Available online at www.sciencedirect.com

ScienceDirect

British Journal of Oral and Maxillofacial Surgery 57 (2019) 529–535

BRITISH Journal of Oral and Maxillofacial Surgery

www.bjoms.com

Long-term skeletal stability in the treatment of mandibular prognathism with a physiological positioning strategy

K. Miura[a,*], S. Yamaoka[b], K. Arizono[b], S. Ohba[a], T. Koga[a], T. Kawasaki[a], N. Yoshida[b], I. Asahina[a]

[a] *Department of Regenerative Oral Surgery, Nagasaki University Graduate School of Biomedical Sciences, Japan*
[b] *Department of Orthodontics and Dentofacial Orthopedics, Nagasaki University Graduate School of Biomedical Sciences, Japan*

Accepted 21 January 2019
Available online 9 May 2019

Abstract

Our aim was to evaluate the long-term skeletal stability of the mandible in 21 patients after orthognathic surgery with physiological positioning. The measurement points SNB, B point (X, Y), Pog (X, Y), and the angle of the ramus were measured on cephalometric photographs to assess skeletal stability preoperatively, immediately after operation, and one and two years postoperatively. In addition, we evaluated the clinical symptoms of disorders of the temporomandibular joint (TMJ). The analysis of the cephalometric photographs showed that SNB, B point X, and Pog X showed no significant differences among the postoperative time points. On the other hand, B point Y and Pog Y showed no significant differences throughout the study period. We compared the angle of the ramus before operation and two years postoperatively, and no significant difference was found. In addition, no cases showed any pathological symptoms of disorders of the TMJ two years postoperatively. The long-term stability after orthognathic surgery with physiological positioning was confirmed, and it seems to be a reliable orthognathic treatment in patients with mandibular prognathism.

Keywords: Orthognathic surgery; Physiological positioning strategy; Long-term stability; SSRO; Mandible

Introduction

Sagittal split ramus osteotomy (SSRO) and intraoral vertical ramus osteotomy (IVRO) are common operations for the treatment of mandibular prognathism.[1,2] One of the drawbacks of SSRO is unfavourable fixation between the proximal and distal segments, which induces postoperative skeletal relapse and disorders of the temporomandibular joint (TMJ).[3] The proximal segment therefore needs to be placed in the ideal position during operation. Previously, to resolve the problem, we have used condylar positioning devices. However, Costa et al concluded in their review of current publications that there is no scientific evidence that these devices position the proximal segment appropriately.[4] Other research workers have also suggested a new fixation plate that will correct the relation between the proximal and distal segments even postoperatively.[5] However, the desirable postoperative position of the proximal segment remains controversial.[6]

As for IVRO, Bell et al showed that IVRO is an effective surgical treatment that leads the proximal segment to the mechanically-balanced position.[7] However, one of the drawbacks of IVRO is that it requires a long period of postoperative intermaxillary fixation (4-6 weeks), which worsens the patient's quality of life.[8] In addition, as the bony

* Corresponding author at: Department of Regenerative Oral Surgery, Nagasaki University Graduate School of Biomedical Sciences, 1-7-1, Sakamoto, Nagasaki, 852-8588 Japan.

E-mail address: kei-miura-e-mail@nagsaki-u.ac.jp (K. Miura).

https://doi.org/10.1016/j.bjoms.2019.01.024
0266-4356/

Table 1
Cephalometric analysis of all cases. Data are mean (SD).

