Long-term stability of intraoral vertical ramus osteotomy with or without pre-surgical orthodontics

Jeong-Hwa Jeong

The Graduate School

Yonsei University

Department of Dentistry

Long-term stability of intraoral vertical ramus osteotomy with or without pre-surgical orthodontics

Directed by Professor Hyung-Seog Yu

A Dissertation Thesis

Submitted to the Department of Dentistry

and the Graduate School of Yonsei University

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy in Dental Science

Jeong-Hwa Jeong

June 2018

This certifies that the dissertation thesis
of Jeong Hwa Jeong is approved.

Thesis Supervisor: Hyung-Seog Yu

Chung-Ju Hwang

Sung-Hwan Choi

Sang-Hwy Lee

Kee-Deog Kim

The Graduate School

Yonsei University

June 2018

감사의 글

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또한 항상 저를 믿어주시고 묵묵히 응원해 주신 부모님과 가족에게도 감사 드립니다. 환자와 동료를 생각하는 교정과 의사가 되도록 노력하겠습니다. 감사합니다.

2018 년 6 월

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Abstract

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Jeong-Hwa Jeong

Department of Dentisry
The Graduate School, Yonsei University
(Directed by Professor Hyung-Seog Yu D.D.S.,M.S., Ph.D.)

The present study aimed to compare stability after surgery of skeletal and soft tissue between conventional surgery with pre-surgical orthodontics (CS) and pre-orthodontic orthognathic surgery (POGS) using intraoral vertical ramus osteotomy (IVRO).

The present retrospective study included 31 patients with skeletal Class III malocclusions who had undergone bimaxillary surgery (Le Fort I osteotomy and bilateral IVRO). Patients were divided into the CS (n=14) and POGS (n=17) groups based on the presence or absence of pre-surgical orthodontic treatment. Lateral cephalograms were obtained before surgery, 1 day after surgery, 1 month after surgery, 1 year after surgery, and 2 years after surgery to evaluate skeletal and soft tissue changes between the 2 groups. The data were analyzed using chi-square tests, Mann-Whitney *U* tests, repeated-measures analyses of variance and independent *t*-tests.

There was no significant difference in skeletal or soft tissue measurements — with the exception of the angle between the sella-nasion plane and the occlusal plane (SN-OP) ($P < 0.001$) — between the CS and POGS groups at 2 years after IVRO. The SN-OP had increased in the CS group but decreased in the POGS group at 2 years after surgery. Therefore, these findings suggest that CS and POGS have similar long-term stability in patients with skeletal Class III malocclusion.

Key words: Long-term stability; Skeletal Class Ⅲ; Intraoral vertical ramus osteotomy (IVRO); Pre-orthodontic orthognathic surgery (POGS)

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Jeong-Hwa Jeong

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I. INTRODUCTION

Orthognathic surgery is chosen when skeletal disharmony is severe and orthodontic treatment cannot achieve normal occlusion. Conventional orthognathic surgery with pre-surgical orthodontics (CS) is disadvantageous because the total duration of treatment is lengthy (Kim et al., 2014; Kim et al., 2014; Luther et al., 2003) and complete dental decompensation during pre-surgical orthodontics is not always possible (Proffit et al.,

1995). Furthermore, because occlusion and esthetic structure gradually worsen before surgery, the patient's cooperation is often poor (Kim et al., 2014). In 1977, Epker and Fish suggested that the surgical procedure should be performed before orthodontic treatment for the surgical repositioning of skeletal and dento‑osseous segments for open-bite patients (Epker and Fish, 1977). Subsequent studies demonstrated several advantages of pre-orthodontic orthognathic surgery (POGS), including early improvement in appearance (Brachvogel et al., 1991; Huang et al., 2014; Liao et al., 2010; Liou et al., 2011; Nagasaka et al., 2009; Tsuruda et al., 2003), tooth function (Huang et al., 2014), adaption of musculature (Huang et al., 2014), swallowing and pronunciation (Huang et al., 2014), high patient satisfaction (Huang et al., 2014) and a shorter duration of treatment (Brachvogel et al., 1991; Huang et al., 2014; Liao et al., 2010; Liou et al., 2011; Nagasaka et al., 2009; Tsuruda et al., 2003)

Despite many studies on the post-surgical stability of POGS, evidence pertaining to the stability of post-surgical occlusion remains controversial. Ko et al. reported differences in stability between CS and POGS (Ko et al., 2011; Ko et al., 2013), whereas Joss et al. reported that CS is a stable procedure for correcting skeletal Class III malocclusion (Joss et al., 2009). Likewise, Kim et al. reported that patients who had underwent POGS exhibited a higher rate of horizontal relapse after debonding time than those who had underwent CS (Kim et al., 2014). Hirose et al. and Kobayashi et al. further reported that CS lowered the postoperative skeletal relapse rate (Hirose et al., 1976; Kobayashi et al., 1986). In addition, Villegas et al. found that CS is sometimes essential for stable

occlusion, which in turn is essential for skeletal stability (Villegas et al., 2010). Kim et al. mentioned that unstable occlusion during bone healing influences final skeletal position (Kim et al., 2014), whereas Yoshida et al. reported that limited occlusal contact after POGS results in relapse (Yoshida et al., 2000).

Despite these controversies, there are many studies reporting successful outcomes with POGS (Baek et al., 2010; Ko et al., 2011; Hernández-Alfaro et al., 2011; Ko et al., 2013; Lee et al., 2013; Liao et al., 2010; Liou et al., 2011; Nagasaka et al., 2009; Oh et al., 2012; Sugawara et al., 2010; Villegas et al., 2010; Yu et al., 2010). In addition, there are many studies reporting successful outcomes with POGS (Ann et al., 2016; Choi et al., 2016a; Choi et al., 2016b; Choi et al., 2016c; Huang et al., 2014; Kim et al., 2014; Sharma et al., 2015). Choi et al. reported that there was no significant difference in relapse between the CS group and POGS group 1 year after sagittal split ramus osteotomy (SSRO) (Choi et al., 2016b). Villega et al. also reported that surgery without prior orthodontic treatment was successful in patients with skeletal Class III malocclusion (Villega et al., 2010).

