognathia with obstructive sleep apnea syndrome improved by a combination of Le Fort I with horseshoe osteotomies, mandibular distraction osteogenesis, and genioplasty

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May 11, 2022

Abstract

Background: The relationship between microgenia and obstructive sleep apnea syndrome is well known. Patients: 27-year-old woman. She underwent a combination of Le Fort I with horseshoe osteotomies and mandibular distraction osteogenesis and genioplasty. Results and Conclusions: She was satisfied with the aesthetics of her face, with an AHI of 7.8/h.

Introduction

Obstructive sleep apnea syndrome (OSA) is a disease in which apnea appears due to obstruction of the pharynx during sleep. Several reports have described that abnormal maxillofacial morphology such as small mandibular disorder is involved in the pathophysiology of OSA [1,2]. Furthermore, the influence of maxillofacial morphology is large in Asian races wherein the incidence of OSA due to obesity is low [3].

Here, we discuss about Le Fort I with horseshoe osteotomies (LF+HS) and mandibular distraction osteotomy for patients with small mandibular disorders with OSA and bilateral mandibular condyle resorption. After performing surgery (mandibular distraction osteogenesis, MDO) and then genioplasty (GP), we encountered a case in which OSA could be improved in addition to small mandibular disease and malocclusion.

Material and Method

Patient: A 27-year-old woman

First visit: March 13, 2012

Primary complaint: Hoping to get treated for micrognathia and malocclusion

Family history and medical history: No special notes

Current medical history: On March 13, 2012, she visited our hospital with a primary complaint of micrognathia and malocclusion. We referred to an orthodontist for the diagnosis of her jaw deformity and preoperative orthodontic treatment. When she returned to our department on March 10, 2013, after the completion of the preoperative orthodontic treatment, she complained of drowsiness during daytime. Therefore, we referred her to the sleep outpatient department, where the Epworth Sleepiness Scale (ESS) score

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was recorded at 14 points and the apnea–hypopnea index (AHI) was 22.5/h, based on which moderate OSA was diagnosed.

Present illness: Systemic findings: Nutritional status was good, height was 163.6 cm, body weight was 61.8 kg, and body mass index was 23.0 kg/m2, indicating the absence of obesity according to the criteria 4) of the Japan Society for the Study of Obesity.

Extraoral findings: Her face was symmetrical and long, the lateral side of the face was convex with marked mandibular retraction, and the chin was markedly retreated. The upper lip measured 14.3 mm, and the lower lip measured 21.4 mm, protruding from the E-line (Fig 1A). No clicking sound or pain was found in the temporomandibular joint.

Intraoral findings: The occlusal state revealed angle II grade on both sides, the horizontal overlap was +3.0 mm, the vertical overlap was -2.0 mm, and the maximum opening was 32 mm (Fig 1B). The exposed gingiva of the maxillary anterior teeth measured 5 mm.

No abnormal findings were detected in the size or morphology of dentition and tongue, and no hypertrophy was observed in the uvula or palatine tonsils.

Imaging findings (Mar 14, 2013): Three-dimensional computed tomography (3D-CT) images revealed absorption images on both mandibular condyles. The distance from the highest point to the mandibular notch at the mandibular condyle was 12.5 mm on the right side and 8.3 mm on the left side (Figs 2A, B).

In the cephalometric analysis, SNA (81°) was within the reference value, and SNB (69°) was smaller than the reference value. The ANB (12°) was larger than the reference value, the facial angle (68°) was smaller than the reference value, the maxilla was within the reference value, and the mandible was in the posterior orientation (Table 1, Fig 3A).

The moderate OSA diagnosed in the sleep outpatient department and the absence of obesity or palatine tonsil hypertrophy suggested that the morphological abnormality of the mandible, termed as small mandible, is the major cause of OSA.

Clinical diagnosis: micrognathia, malocclusion, open bite, OSA, progressive condylar resorption (PCR).

Treatment plan: In this patient, the gingival exposure of the maxillary anterior teeth was as large as 5 mm, and the mandibular angle was large, and a long face was observed due to occlusal insufficiency due to small mandibular disease and open bite. Hence, the purpose was to improve the occlusal insufficiency and aesthetics. The patient received LF+HS on the maxilla, the palate and dentition were divided into horseshoe shapes, and the maxillary gingival fragments were planned to be elevated by 5 mm in the maxillary molars, 7 mm in the anterior teeth, and counterclockwise.

There are two possible conditions for mandibular surgery in this patient: SSOR, which moves the mandible forward, and MDO, which extends the mandible forward. In this case, absorption was observed in both mandibular condyles before surgery, and hence when the mandible was rapidly moved anteriorly by SSRO, the mechanical burden on the mandibular condyle was large as indicated by Shimizu et al [5]. It is considered that there exists a high possibility that PCR will progress after surgery due to a decrease in blood flow from soft tissues due to mechanical stimulation. In contrast, MDO was selected because it is recommended as a method that can reduce the mechanical burden on the mandibular condyle and maintain blood flow to the mandibular condyle with minimal periosteal detachment. In addition, one of the complications of MDO surgery has been reported to be postoperative relapse [6,7]. Therefore, in consideration of relapse, we planned to perform overcorrection to extend the mandible to the incisal occlusion position. We decided to obtain a stable jaw position by tightening the occlusion through postoperative orthodontic treatment. Furthermore, extending the mandible anteriorly expands the tongue anteriorly and extends the tongue anteriorly, so that the anterior–posterior diameter of the pharynx behind the tongue also increases, and improvement of OSA can be anticipated. We explained to the patient and her parents before surgery that the surgical procedure involves cutting and lifting the upper jaw and extending the lower jaw forward and that there is a risk of

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surgical complications including PCR and relapse. The patient and her parents were also informed regarding the prolonged hospitalization, and their consent was obtained. Moreover, if she still felt the mandibular retraction after surgery, GP can be used to move the chin forward to eliminate the mandibular retraction. Regarding the administration of GP, we decided to consult again after the operation based on the result of the operation.