	T0-T1	T0-T2	T0-T3	T1-T2	T1-T3	T2-T3
SNB (°)	3.41 (0.38)*	3.05 (0.38)*	2.97 (0.40)*	0.37 (0.38)	0.45 (0.40)	0.08 (0.40)
B point X (mm)	6.51 (0.72)*	5.84 (0.73)*	5.72 (0.76)*	0.67 (0.73)	0.80 (0.76)	0.13 (0.77)
B point Y (mm)	0.73 (0.44)	0.88 (0.45)	0.97 (0.47)	0.15 (0.45)	0.23 (0.47)	0.09 (0.47)
Pog point X (mm)	6.27 (0.83)*	5.46 (0.84)*	4.84 (0.87)*	0.81 (0.84)	1.43 (0.87)	0.61 (0.88)
Pog point Y (mm)	0.03 (0.32)	0.40 (0.32)	0.67 (0.33)	0.37 (0.32)	0.65 (0.33)	0.28 (0.34)
Angle of ramus (°)	2.28 (0.98)	2.00 (0.99)	1.58 (1.03)	4.28 (0.99)**	3.86 (1.03)***	0.42 (1.05)

T0=preoperatively; T1=immediately postoperatively; T2=one year postoperatively; and T3=two years postoperatively.
* $p < 0.0001$.
** $p = 0.0003$.
*** $p = 0.02$.

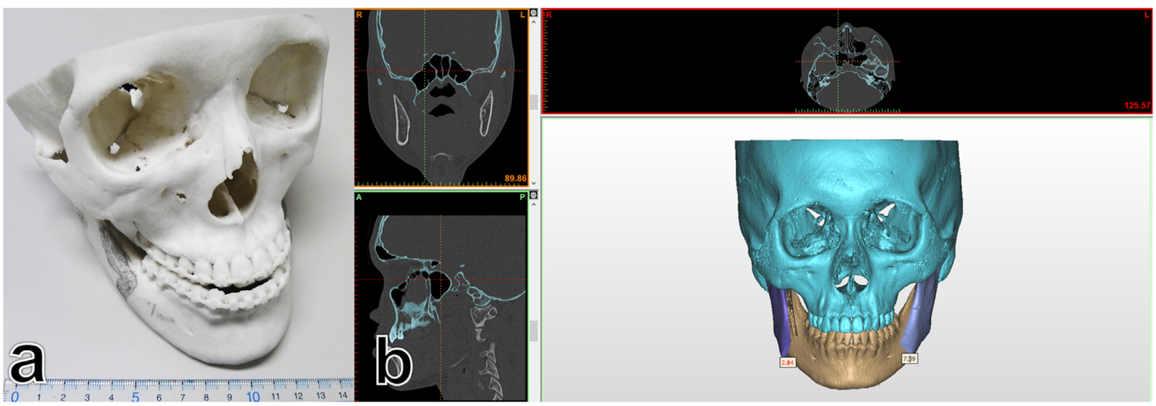

Fig. 1. Preoperative surgical simulation. (A) Full-scale three-dimensional model. (B) Computed surgical imaging with SimPlant ® OMS (Materialise Medical).

contact between the proximal and distal segments is smaller in IVRO than in SSRO, healing takes a long time. IVRO also induces postoperative protrusion towards the buccal side of the proximal segment.[9]

To resolve these drawbacks of SSRO and IVRO, we have developed a new orthognathic surgical treatment plan, referred to as physiological positioning, and used it with a modified SSRO technique. It is summarised briefly as follows: we do a short lingual osteotomy, which can minimise bony interference after mandibular setback,[3] without fixation of the bone segments, then initiate jaw exercises on the second postoperative day to seat the proximal segment in the physiologically ideal position.[10–12] We have already shown that this leads to good skeletal stability in patients having mandibular osteotomy,[10] maxillomandibular osteotomy,[11] and mandibular osteotomy with facial asymmetry.[12] However, its long-term stability remains unclear. As far as postoperative stability is concerned, Proffit et al have shown that skeletal relapse of the mandible typically occurs within one year postoperatively,[13] and Ayoub et al showed that skeletal relapse occurs even during the first postoperative year.[14] As Schilbred Eriksen et al stated previously, the success or failure of an operation depends on its long-term stability.[15] We have therefore evaluated skeletal stability one and two years postoperatively to confirm its long-term reliability.

