Postoperative stability following intraoral vertical ramus osteotomy in skeletal Class III patients with high mandibular plane angle

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Postoperative stability following intraoral vertical ramus osteotomy in skeletal Class III patients with high mandibular plane angle

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감사의 글

수련기간부터 지금까지 부족한 저를 이끌어 주시고 논문의 시작부터 완성되기까지 세심한 배려와 가르침으로 지도해 주신 황충주 지도 교수님께 진심으로 감사 드립니다. 바쁘신 와중에도 논문에 귀중한 시간을 내주시어 관심과 조언을 아끼지 않으신 백형선 교수님, 차정열 교수님, 정영수 교수님, 정휘동 교수님께 감사 드립니다.

저에게 교정을 배울 수 있는 기회를 주시고 많은 가르침을 주신 박영철 명예교수님, 김경호 교수님, 유형석 교수님, 이기준 교수님, 정주령 교수님, 최윤정 교수님께 감사 드립니다.

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마지막으로 사랑하는 예쁜 딸 수현이와 항상 따뜻한 배려와 든든한 지원으로 많은 힘이 되어 주는 최성환 선생님께 감사의 마음을 전합니다.

2016년 12 월 저자

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Abstract

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The treatment of mandibular prognathism and skeletal open bite, including an anterior open bite and a steep mandibular plane, in adults requires mandibular setback surgery, involving sagittal split ramus osteotomy (SSRO) or intraoral vertical ramus osteotomy (IVRO). Double-jaw surgery, using SSRO, for Class III malocclusion with an anterior open bite promotes open bite correction because postoperative superior movement of the mandible occurs after surgery as a result of counterclockwise autorotation. In contrast, because of the backward and downward movement of the distal segment after IVRO due

to condylar sagging and a muscular pull, the patient can exhibit a tendency to develop an anterior open bite in the early postoperative period after IVRO. Few studies have evaluated the relapse pattern of IVRO for the correction of mandibular prognathism with a high angle. The aim of this study was to measure the association between vertical facial types (high and normal mandibular plane angle) and relapse after intraoral vertical ramus osteotomy for the management of mandibular prognathism.

The retrospective cohort study sample (skeletal Class III subjects) was divided into 2 groups according to the angle of the sella-nasion plane relative to the mandibular plane (SN-MP) at the initial examination. Lateral cephalograms were analyzed for the predictor (facial type) and outcome (cephalometric changes over time) variables before, and at 7 days and 12 months after surgery. The 2 groups were matched for sample size (n = 20 each). Data were analyzed using repeated measures analysis of variance with Bonferroni correction.

Group N (SN-MP from 27° to 37°) and group H (SN-MP over 37°) were not significantly different in terms of sex and age at the initial examination. Seven days after surgery, the mandibles in group H moved 2.5 mm more superiorly than those in group N (P = 0.013); consequently the amount of overbite correction in group H was approximately 2 mm greater than that in group N (P = 0.002). Nevertheless, 12 months after surgery, there was no statistically significant difference in relapse of the maxilla and mandible between the two groups. In the two groups, the mandible moved approximately 0.7 mm superiorly during retention.

We found that, skeletal and dental relapse at 12 months after bimaxillary surgery using IVRO did not differ significantly according to the vertical facial type. These findings suggest that IVRO can be a clinically acceptable and stable treatment modality for mandibular prognathism with a high angle.

Key words: High angle; Intraoral vertical ramus osteotomy; Mandibular prognathism; Skeletal Class III; Stability

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I. INTRODUCTION

The treatment of mandibular prognathism and skeletal open bite, including an anterior open bite, a short ramus height, and a steep mandibular plane, in adults requires mandibular setback surgery, involving sagittal split ramus osteotomy (SSRO) or intraoral vertical ramus osteotomy (IVRO) (Solano-Hernandez et al., 2013).

The major advantages of SSRO include a broad bony interface between the proximal and distal segments to enhance healing potential and shorter duration for intermaxillary fixation via rigid internal fixation of the mandible (Wolford, 2000). IVRO without any fixation system has been reported to cause less injury to inferior alveolar nerve and is preferred in patients with temporomandibular disorder due to functional rehabilitation of the disc-condyle relationship (Choi et al., 2016a; Ueki et al., 2002).

However, mandibular setback surgery alone has several limitations, because correcting a vertical skeletal discrepancy using only mandibular surgery results in the counterclockwise rotation of the mandible and lengthening of the posterior facial height (Kwon et al., 2014). This can influence the extension of the pterygomassetric sling and postoperative stability. Therefore, in most cases, bimaxillary surgery, including Le Fort I osteotomy with posterior impaction, is performed to achieve better facial esthetics and function (Kor et al., 2014).

Previous studies have reported that double-jaw surgery, using SSRO, for Class III malocclusion with an anterior open bite promotes open bite correction, because postoperative superior movement of the mandible occurs after surgery due to autorotation (Kor et al., 2014; Liao et al., 2010). Kor et al. reported that bimaxillary surgery with SSRO for the correction of mandibular prognathism with an anterior open bite was a relative stable procedure, regardless of clockwise or counterclockwise rotation of the occlusal plane (Kor et al., 2014). Liao et al. reported superior movement of the mandible after SSRO, which was favorable for open bite correction in patients with skeletal Class III malocclusion (Liao et al., 2010).

However, the skeletal relapse pattern between SSRO and IVRO has been reported significantly different and the mandible after IVRO has shown a retromandibular position, compared with SSRO (Al-Moraissi and Ellis, 2015; Kitahara et al., 2009; Ueki et al., 2005; Yoshioka et al., 2008). Yoshioka et al. reported that clockwise rotation and posterior movement of the distal segment are likely to be caused by condylar sagging and a muscular pull (Yoshioka et al., 2008). Because of this postoperative clockwise rotation, patients may exhibit a tendency to develop an anterior open bite in the early postoperative period of IVRO. Therefore, the selection of IVRO for the management of skeletal Class III malocclusion with an anterior open bite is a difficult decision for the surgeon.