Treatment and course: On May 10, 2013, both LF+HS and MDO were performed.

Intraoperative findings of LF+HS and MDO: For LF+HS, we first performed a conventional Le Fort I type osteotomy, and after down fracture, we avoided the descending palatine artery and performed anterior osteotomy of the maxillary sinus floor from the outside, and then performed an osteotomy crossing the anterior nasal cavity floor. We then divided the dentition and palatine bone pieces into horseshoe shapes. The dentition fragments were raised 7 mm upward for the maxillary anterior teeth and 5 mm upward for the molars, and we fixed the maxillary dentition fragments to the lateral edges of the left and right piriform apertures and the lower alveolar ridge of the left and right zygomatic bones using Stryker U-CMF plates and locking plates.

After dividing the mandible into sagittal planes, we attached a Zurich distractor Lamas type Y-shaped plate manufactured by KLS Martin to the mandible and extended the extenders on both sides by 3 mm to complete the operation.

Results

Postoperative course: From the day after the operation, the length of the extenders was extended by 1 mm per day, and in consideration of relapse, a 7-mm extension was performed in 7 days to the incisal occlusion including the overcorrection (total, 10 mm), and the device was indwelled. Intermaxillary rubber traction was applied to the anterior teeth to prevent bite.

On Oct 10, 2013 (LF+HS, 5 months after MDO), the AHI decreased from 22.5 to 9.8/h, and the ESS score decreased from 14 to 2 points, and she said her drowsiness had disappeared (Table 1). Moreover, in the cephalometric analysis of the cephalometric profile image obtained on Nov 6, 2013 (LF+HS, 7 months after MDO), the SNB was increased from 69° to 73° (Table 1, Fig 3B, 4). The occlusal state was Angle I, the horizontal overlap was 1 mm, and the vertical overlap was 1 mm. The occlusal state was improved, and the facial angle increased from 68° to 72°. However, as the patient was still worried about the feeling of receding of the chin, we planned to move the chin forward and applied the callus extension device on Dec 6, 2013 (LF+HS, 7 months after MDO). GP was performed at the time of removal.

Intraoperative findings of GP: GP was started from 20 mm above the lower edge of the mandible in the midline of the mandible, passed through the anterior part of the mental foramen, and cut the bones toward the lower edges of the mandible on both sides to form small bone fragments. This small bone fragment was towed forward 13 mm and fixed with one Depuy Synthes Matrix LOCK Chin Plate. Biopex® (calcium phosphate bone paste; manufactured by Nipro) 3 cc was inserted into the bone gap created by the movement of the bone fragments. No bone fixation was performed after the removal of the callus extension device.

Postoperative course: On Sep 1, 2014 (9 months after GP), the AHI further decreased from 9.8 to 7.8/h. ESS score was not remeasured because improvement was already observed after LF+HS and MDO (Oct 10, 2013: 5 months after LF+HS and MDO). She stated that the drowsiness felt during the day had completely disappeared.

Postoperative orthodontic treatment resulted in closer occlusion and stable upper and lower jaws. Cephalometric analysis was performed on the cephalometric profile image taken on Nov 17, 2015 (1 year and 11 months after GP) and Dec 9, 2013 (7 months after LF+HS, MDO). The SNB decreased from 73° to 72°, and the facial angle increased from 72° to 76° (Figs 3C, 4, Table 1).

The patient reported that she was satisfied with her facial appearance and occlusion, and after the surgery, she did not experience drowsiness again during the day and her OSA improved.

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As mentioned earlier, in this case, the anterior extension of the mandible was performed for small mandibular disease, and it was expected that the load on the mandibular condyle would cause PCR enhancement and relapse after surgery. We were planning to observe it closely for a long period of time. However, due to family reasons, the patient abruptly moved to a distant place 2 years and 6 months after the LF+HS and MDO surgery, and our department was closed.

The anterior–posterior diameter of the pharynx: According to the method described by Shimamine et al., the anterior–posterior pharyngeal diameter and the amount of movement of the hyoid bone were measured using the cephalometric profile images taken before surgery, after LF+HS and MDO and GP (Fig. 5, Table 1) [8].

1. June 14, 2013 (1 month after LF+HS and MDO): (1) PPS decreased from 35.1 to 32.6 mm (-2.5 mm), (2) SPPS increased from 17.7 to 18.0 mm (+ 0.3 mm), (3) MPS increased from 4.6 to 10.1 mm (+5.5mm), (4) IPS increased from 7.4 to 12.2 mm (+4.8mm), (5) EPS increased from 6.7 to 11.6 mm (+4.9 mm). These parameters were measured parallel to the virtual FH plane. (6) S-H decreased from 106.4 to 104.9 mm (-1.5 mm), and (7) C3-H decreased from 42.7 to 41.1 mm (-1.6 mm) (Table 1).