Patients and methods

Patients

We studied 21 patients (three male, 18 female; mean (range) age 24 (17-37) years) who underwent SSRO with physiological positioning for the correction of mandibular prognathism (Table 1). Mean setback was 5.6 mm on the right side and 5.2 mm on the left side. No patients had had previous orthognathic surgery.

Surgical technique and postoperative management

In addition to cephalometric radiography and computed tomography (CT) preoperatively, we have constructed a preoperative surgical simulation with full-scale three-dimensional model and computed surgical imaging with SimPlant ® OMS (Materialise Medical) to reduce the risk of morbidity to the inferior dental nerve and an unfavourable mandibular split (Fig. 1).

Based on this simulation, we did a modified SSRO (short lingual osteotomy) as previously reported by Hunsuck[16] and Epker.[17] All operations were done under general anaesthesia. After local injection of 2% lidocaine hydrochloride including 0.0125% adrenaline around both the ramus and inferior border of the mandible, we made an extended vestibular incision,

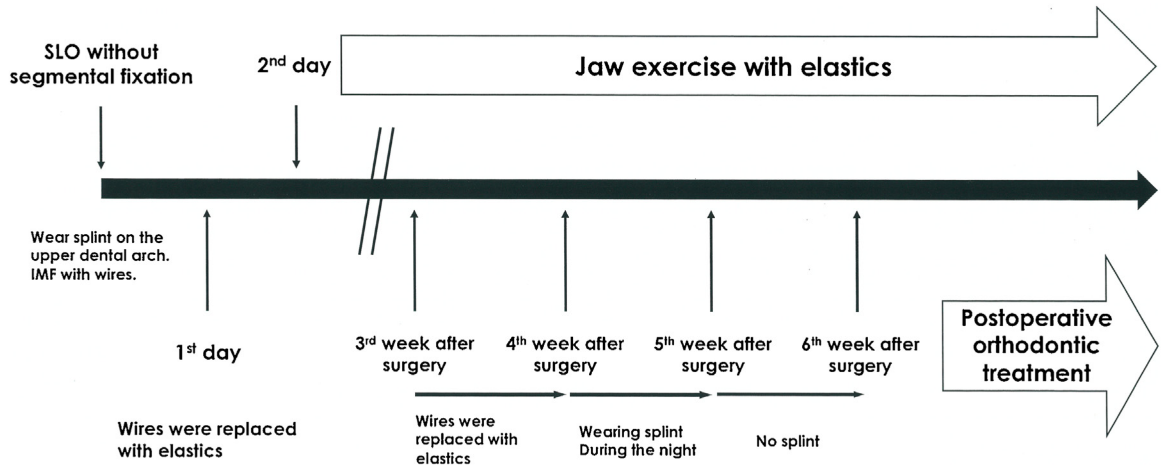

Fig. 2. Postoperative treatment regimen involving physiological positioning strategy. SLO = short lingual osteotomy. Jaw exercises with elastics were continued for three months postoperatively.

followed by corticotomies of the lingual cortex just above the mandibular foramen, the buccal cortex, and the anterior border of the ramus. The sagittal split was completed with an osteotome and a bone spreader. The pterygomasseteric sling was preserved with a minimal periosteal strip. To avoid the inadequate postoperative counter-clockwise rotation of the proximal segment, we almost completely stripped the temporalis from the coronoid process. The proximal segments were trimmed according to the setback amount so as not to cause bony interference, which induces external rotation of the condyle. After we had confirmed the placement of the surgical wafer on the maxillary arch with metal wire, we inserted the drainage device into the operation site. The wound was then closed without fixation of the bone segments after intermaxillary fixation with wire.

For postoperative pain control, paracetamol (daily dose up to 4000 mg) was used. The postoperative respiratory condition was evaluated using a pulse oximeter on the day of operation, and it was removed on the second postoperative day if uneventful. For meals, a liquid diet was given on the first and the second days postoperatively, blended food from the third day, and minced food after the seventh day. For the achievement of both good occlusion and a physiologically ideally positioned proximal segment, postoperative management was instituted (Fig. 2).