Recently, Choi et al. reported that bimaxillary surgery with IVRO for mandibular prognathism and anterior open bite results in acceptable postoperative horizontal and vertical mandibular stability (Choi et al., 2016a). However, these studies did not consider any vertical facial profile. Yoshida et al. reported that the only SSRO that can decrease anterior facial height for the dolichofacial type with a high angle results in a clockwise pattern of mandibular relapse, which indicates the occurrence of posterior and inferior postoperative mandibular changes with a reduced anterior overbite (Yoshida et al., 2000).

To the best our knowledge, few studies have investigated postoperative stability after bimaxillary surgery with IVRO according to vertical facial pattern in skeletal Class III patients. To ensure stability after IVRO without the use of a rigid fixation system, there is a need to evaluate postoperative skeletal and dental changes after IVRO for mandibular prognathism with a high angle.

The aim of this study was to measure the association between vertical facial types (high and normal mandibular plane angle) and relapse after IVRO performed as management of mandibular prognathism. We hypothesized that the stability of the outcomes after IVRO would differ between the normal angle group and the high angle group. The specific aims of the study were to compare the postoperative skeletal and dental variables at 12 months after IVRO for skeletal Class III malocclusion in these 2 different facial types.

II. MATERIALS AND METHODS

1. Study design and subjects

The authors designed and implemented this retrospective study. The study sample was composed of patients who presented for the evaluation and management of skeletal Class III malocclusion with either of 2 vertical facial profiles between 2007 and 2012 at the Department of Oral and Maxillofacial Surgery, Yonsei Dental Hospital, Seoul, Korea.

The inclusion criteria for the study were as follows: (1) age ≥ 18 years; (2) no loss of teeth except extraction of third molars; (3) presence of skeletal Class III malocclusion with the angle formed by point A, the nasion, and point B (ANB) smaller than 0°; (4) requirement for conventional orthognathic double-jaw surgery with presurgical orthodontics (1-piece Le Fort I osteotomy and bilateral IVRO); (5) no severe dentofacial anomalies, such as a cleft lip or palate. To be eligible, the participant also had to be in good general health.

The exclusion criteria were as follows: (1) existing serious medical conditions for which the patient had been hospitalized in the past 3 months; (2) history of orthodontic treatment or orthognathic surgery; (3) requirement of single-jaw surgery or preorthodontic orthognathic surgery; (4) menton deviation > 4 mm from the facial midline; (5) the loss of or an incomplete series of identifiable lateral cephalometric radiographs. This study followed the guidelines of the Declaration of Helsinki and was approved by the institutional review board of Yonsei Dental Hospital (2-201500035).

2. Surgical and orthognathic treatment

All patients underwent conventional bimaxillary surgery, including maxillary Le Fort I osteotomy with posterior impaction and bilateral IVRO for mandibular setback. The same protocol was used for all surgeries, which were performed by 2 surgeons. All patients also underwent pre- and postoperative orthodontic treatment at the Department of Orthodontics, Yonsei Dental Hospital, Seoul, Korea.

For rigid internal fixation, 4 titanium miniplates with monocortical screws were used to stabilize the maxilla after 1-piece Le Fort I osteotomy in the canine fossa and zygomatic buttress, bilaterally. Bilateral IVRO was carried out for mandibular setback. The IVRO operation began with an approximately 4-cm long incision over the external oblique ridge. The mucoperiosteal flap was extended from the antegonial notch to the level of the sigmoid notch. A pair of Bauer retractors was placed in the sigmoid and antegonial notches to visualize the antelingular prominence and to prevent bleeding from the internal maxillary artery, and a conventional double slide osteotomy was performed. A round oscillating saw was used to simplify the angle at the antelingular prominence. Next, the saw blade was directed anterosuperiorly toward the sigmoid notch (Choi et al., 2013; Jung et al., 2014). Some patients were undertaken a genioplasty to advance the chin horizontally during two-jaw surgery. The patients' sutures were removed, and radiographs were taken postoperatively within 7 days. The mean length of time of maxillomandibular fixation (MMF) was 13.5 days (standard deviation: 3.2; range: 8–19 days) after surgery in the 2 groups.

As previously described (Jung et al., 2012), after MMF, the patients were given instructions on how to use intermaxillary elastics, including Class I or Class II guiding elastics, in order to prevent the an open bite immediately after surgery. To ensure sound postoperative rehabilitation (Jung et al., 2013; Jung et al., 2012), mouth-opening exercise was performed with an occlusal splint during active physiotherapy (PT). The daily PT protocol consisted of 4 cycles of mandibular movements for 1 h and MMF using elastics for 2 h and during sleep. One cycle of mandibular movement included 3 repetitions of maximum mouth opening, right and left lateral excursion, and protrusive movement. The patients continued PT on a daily basis, with a surgeon assessing occlusal stability and the patient’s cooperation every 1 or 2 days (Jung et al., 2012). Even when an open bite event was less than 1 mm for more than 2 days, rigid MMF was applied by a surgeon, using wire and elastic bands, for 2–3 days. When a maximum mouth opening of at least 30 mm was obtained, the splint was removed after 1–2 weeks of PT. PT was continued until an adequate (more than 40 mm) range of jaw movement and stable occlusion was achieved (Choi et al., 2016d; Jung et al., 2013; Jung et al., 2012).

3. Lateral cephalometric analysis

Skeletal and dental relapse were evaluated using lateral cephalograms obtained 1 month before (T1), 7 days after (T2), and 12 months after surgery (T3). The surgical change was defined as the values obtained at T2 minus those obtained at T1, and the relapse at 12 months after surgery was defined as the values obtained at T3 minus those obtained at T2. The lateral cephalograms were digitized using V-ceph 5.5 (Osstem, Seoul, Korea) by an observer who was blinded to the clinical status of the patients. All reference planes were transferred from the T1 to T3 cephalograms based on superimposition of the sella (S)–nasion (N) plane.

The reference plane was constructed for serial linear measurements. The horizontal reference plane (x-axis) originated at N and formed an angle of 7° upward from the SN plane (Figure 1). The vertical reference plane (y-axis) was defined as the line perpendicular to the x-axis and passing through S. The positions of the landmarks in relation to the x- and y-axes were recorded for linear measurements.