However, many previous studies on POGS have been conducted in patients treated with SSRO, whereas only a few studies have examined the stability of POGS using intraoral vertical ramus osteotomy (IVRO). In addition, the average duration of post-surgical orthodontic treatment following POGS is approximately 1 year. Moreover, few studies have investigated changes in soft tissue after IVRO. Therefore, the present study compared the long-term stability of CS with that of POGS using IVRO. The authors

hypothesized there would be no significant difference in long-term post-surgical stability between CS and POGS using IVRO.

Ⅱ. MATERIALS AND METHODS

1. Study design and patients

The present retrospective study included 31 patients (16 men and 15 women) who had been diagnosed with skeletal Class III malocclusion accompanied by mandibular prognathism and had undergone mandibular setback surgery using IVRO between 2008 through 2015 at the Department of Oral and Maxillofacial Surgery of Yonsei Dental College Hospital (Seoul, Korea). Patients were divided into the CS and POGS groups based on the presence or absence of pre-surgical orthodontic treatment. The POGS group included patients who did not undergo any pre-surgical orthodontic treatment. The mean age at the time of surgery was 21.5 ± 2.5 years (n=14, age range: 18 to 24 years) in the CS group and 20.3 ± 2.2 years (n=17, age range: 18 to 26 years) in the POGS group (Table 1).

Table 1. Characteristics of patients (N=31)

Variable	CS (n=14)	POGS (n=17)	*P* value
Gender, n (%)			
Men	7 (50.0)	9 (52.9)	0.889[a]
Women	7 (50.0)	8 (47.1)	
Age (y)			
Mean ± SD	21.5 ± 2.5	20.3 ± 2.2	0.891[b]
Range	18-24	18-26	
Duration of treatment (m)			
Pre-surgical	9.2 ± 4.8	0 ± 0	< 0.001[b]
Post-surgical	9.3 ± 6.6	14.1 ± 9.7	0.048[b]
Total	18.8 ± 6.7	14.1 ± 9.7	0.012[b]

Abbreviations: CS, Conventional orthognathic Surgery; POGS, Pre-Orthodontic Orthognathic Surgery
SD, standard deviation
[a] By the chi-square test
[b] By the Mann-Whitney *U* test

Inclusion criteria were (a) skeletal Class III dentofacial deformities with an ANB angle (formed by A point, nasion, and B point) < 0˚; (b) history of bimaxillary surgery (1-piece Le Fort I osteotomy and IVRO); (c) no history of tooth extraction, except for the third molars; and (d) a complete series of identifiable lateral cephalograms.

Exclusion criteria were (a) previous orthognathic surgery; (b) current medical, physical, or cognitive disorders likely to influence or interrupt the healing process (e.g., syndromic craniofacial deformities such as cleft lip and palate); (c) major menton deviation greater than 4 mm from the facial midline; (d) previous genioplasty.

The present study was conducted in accordance with the guidelines outlined in the Declaration of Helsinki and was approved by the institutional review board of Yonsei Dental Hospital (approval number 2-2016-0005). Written informed consent was obtained from all patients before the initiation of treatment.

2. Orthodontic and surgical treatment

All orthodontic and surgical treatments were performed by 1 surgeon and 1 orthodontist, respectively. Pre-surgical orthodontic treatments were utilized for an average of 9.2 months (standard deviation [SD], 4.8 months) in the CS group. The objective of pre-surgical orthodontic treatment was to level and align the teeth to ensure decompensation of teeth axes, and to coordinate the upper and lower arches.

In the POGS group, a stainless-steel surgical arch wire measuring 0.017 × 0.025 inches was passively bonded directly onto the teeth after placement of bands on the first molars 1 month before surgery. No pre-surgical orthodontic treatment was performed in the POGS group.

All surgeries were performed by a single surgeon, and the same protocol was used for all patients. All patients underwent conventional bimaxillary surgery consisting of maxillary 1-piece Le Fort I osteotomy and IVRO for mandibular setback. After 1-piece Le Fort I osteotomy, the maxilla was stabilized by rigid internal fixation using 4 L-shaped titanium plates. No bony fixation was performed in the mandible. The osteotomy line was

vertically extended from the mandibular angle to the sigmoid notch. Intermaxillary fixation was maintained for 7 days after surgery, after which patients engaged in active physiotherapy (PT).

Post-surgical management was identical in the CS and POGS groups. Patients performed exercises designed to aid in keeping the correct position of the mandible and functioning it. During the first 6 to 8 weeks of the post-surgical period, patients wore intermaxillary elastics (1/8 inch, 3.5 oz), which were changed every 24 hours. The duration of elastic use and exercises were gradually reduced during the post-surgical period. PT was maintained until jaw opening was within the proper (> 40 mm) range and stable occlusion had been obtained. A final wafer was used for mandibular tooth positioning during PT. The final wafer was removed 3 weeks after surgery but night time use was maintained.

3. Lateral cephalometric analysis

Serial lateral cephalometric radiographs were obtained to evaluate skeletal and soft tissue changes before surgery (T1), 1 day after surgery (S), 1 month after surgery (T2), 1 year after surgery (T3), and 2 years after surgery (T4). All lateral cephalograms were obtained with the teeth together in centric occlusion and the lips in repose. Skeletal changes were observed at T1, S, T2, T3, and T4. Soft tissue changes were observed at T1, T2, and T4.