For the first 24 hours, intermaxillary fixation with wire had been used, as postoperative nausea and vomiting is known to occur most frequently during the first 24 hours.[18] We therefore considered the urgent removal of the wire at this point; metal wire is easy to remove compared with elastics wire, and is easy to find in case it has moved into the operation site as it is radiopaque. On the second postoperative day, the wire was removed together with the drainage tube, and replaced with elastic intermaxillary fixation (1/8", 3.5 oz. / 1 elastic) (Fig. 3). The patient was then instructed to start jaw exercises.

The exercise technique is shown in Fig.4. It was done for 15 minutes, and repeated four times a day. During the exercise

Fig. 3. Postoperative intermaxillary fixation with elastics.

the chin was supported with the fingers to open and close the mouth vertically. From the third postoperative week, the duration for which the surgical wafer was worn was decreased step by step every week. At the sixth postoperative week, postoperative orthodontic treatment was allowed if the course had so far been uneventful. Jaw exercises with elastics were continued for at least three months, as callus does not start to form until two months postoperatively,[19] and bone is becoming mature by three months.[9]

Analysis of cephalometric photographs

Cephalometric photographs were taken preoperatively (T0), and then immediately (T1), one year (T2), and two years postoperatively (T3) to assess the long-term skeletal stability, which was evaluated by a well-known method. The angles between the Sella-Nasion and Nasion-B point (SNB), and between the ramus plane, were measured. In addition, to evaluate postoperative skeletal relapse in detail, both B point and pogonion were separated into horizontal and vertical elements, respectively. A line which passes through S and rotates 7 degrees from the Nasion-Sella line, was defined as the hor-

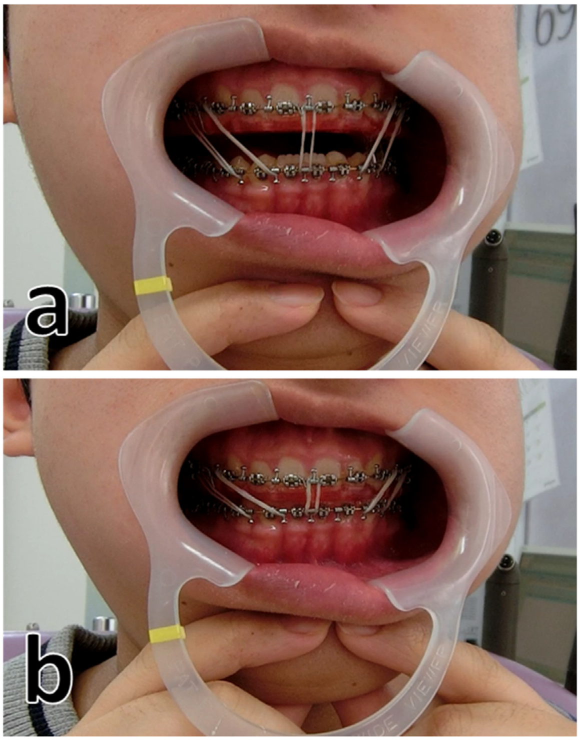

Fig. 4. Jaw exercise with elastics. The exercise was done for 15 minutes four times a day. During the exercise the chin was supported with the fingers to open and close the mouth vertically. (A) The mouth of [A] to the maximum extent. (B) The mouth of [I] with tight occlusion to the surgical wafer.

izontal reference line. The vertical reference line was defined as a line that is perpendicular to the horizontal line and passes through S. According to the two reference lines, both horizontal and vertical distances were measured as B point (X, Y) and Pog (X, Y), respectively (Fig.5).

Statistical analysis

The significance of differences between measurements from the cephalometric photographs was assessed using the Friedman test. For comparison of opening amounts we used the *t* test. Probabilities of less than 0.05 were accepted as significant. JMP Pro® version 13 (SAS Institute, Cary, NC) was used for statistical analyses.