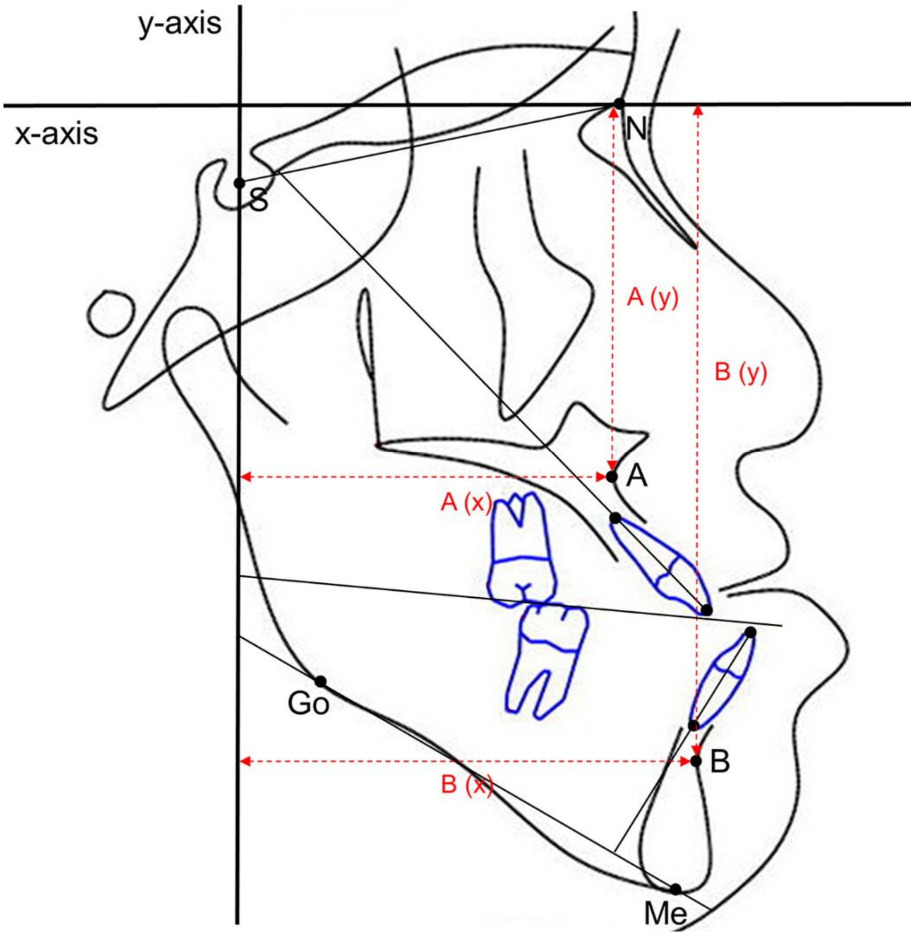

Figure 1. Skeletal and dental landmarks used in the cephalometric analysis are shown. S, sella; N, nasion; A, point A; B, point B; Me, menton; Go, gonion; x-axis, defined with the origin at N and forming a 7º angle upward from the SN plane; and y-axis, defined as the line perpendicular to the x-axis and passing through S; A(x), horizontal position of point A; A(y), vertical position of point A; B(x), horizontal position of point B; B(y), vertical position of point B.

4. Study variables

1) Primary predictor

Vertical facial type was the primary predictor variable in this study. Baik et el. reported that the normal values of the angle of the SN plane to the mandibular plane (SN-MP) in Korea are 31.8° (standard deviation [SD]: 3.5°) in men and 33.4° (SD: 3.5°) in women (Baik et al., 2000). Based on the previous study, this study sample was divided into 2 groups according to SN–MP at the initial examination: a normal angle group (group N), including patients with an SN–MP from 27° to 37°, and a high angle group (group H), including patients with an SN–MP over 37° (Baik et al., 2000; Macari and Hanna, 2014; Ozdemir et al., 2013; Ozdemir et al., 2014).

2) Primary outcomes

6 angular and 6 linear cephalometric measurements were identified to determine skeletal and dental relapse. The 6 angular measurements included SNA, defined as the angle made by the lines connecting the SN plane and point A; SNB, defined as the angle of the SN plane and point B; SN–OP, defined as the angle of the SN plane to the occlusal plane; SN–MP, defined as the angle of the SN plane to the mandibular plane; U1–SN, defined as the angle of the SN plane to the upper incisor axis; and IMPA, defined as the angle of the mandibular plane to the lower incisor axis. The 6 linear measurements included the horizontal distance from points A [A(x)] and B [B(x)] to the y-axis and the

vertical distance from points A [A(y)] and B [B(y)] to the x-axis. The overjet (OJ) and overbite (OB) were also measured at different time points.

5. Reliability

Reproducibility was determined by comparing the measurements obtained from the original examinations with those obtained from repeated examinations. All measurements were repeated by the same examiner after 2 weeks. The method error was calculated using the intraclass correlation coefficient (ICC), which was 0.85 to 0.90 for all angular and linear measurements in this study.

6. Statistical analysis

All statistical analyses were performed using IBM SPSS software, version 21.0 (IBM Korea Inc., Seoul, Korea) for Windows. Based on the preliminary study, a minimum sample size of 18 was required (G*Power 3, Dusseldorf, Germany), with a P value less than 0.05 indicating statistical significance, a power of 95%, and an effect size of 0.25 for detecting differences in skeletal and dental changes over time (T1, T2, and T3) within each group.

To verify the normality of the data distribution, the Shapiro–Wilk test was applied. Descriptive statistics, such as the mean and the standard deviation, were used to describe the distribution of each variable in the study. Differences in demographic characteristics, including sex and age, between the 2 groups were analyzed using the chi-square test and the Mann–Whitney U test.

RMANOVA was used to compare surgical and postoperative angular and linear measurement changes in each group and between the 2 groups over time (T1, T2, and T3). If there were any significant differences between the groups, an independent t test with Bonferroni correction ($\alpha = 0.05/3$) followed by post-hoc tests was performed.