An *x*-*y* coordinate system was constructed for serial linear measurements. The *x*-axis originated at the nasion and was defined as the line 7° upward from the line connecting the sella and nasion line. The *y*-axis was defined as the line perpendicular to the *x*-axis and passing through the sella. The positions of the landmarks were measured to determine the linear distance from the *x*- and *y*- axes (Fig. 1).

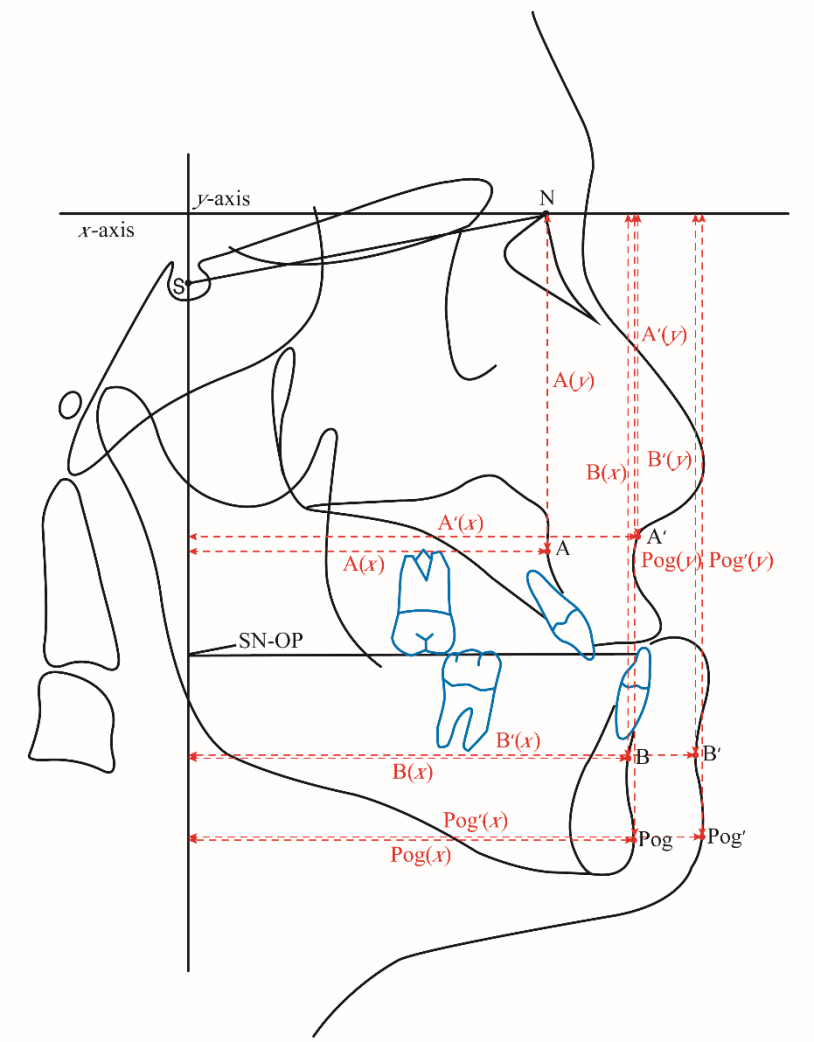

Figure 1. Skeletal and soft tissue landmarks used in the cephalometric analysis. S, sella; N, nasion; A, point A; B, point B; Pog, point Pog; A', point A'; B', point B'; Pog', point Pog'; *x*-axis, defined with the origin at N and forming a 7° angle upward from the SN plane; and *y*-axis, defined as 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; Pog(*x*), horizontal position of point Pog; Pog(*y*), vertical position of point Pog; 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'; Pog'(*x*), horizontal position of point Pog'; Pog'(*y*), vertical position of point Pog'; SN-OP, the angle of the SN plane to the occlusal plane

4. Reliability

An observer blinded to the clinical details of the patients digitized and evaluated the lateral cephalograms using V-ceph 5.5 (Osstem, Seoul, Korea). All cephalograms were traced twice by 1 observer at intervals of 2 weeks. Reproducibility was evaluated by randomly selecting 24 cephalometric films and comparing the values obtained from the original examinations with those obtained from repeated examinations.

5. Statistical analysis

Differences in baseline characteristics between the 2 groups were analyzed with the chi-square test and the Mann-Whitney *U* test. Repeated-measures analyses of variance (Repeated-measures ANOVAs) were used to compare skeletal and soft changes over time between the CS and POGS groups. When significant differences were observed between groups, an independent *t* test with Bonferroni correction was performed, followed by post hoc tests. Likewise, *P* values in each group were calculated by Repeated-measures ANOVA with Bonferroni correction ($\alpha = 0.05/10$) followed by post hoc tests. All statistical analyses were performed using IBM SPSS software version 21.0 for Windows (IBM Korea Inc., Seoul, Korea). The level of statistical significance was set at a *P* value less than 0.05.

Ⅲ. RESULTS

The method error was calculated using the intra-class correlation coefficient (ICC), which was 0.97 to 1.0 for all linear and angular cephalometric variables.

Patients in the CS group underwent pre-surgical orthodontic treatments for an average of 9.2 months (SD, 4.8 months), whereas those in the POGS group did not undergo pre-surgical treatment. The duration of orthodontic treatment after surgery was 9.3 months (SD, 6.6 months) in the CS group and 14.1 months (SD, 9.7 months) in the POGS group. The total duration of treatment was 18.8 months (SD, 6.7 months) in the CS group and 14.1 months (SD, 9.7 months) in the POGS group. Thus, there were significant differences in pre-surgical ($P < 0.001$), post-surgical ($P = 0.048$), and total treatment ($P = 0.012$) durations between the 2 groups (Table 1).