Table 2
Details of patients who took part.

Case No.	Sex (M/F)	Age (years)	Setback: right (mm)	Setback: left (mm)
1	F	37	2	5
2	F	21	3	−2
3	F	20	4	4
4	F	34	5	6.5
5	F	22	3	0
6	F	18	8	8
7	F	30	5.5	2.5
8	F	21	5	6
9	F	21	5.5	9
10	M	20	3.5	4.5
11	F	30	8.8	6.7
12	F	20	7.5	7
13	F	29	7	6
14	F	27	8	5
15	F	37	6	0
16	F	18	5	5
17	F	22	5	6
18	M	20	9	7.5
19	F	25	7	10
20	M	21	3	9
21	F	215	7	4.5

Results

Based on our management regimen, all the patients had uneventful recoveries with good pain control, no respiratory problems, and good dietary intake. SNB, B point X, and Pog X decreased postoperatively by 3.41°, 6.51 mm, and 6.27 mm, respectively, and there were no significant differences between the respective postoperative time points. B point Y and Pog Y showed no significant differences throughout the entire study period. According to SNB, B point X, and Pog X, skeletal stability was confirmed at two years postoperatively. The angle of the ramus did not differ significantly between T0 - T2 and T0 - T3 (Table 2). There were no pathological postoperative complications. In particular there were no signs of skeletal relapse or symptoms of dysfunction of

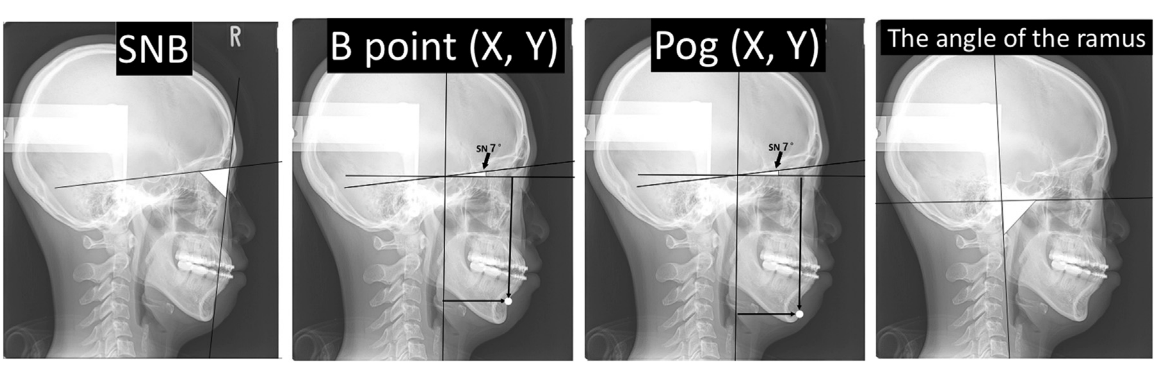

Fig. 5. The angles and point for the cephalometric analysis.