III. RESULTS

1. Observation at 7 days after surgery

Among 84 patients, 40 patients (16 men and 24 women) were included in this study (Table 1). The group with a normal angle (N) included 20 patients (8 men and 12 women) with a mean age of 21.7 years (SD: 2.9 years) and the group with a high angle (H) included 20 patients (8 men and 12 women) with a mean age of 23.3 years (SD: 4.5 years). There were no significant between-group differences for demographic characteristics and the mean ANB, defined as the angle of lines formed by point A, the N, and point B, at the initial examination. The mean SN-MP was 32.6° (SD: 2.8°) in group N and 40.6° (SD: 2.7°) in group H. There was a significant difference in the SN-MP value between the 2 groups ($P < 0.001$).

Table 1. Sample characteristics (N =40).

Variable	Group N (n = 20)	Group H (n = 20)	*P* value
SN-MP (°)	27 to 37	> 37	
Mean ± SD	32.6 ± 2.9	40.6 ± 2.7	< 0.001***[a]
ANB (°) Mean ± SD	-3.6 ± 2.9	-1.8 ± 1.8	0.062[a]
Sex, n (%)			1.000[b]
Men	8 (40.0)	8 (40.0)	
Women	12 (60.0)	12 (60.0)	
Age (year)			
Mean ± SD	21.7 ± 2.9	23.3 ± 4.5	0.174[c]

Abbreviations: Group N, normal mandibular plane angle group; Group H, high mandibular plane angle group; SN-MP, angle of the sella-nasion plane to the mandibular plane; SD, standard deviation; ANB, angle of lines formed by point A, the nasion, and point B.

[a] *P* value calculated with the independent *t* test.
[b] *P* value calculated with chi-squared test.
[c] *P* value calculated with Mann-Whitney U test.
*** $P < 0.001$.

Table 2 showed that the 6 angular measurements were not statistically different between the 2 groups over time. There was no significant difference in the horizontal position of point B over time (P = 0.487; Figure 2). However, there were significant differences in the vertical position of point B and overbite between the 2 groups over time (P = 0.007 and P < 0.001, respectively; Figures 3 and 4). At T1, the overbite in group N was 0.1 mm (SD: 1.3 mm) and that in group H was -1.7 mm (SD: 1.7 mm; Table 3).

Table 2. Mean and standard deviation of the outcome variable (angular measurements, degree) according to the predictor variable (group) at different time periods.

Outcome variable	Time	Group N	Group H	Time x group *P* value
SNA (°)	T1	81.7 ± 3.6^{A}	80.0 ± 3.3^{AB}	0.232
	T2	83.8 ± 4.4^{B}	81.5 ± 3.3^{B}	
	T3	83.2 ± 4.0^{B}	80.5 ± 3.3^{A}	
SNB (°)	T1	85.3 ± 5.2^{B}	81.8 ± 3.1^{B}	0.457
	T2	79.2 ± 3.7^{A}	76.8 ± 2.3^{A}	
	T3	79.1 ± 4.5^{A}	75.8 ± 2.8^{A}	
SN-OP (°)	T1	14.3 ± 4.3^{A}	20.3 ± 3.1^{A}	0.217
	T2	20.6 ± 3.1^{B}	25.1 ± 4.1^{B}	
	T3	20.8 ± 4.1^{B}	26.9 ± 3.4^{B}	
SN-MP (°)	T1	32.6 ± 2.8^{A}	40.6 ± 2.7^{A}	0.134
	T2	39.1 ± 4.6^{B}	44.6 ± 5.9^{B}	
	T3	41.2 ± 4.6^{C}	47.8 ± 5.3^{C}	
U1-SN (°)	T1	110.1 ± 5.6^{B}	107.2 ± 7.6^{B}	0.280
	T2	103.2 ± 3.4^{A}	100.2 ± 5.4^{A}	
	T3	104.6 ± 5.6^{A}	99.5 ± 5.3^{A}	
IMPA (°)	T1	89.1 ± 7.4^{B}	89.9 ± 5.8^{B}	0.656
	T2	87.0 ± 6.7^{A}	88.7 ± 4.8^{AB}	
	T3	84.1 ± 8.7^{A}	85.6 ± 5.6^{A}	

P value calculated with repeated measures analysis of variance with Bonferroni correction.
Within each column, significant differences are represented by uppercase letters.

Table 3. Mean and standard deviation of the outcome variable (linear measurements, mm) according to the predictor variable (group) at different time periods.

Outcome variable	Time	Group N	Group H	Time x group *P* value
A(x) (mm)	T1	69.8 ± 5.4^{A}	65.2 ± 4.1^{A}	
	T2	71.8 ± 6.0^{B}	67.0 ± 4.2^{B}	0.632
	T3	71.3 ± 5.6^{B}	66.0 ± 4.6^{A}	
B(x) (mm)	T1	75.9 ± 10.1^{B}	66.6 ± 6.2^{B}	
	T2	65.0 ± 7.9^{A}	56.8 ± 4.7^{A}	0.487
	T3	64.7 ± 9.1^{A}	55.0 ± 5.8^{A}	
A(y) (mm)	T1	66.3 ± 3.5^{A}	67.7 ± 2.9^{B}	
	T2	65.6 ± 4.6^{A}	66.0 ± 3.6^{A}	0.344
	T3	65.2 ± 4.2^{A}	66.3 ± 3.2^{A}	
B(y) (mm)	T1	111.1 ± 6.5^{B}	115.9 ± 6.2^{B}	
	T2	109.7 ± 6.1^{AB}	112.0 ± 5.2^{A}	0.007**
	T3	108.9 ± 6.6^{A}	111.4 ± 6.0^{A}	
Overjet (mm)	T1	-5.4 ± 5.2^{A}	-5.1 ± 4.2^{A}	
	T2	3.2 ± 0.8^{B}	2.6 ± 0.6^{B}	0.555
	T3	3.3 ± 1.0^{B}	2.9 ± 0.7^{B}	
Overbite (mm)	T1	0.1 ± 1.3^{A}	-1.7 ± 1.7^{A}	
	T2	1.8 ± 1.1^{B}	1.8 ± 1.0^{B}	< 0.001***
	T3	2.6 ± 1.1^{B}	2.5 ± 1.0^{B}	

P value calculated with repeated measures analysis of variance with Bonferroni correction.
Within each column, significant differences are represented by uppercase letters.
** $P < 0.01$; *** $P < 0.001$.