2. Nov 6, 2013 (7 months after LF+HS and MDO); (1) PPS increased from 32.6 to 34.8 mm (+2.2 mm), (2) SPPS increased from 18.0 to 19.3 mm (+1.3 mm), (3) MPS decreased from 10.1 to 10.0 mm (-0.1mm), (4) IPS decreased from 12.2 to 11.2 mm (-1.0mm), (5) EPS decreased from 11.6 to 10.3 mm (-1.3 mm), (6) S-H decreased from 104.9 to 104.4 mm (-0.5 mm), and (7) C3-H increased from 41.1 to 48.2 mm (+7.1 mm) (Table 1).

3. Dec 13, 2013 (LF+HS, 7 months after MDO, immediately after GP operation); (1) PPS increased from 34.8 to 35.9 mm (+1.1 mm), (2) SPPS increased from 19.3 to 19.7 mm (+0.4 mm), (3) MPS decreased from 10.0 to 6.6 mm (-3.4 mm), (4) IPS increased from 11.2 to 11.8 mm (+0.6 mm), (5) EPS decreased from 10.3 to 8.6 mm (-1.7 mm), (6) S-H increased from 104.4 to 107.8 mm (+3.4 mm), and (7) C3-H decreased from 48.2 to 46.5 mm (-1.7 mm) (Table 1).

4. Nov 17, 2015 (LF+HS, 2 years and 6 months after MDO, 1 year and 11 months after GP); (1) PPS increased from 35.9 to 41.2 mm (+5.3 mm), (2) SPPS increased from 20.1 to 19.7 mm (+0.4 mm), (3) MPS increased from 6.6 to 6.7 mm (+0.1 mm), (4) IPS decreased from 11.8 to 11.1 mm (-0.7 mm), (5) EPS decreased from 8.6 to 7.6 mm (-1.0 mm), (6) S-H decreased from 107.8 to 105.8 mm (-2.0 mm), and (7) C3-H decreased from 46.5 to 44.5 mm (-2.0 mm) (Table 1).

Comparison of preoperative values with final follow-up values (Nov 17, 2015); (1) PPS (+6.1 mm), (2) SPPS (+2.4 mm), (3) MPS (+2.1 mm), (4) IPS (+3.7 mm), (5) EPS (+0.9 mm), (7) C3-H (+1.8 mm) increased, and (6) S-H decreased (-0.6 mm).

Regarding PCR: When the distance from the mandibular condyle to the mandibular notch was measured using 3D-CT images, it was 12.5 mm on the right side and 8.3 mm on the left side before the operation in March 7, 2013. However, in August 14, 2014 after the operation (LF+HS, 1 year and 3 months after MDO, 9 months after GP), it was 12.1 mm (-0.4 mm) on the right side and 6.7 mm (-1.6 mm) on the left side, compared with values measured preoperatively. The right mandibular condyle was similar, but the left side showed mild PCR progression (Figs 2C, D).

Regarding relapse: The amount of anterior extension of the mandible achieved by LF+HS and MDO was evaluated by measuring the distance between Condylion-B points on both sides using the cephalometric profile image obtained before and after the modification of reported by Miyamoto et al. The amount of relapse was then calculated (Fig. 5) [7]. The distance between Condylion-B points was 89.5 mm on the right side and 92.7 mm on the left side before surgery. Immediately after LF+HS and MDO (Jun 14, 2013), it was 101.3 mm on the right side and 101.8 mm on the left side. In other words, the extension amount was +11.8 mm on the right side and +9.1 mm on the left side. Seven months after LF+HS and MDO, the size was 98.7 mm on the right side and 99.6 mm on the left side immediately before GP surgery (Dec 13, 2013) and 98.6 mm on the right side and 98.9 mm on the left side immediately after GP. It was 98.2 mm on the

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right side and 98.8 mm on the left side 2 years and 6 months after LF+HS and MDO and 1 year and 11 months after GP (Nov 17, 2015).

A difference of +11.8 mm on the right side and +9.1 mm on the left side was observed between before surgery and immediately after LF+HS and MDO and 8.7 mm on the right side compared with values measured 2 years and 6 months after LF+HS and MDO surgery. The left side was 6.1 mm, the right side was 25.6% relapse, and the left side was 33.0% relapse (Table 1, Figs 1C, D).

3. Discussion and Conclusions

Morphological changes in the upper respiratory tract and pharynx occur due to morphological changes and position movements of the mandible due to correction surgery, and changes in respiratory physiology are observed [9]. Therefore, in Europe and the United States, one of the treatment methods for OSA is corrective surgery such as simultaneous upper and lower jawbone movement and genioglossus/anterior traction of the tongue muscle group, and its usefulness has also been reported [10]; however, it is not yet common in Japan. In our literature search, we found that LF+HS and MDO and GP were performed on patients with mandibular condyle who had resorption changes in the mandibular condyle, as in the present case, and had OSA. Consequently, mandibular and malocclusion failures occur. In addition, there are no reports on improvements in OSA.