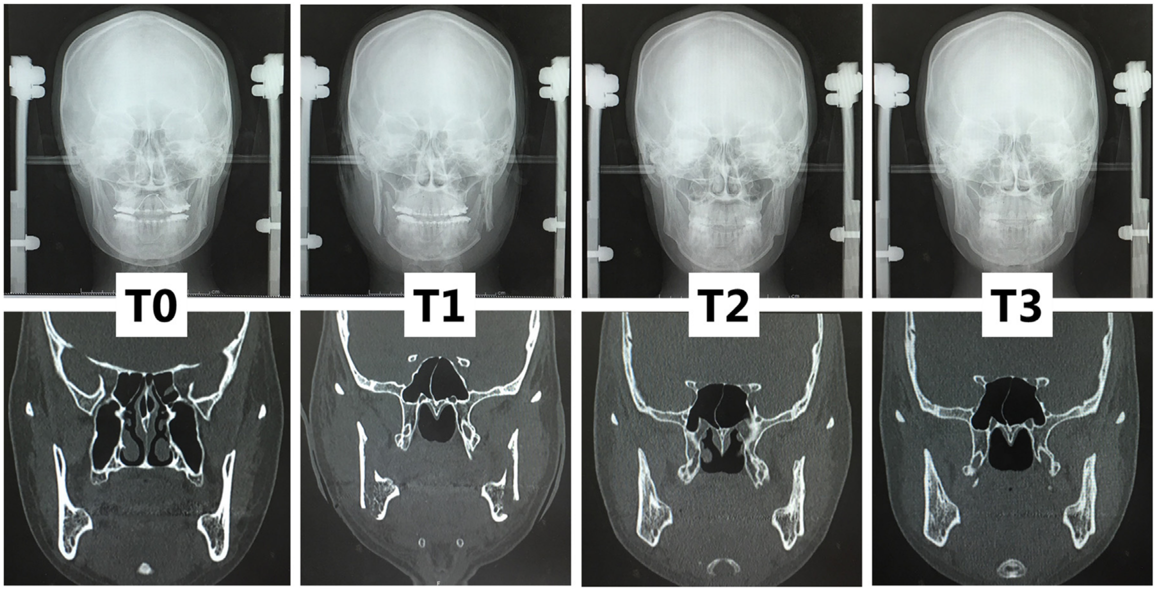

Fig. 6. Radiographic findings from cephalometric photographs and computed tomographic scan.

the TMJ within two years of operation. Based on the findings of the posteroanterior cephalogram, no patients have had any serious consequences such as fibrous union, malunion, or non-union of the osteotomy site with permanent disability (Fig. 6).

Discussion

In SSRO, the position of the postoperative proximal segment has been reported to cause early postoperative skeletal relapse and dysfunction of the TMJ.[20] The proximal segment therefore needs to be guided to its optimal position during the operation. However, the position of the proximal segment that is desirable postoperatively remains controversial.[6] Previously, condylar positioning devices have been inserted to resolve the problem, but Costa et al have concluded that there is no scientific evidence that they do any good.[4] They require a longer operating time, the intermaxillary fixation should be maintained as stable as possible, and the technique is complicated. In addition, there is also no significant advantage in postoperative skeletal stability and function of the TMJ compared with traditional methods, and the rotation of the proximal segment could not be avoided even with condylar positioning devices.[4] As the bone segments are not fixed with physiological positioning, inappropriate forces caused by inadequate fixation could be minimised.

We have experienced no symptoms of dysfunction of the TMJ in any patient during the evaluation period, which indicates that inappropriate force was not loaded on to the proximal segment, and the proximal segment (including the TMJ) was therefore seated in the physiologically ideal position. In addition, functions of the masticatory muscles may be adapted soon after operation by early initiation of exercises to move the jaws, which could also contribute to skeletal stability.

It has been shown that disorders of the TMJ were improved by orthognathic surgery.[21] In SSRO, they developed preoperatively in 88.3% of patients, but improved to 34.7% postoperatively.[22] In IVRO, the TMJ was improved in all cases but one postoperatively.[23] A comparison between previous research and ours is difficult because we had no patients with preoperative symptoms associated with the TMJ. However, according to our treatment plan, the TMJ symptoms did not appear after a long postoperative period, so it might be possible to discuss the use of physiological positioning for patients with disorders of the TMJ in future.

Although the angle of the ramus increases immediately after the operation, it returns to almost the same level after one and two years postoperatively. A postoperative temporary increase of the angle of the ramus means that the proximal segment has rotated clockwise and, as Jakobsone et al showed, this could be the cause of the postoperative skeletal relapse.[24] It is certain that backward traction is induced by the pterygomasseteric sling, sphenomandibular ligament, stylomandibular ligament, and lateral pterygoid muscle, and those forces might be the cause of the skeletal relapse. However, the long-term stability of the mandible was achieved as a result of postoperative jaw exercises for at least three months, which offsets the force of backward traction.