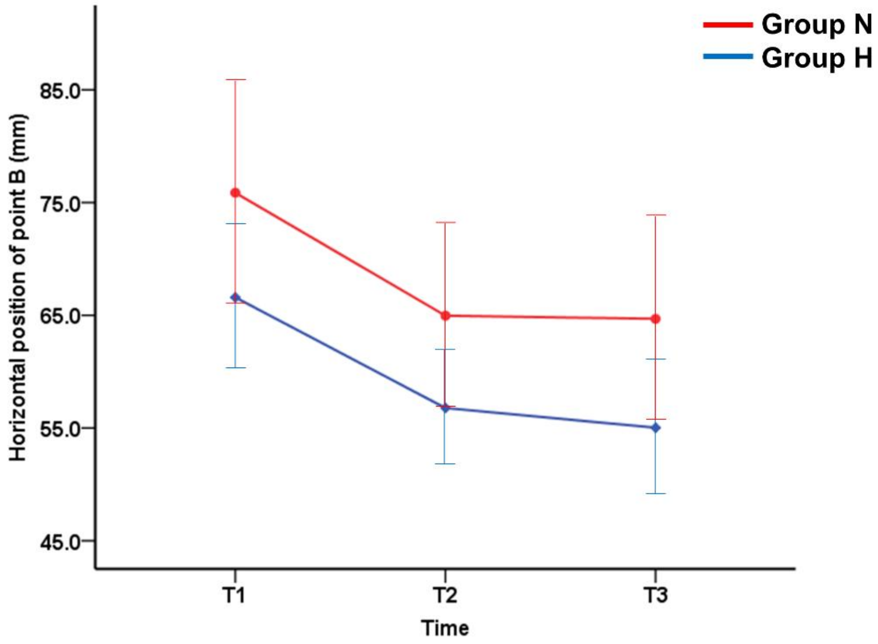

Figure 2. Horizontal distances between point B and the y-axis [B(x)] in the two groups at different time points. There was no significant difference in the horizontal movement of point B between the 2 groups over time (P = 0.487). Group N, normal mandibular plane angle group; Group H, high mandibular plane angle group; T1, 1 month before surgery; T2, 7 days after surgery; and T3, 12 months after surgery; error bar, standard deviation.

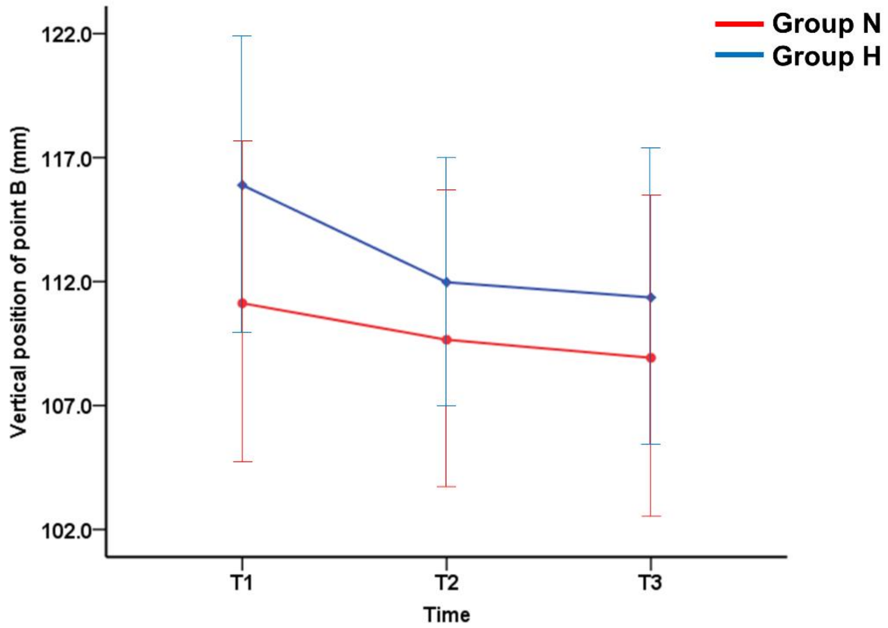

Figure 3. Vertical distances between point B and the x-axis [B(y)] in the two groups at different time points. Point B in group H exhibited more upward movement than that in group N (P = 0.013) between T1 and T2, but there was no significant difference in the vertical postoperative movement of point B between the 2 groups. Group N, normal mandibular plane angle group; Group H, high mandibular plane angle group; T1, 1 month before surgery; T2, 7 days after surgery; and T3, 12 months after surgery; error bar, standard deviation.