1. Skeletal changes over the first 2 years following surgery

1.1. Changes observed 1 day after surgery (S-T1)

One day after surgery, the angle formed by the sella, nasion, and A point (SNA) had increased by 0.4 ± 2.3° in the CS group and by 0.3 ± 2.3° in the POGS group, whereas the angle formed by the sella, nasion and B point (SNB) had decreased by 4.9 ± 2.1° in the CS group and by 5.7 ± 2.6° in the POGS group. Clockwise rotation of the SN plane to

occlusal plane (SN-OP) was 4.4 ± 3.6° in the CS group and 5.3 ± 3.9° in the POGS group. Point A had shifted 0.8 ± 2.2 mm forward and 0.4 ± 1.8 mm upward in the CS group versus 0.1 ± 2.7 mm forward and 0.9 ± 1.4 mm upward in the POGS group. Point B had shifted 8.4 ± 3.8 mm backward and 4.1 ± 3.0 mm upward in the CS group versus 11.4 ± 5.7 mm backward and 3.1 ± 3.3 mm upward in the POGS group (Table 2, Fig 2). The pogonion (Pog) point had shifted 10.1 ± 4.4 mm backward and 3.9 ± 2.7 mm upward in the CS group versus 13.1± 6.7 mm backward and 2.9 ± 3.2 mm upward in the POGS group. However, no significant changes were observed between 2 groups for any measurements 1 day after surgery.

Table 2. Comparison of surgical changes (S-T1) in skeletal measurements in the 2 groups

S-T1	CS		POGS		Between groups
	Difference	*P* value[a]	Difference	*P* value[a]	
SNA (°)	0.4 ± 2.3	1.000	0.3 ± 2.3	1.000	0.874
SNB (°)	-4.9 ± 2.1	< 0.001	-5.7 ± 2.6	< 0.001	0.318
SN-OP (°)	4.4 ± 3.6	0.005	5.3 ± 3.9	< 0.001	0.503
A(*x*) (mm)	0.8 ± 2.2	0.310	0.1 ± 2.7	1.000	0.245
A(*y*) (mm)	-0.4 ± 1.8	1.000	-0.9 ± 1.4	0.175	0.393
B(*x*) (mm)	-8.4 ± 3.8	< 0.001	-11.4 ± 5.7	< 0.001	0.096
B(*y*) (mm)	-4.1± 3.0	0.002	-3.1 ± 3.3	0.019	0.399
Pog(*x*) (mm)	-10.1 ± 4.4	< 0.001	-13.1± 6.7	< 0.001	0.158
Pog(*y*) (mm)	-3.9 ± 2.7	0.001	-2.9 ± 3.2	0.018	0.326

Group comparisons were tested with an independent *t* test with Bonferroni correction. [a] By repeated measures analysis of variance with Bonferroni correction. Positive and negative values indicate anterior and posterior horizontal changes, inferior and superior vertical changes, and increased and decreased dimensional changes, respectively. Abbreviations: CS group, conventional surgery with pre-surgical orthodontics; POGS group, pre-orthodontics orthognathic surgery group; T1, before surgery; S, 1 day after surgery; SNA, angle of the lines connecting the sella, nasion, and point A; SNB, angle of the lines connecting the sella, nasion, and point B; SN-OP, angle of the sella-nasion plane to the occlusal plane; A(*x*), horizontal position of point A; B(*x*), horizontal position of point B; Pog(*x*), horizontal position of point Pog; A(*y*), vertical position of point A; B(*y*), vertical position of point B; Pog(*y*), vertical position of point Pog.

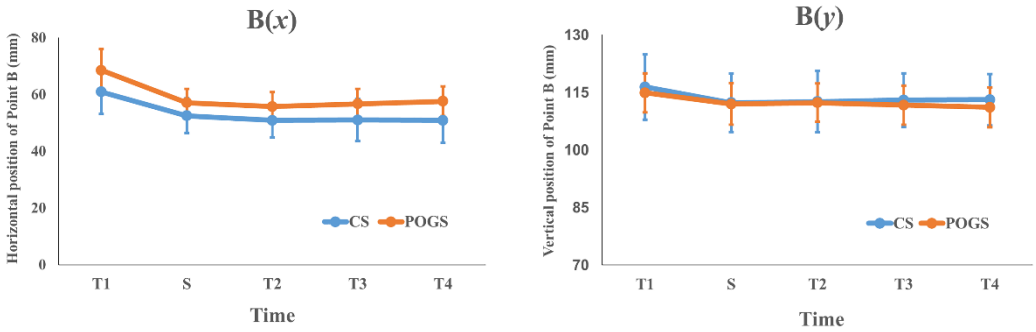

Figure 2. Horizontal distances between point B and the y-axis [B(*x*)] and vertical distances between point B and the *x*-axis [B(*y*)] in the 2 groups at different time points. Point B of the POGS group exhibited more upward movement than that of the CS group from T3 to T4, although there was no significant difference in horizontal or vertical postoperative movement of point B between the two groups. B(*x*), horizontal position of point B; B(*y*), vertical position of point B; CS, conventional surgery with pre-surgical orthodontic treatment; POGS, pre-orthodontic orthognathic surgery; T1, before surgery; S, 1 day after surgery; T2, 1 month after surgery; T3, 1 year after surgery; T4, 2 years after surgery. Error bars indicate standard deviations.

1.2. Changes observed 1 month after surgery (T2-S)

One month after surgery, clockwise rotation of the occlusal plane and decreases in SNB were observed in both groups relative to their positions the day after surgery in the 2 groups compared with their positions the day after surgery. Points A, B and Pog had shifted backward and downward in the 2 groups compared with their positions 1 day after surgery (Table 3). For all measurements, post-surgical changes at 1 month did not significantly differ between 2 groups.

