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Changes and Remodeling of Intersegmental Interferences following Bilateral Sagittal Split Ramus Osteotomy in Patients with Mandibular Prognathism

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Abstract: Purpose: This study aimed to measure the amount of change in the mandibular angle, intergonial width, and ramus angulation due to intersegmental interference and changes in condyle position after mandibular bilateral sagittal split ramus osteotomy (BSSRO) in patients with mandibular prognathism and to evaluate the correlation between them. Materials and Methods: A total of 32 patients who underwent mandibular setback using the BSSRO of the mandible to manage skeletal prognathism during the years 2018 to 2020 at the Department of Oral and Maxillofacial Surgery, Pusan National University were followed both clinically and with cone beam computed tomography (CBCT) for at least one year. Those who were also treated with genioplasty or other orthognathic surgery were excluded from the study. The mandibular angle (gonial angle: Ar–Go–Me), intergonial width (Go–Go), and total angle (sum of left and right proximal segmental angle) were recorded. Changes in the ramus were compared and analyzed before surgery (T1), immediately after surgery (T2), and one year following surgery (T3). Results: The mandibular angle increased by an average of 0.14 degrees immediately after surgery (T2–T1) and increased by 0.97 degrees at 12 months postoperatively (T3–T2). No correlation was observed with the amount of change in each group relative to the amount of mandibular setback. The mandibular width decreased by 0.01 mm on average immediately after surgery (T2–T1), and by 4.2 mm on average at 12 months after surgery (T3–T2). The angle of the mesial fragment of the mandible increased by 1.04 degrees immediately after surgery (T2–T1), compared to the preoperative state. It decreased by 0.86 degrees at 12 months postoperatively (T3–T2). Conclusion: The increase in the mandibular angle from immediately after surgery to 12 months after BSSRO reflects the counterclockwise rotational tendency to prevent opening restriction when intentionally selecting the condylar position. The decrease in the intergonial width immediately after surgery is thought to be due to the effect of internal trimming to minimize the bone interference between the outer surface of the distal bone fragment and the inner surface of the mesial fragment, and the decrease 1 year after surgery can be considered to be due to bone remodeling. Interosseous interference during mandibular setback osteotomy does not necessarily cause an increase in the width of the mandibular angle after surgery.

Keywords: orthognathic surgery; relapse; bone remodeling; stability; intergonial distance; interference

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1. Introduction

Mandibular prognathism is a developmental dentofacial deformity, which is characterized by skeletal class III malocclusion and either excessive antero-posterior mandibular growth or relatively insufficient growth of the maxilla.

Recently, in addition to the benefits of functional improvement, the importance of aesthetic aspects has been emphasized in mandibular setback surgery [1–3]. Therefore, the accurate prediction of facial changes following setback surgery is important when diagnosing a patient and establishing a treatment plan.

Facial changes after orthognathic surgery are expressed in a complex way by changes in both hard and soft tissues. Even if the osteotomy is performed as planned, unexpected bone regeneration may occur immediately after surgery [1–3]. Most of the studies on the prediction of the face after surgery are on the hard and soft tissue changes on the frontal aspect from the lateral view. Relatively few studies concern the changes in the posterior side. In addition, there have been many reports on the changes after surgery, focusing on the gonial angle of the mandible from the lateral view. Reports regarding changes in the angle of the mandible including the condyle are lacking [4,5].

Following mandibular bilateral sagittal split ramus osteotomy (BSSRO) in the prognathic mandible, it is essential to predict the change in the position of the condyle and the change in the width of the mandibular angle. This study investigated if the change in width was due to mesial and distal intersegmental bone interference, which decreased after healing. The mesial distal intersegmental interference was trimmed in the direction favoring increasing the width of the face during mandibular osteotomy. This study was therefore conducted to help understand the accurate prediction of postoperative changes at the mandibular angle following the setback of the prognathic mandible.