Regarding the selection of technique: Regarding the maxillary procedure, LF has a limited amount of upward movement of the maxilla, but when HS is used in combination with LF, it is possible to move the maxillary bone fragment significantly upward. As it has been reported that LF+HS is indicated for cases with an upward movement of [?]4 mm [11], in the present case, the maxillary alveolar bone fragment was used for maxillary molars measuring 5 mm and anterior teeth measuring 7 mm. The mandibular movement was secured by raising it counterclockwise.

Regarding the mandibular procedure, PCR is one of the complications after anterior mandibular movement by SSRO, and its incidence has been reported to be from 4.5% to 21% [12, 13]. In contrast, compared with SSRO, MDO can avoid the generation of tension and overloading of mandibular condyle due to the rapid extension of soft tissue caused by surgical procedures and blood flow to the mandibular condyle due to minimal periosteal detachment. Several reports [5, 14] indicate that it is more suitable than SSRO as a treatment method considering PCR because it can maintain the blood flow. In particular, Strijen et al. mentioned that the one-time anterior movement of the mandible by SSRO causes heavy burden on the mandibular condyle, and as a result of slow anterior extension of the mandible by MDO in 40 patients with PCR, we have reported the usefulness of MDO for these patients, describing that PCR was not observed in 39 of those patients (97.5%)[15]. Therefore, in the present case, in which an absorption image was observed in the mandibular condyle before surgery, MDO was selected to prevent the enhancement of PCR.

PCR: The distance from the mandibular condyle to the mandibular notch was measured using 3D-CT images obtained preoperatively March 7, 2013) and 1 year and 3 months after LF+HS and MDO (August 14, 2014). Comparing the distances, the right side decreased by 0.4 mm from 12.5 to 12.1 mm, and the left side decreased by 1.6 mm from 8.3 to 6.7 mm. In other words, the right side was almost the same as before the operation, but the left side demonstrated mild bone resorption.

Sato et al. stated that follow-up is important for at least 2 years, as bone changes in PCR can last for more than 1 year after surgery [16]. We also planned a long-term follow-up, and because of the difficulty to assess PCR from the cephalometric profile image alone, we planned to follow up with CT images, especially 3D-CD images, in addition to the cephalometric profile image. However, although the cephalometric profile image could be tracked until Nov 17, 2015 (LF+HS, 2 years and 6 months after MDO) just before the patient moved to a distant place, CT imaging was obtained at good timing. However, we were reluctant to complete the examination without realizing it.

Relapse: Regarding relapse, McCarthy et al. reported a rate of 22% and Miyamoto et al. reported a rate of 30%–40% relapse [6,7]. To evaluate the relapse in the present case, we modified the method described by

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Miyamoto et al. to measure the distance between the left and right Condylion-B points in the cephalometric side view image [7]. As a result, when the time points immediately after LF+HS and MDO surgery and 2 years and 6 months after surgery were compared, 25.6% relapse was observed on the right side and 33.0% relapse was observed on the left side, but we considered that the upper and lower jaws were stable because occlusal tightness was obtained by the postoperative orthodontic treatment.

The anterior–posterior diameter of the pharynx: Comparing the posterior part of the soft palate before surgery with that 7 months after LF+HS and MDO (Dec 9, 2013), (1) PPS decreased from 35.1 to 34.8 mm (-0.3 mm), and (2) SPPS decreased from 17.7 to 19.3 mm. It increased by +1.6 mm, and (3) MPS increased from 4.6 to 10 mm (+5.4 mm).

In the posterior part of the tongue, (4) IPS increased from 7.4 to 11.2 mm (+3.8 mm), and (5) EPS increased from 6.7 to 10.3 mm (+3.6 mm). It is considered that this finding is because the tongue tuft became larger due to the anterior extension of the mandible by MDO, and the anterior–posterior diameter of the pharynx behind the tongue increased due to the anterior extension of the tongue.

Regarding the position of the hyoid bone: Comparing preoperative values and those measured 7 months after LF+HS and MDO (Nov 6, 2013), it was observed that (6) S-H decreased from 106.4 to 104.4 mm (-2.0 mm), and (7) C3-H decreased from 42.7 to 48.2. It increased to mm (+5.5 mm), and the hyoid bone moved upward and anteriorly. It is speculated that this is because the hyoid muscles and geniohyoid muscles attached to the hyoid bone and geniohyoid spines were pulled upward and anteriorly by the MDO, and the hyoid bones to which these muscles were attached moved upward and anteriorly. Moreover, the AHI measured 5 months after LF+HS and MDO (Oct 10, 2013) decreased from 22.5 to 9.8/h, and the ESS score decreased from 14 to 2 points, which we felt were during the daytime. The drowsiness almost disappeared.