Table 3. Comparison of post-surgical changes (T2-S) in skeletal measurements in the 2 groups

T2-S	CS		POGS		Between groups
	Difference	*P* value[a]	Difference	*P* value[a]	
SNA (°)	0.1 ± 1.5	1.000	-0.6 ± 0.9	0.265	0.111
SNB (°)	-0.3 ± 1.7	1.000	-1.0 ± 1.0	0.026	0.239
SN-OP (°)	1.0 ± 2.3	1.000	1.1 ± 1.6	0.130	0.883
A(*x*) (mm)	-0.8 ± 1.0	0.117	-0.1 ± 0.9	1.000	0.064
A(*y*) (mm)	0.1 ± 0.4	1.000	0.4 ± 1.1	1.000	0.379
B(*x*) (mm)	-1.6 ± 2.4	0.284	-1.4 ± 2.1	0.189	0.850
B(*y*) (mm)	0.3 ± 1.0	1.000	0.5 ± 1.5	1.000	0.629
Pog(*x*) (mm)	-2.1 ± 3.2	0.284	-1.8 ± 2.1	0.103	0.692
Pog(*y*) (mm)	1.9 ± 2.5	0.146	0.9 ± 1.6	0.352	0.199

Group comparisons were tested with an independent *t* test with Bonferroni correction. [a] By repeated measures analysis of variance with Bonferroni correction. Positive and negative values indicate anterior and posterior horizontal changes, inferior and superior vertical changes, and increased and decreased dimensional changes, respectively. Abbreviations: CS group, conventional surgery with pre-surgical orthodontics; POGS group, pre-orthodontics orthognathic surgery group; S, 1 day after surgery; T2,1 month after surgery; SNA, angle of the lines connecting the sella, nasion, and point A; SNB, angle of the lines connecting the sella, nasion, and point B; SN-OP, angle of the sella-nasion plane to the occlusal plane; A(*x*), horizontal position of point A; B(*x*), horizontal position of point B; Pog(*x*), horizontal position of point Pog; A(*y*), vertical position of point A; B(*y*), vertical position of point B; Pog(*y*), vertical position of point Pog.

1.3. Changes observed between 1 months and 1 year after surgery (T3-T2)

From 1 month to 1 year after surgery, the SNB had exhibited little change in the CS group but increased in the POGS group. The SN-OP had increased in the CS group and decreased in the POGS group. Points B and Pog had shifted little in the horizontal direction but had shifted downwards in the CS group and forward and upward in the POGS group. One month to 1 year after surgery, no significant differences in any skeletal measurements were observed between the 2 groups (Table 4).

Table 4. Comparison of post-surgical changes (T3-T2) in skeletal measurements in the 2 groups

T3-T2	CS		POGS		Between groups
	Difference	*P* value[a]	Difference	*P* value[a]	
SNA (°)	-0.1 ± 1.0	1.000	0.1 ± 0.9	1.000	0.598
SNB (°)	0.0 ± 1.2	1.000	0.5 ± 0.9	0.256	0.166
SN-OP (°)	0.7 ± 1.8	1.000	-0.8 ± 1.5	0.506	0.023
A(*x*) (mm)	-0.2 ± 0.8	1.000	0.0 ± 0.6	1.000	0.322
A(*y*) (mm)	0.0 ± 0.5	1.000	0.3 ± 0.8	1.000	0.237
B(*x*) (mm)	0.0 ± 2.0	1.000	1.0 ± 1.4	0.110	0.134
B(*y*) (mm)	0.4 ± 1.7	1.000	-0.6 ± 1.0	0.198	0.059
Pog(*x*) (mm)	0.0 ± 2.4	1.000	1.1 ± 1.9	0.271	0.150
Pog(*y*) (mm)	0.2 ± 0.8	1.000	-0.3 ± 0.9	1.000	0.104

Group comparisons were tested with an independent *t* test with Bonferroni correction. [a] By repeated measures analysis of variance with Bonferroni correction. Positive and negative values indicate anterior and posterior horizontal changes, inferior and superior vertical changes, and increased and decreased dimensional changes, respectively. Abbreviations: CS group, conventional surgery with pre-surgical orthodontics; POGS group, pre-orthodontics orthognathic surgery group; T2,1 month after surgery; T3, 1 year after surgery; SNA, angle of the lines connecting the sella, nasion, and point A; SNB, angle of the lines connecting the sella, nasion, and point B; SN-OP, angle of the sella-nasion plane to the occlusal plane; A(*x*), horizontal position of point A; B(*x*), horizontal position of point B; Pog(*x*), horizontal position of point Pog; A(*y*), vertical position of point A; B(*y*), vertical position of point B; Pog(*y*), vertical position of point Pog.

1.4. Changes observed between 1 and 2 years after surgery (T4-T3)

From 1 to 2 years after surgery, the SNB had changed little in the CS group and continued to increase in the POGS group. The SN-OP had continued to increase significantly in the CS group and decrease in the POGS group ($P < 0.001$) (Table 5 and Fig 3). Point A had shifted backward and downward in the 2 groups. Points B and Pog had shifted backward and downward in the CS group versus forward and upward in the POGS group. With the exception of the SN-OP ($P < 0.001$), no significant differences in any measurements were observed between the 2 groups between the first and second years after surgery.