We have previously shown that physiological positioning did not induce important structural changes of the condyle postoperatively, and indicated that the change of the angle of the ramus was not influenced by the postoperative condylar structure.[6] It might therefore be suggested that the clockwise rotation of the proximal segment was improved by early introduction of postoperative jaw exercises by which the relation between the soft tissues, including muscles and ligaments, and the proximal segment became correct. Given these considerations, physiological positioning seems to be more flexible than SSRO with fixation even after operation for clockwise rotation of the proximal segment.

As for no fixation between the bony segments, IVRO is similar in treatment. The drawback of IVRO is the long intermaxillary fixation, which lasts for 4-6 weeks and worsens the patient's quality of life.[8] In addition, as the area of bony contact between the segments is small, IVRO is generally considered to be inferior to SSRO in terms of postoperative healing, and IVRO also induces protrusion of the proximal segment towards the buccal side postoperatively.[9] It might be that IVRO has the advantage over SSRO of a low risk of morbidity to the inferior dental nerve and unfavourable mandibular split. However, to reduce these risks, we have been engaged in preoperative simulation for minimal surgical invasion (Fig. 1). Physiological positioning could be suggested as a new treatment, possibly comparable to IVRO.

As we reported previously, skeletal stability with physiological positioning was confirmed six months postoperatively,[10] and the results reported here show that it provided good skeletal stability two years after operation, which could be proof of its reliability for orthognathic treatment of jaw deformity. It would therefore be more desirable than IVRO for reducing the proximal segment to a physiologically ideal position.

A limitation of this research is that the number of patients in this research is small and balanced towards female patients. In addition, we focused on only class III cases. We reported four class II cases previously,[25] but have made no evaluation of long-term stability in these. Further investigations are therefore necessary to increase the number of both class II and III patients in the future.

Conclusion

We have shown the physiological positioning offers reliable orthognathic treatment for patients with mandibular prognathism. Short lingual osteotomy without fixation and early postoperative jaw exercises contribute to long-term skeletal stability.

Conflict of interest

We have no conflicts of interest.

Ethics statement/confirmation of patients' permission

This study adhered to the principles of the Declaration of Helsinki in terms of medical protocols and ethics and was approved by our local institutional review board (approved number: 18091003). Patients' permission not required.