Comparing the values measured immediately before GP (Nov 6, 2013) and after GP (Dec 13, 2013), it was observed that (4) IPS behind the tongue increased from 11.2 to 11.8 mm (+0.6 mm), and (5) EPS increased from 10.3 to 8.6. It decreased to (-1.7 mm). In other words, no significant change was observed in the anterior–posterior diameter of the pharynx behind the tongue depending on the GP. However, the AHI before and after GP decreased from 9.8 to 7.8/h, and daytime sleepiness disappeared completely. Tonogi et al. reported that when the pharynx was observed using an endoscope after SSRO, the pharynx expanded not only in the anterior–posterior diameter but also in the left–right diameter [17]. In the present case, MDO was performed instead of SSRO, but as reported by Tonogi et al., the changes in the size of pharynx after MDO are not limited to the anterior–posterior diameter of the cephalometric profile image but will be affected by result of endoscopy and CT in the future. It was suggested that the change in diameter should be measured and examined.

Comparing the values of (6) S-H and (7) C3-H, which indicate the position of the hyoid bone, immediately before GP (Nov 6, 2013) and 1 week after GP (Dec 13, 2013), (6) S-H was 104.4 mm. It increased from 107.8 mm (+3.4 mm), and (7) C3-H decreased from 48.2 to 46.5 mm (-1.7 mm). Since GP pulls the genioglossus muscle and geniohyoid muscle attached to the genioglossus anteriorly, it is considered that the hyoid bone moves upward and anteriorly after GP. However, as indicated by Shimamine et al., MDO performed before GP caused the infrahyoid muscles that had once stretched to contract again as the anterior movement of the mandible caused the tongue to expand forward[8]. Therefore, (5) EPS decreased, and it was considered that the force to move the hyoid bone downward was exerted.

The increase in pharyngeal anterior–posterior diameter before surgery, after LF+HS and MDO and after GP, was the largest in (1) PPS (+6.1 mm). This result and AHI, which was 22.5/h at the first visit, decreased significantly to 7.8/h after all surgeries (LF+HS and MDO and GP), and daytime sleepiness disappeared completely as a clinical symptom. Therefore, it was speculated that the site of obstruction in the present case was the posterior part of the soft palate, especially (1) PPS. Isono reported that among the 124 patients with OSA who underwent general anesthesia hypopharyngeal endoscopy, 111 patients whose obstruction pressure was above the atmosphere were examined, and the obstruction site was found to be the soft palate. The number of patients was 54% [18].

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After LF+HS and MDO surgery, drowsiness did not appear during the daytime, and fortunately, in the present case, the corrective surgery was able to improve both small mandibular disease and OSA. However, the criteria for adaptation and the prediction of improvement in symptoms associated with jawbone movement are not yet sufficient. Especially, Takehiro et al. report that it is necessary to consider the balance between the amount of change in soft tissues and the size of bone around the soft tissue for the mechanism of OSA onset [19]; also, it is necessary to consider that not only changes in bone movement but also neural regulatory mechanisms by orthognatic surgery are involved. Moreover, it is necessary to evaluate the size of soft tissues such as the tongue and soft palate and analyze the functional changes, and we believe that elucidation of these aspects will be the future task.

Ethical approval

Written informed consent was obtained from the patient to publish this case report, laboratory data, and accompanying clinical images. Any investigation on the patient was performed in accordance with the Declaration of Helsinki.

Author Contributions

Shinya Koshinuma: Conception and design of study, acquisition of data, analysis and/or interpretation of data, Drafting the manuscript

Takafumi Fujii: Conception and design of study, acquisition of data, analysis and/or interpretation of data, Drafting the manuscript

Takeshi Okamura: acquisition of data

Yasuyuki Asada: analysis and/or interpretation of data

Yoshisato Machida: revising the manuscript critically for important intellectual content

Gaku Yamamoto: Conception and design of study, revising the manuscript critically for important intellectual content

All authors critically revised the report, commented on drafts of the manuscript, and approved the final report.

Acknowledgments

None.

Conflict of Interest

There are no conflicts of interest to disclose regarding this paper.

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Figure and table legends

Fig 1

A: Preoperative side view photograph (March 7, 2013).

B: Preoperative intraoral photograph (March 7. 2013).

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C: Profile photograph at the end of our hospital examination 1 year and 3 months after GP (February 17, 2015).

D: Intraoral photograph at the end of our hospital examination 1 year and 3 months after GP (February 17, 2015).

Fig 2 :3D-CT image of the mandibular condyle.

A: Preoperative right mandibular condyle (March 7, 2013)

B: Preoperative left mandibular condyle (March 7, 2013)

C: Right mandibular condyle 1 year and 3 months after LF+HS and MDO and 11 months after GP (August 14, 2014).

D: Left mandibular condyle 1 year and 3 months after LF+HS and MDO and 11 months after GP (August 14, 2014).

Fig 3 : Cephalogram.

A: Black line: Preoperative (March 7, 2013).

B: Red line: LF+HS, 7 months after MDO (December 13, 2013).

C: Blue line: LF+HS, 2 years and 6 months after MDO, 1 year and 11 months after GP at the end of the examination (November 17, 2015).

Fig 4 : Superposition of cephalograms

Black line: Preoperative (Mar 7, 2013), Red line: LF+HS, 7 months after MDO (Nov 6, 2013), Blue line: LF+HS, 2 years and 6 months after MDO, 1 year and 11 months after GP (November 17, 2015)

Fig 5 : Measurement site (modified by Shimamine et al. 8))

Posterior soft palate: (1) PPS: Distance from the posterior pharyngeal wall to PNS. (2) SPPS: Distance from the posterior pharyngeal wall passing through the midpoint between the PNS and the lowest point of the soft palate to the soft palate. (3) MPS: Distance from the posterior wall of the pharynx passing through the lowest point of the soft palate to the soft palate.