Table 5. Comparison of post-surgical changes (T4-T3) in skeletal measurements in the 2 groups

T4-T3	CS		POGS		Between groups
	Difference	*P* value[a]	Difference	*P* value[a]	
SNA (°)	-0.6 ± 0.7	1.000	0.0 ± 0.7	1.000	0.022
SNB (°)	0.0± 0.7	1.000	0.4 ± 0.7	1.000	0.111
SN-OP (°)	0.2 ± 0.7	0.093	-1.0 ± 1.2	0.273	< 0.001
A(*x*) (mm)	-0.5 ± 0.4	0.052	-0.2 ± 0.6	1.000	0.093
A(*y*) (mm)	0.1 ± 0.4	1.000	0.1 ± 0.6	0.199	0.877
B(*x*) (mm)	-0.1 ± 1.0	0.752	0.9 ± 1.5	1.000	0.039
B(*y*) (mm)	0.1 ± 1.2	1.000	-0.5 ± 0.9	0.225	0.156
Pog(*x*) (mm)	-0.1 ± 0.9	0.392	0.9 ± 1.3	1.000	0.019
Pog(*y*) (mm)	0.2 ± 0.8	1.000	-0.6 ± 0.8	1.000	0.013

Group comparisons were tested with an independent *t* test with Bonferroni correction. [a] By repeated measures analysis of variance with Bonferroni correction. Positive and negative values indicate anterior and posterior horizontal changes, inferior and superior vertical changes, and increased and decreased dimensional changes, respectively. Abbreviations: CS group, conventional surgery with pre-surgical orthodontics; POGS group, pre-orthodontics orthognathic surgery group; T3, 1 year after surgery; T4, 2 years after surgery; SNA, angle of the lines connecting the sella, nasion, and point A; SNB, angle of the lines connecting the sella, nasion, and point B; SN-OP, angle of the sella-nasion plane to the occlusal plane; A(*x*), horizontal position of point A; B(*x*), horizontal position of point B; Pog(*x*), horizontal position of point Pog; A(*y*), vertical position of point A; B(*y*), vertical position of point B; Pog(*y*), vertical position of point Pog.

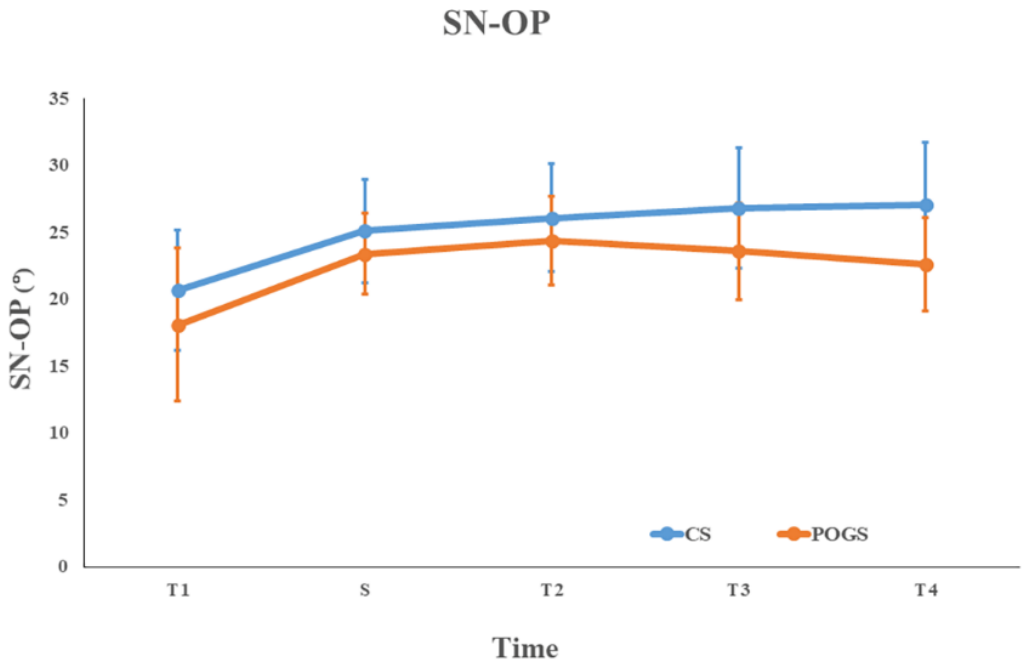

Figure 3. The SN-OP in the 2 groups at different time points. The SN-OP of the POGS group exhibited more upward movement than that of the CS group ($P < 0.001$) for T3 to T4. CS, conventional surgery with pre-surgical orthodontic treatment; POGS, pre-orthodontic orthognathic surgery; SN-OP, angle of the sella-nasion plane to the occlusal plane; T1, before surgery; S, 1 day after surgery; T2, 1 month after surgery; T3, 1 year after surgery; T4, 2 years after surgery. *Error bars* indicate standard deviations.

2. Skeletal changes over the first 2 years following surgery

2.1. Changes observed 1 month after surgery (T2-T1)

One month after surgery, Point A' had shifted forward and upward in the 2 groups compared with their positions before surgery, although these differences were not significant. However, point B' had shifted significantly backward and upward in the 2 groups compared with their positions before surgery. Although point Pog' had shifted significantly backward in the 2 groups ($P < 0.001$), upward movement of point Pog' was not significant in either group. No significant differences were observed between the 2 groups at this time (Table 6).

Table 6. Comparison of surgical changes (T2-T1) in soft tissue measurements in the 2 groups

T2-T1	CS		POGS		Between groups
	Difference	*P* value[a]	Difference	*P* value[a]	
A'(*x*) (mm)	0.3 ± 1.2	1.000	0.0 ± 1.3	1.000	0.451
A'(*y*) (mm)	-0.1 ± 0.9	1.000	-0.2 ± 0.5	0.347	0.597
B'(*x*) (mm)	-10.3 ± 3.3	< 0.001	-12.7 ± 5.3	< 0.001	0.135
B'(*y*) (mm)	-3.7 ± 3.0	0.003	-2.3 ± 2.7	0.016	0.200
Pog'(*x*) (mm)	-11.1 ± 4.2	< 0.001	-13.7 ± 5.8	< 0.001	0.165
Pog'(*y*) (mm)	-1.6 ± 2.3	0.138	-1.8 ± 2.7	0.086	0.830

Group comparisons were tested with an independent *t* test with Bonferroni correction. [a] By repeated measures analysis of variance with Bonferroni correction. Positive and negative values indicate anterior and posterior horizontal changes, inferior and superior vertical changes, and increased and decreased dimensional changes, respectively. Abbreviations: CS group, conventional surgery with pre-surgical orthodontics; POGS group, pre-orthodontics orthognathic surgery group; T1, before surgery; T2,1 month after surgery; A'(*x*), horizontal position of point A'; B'(*x*), horizontal position of point B'; Pog'(*x*), horizontal position of point Pog'; A'(*y*), vertical position of point A'; B'(*y*), vertical position of point B'; Pog'(*y*), vertical position of point Pog.

