Stability of bimaxillary surgery involving intraoral vertical ramus osteotomy with or without presurgical miniscrew-assisted rapid palatal expansion in adult patients with skeletal Class III malocclusion

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감사의 글

수련기간동안 부족한 제자를 잘 가르쳐주시고 박사 학위 논문 완성까지도 따뜻한 배려와 함께 세심한 지도와 격려를 아끼지 않으신 유형석 지도교수님께 진심으로 감사드립니다. 전공의 때부터 바쁘신 와중에도 본 연구의 기틀을 잡아주시고 방향을 설정해주시며 이끌어주신 최성환 교수님께 매우 감사드립니다. 새로운 접근 방식을 제안해주시고 끊임없는 고찰을 통해 좋은 논문이 완성될 수 있도록 아낌없는 조언을 주신 이기준 교수님, 차정열 교수님, 정영수 교수님께 깊이 감사드립니다. 많이 부족한 저를 연세대학교 치과교정학교실에서 교정과학을 공부할 수 있도록 기회를 주시고 교정과 전문의로서 올바른 의술을 펼칠 수 있도록 이끌어 주신 황충주 교수님, 김경호 교수님, 정주령 교수님, 최윤정 교수님, 박선형 교수님께도 감사드립니다.

전공의 생활뿐만 아니라 수련이 끝난 뒤에도 서로 힘이 되어주는 교정과 의국 동기들, 많은 것을 알려주시고 이끌어주시는 의국 선배님들, 부족한 선배였지만 잘 따라준 의국 후배님들 모두에게 감사의 마음을 전합니다.

늘 저를 믿고 지지해주시는 부모님과 형, 새로이 가족이 된 나탈리 형수님, 친아들처럼 편하게 대해주시는 장인어른과 장모님, 항상 긍정적인 에너지로 저에게 큰 힘이 되어주는 사랑하는 아내와 3주 동안의 신생아 중환자실 생활을 잘 이겨내고 건강하게 우리 가족의 품으로 돌아와준 여울이에게도 고마움을 전합니다.

2022년 12월 저자 씀.

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ABSTRACT

Stability of bimaxillary surgery involving intraoral vertical ramus osteotomy with or without presurgical miniscrew-assisted rapid palatal expansion in adult patients with skeletal Class III malocclusion

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(Directed by Professor Hyung Seog Yu, D.D.S., M.S., Ph.D.)

The purpose of this study was to measure the association between nonsurgical maxillary expansion by miniscrew-assisted rapid palatal expansion (MARPE) and relapse after bimaxillary surgery using intraoral vertical ramus osteotomy (IVRO).

The retrospective cohort study sample (skeletal Class III subjects) was divided into 2 groups (MARPE and control) according to nonsurgical maxillary expansion at the presurgical orthodontic treatment. The 2 groups were matched for sample size (n = 20 each). Lateral cephalograms and dental casts were analyzed for the predictor (nonsurgical maxillary expansion) and outcome (cephalometric changes over time) variables before, at 2 days, and at least 6 months (mean: 9.4 months) after surgery.

The control group and the MARPE group were not significantly different in terms of sex and age at the initial examination, but different in terms of transverse arch width difference. 2 days after surgery, mandible was moved backward and upward without any statistical intergroup difference. Thereafter, at least 6 months after surgery, there were no statistically significant differences in relapse pattern of the maxilla and mandible between the 2 groups. In addition, there were no meaningful correlations between the amount of expansion and the skeletal relapse after IVRO.

These findings suggest that nonsurgical maxillary expansion (MARPE appliance) followed by bimaxillary surgery (Le Fort I osteotomy and bilateral IVRO) for skeletal Class III patients with moderate transverse discrepancy shows good postoperative stability.

Keywords : nonsurgical maxillary expansion, bimaxillary surgery, postoperative stability, miniscrew-assisted rapid palatal expansion (MARPE), intraoral vertical ramus osteotomy (IVRO), skeletal Class III malocclusion.

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I. INTRODUCTION

Sagittal discrepancy of skeletal Class III malocclusion in adults can be corrected with orthognathic surgery; Le Fort I osteotomy, sagittal split ramus osteotomy (SSRO), and intraoral vertical ramus osteotomy (IVRO) are common surgical methods. Many studies have been reported stability of these methods in skeletal Class III patients with mandiblular prognathism.

Some of skeletal Class III patients show not only sagittal discrepancy but also transverse discrepancy, which is more frequently found in skeletal Class III patients and makes treatment more challenging (Ahn et al., 2017). For this type of patients, practitioners can make a decision to extract upper premolars in presurgical orthodontic treatment (Lee et al., 2006). However, premolar extraction loses its validity if the patients' maxilla has mild or no crowding. Furthermore, this modality lengthens presurgical orthodontic treatment period which deteriorates patients' quality of life, and may even increase the relapse after orthognathic surgery by increasing amount of mandible setback (Choi et al., 2016b). In other ways, expansion of maxilla using segmental osteotomy can be additionally applied, which has been shown to be quite unstable (Phillips et al., 1992; Proffit et al., 2007). Therefore, for more stable and predictable results, surgically assisted rapid palatal expansion (SARPE) followed by bimaxillary surgery has been advocated (Bays and Greco, 1992). However, patients and practitioners are reluctant to bear the burden, such as, hospitalization, attendant morbidity, more cost, and surgical complications (Dergin et al., 2015; Haas Junior et al., 2017). So, careful cost-effectiveness analysis should be made by practitioners before these procedures.