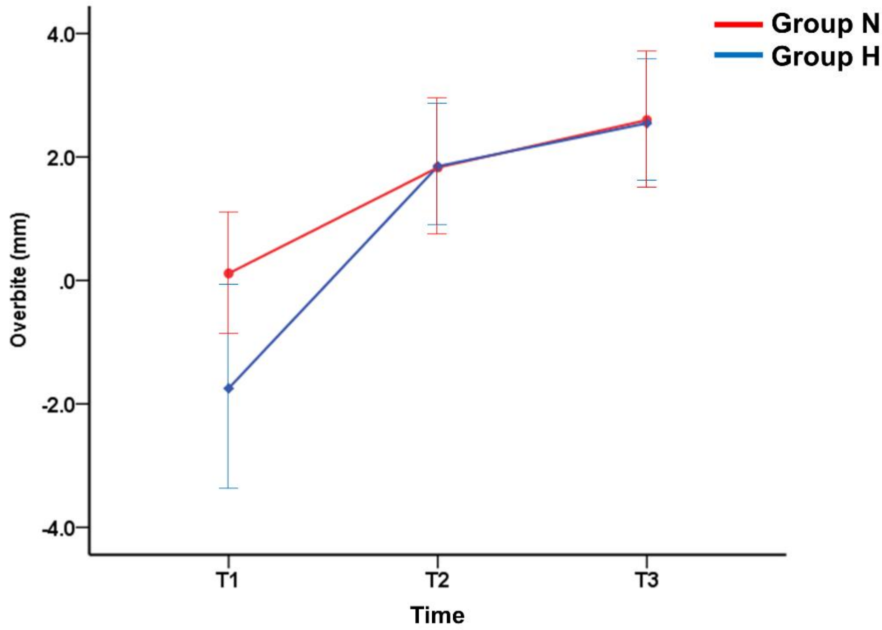

Figure 4. Overbite in the 2 groups at different time points. The amount of overbite correction in group H was greater than that in group N (P = 0.012) between T1 and T2, but there was no significant difference in the postoperative change in the overbite between the 2 groups. Group N, normal mandibular plane angle group; Group H, high mandibular plane angle group; T1, 1 month before surgery; T2, 7 days after surgery; and T3, 12 months after surgery; error bar, standard deviation.

The mean surgical movement at point A was 2.0 mm (SD: 2.7 mm) anteriorly (P = 0.013) and 0.8 mm (SD: 2.1 mm) superiorly ($P > 0.05$) in group N, and 1.8 mm (SD: 2.1 mm) anteriorly (P = 0.003) and 1.7 mm (SD: 2.2 mm) superiorly in group H (Table 4). The mean surgical change at point B was 10.9 mm (SD: 5.2 mm) posteriorly ($P < 0.001$) and 1.5 mm (SD: 2.3 mm) superiorly (P = 0.032) in group N, and 9.8 mm (SD: 5.2 mm) posteriorly ($P < 0.001$) and 3.9 mm (SD: 3.5 mm) superiorly in group H (Table 4). There was a statistically significant difference in the amount of vertical movement of the mandible between the 2 groups during surgery ($P = 0.013 < 0.05/3$). As the mandible moved more superiorly in group H than in group N, the amount of overbite correction in group H was greater than that in group N (Figures 3 and 4).

Table 4. Comparison of surgical changes (T2-T1) in cephalometric measurements in the two groups.

T2-T1	Group N		Group H		Between groups
	Difference	*P* value[a]	Difference	*P* value[a]	
SNA (°)	2.1 ± 1.7	< 0.001	1.4 ± 2.2	0.028	0.297
SNB (°)	-5.6 ± 2.7	< 0.001	-5.0 ± 2.7	< 0.001	0.531
SN-OP (°)	6.3 ± 3.7	< 0.001	4.8 ± 4.1	< 0.001	0.234
SN-MP (°)	6.5 ± 3.4	< 0.001	4.0 ± 5.4	0.011	0.087
U1-SN (°)	-6.9 ± 3.8	< 0.001	-7.0 ± 4.6	< 0.001	0.950
IMPA (°)	-2.1 ± 2.6	0.005	-1.1 ± 3.0	0.330	0.261
A(x) (mm)	2.0 ± 2.7	0.013	1.8 ± 2.1	0.003	0.883
B(x) (mm)	-10.9 ± 5.2	< 0.001	-9.8 ± 5.2	< 0.001	0.510
A(y) (mm)	-0.8 ± 2.1	0.386	-1.7 ± 2.2	0.010	0.210
B(y) (mm)	-1.5 ± 2.3	0.032	-3.9 ± 3.5	< 0.001	0.013*
Overjet (mm)	8.6 ± 4.9	< 0.001	7.7 ± 4.1	< 0.001	0.531
Overbite (mm)	1.7 ± 1.5	< 0.001	3.6 ± 1.9	< 0.001	0.002**

Positive and negative values indicate anterior and posterior horizontal changes, inferior and superior vertical changes, and increased and decreased dimensional changes, respectively.
Group comparisons were tested with an independent *t* test with Bonferroni correction.
[a]By repeated measures analysis of variance with Bonferroni correction.
* $P < 0.05/3$; ** $P < 0.01$.

2. Observation at 12 months after surgery

During the postoperative period, SNA and SNB decreased by 0.6° (SD: 1.3 mm) and 0.1° (SD: 1.8°), respectively, in group N, but this change was not clinically meaningful (Table 5). In group H, point B moved backward by 1.8 mm (SD: 3.2 mm) and upward by 0.6 mm (SD: 1.9 mm). These values were not significantly different between T2 and T3. Consequently, there was no statistically significant difference in the amounts of postoperative angular and linear changes between the groups ($P > 0.05/3$).

SN-MP had slightly but significantly increased, by approximately 2° to 3°, in both groups by 12 months after surgery. Additionally, the lower incisors were also tilted approximately 3° lingually in the two groups at T3. Only group H exhibited a significant decrease in IMPA over time ($P < 0.001$), with an increase in SN-MP ($P = 0.012$).

Table 5. Comparison of postoperative relapse (T3-T2) in cephalometric measurements in the two groups.

T3-T2	Group N		Group H		Between groups
	Difference	*P* value[a]	Difference	*P* value[a]	
SNA (°)	-0.6 ± 1.3	0.101	-1.0 ± 1.3	1.000	0.451
SNB (°)	-0.1 ± 1.8	1.000	-1.0 ± 1.6	0.044	0.131
SN-OP (°)	0.2 ± 2.9	1.000	1.9 ± 2.7	0.017	0.067
SN-MP (°)	2.1 ± 2.9	0.015	3.2 ± 2.6	< 0.001	0.205
U1-SN (°)	1.5 ± 4.9	0.603	-0.7 ± 4.8	1.000	0.165
IMPA (°)	-2.9 ± 4.3	0.023	-3.1 ± 4.3	0.012	0.855
A(x) (mm)	-0.5 ± 2.3	1.000	-1.0 ± 1.5	0.018	0.402
B(x) (mm)	-0.3 ± 3.2	1.000	-1.8 ± 3.2	0.072	0.156
A(y) (mm)	-0.3 ± 1.5	0.955	0.3 ± 1.6	1.000	0.240
B(y) (mm)	-0.7 ± 1.5	0.121	-0.6 ± 1.9	0.466	0.831
Overjet (mm)	0.1 ± 0.9	1.000	0.1 ± 0.8	1.000	0.954
Overbite (mm)	0.8 ± 1.4	0.072	0.7 ± 1.4	0.117	0.872

Positive and negative values indicate anterior and posterior horizontal changes, inferior and superior vertical changes, and increased and decreased dimensional changes, respectively.
Group comparisons were tested with an independent *t* test with Bonferroni correction.
[a]By repeated measures analysis of variance with Bonferroni correction.