2.2. Changes observed 2 years after surgery (T4-T2)

At 2 years after surgery, point A' had shifted backward and downward in the 2 groups. Points B' and Pog' had shifted backward and downwards in the CS group and forward and upward in the POGS group. No significant differences were observed for any soft tissue measurements between the 2 groups at this time (Table 7).

Table 7. Comparison of post-surgical changes (T4-T2) in soft tissue measurements in the 2 groups

T4-T2	CS		POGS		Between groups
	Difference	*P* value[a]	Differenc	*P* value[a]	
A'(*x*) (mm)	-0.4 ± 0.5	0.081	-0.1 ± 0.4	1.000	0.070
A'(*y*) (mm)	0.1 ± 0.4	1.000	0.3 ± 0.6	0.600	0.347
B'(*x*) (mm)	-0.2 ± 2.4	1.000	1.9 ± 2.2	0.017	0.019
B'(*y*) (mm)	0.2 ± 1.7	1.000	-1.1 ± 1.5	0.058	0.032
Pog'(*x*) (mm)	0.0 ± 3.3	1.000	1.9 ± 2.8	0.073	0.102
Pog'(*y*) (mm)	0.3 ± 1.3	1.000	-0.7 ± 0.9	0.036	0.021

Group comparisons were tested with an independent *t* test with Bonferroni correction. [a] By repeated measures analysis of variance with Bonferroni correction. Positive and negative values indicate anterior and posterior horizontal changes, inferior and superior vertical changes, and increased and decreased dimensional changes, respectively. Abbreviations: CS group, conventional surgery with pre-surgical orthodontics; POGS group, pre-orthodontics orthognathic surgery group; T2,1 month after surgery; T4, 2 years after surgery; A'(*x*), horizontal position of point A'; B'(*x*), horizontal position of point B'; Pog'(*x*), horizontal position of point Pog'; A'(*y*), vertical position of point A'; B'(*y*), vertical position of point B'; Pog'(*y*), vertical position of point Pog.

IV. DISCUSSION

The aim of the present study was to compare the long-term stability of POGS and CS using IVRO. The authors hypothesized there would be no significant difference in long-term post-surgical stability between CS and POGS. During the 2-year post-surgical period, point B had shifted 1.7 ± 3.3 mm backward and 0.7 ± 2.0 mm downward in the CS group. In contrast, point B had shifted 0.5 ± 2.3 mm forward and 0.6 ± 1.5 mm upward in the POGS group. These findings are in accord with those of several previous studies, which reported that the mandible had shifted backward at debonding time or 1 year after IVRO without rigid fixation in patients who had undergone CS, although no significant difference was observed during the postsurgical period (Ayoub et al., 2000; Choi et al., 2016c; Jung et al., 2013; Toru et al., 2009). This is believed to be due to the lack of rigid fixation in IVRO. Furthermore, several other studies reported upward shift of the mandible in patients who had undergone POGS at 1 year after IVRO (Ann et al., 2016; Choi et al., 2016c; Kim et al., 2014). These findings indicate that occlusal instability originating from the lack of pre-surgical orthodontic treatment could have been alleviated by post-surgical orthodontic treatment in the POGS group.

Point B had shifted backward and downward within 1 month after surgery in the POGS group, but forward and upwards 1 month later. This is because point B shifts in the direction of IVRO immediately after surgery, although changes are observed when orthodontic treatment is initiated at 1 month after surgery.

However, there was no significant difference in the extent of post-surgical changes in point B between the 2 groups at the 2-year follow-up. These findings are in accord with those of several previous studies. Ann et al. reported no significant differences in point B between the CS and POGS groups at 1 year after IVRO (Ann et al., 2016). However, neither of these previous studies examined point B more than 1 year after IVRO. Further studies are required to determine whether differences can be observed over a longer follow-up period. Because the average duration of post-surgical orthodontic treatment for patients who have undergone POGS is 1 year (Baek et al., 2010; Liao et al., 2010; Nagasaka et al., 2009; Wang et al., 2010), future studies should examine surgical stability after debonding.

In addition, none of the measurements obtained in the present study were significant at all time points, and only the SN-OP exhibited significant differences between groups at 2 years after surgery ($P < 0.001$). The SN-OP had increased by $2.0^\circ \pm 2.4^\circ$ in the CS group and decreased by $0.8^\circ \pm 1.5^\circ$ in the POGS group during the first 2 years after surgery. Previous studies have reported similar results. Choi et al. and Nihara et al. reported that patients of the CS group exhibited slight increases in the angle of occlusal plane (approximately 0.5°) at 1 or 2 years after IVRO (Choi et al., 2015; Nihara et al., 2013). Such increases in SN-OP might be associated with backward and downward movement of the mandible at 2 years after surgery. The present findings further suggest that post-surgical orthodontic treatment enhanced occlusion, after which gradually adaptation of the masticatory muscles occurred.