Posterior tongue: (4) IPS: Distance from the posterior pharyngeal wall through the lowest point of the anterior part of the second cervical spine to the tongue. (5) EPS: Distance from the posterior wall of the pharynx through the anterior end of the epiglottis to the tongue. These were measured parallel to the virtual FH plane.

Hyoid bone position: (6) S-H: Distance from the lowest point of the hyoid bone to Sella. (7) C3-H: Distance from the lowest point of the hyoid bone to the lowest point of the anterior part of the third cervical spine. Mandibular body distance: Cd –B: Distance from Condylion to point B.

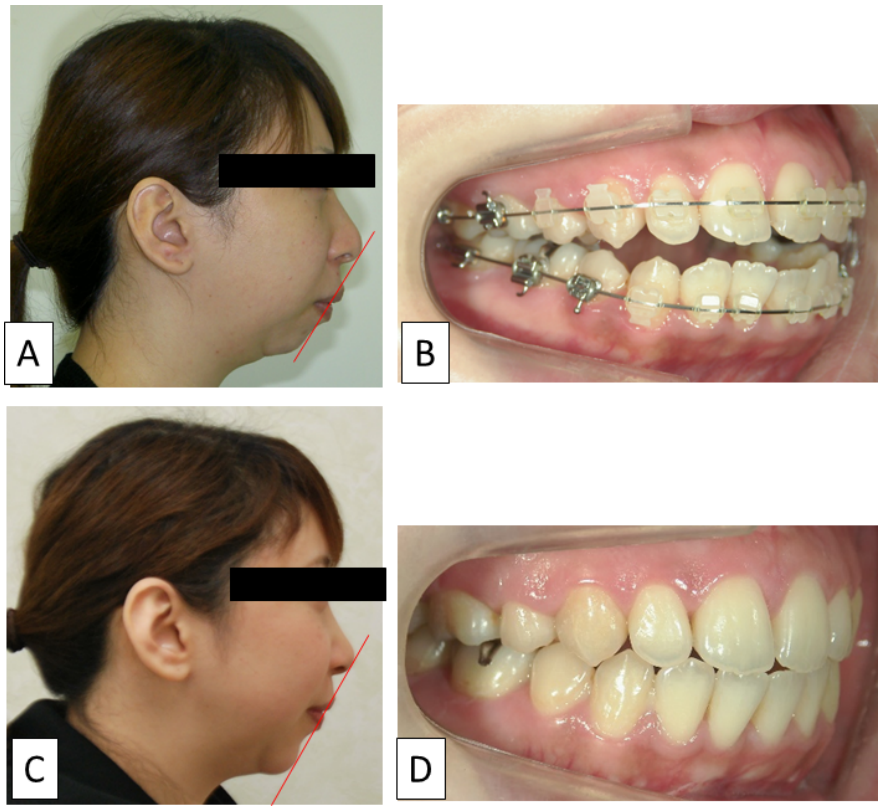
Table 1

Values of ESS and AHI, before surgery (Apr 18, 2013), 5 months after LF+HS and MDO (Oct 10, 2013), 9 months after GP (September 1, 2014).

Cephalometric analysis results (SNA, SNB, ANB, facial angle, Cd – B point distance, and measurement results of anterior–posterior pharyngeal diameter and tongue bone position), before surgery (Mar 7, 2013), immediately after LF+HS and MDO surgery (June 14, 2013), 7 months after LF+HS and MDO surgery (Nov 6, 2013), immediately after GP surgery (Dec 13, 2013), 2 years and 6 months after LF+HS and MDO, 1 year and 11 months after GP (Nov 17, 2015).

The figures in parentheses are the difference between Jun 14, 2013 (1 month after LF+HS, MDO) and Mar 7, 2013 (preoperative), and the difference between Nov 6, 2013 (7 months after LF+HS, MDO) and June 14,

2013 (1 month after LF+HS, MDO), the difference between Dec 13, 2013 (7 months after LF+HS, MDO, immediately after GP surgery) and Nov 6, 2013 (6 months after LF+HS, MDO), the difference between Nov 6, 2015 (2 years and 6 months after LF+HS, MDO, 1 year and 11 months after GP) and Dec 13, 2013 (7 months after LF+HS, MDO, immediately after GP operation).