2. Materials and Methods

2.1. Patients

A total of 32 Korean adults (15 males, 17 females) were diagnosed with a class III skeletal malocclusion at the Department of Oral and Maxillofacial Surgery, Pusan National University Dental Hospital, during the years 2018 to 2020. Those patients with a history of trauma, a head and neck malformation including cleft lip and palate, or craniofacial syndrome were not included in the study. Those patients were included in the study who underwent mandibular setback using a bilateral sagittal split ramus osteotomy (BSSRO). Those patients who were treated with a genioplasty were also excluded from the study. Other inclusion criteria comprised the availability of complete records, radiographs as well as preoperative and postoperative cone-beam computed tomography (CBCT) images with 1 year follow-up images. Among the study population, 21 patients (65.6%) under the age of 22 accounted for the majority, a total of 5 patients (15.6%) from the age group of 23–25 years, and 6 patients (18.7%) over the age of 26 years. The male to female ratio was 15 males (46.87%) to 17 females (53.13%), respectively. (Table 1).

Table 1. Sex and age distribution of the patients.

Age (Years)	Male	Female	Total (%)
22	7	14	21 (65.6)
23–25	4	1	5 (15.6)
26	4	2	6 (18.7)
Total (%)	15 (46.87)	17 (53.13)	32 (100)

Written informed consent was obtained from all patients included in this study, which was performed retrospectively, using radiographic data, and medical anesthesia records were obtained after receiving approval from the Institutional Review Board of Pusan National University Hospital (IRB No. PNUDH-2021-037). All patients and their records were treated consistently with the principles of the Helsinki declaration. The patients were divided according to the setback amount into three groups. In Group 1, the setback was 8 mm or less (8 patients, 25%), in Group II there was 8 to10 mm of setback (10 patients, 31.2%), and in Group III, the setback was 11 mm or more (13 patients, 43.8%) (Table 2).

Table 2. Number of patients according to amount of setback.

Age (Years)	Groups		No. of Patients (%)
Amount of setback	I	7 mm	8 (25)
	II	8–10 mm	10 (31.2)
	III	11 mm	13 (43.8)
Total (%)			32 (100)

2.2. Surgery

All patients underwent BSSRO using a modified Obwegeser–Dal Pont approach. All osteotomies were performed by the same surgeon. At the proximal segment of the mandible, it was fixed using a sliding plate with two 2.0 mm diameter monocortical screws, and the pterygomasseteric slings at the inferior border were removed. Only 1 case required the use of a bi-cortical screw fixation on one side with a sliding plate for the other side. The average posterior displacement of screws to the proximal segment and another screw to the distal segment was determined by 3D analysis before surgery. The average posterior displacement of one screw to the proximal segment and another to the distal segment was determined by preoperative 3D analysis. The position of the mesial fragment was passively moved from the condylar fossa to the most superior position. The position was selected in a slightly counterclockwise direction to avoid restriction of the mouth opening. After removing the intersegmental bone interference, the proximal and distal segments of the mandible were fixed with screws and one titanium mini plate on both sides, and the occlusal relationship was reconfirmed. To maintain postoperative occlusion, inter-maxillary fixation (IMF) with an inter-occlusal splint was applied for the first week following surgery. After releasing the IMF, orthodontic elastic rubber bands were applied for 2 to 3 weeks. Postoperative orthodontic treatment was started 1 month after the operation.

2.3. Measurements

Factors to be evaluated included the postoperative mandibular angle (gonial angle: Ar–Go–Me) (Figure 1), intergonial width (Go–Go) (Figure 2) and ramus angle (total angle: sum of the left and right proximal segmental angle) (Figure 3). The changes in the ramus were compared before surgery (T1), immediately after surgery (T2), and one year after surgery (T3). The left and right proximal segmental angles were measured using a CBCT scanner (DCT Pro, Vatech, Seoul, South Korea).

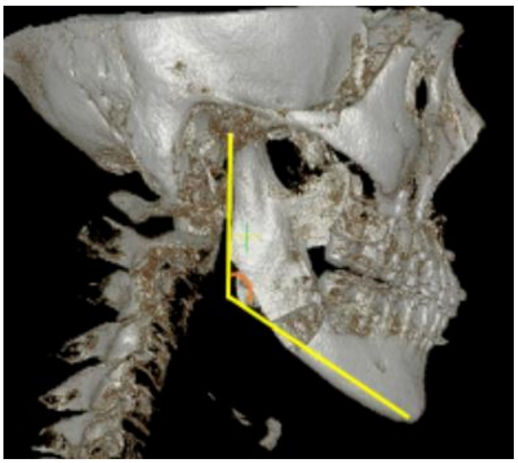

Figure 1. Mandibular angle: Ar–Go–Me.