IV. DISCUSSION

The aim of this study was to measure the association between the vertical facial types (high and normal mandibular plane angle) and relapse following IVRO performed as management of mandibular prognathism. We hypothesized that the skeletal and dental relapse pattern after IVRO would differ significantly between patients, according to the vertical facial profile. To test this hypothesis, we assessed angular and linear outcome variables in patients with mandibular prognathism relative to the vertical facial profile using serial lateral cephalograms taken over a period of 12 months. We found no clinically or statistically meaningful intergroup differences in the rates of skeletal and dental relapse between the 2 groups over time.

At the initial examination, group H showed an approximately 8° greater mandibular plane angle than group N, and an anterior open bite of 1.7 mm (Tables 2 and 3). Previous studies have reported that an anterior open bite is caused by several factors, including a vertical growth pattern with a clockwise rotation of the mandible and a downward rotation of the posterior maxilla, with relative extrusion of the posterior teeth (Proffit et al., 2000). In addition, the extension of the pterygoid muscle, soft tissue stretching, and postoperative masticatory muscle strength can contribute to relapse after mandibular setback surgery (Fontes et al., 2012; Joss and Vassalli, 2009). Although the role of vertical facial morphology is unclear, many studies have shown that the lowest muscle activity measured by electomyographic examination is observed in individuals with a dolichofacial profile, and may be a consequence of unstable occlusion, with lower occlusal contacts. Therefore, patients with a high angle may have lower masticatory muscle function than individuals with brachyfacial and mesofacial morphologies (Custodio et al., 2011; Gomes et al., 2010; Wong et al., 2016). Differences in the vertical dimensions of the face can be caused by functional differences, including variations in muscle thickness and position, and recent studies have reported that the cortical bone thickness of the alveolar bone in the maxilla and mandible differs according the vertical facial profile (Ozdemir et al., 2013; Ozdemir et al., 2014). Therefore, in order to prevent stretching the weakened masseter and temporal muscles, due to counterclockwise rotation of the mandible to close the bite, it is necessary to achieve maxillary posterior impaction when treating patients with mandibular prognathism and a high angle. This can correct the anterior open bite with a high angle and prevent the lengthening of the pterygomasseteric sling.

Seven days after surgery, the mandibles of patients in group H moved 2.5 mm more superiorly than those of patients in group N; consequently, the amount of overbite correction in group H was approximately 2 mm greater than that of group N (Table 4). Nevertheless, 12 months after surgery, there was no statistically significant difference in the relapse of the maxilla and mandible between the 2 groups (Table 5). In both groups, the mandible moved approximately 0.7 mm superiorly between T2 and T3. This result is consistent with those of previous studies, regardless of the type of mandibular setback surgery.

In SSRO cases, due to the use of a rigid fixation system, as the proximal segment rotated clockwise intraoperatively, the distal segment rotated counterclockwise and continuously moved superiorly during retention (Han et al., 2014; Pan et al., 2013; Yang and Hwang, 2014). Alternatively, in IVRO cases, because IVRO does not use any fixation system, more upward movement was seen in this group than in the SSRO group during the MMF period with active PT using intermaxillary vertical elastics; therefore, appropriate condylar repositioning can contribute to the upward movement of the mandible (Choi et al., 2016a; Choi et al., 2016d; Kitahara et al., 2009). Kitahara et al. reported that upward movement of Pog during intermaxillary fixation was greater in the IVRO group than in the SSRO group, with this change being maintained after surgery (Kitahara et al., 2009). This postoperative upward movement of the mandible after IVRO can be helpful for correcting Class III malocclusion in patients with a high angle.

In this study, the two groups were matched for the magnitude of surgical setback (Table 4). Jung et al reported that the difference in the amount of horizontal and vertical repositioning that resulted from the differing amounts of setback was not significant, and that the amount of setback cannot be considered solely as a variable that affects the degree of stability after IVRO (Jung et al., 2013). However, according to the purpose of this study, the two groups must be matched for all relevant variables, particularly the magnitude of horizontal change because the effect of differing amounts of mandibular setback on vertical changes and overbite is important and could be a confounding factor.

Yoshida et al. suggested that the postoperative outcome after mandibular setback surgery can be predicted according to the vertical facial type, because the relapse pattern differs based on the postoperative changes of each facial type. In particular, because patients with the dolichofacial type tend to have open anterior teeth that overlap postoperatively, pre- and postsurgical orthodontics should focus on preparing a sufficient overbite (Yoshida et al., 2000). Likewise, in this study, although no statistically significant inter-group differences were observed, as mandibular and occlusal plane angles increased in group H between T2 and T3, the mandible of group H moved more backward than that of group N at T3. However, due to the decrease of the U1-SN and IMPA, overjet might be maintained for 12 months after surgery in group H and there was no significant difference in overjet between the two groups. Previous studies also stated that the mandible after conventional IVRO can be rotated backward by pulling of muscles such as masseter and medial pterygoid muscles due to lack of bone fixation in short term after IVRO (Choi et al., 2016d; Jung et al., 2013; Nihara et al., 2013; Ueki et al., 2005).

However, in this study, no meaningful downward movement of the mandible was observed. The first reason for the difference between the results of the study of Yoshida et al. and this study could be related to the use of posterior impaction in maxillary surgery (Yoshida et al., 2000). Due to posterior impaction of maxilla, after the mandibular setback using IVRO, the possibilities of the extension of the pterygomassetric sling and postoperative counterclockwise rotation of the mandible might be rare. Another reason why there is no difference in postoperative stability between the two groups could be associated with well-organized PT instruction of Yonsei Dental hospital. The active PT instruction was designed so that the patients can easily follow the instruction. Moreover, the surgeons confirmed on a daily basis whether or not the patients keep the instruction well. Finally, to secure postoperative skeletal and dental stability, presurgical orthodontic treatment provided a stable occlusion with removing of the possibility of premature occlusal contacts during surgery. As a result, an appropriate overjet and overbite were maintained 12 months after surgery in this study, regardless of the vertical facial type (Table 5).