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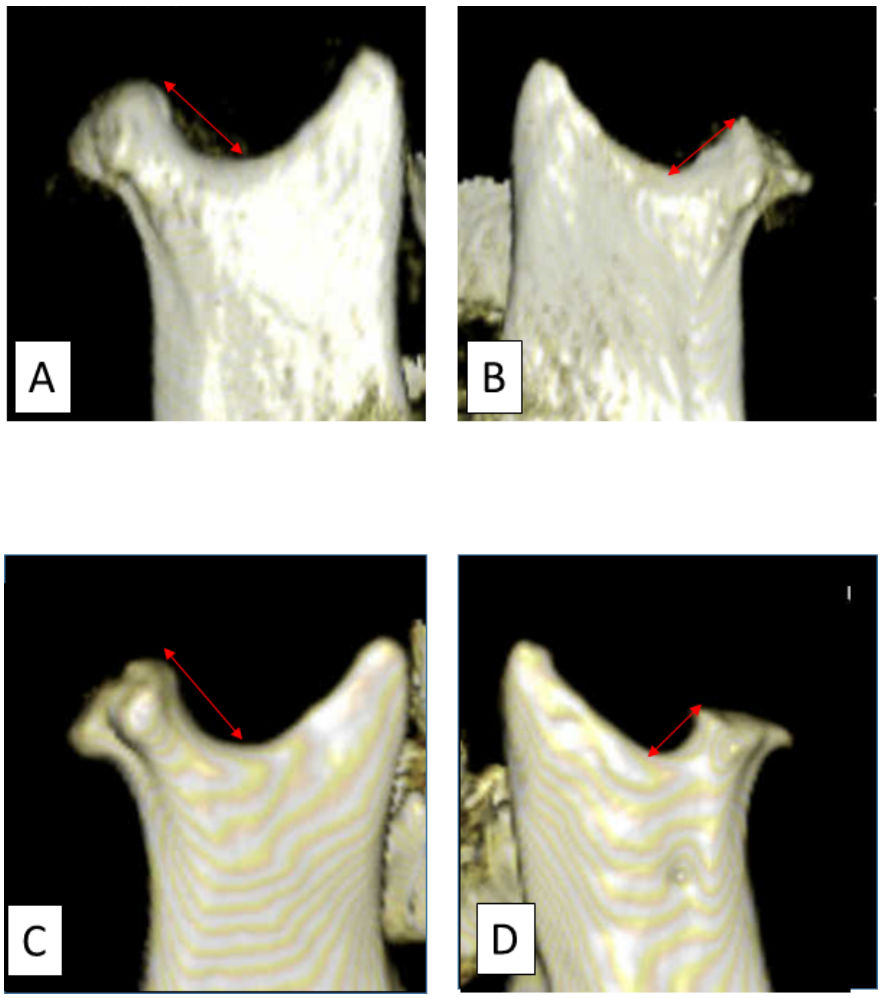

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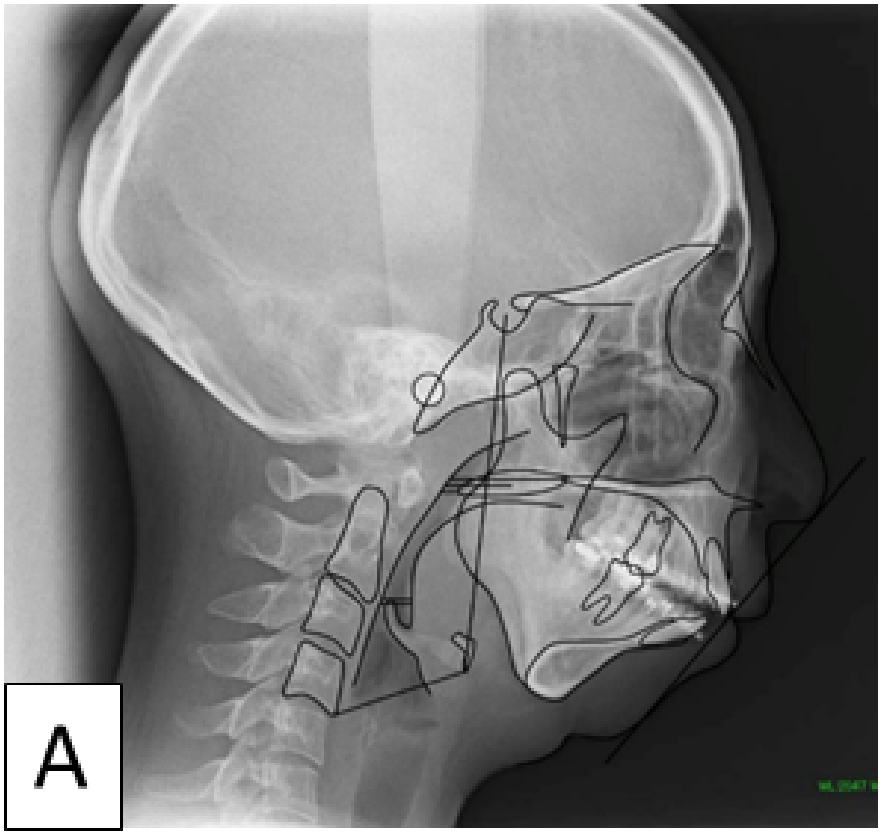