In the present study, soft tissue changes were evaluated based on lateral cephalograms obtained 1 month after surgery, rather than the day after surgery, because of the potential effects of soft tissue swelling. In contrast to many previous studies, changes in soft tissue also were examined, because these changes might be more important to patients than those involving skeletal tissue. The authors observed similar patterns of change between skeletal and soft tissue during the 2-year post-surgical period. However, soft tissue changes were less extensive than skeletal tissue changes. In the present study, point A' had shifted approximately half the distance of point A in the horizontal and vertical directions, whereas point B' had shifted horizontally by almost the same amount and vertically by 0.78 to 0.98 of point B. Point Pog' had shifted 0.9 to 1.09 and 0.81 to 0.88 the distance shifted by point Pog in the horizontal and vertical directions, respectively. Similar post-surgical results have been reported for patients with mandibular prognathism. Several studies reported horizontal movement ratios of 0.9 to 1.03 for point B' and Pog', in relation to the corresponding skeletal measurement point (Bjork et al., 1971; Chen et al., 2012; Hershey et al., 1974; Kajikawa et al., 1979; Kitahara et al., 2009; Lines et al., 1974; Rustemeyer et al., 2013; Wilmot et al., 1981; Wisth et al., 1975). Consistent with the present findings, previous studies reported that point A' had shifted horizontally by 0.39 to 0.64 of point A (Chew et al., 2005; Lin et al., 1998; Rustemeyer et al., 2013). However, such studies reported vertical shifts of 0.09 to 0.20 for point A' in contrast to the present findings (Lin et al., 1998; Rustemeyer et al., 2013). This discrepancy can be explained by differences in the movement of soft tissue based on region, direction of movement, and

unique characteristics of the tissue itself. Previous studies also have observed inconsistent movement between soft and hard tissues. Chew et al. reported that the movement patterns of the soft and hard tissues of the maxilla exhibit a weaker correlation than those of the mandible in the horizontal and vertical directions (Chew et al., 2005). Likewise, the vertical position of the soft tissue was less consistent with that of the skeletal pattern than the horizontal position (Chew et al., 2005; Hans et al., 1991). Furthermore, previous studies have reported that reproducing the vertical position of soft tissue remains difficult (Wisth et al., 1975). Moreover, other researchers have stated that it can be difficult to predict soft tissue movement after orthognathic surgery owing to differences in soft tissue type, elasticity, thickness, race, facial type, and patient gender (Chew et al., 2005; Fanibunda et al., 1989; Hu et al., 1999; Jakobsone et al., 2013).

In the POGS group, 1 patient underwent traction because of an impacted tooth and 1 patient in whom debonding was postponed until receipt of the implant prosthesis. Thus, the mean total duration of treatment and the standard deviation were greater in the present study. However, the duration of total treatment was significantly shorter in the POGS group than in the CS group (P = 0.012). These results suggest that although POGS has more limitation than CS, POGS can be used to shorten the duration of treatment in appropriately selected cases.

The present study have several limitations of note. First, it is difficult to generalize the results of this study because of the small sample size, because patients who previously underwent genioplasty were excluded. In addition, the retrospective and non-randomized

design of the present study could have introduced some level of bias. Furthermore, because IVRO does not use rigid fixation, greater changes can occur immediately after IVRO than after SSRO. Moreover, patients with tooth extraction except for third molars or facial asymmetry (menton deviation > 4 mm) were exclude from this study. In these patients, the amount of anteroposterior or transverse dental decompensation through orthodontic treatment is relatively larger, which makes it difficult to predict skeletal tissue and soft tissue changes, especially after POGS. Thus, further prospective and randomized studies using larger samples should evaluate the long-term stability of IVRO.

V. CONCLUSION

In the present study, the authors observed no significant difference in skeletal or soft tissue measurements between the CS and POGS groups at 2 years after IVRO, with the exception of the SN-OP. Therefore, the present findings suggest that CS and POGS have similar long-term stability in patients with skeletal Class III malocclusion.

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Abstract(in Korean)

술전 교정 유무에 따른 구내 하악골 상행지 수직 골절단술 후 골격 및 연조직의 장기간의 안정성

정 정 화

연세대학교 대학원 치의학과

(지도교수 : 유 형 석)

본 연구는 구내 하악골 상행지 수직 골절단술 시 술전 교정치료를 동반한 악교정 수술과 비교하여 선수술 교정의 골격 및 연조직의 장기적인 안정성을 비교하고자 하였다.

골격성 III 급 부정교합자로 진단 받고 상악 Le Fort I 골절단술과 구내 하악골 상행지 수직 골절단술을 받은 31 명의 환자들을 대상으로 하였다. 환자들은 선수술 교정을 받은 17 명의 환자와 술전 교정치료를 동반한 악교정 수술을 받은 14 명의 환자로 나뉘었다. 골격 및 연조직의 변화를 평가하기 위해 수술 전, 수술 1 일 후, 수술 1 달 후, 수술 1 년 후, 수술 2 년 후에 측모 두부 방사선 사진을 촬영하였다. 수집된 데이터는 chi-square 테스트, Mann- Whitney U 테스트, repeated-

measures analyses of variance, independent t 테스트 그리고 Fisher ' s exact 테스트로 분석하였다.

SN-OP (sella-nasion 평면과 교합 평면이 이루는 각) ($P < 0.001$)를 제외한 모든 골격 및 연조직 계측 항목은 술후 2 년에 술전 교정치료를 동반한 악교정수술그룹과 선수술 교정그룹 사이에 유의한 차이는 없었다.

따라서 본 연구 결과를 토대로, 선수술 교정은 술전 교정치료를 동반한 악교정수술과 비교해 볼 때, 골격성 III 급 부정교합자에게 장기적으로도 임상적으로 안정된 수술 결과를 보여 준다고 할 수 있다.

핵심되는 말 : 장기간 안정성; 골격성 III 급 부정교합; 구내 하악골 상행지 수직골절단술; 선수술 교정