References

1. Paeng J-Y, Hong J, Kim C-S, et al. Comparative study of skeletal stability between bicortical resorbable and titanium screw fixation after sagittal split ramus osteotomy for mandibular prognathism. *J Craniomaxillofac Surg* 2012;**40**:660–4.
2. Ghali GE, Sikes Jr JW. Intraoral vertical ramus osteotomy as the preferred treatment for mandibular prognathism. *J Oral Maxillofac Surg* 2000;**58**:313–5.
3. Yang HJ, Lee WJ, Yi WJ, et al. Interferences between mandibular proximal and distal segments in orthognathic surgery for patients with asymmetric mandibular prognathism depending on different osteotomy techniques. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2010;**110**:18–24.
4. Costa F, Robiony M, Toro C, et al. Condylar positioning devices for orthognathic surgery: a literature review. *Oral Surg Oral Med, Oral Pathol Oral Radiol Endod* 2008;**106**:179–90.
5. Baek RM, Lee SW. A new condyle repositionable plate for sagittal split ramus osteotomy. *J Craniofac Surg* 2010;**21**:489–90.
6. Ohba S, Ozaki H, Miura KI, et al. Physiological positioning strategy alters condylar position after mandibular ramus sagittal split osteotomies for mandibular prognathism. *Cranio* 2018;**36**:181–8.
7. Bell WH, Yamaguchi Y, Poor MR. Treatment of temporomandibular joint dysfunction by intraoral vertical ramus osteotomy. *Int J Adult Orthodon Orthognath Surg* 1990;**5**:9–27.
8. Ohba S, Tasaki H, Tobita T, et al. Assessment of skeletal stability of intraoral vertical ramus osteotomy with one-day maxillary-mandibular fixation followed by early jaw exercise. *J Craniomaxillofac Surg* 2013;**41**:586–92.
9. Rokutanda S, Yamada S, Yanamoto S, et al. Comparison of osseous healing after sagittal split ramus osteotomy and intraoral vertical ramus osteotomy. *Int J Oral Maxillofac Surg* 2018;**47**:1316–21.
10. Ohba S, Yoshida M, Kohara H, et al. Short lingual osteotomy without fixation: a new strategy for mandibular osteotomy known as physiological positioning. *Br J Oral Maxillofac Surg* 2014;**52**:e9–13.
11. Ohba S, Nakao N, Nakatani Y, et al. The skeletal stability after maxillo-mandibular osteotomy with a physiological positioning strategy. *Br J Oral Maxillofac Surg* 2014;**52**:965–9.
12. Ohba S, Nakao N, Kawasaki T, et al. Skeletal stability after sagittal split ramus osteotomy with physiological positioning in patients with skeletal mandibular prognathism and facial asymmetry. *Br J Oral Maxillofac Surg* 2016;**54**:920–6.
13. Proffit WR, Turvey TA, Phillips C. The hierarchy of stability and predictability in orthognathic surgery with rigid fixation: an update and extension. *Head Face Med* 2007;**3**:21.
14. Ayoub AF, Millett DT, Hasan S. Evaluation of skeletal stability following surgical correction of mandibular prognathism. *Br J Oral Maxillofac Surg* 2000;**38**:305–11.
15. Schilbred Eriksen E, Wisth PJ, Loes S, et al. Skeletal and dental stability after intraoral vertical ramus osteotomy: a long-term follow-up. *Int J Oral Maxillofac Surg* 2017;**46**:72–9.
16. Hunsuck EE. A modified intraoral sagittal splitting technic for correction of mandibular prognathism. *J Oral Surg* 1968;**26**:250–3.
17. Epker BN. Modifications in the sagittal osteotomy of the mandible. *J Oral Surg* 1977;**35**:157–9.
18. Silva AC, O'Ryan F, Poor DB. Postoperative nausea and vomiting (PONV) after orthognathic surgery: a retrospective study and literature review. *J Oral Maxillofac Surg* 2006;**64**:1385–97.
19. Miura K, Yoshida M, Yamaguchi K, et al. Sonographic evaluation of bone formation after sagittal split ramus osteotomy. *J Ultrasound Med* 2016;**35**:395–400.
20. Yang HJ, Hwang SJ. Change in condylar position in posterior bending osteotomy minimizing condylar torque in BSSRO for facial asymmetry. *J Craniomaxillofac Surg* 2014;**42**:325–32.

21. Liu Z, Shu J, Zhang Y, et al. The biomechanical effects of sagittal split ramus osteotomy on temporomandibular joint. *Comput Methods Biomech Biomed Engin* 2018;**21**:617–24.
22. Sebastiani AM, Baratto-Filho F, Bonotto D, et al. Influence of orthognathic surgery for symptoms of temporomandibular dysfunction. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2016;**121**:119–25.
23. Ueki K, Hashiba Y, Marukawa K, et al. The effects of changing position and angle of the proximal segment after intraoral vertical ramus osteotomy. *Int J Oral Maxillofac Surg* 2009;**38**:1041–7.
24. Jakobsone G, Stenvik A, Sandvik L, et al. Three-year follow-up of bimaxillary surgery to correct skeletal Class III malocclusion: stability and risk factors for relapse. *Am J Orthod Dentofacial Orthop* 2011;**139**:80–9.
25. Ohba S, Yoshimura H, Matsuura T, et al. Bimaxillary osteotomy using a physiological positioning strategy for skeletal class ii with anterior open bite and gummy smile: case reports and review of the literature. *Dentistry* 2016;**6**:356.