Figure 2. Mandibular intergonial width: Go–Go.

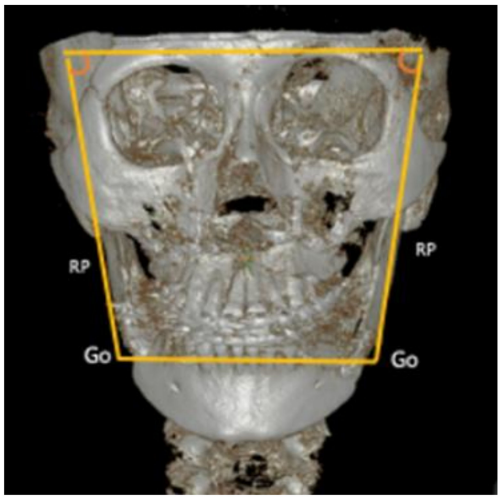

Figure 3. Total angle: angle of RP–Go.

In this study, all images were analyzed by the same individual investigator (MAJ) with preset reference points and planes. Each measurement was repeated three times. The distance between each of the reference points was measured to the nearest 0.01 mm from CT images, using the picture archiving and communications system (PACS) viewer program Marosis M-view 5.4 (Marotech, Seoul, Korea). The subjects were in an upright standing position with maximum intercuspation; the Frankfort horizontal (FH) plane of all subjects was parallel to the floor.

The gonial angle (G) was measured as the angle formed by Ar–Go–Me, and the intergonial width was measured as the distance between the uppermost points (Go–Go) of Gonion. Angular changes in the condyle (TA) in axial, coronary, and sagittal images were also measured according to the axial condyle angle. The condylar axial axis was drawn from the outermost part or the condylar lateral pole to the innermost part of the medial pole of the condyle, in its greatest mesio-lateral dimension, as described originally by Becktor et al. [6], analyzed using the SPSS program, and the significance was verified by the analysis of variance (ANOVA). The difference within the three groups was assessed using a one-way ANOVA. The level of $p < 0.05$ was accepted as being of statistical significance.

(1) Landmarks

Go (gonion): the cephalometric point on which the jaw angle is the most inferiorly, posteriorly and outwardly directed.

Pog (pogonion): the most anterior point in the contour of the chin.

Me (menton): the lowermost point on the symphyseal shadow.

ANS (anterior nasal spine): the tip of the anterior nasal spine of the palatal bone in the hard palate.

RP (ramus point): the most lateral and superior.

(2) Measurements

Gonial angle: Ar–Go–Me.

Intergonial width: Go–Go.

Total angle (TA): sum of right and left inferior–medial angles formed between UOML (upper orbital margin line) and Go–RP lines.

3. Results

Each time point index changed from before to after surgery in all 32 patients. The gonial angle was noted to increase immediately after surgery (T2–T1). The gonial angle increased by 1.12 degrees at 12 months after surgery (T3–T1) (Table 3).

Table 3. Changes in gonial angle according to amount of mandibular setback.

Gonial Angle	T1 Mean ± SD	T2 Mean ± SD	T3 Mean ± SD	T2–T1 Mean ± SD	T3–T2 Mean ± SD	T3–T1 Mean ± SD
GI	128.25 ± 4.40	128.68 ± 5.71	129.60 ± 4.52	0.37 ± 6.02	0.98 ± 4.02	1.35 ± 4.39
GII	128.41 ± 4.10	129.49 ± 4.12	130.00 ± 4.19	1.07 ± 3.04	0.51 ± 3.76	1.59 ± 4.84
GIII	132.06 ± 5.49	131.41 ± 7.57	132.71 ± 6.04	−0.64 ± 5.27	1.30 ± 4.16	0.66 ± 4.18
F(p)	2.329 (0.115)	0.585 (0564)	1.245 (0.303)	0.369 (0.685)	0.112 (0.895)	0.142 (0.868)

GI, amount of setback ≤7 mm; GII, 8–10 mm; GIII ≥ 11 mm.