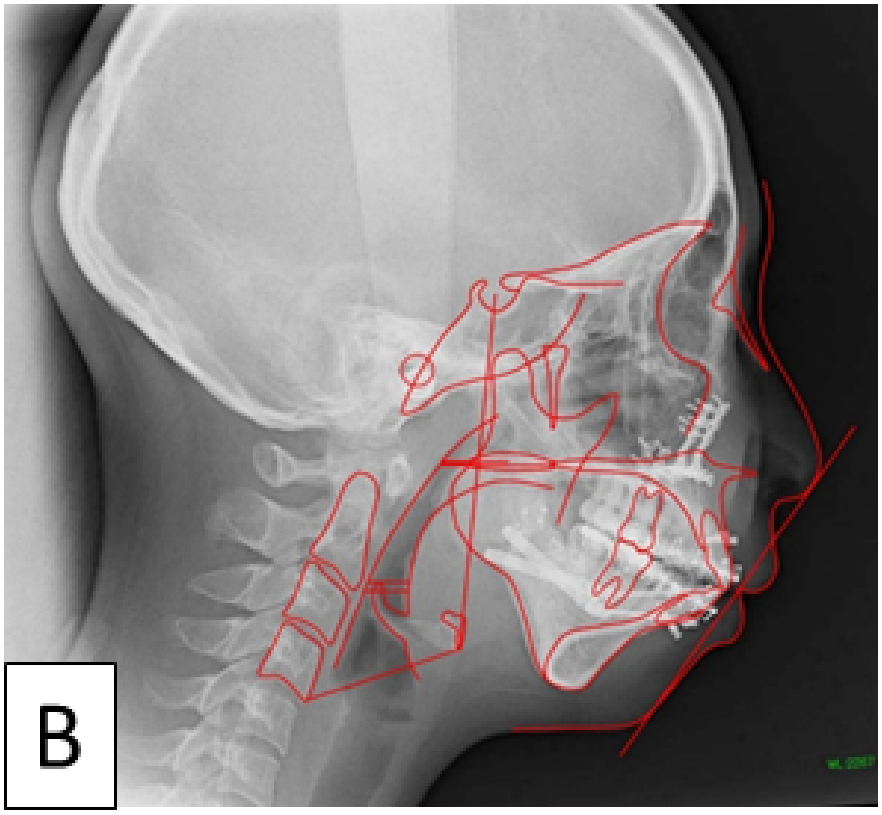

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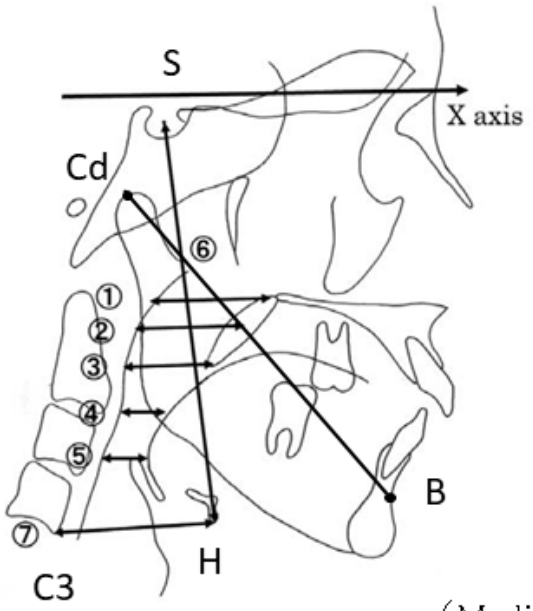

(Modified Shimamine et al[8])

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項目		Pre ope Apil/18/2013	5 months after LF＋HS, MDO Oct/10/2013		9 months after GP Sep/1/2014		Total Score
ESS（point）		14	2		−		−
AHI（/h）		22.5 /h	9.8 /h		7.8 /h		−
		Pre ope Mar/7/2013	1month after LF＋HS, MDO Jun/14/2013	7 months after LF＋HS, MDO Nov/6/2013	7 days after GP Dec/13/2013	GP post ope 2years 6months Nov/17//2015	total
Cefalometric analysis	SNA（°）	81°	82°	82°	82°	82°	−
	SNB（°）	69°	73°	73°	72°	72°	−
	ANB（°）	12°	9°	9°	10°	10°	−
	Facial Angle（°）	68°	72°	72°	76°	76°	−
	Cd-B(mm) 右	89.5	101.3 (＋11.8)	98.7 (-2.6)	98.6 (-0.1)	98.2 (-0.4)	＋8.7
	Cd-B(mm) 左	92.7	101.8 (＋9.1)	99.6 (-2.2)	98.9 (-0.7)	98.8 (-0.1)	＋6.1
Pharyngeal front and rear diameters / Rear Soft cap	① PPS (mm)	35.1	32.6 (-2.5)	34.8 (＋2.2)	35.9 (＋1.1)	41.2 (＋5.3)	＋6.1
	② SPPS (mm)	17.7	18.0 (＋0.3)	19.3 (＋1.3)	19.7 (＋0.4)	20.1 (＋0.4)	＋2.4
	③ MPS (mm)	4.6	10.1 (＋5.5)	10.0 (-0.1)	6.6 (-3.4)	6.7 (＋0.1)	＋2.1
Rear tounge	④ IPS (mm)	7.4	12.2 (＋4.8)	11.2 (-1.0)	11.8 (＋0.6)	11.1 (-0.7)	＋3.7
	⑤ EPS (mm)	6.7	11.6 (＋4.9)	10.3 (-1.3)	8.6 (-1.7)	7.6 (-1.0)	＋0.9
Position of Tounge bone	⑥ S-H (mm)	106.4	104.9 (＋-1.5)	104.4 (-0.5)	107.8 (＋3.4)	105.8 (-2.0)	-0.6
	⑦ C3-H (mm)	42.7	41.1 (-1.6)	48.2 (＋7.1)	46.5 (-1.7)	44.5 (-2.0)	＋1.8