To the best of our knowledge, this is the first study to show that the relapse pattern after IVRO in patients with skeletal Class III malocclusion did not change over time in relation to the vertical facial type. However, this study was limited by its retrospective design and short observation period. A 12-month observation period may be too short to evaluate relapse after IVRO. In order to evaluate the long-term stability of anterior open bite closure with skeletal Class II malocclusion, previous studies have observed patients for 4 to 5 years after orthodontic appliance removal (Fontes et al., 2012; Yoshida et al., 2000). However, the change in craniofacial structure over 2 years after surgery may be partially accounted for by residual growth, rather than simply by postoperative relapse (Behrents, 1985; Kendrick and Risinger, 1967). Choi et al. reported that although the amount of change in the skeletal, dental, and soft tissue, and the alveolar bone height were very small, these time-dependent changes were statistically significant in young adults during a 4-year observation period (Choi et al., 2016c). Secondly, only 2 weeks of short MMF and the use of intermaxillary elastics during PT could be confounding factors in this study, because relatively forceful elastics would contribute movement at the osteotomy sites and lead to changes in the distal segment position without full bony healing and consolidation (Choi et al., 2016b). However, previous studies have revealed that early mobilization with a short MMF can reduce anxiety about MMF, facilitate the rehabilitation of masticatory muscles, lead to faster recovery of mandibular movement, and consequently improve dietary status (Jung et al., 2012; Ueki et al., 2008). Moreover, soft internal and external calluses form between segments 7 days post-operatively (Reitzik, 1983). Finally, although all patients underwent presurgical orthodontic treatment and had a stable occlusion at the time of surgery, we could not confirm whether the thickness of the splint was uniform regardless of vertical facial type. The thickness of the splint may affect the amount of upward movement of the mandible during postsurgical orthodontic treatment. Future well-designed prospective studies, investigating large homogeneous patient groups with mandibular prognathism and different vertical facial patterns, are warranted. It is also necessary to investigate whether the positional change of the distal segment of the mandible occurs due to the use of elastic bands during PT or due to the difference in the splint thickness during postsurgical orthodontic treatment.

V. CONCLUSION

Despite the limitations of this study, we found that, skeletal and dental relapse at 12 months after bimaxillary surgery using IVRO did not differ significantly according to the vertical facial type. These findings suggest that IVRO can be a clinically acceptable and stable treatment modality for mandibular prognathism with a high angle.

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Abstract (Korean)

하악 평면각이 큰 골격성 III급 환자의 구내 하악지 수직 골절단술 후 안정성

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큰 하악 평면각과 전치부 개방교합을 동반한 골격성 III 급 환자의 치료를 위해서 하악지 시상 분할 골절단술(SSRO) 또는 구내 하악지 수직 골절단술(IVRO)을 시행할 수 있다. SSRO 를 시행하였을 때 술후 하악의 반시계방향 회전 경향은 개방교합의 개선에 도움을 줄 수 있으나 수술 시 강성 고정을 시행하지 않는 IVRO 는 수술 직후 주위 근육의 작용에 의해 개방교합이 재발할 수 있음이 보고 되었다. 지금까지 하악 평면각이 큰 하악 전돌 환자의 구내 하악지 수직 골절단술(IVRO) 후 재발 양상을 평가한 연구는 거의 없었다.

본 연구는 후향적 연구로서 상악 LeFort I 골절단술과 하악 양측 IVRO 를 동반한 양악 수술로 치료 받은 골격성 III 급 환자들을 초진 시 두개저 평면과 하악 평면이 이루는 각도(SN-MP)에 따라 두 군으로 나누었다. 수술 전, 수술 7 일 후, 수술 12 개월 후에 촬영한 측모 두부 방사선 사진을 이용하여 두 군간 시간에 따른 수평 및 수직적 방사선 계측치의 변화를 반복측정 분산분석(RMANOVA)과 본페로니 사후검정(Bonferroni correction)을 이용하여 분석하였다.

정상 하악 평면각을 가진 그룹(그룹 N, 27° ≤ SN-MP ≤ 37°)과 하악 평면각이 큰 그룹(그룹 H, SN-MP > 37°)간에는 초진 시 성별과 연령에 유의한 차이가 없었다. 수술 7 일 후, 두 그룹 간의 하악 후방 이동량에는 유의한 차이가 없었으나 그룹 H 의 하악은 그룹 N 보다 약 2.5 mm 더 상방 이동하였다 (P = 0.013). 결과적으로 그룹 H 의 수직 피개 개선량은 그룹 N 과 비교하였을 때 약 2 mm 더 크게 나타났다 (P = 0.002). 수술 12 개월 후, 두 그룹간 상하악의 수평 및 수직 재발 양상은 통계적으로 유의한 차이가 없었다. 두 그룹 모두에서, 하악은 술후 1 년간 약 0.7 mm 상방 이동하였다.

큰 하악 평면각을 가진 골격성 III 급 개방교합 환자에서 IVRO 를 동반한 양악 수술을 시행하였을 때 술후 1 년간의 재발 양상은 정상 하악 평면각을 가진 환자와 비교 시 통계적으로 유의한 차이가 없었다. 두 그룹 모두에서 술후

하악은 안정적으로 위치하였으며 술후 약간의 상방 이동 경향은 개방 교합의 개선에 도움을 줄 수 있을 것으로 생각된다.

본 연구 결과를 토대로 IVRO 는 하악 평면각의 크기에 상관없이 골격성 III 급 개방 교합 환자의 치료 시 적용 가능한 안정적인 수술 방식이라 볼 수 있다.

핵심되는 말: 하악 평면각; 구내 하악지 수직 골절단술; 하악 전돌; 골격성 III 급; 안정성