The intergonial width decreased by 0.01 mm on average immediately after surgery compared to before surgery (T2–T1), and by 4.2 mm on average at 12 months after surgery compared to immediately before surgery (T3–T1). There was no correlation with the amount of mandibular setback (Table 4).

Table 4. Changes in intermandibular intergonial width (IGW) according to amount of mandibular setback.

IGW	T1 Mean ± SD	T2 Mean ± SD	T3 Mean ±SD	T2–T1 Mean ± SD	T3–T2 Mean ± SD	T3–T1 Mean ± SD
GI	110.37 ± 6.80	111.45 ± 7.92	109.91 ± 7.57	1.08 ± 6.42	−1.54 ± 1.65	−0.46 ± 5.62
GII	112.20 ± 5.21	112.16 ± 8.17	100.84 ± 33.80	−0.04 ± 6.71	−11.32 ± 29.68	−11.36 ± 34.54
GIII	110.80 ± 4.77	110.18 ± 5.37	109.44 ± 5.29	−0.62 ± 2.85	−0.74 ± 2.60	−1.36 ± 1.98
F(p)	0.295 (0.747)	0.246 (0.783)	0.696 (0.507)	0.266 (0.768)	1.319 (0.283)	0.972 (0.390)

The total angulation of the mesial fragment increased by 1.04 degrees immediately after surgery compared to preoperatively (T2–T1) and decreased by 0.18 degrees at 12 months after surgery (T3–T1) but by 0.86 degrees at 12 months after surgery, compared to immediately after surgery (T3–T2). In addition, the greater the amount of mandibular setback, the greater the decrease (GI < GII < GIII), but there was no statistical significance.

4. Discussion

Many studies have reported sagittal and vertical postoperative stability of BSSRO with significant variability ranging from 1.0% to 91.3% [7–11].

The risk factors of postoperative relapse include the amount of setback [12,13], change in the gonial angle [14,15], rotation of the proximal segment [16,17], stability of the distal segment [18], change in the condylar long axis [13], retention of fixation [14], and stretching and alteration of the pterygo-masseteric sling [19]. The amount of mandibular setback is

usually considered the single most important factor that affects relapse following BSSRO or IVRO.

The practical significance of the trimming and removal of the posterior part of the mandible aims at reducing inter-segmental interferences, thus improving the patient's facial appearance through muscle atrophy or by volume reduction through the remodeling process as reported in previous studies [20–22].

Many authors have addressed the issue that both degrees of downward and forward movements of the condyle in the IVRO are greater than those in the BSSRO [19,23].

Pan et al. [18] reported that after both surgical procedures, namely the BSSRO and IVRO, the increase in the transverse or frontal ramus angle was significantly related to the rotation of the distal segment during the remodeling phase. Therefore, lateral and frontal differences between the proximal and distal segments are commonly found between BSSRO and IVRO during the bony remodeling process. In particular, when the distal segment is set back further, it can push the proximal segment more laterally. Therefore, a larger than expected frontal gap can occur.

Since patients with mandibular protrusion generally have a prominent mandibular angle, mandibular setback surgery without considering the mandibular angle potentially reduces the aesthetic satisfaction of the patient.

The condyle head tended to move downwards, rotating inward in the axial view and backward by a statistically significant amount in the sagittal view. Isaacon et al. [24] pointed out that proximal segment displacement during surgery not fixed to the distal segment frequently returned to the preoperative positions or assumed positions of biologic equilibrium after removal of intermaxillary fixation. Johanson et al. [25] studied cranial radiographs that showed the remodeling activity on the posterior part of the condyle, resulting in a normalized position of the condyle in the glenoid fossa after 6 months. Kawamata et al. [20] investigated post-BSSRO condyle displacement with rigid osteosynthesis in patients with mandibular prognathism using 3D computer tomography taken within 3–6 months after surgery. A posterior tilt of the condylar neck axis and a lateral tilt of the long axis of the condyle were seen on both sides. Nishimura et al. [26] investigated the postoperative position change of the mandibular condyle by measuring the angle of the long axis. Patients with mandibular prognathism undergoing BSSRO were reported to have frequent inward rotation of the condyle.

In this study, the position of the mesial fragment was passively moved in the fossa to the uppermost position during the operation. The position was selected in a slightly counterclockwise direction to avoid restriction of the mouth opening. The total angulation of the mesial fragment of the mandible increased by 1.04 degrees in T2–T1 and decreased by 0.18 degrees in T3–T2 but decreased by 0.96 degrees in T3–T1. This can be seen as an increase in the angle due to the counterclockwise position of the mesial fragment by the intentional condylar positioning method immediately after the operation, and the angle gradually decreased due to the physiological repositioning during function.

Guglielmi et al. [15] stressed the importance of assessing changes in the gonial angle. In particular, IVRO involves cutting through the gonial region and overlapping these divided segments, and this change was more than that achieved with BSSRO. Due to differences in the surgical technique, the dimensions of the frontal gap between the proximal and distal segments of the mandible are significantly different between the BSSRO and IVRO osteotomies. Jonsson et al. [27] studied mandibular ramus osteotomies and their effect on the gonial angle. The gonial angle was noted to have increased by 5 degrees in patients treated by the BSSRO and to decrease by 3.3 degrees in patients treated using the oblique sliding osteotomy. In this study, as in previous studies, the gonial angle increased by 0.14 degrees on average in T2–T1, 0.97 degrees in T3–T2, and 1.12 degrees on average in T3–T1. Kitahara et al. [28] reported inverse results between BSSRO (decrease by 4.48 degree) and IVRO (increase by 3.38 degree). It still remains unclear whether relapse is statistically significantly correlated with changes in the gonial angle.

Yoshioka et al. [29] investigated the postoperative differences in the proximal and distal segments after BSSRO and found the intergonial width to have increased to 0.45 mm at 1 year postoperatively. Choi at al. [30] reported that all 42 of their patients had an increased intergonial width, which was statistically significant between T1 and T2. The right and left ramus angles and the total angle were significantly increased between T1 and T2 ($p < 0.01$). The intergonial width and proximal segment angulations significantly increased to 2.1 mm and 1.8 degrees, respectively, between T1 and T3. However, widening the mandibular width is not always what the patient wants. In addition, increased mandibular width in patients with a small mandible may be a favorable side effect of BSSRO, but may be aesthetically undesirable in patients with a large mandible. For example, in Asian culture, a wide and square faced female may desire a mandibular angle reduction or corticotomy for a more oval and thinner face [31]. In our study, three groups were divided according to the amount of mandibular setback, and compared with each other, no correlation was observed with the mandibular angle, mandibular width, and angle change of the mandibular mesial fragment. Contrary to the previous study, in our study with BSSRO, the mandibular width decreased from T2–T1 (average 0.01 mm) to T3–T1 (average 4.2 mm), which is in agreement with the results of Kitahara's study [28]. In particular, the decrease in the width of the mandible was larger one year after the operation. The decrease immediately after surgery was due to intraoperative contouring or internal angle reduction, and the decrease in T3–T1 was attributed to bone remodeling.

From an aesthetic point of view, removing the bony interferences by performing an internal angle reduction and allowing for subsequent bone remodeling over the course of the one-year follow-up resulted in an acceptable outcome for those Asian patients with the combination of a protruding gonial angle and brachycephalic facial morphology.

The practical significance of removing the bony interferences is this resulting bone remodeling, which occurs as the mandibular condyle returns to its original position during healing and function. Therefore, some degree of interosseous interference during surgery does not cause an increase in the width of the mandibular angle in the face after surgery.

5. Conclusions

The decrease in mandibular width immediately following surgery is attributable to contouring or angle reduction of the mandible. The decrease 1 year after surgery can be considered to be due to bone remodeling. This bone remodeling can be seen as the result of the mandibular condyle returning to its original position during healing and function. Therefore, some degree of interosseous interference during surgery does not necessarily cause an increase in the width of the mandibular angle in the face after surgery. It can be said that the bone remodeling occurred after surgery in a direction favoring esthetic improvement.

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Informed Consent Statement: Patient consent was waived from the approval of the the Institutional Review Board of Pusan National University Dental Hospital (PNUDH-2021-037, 09-09-21).

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy restrictions.

Conflicts of Interest: The authors declare no conflict of interest.

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