Nonsurgical maxillary expansion in adults has been regarded to unfeasible due to possible side effects, such as, lateral tipping of anchor teeth, root resorption, fenestration of buccal plate (Gunyuz Toklu et al., 2015). Recently, Choi et al. (Choi et al., 2016c) advocated successful clinical outcome and stability of nonsurgical maxillary expansion in young adults using tooth-bone-borne rapid maxillary expander which is assisted by 4 palatal miniscrews (miniscrew-assisted rapid palatal expansion [MARPE]). At finite element analysis study, MARPE appliance showed relatively even stress distribution and lower stress on buccal alveolar plate and anchor teeth, compared to conventional tooth-borne RPE & bone-borne RPE (Seong et al., 2018). These reports could justify applying MARPE appliance in young adults with transverse discrepancy. Lee et al. (Lee et al., 2010) previously introduced this appliance and reported efficient application to a young adult skeletal Class III patient with severe maxillary constriction, who underwent subsequent orthognathic surgery.

Meanwhile, anterior and inferior movement of maxilla and subsequent clockwise rotation of mandible are reported by above-mentioned surgical and nonsurgical maxillary expansions (Chung and Font, 2004; Chung et al., 2001; Habeeb et al., 2013; Hong, 2019). If maxillary transverse expansion can make such vertical and sagittal changes of maxillo-mandibular complex, its relapse can have considerable effects on the relapse after orthognathic surgery. To the best of our knowledge, few studies have evaluated the effect of nonsurgical rapid maxillary expansion to postoperative stability after bimaxillary surgery with IVRO which lacks rigid fixation system.

The purpose of this retrospective cohort study was to compare the postoperative stability after bimaxillary surgery using IVRO for mandibular prognathism patients with or without nonsurgical maxillary expansion using MARPE appliance. The author hypothesized that the stability of the outcomes after IVRO would differ depending on whether the patients' maxillae are nonsurgically expanded during presurgical orthodontic treatment. The specific aim of the study was to validate the postoperative stability at least 6 months after IVRO for skeletal Class III maloclussion patients with presurgical MARPE expansion.

II. MATERIALS AND METHODS

1. Study design and subjects

The study sample was composed of patients who presented for the evaluation and management of skeletal Class III malocclusion and underwent mandible setback surgery using IVRO technique from 2013 through 2017 at the Department of Oral and Maxillofacial Surgery, Yonsei University Dental Hospital, Seoul, Korea.

The inclusion criteria were as follows: (1) age ≥ 18 years; (2) no loss of teeth except third molars; (3) diagnosed to skeletal Class III malocclusion with the negative value of angle formed by point A, the nasion, and point B (ANB); (4) requirement for conventional orthognathic bimaxillary surgery with presurgical orthodontic treatment (1-piece Le Fort I osteotomy and bilateral IVRO); (5) no syndromic dentofacial deformities, such as a cleft lip and palate. To be eligible, the patient also had to have normal general health state.

The exclusion criteria were as follows: (1) presence of medical conditions for which the patient had been hospitalized in the past 3 months; (2) previous history of orthognathic surgery; (3) requirement of single-jaw surgery or preorthodontic orthognathic surgery (presurgical orthodontic treatment period less than 6 months); (4) menton deviation > 4 mm from the skeletal facial midline in posteroanterior cephalogram; (5) the loss of or an incomplete series of identifiable lateral cephalometric radiographs or dental casts.

The subjects in the MARPE group were collected by searching electronic medical record (EMR) of Yonsei Dental Hospital. First of all, among patients undergone orthognathic surgery, 128 patients had keyword “MARPE” on their orthodontic chart. 19 patients were excluded because MARPE was just considered in treatment planning and was not applied actually. Among 109 patients, preorthodontic orthognathic surgery (POGS) was done in 32 patients; facial asymmetry (menton deviation > 4 mm) was observed in 27 patients; 16 patients were Class I or II malocclusion; 11 patients had missing teeth or got premolar extraction; digital cephalogram or dental cast was missing in 3 patients. Eventually, 20 patients were included in the MARPE group. Those of the control group were collected by the same way except keyword “MARPE”.

40 patients (19 men and 21 women) who fulfilled the inclusion criteria were enrolled in this study: 20 in the control group (mean age, 21.1 ± 2.6 years) and 20 in the MARPE group (mean age, 21.2 ± 2.9 years) (Table 1). This study followed the guidelines of the Declaration of Helsinki and was approved by the institutional review board (IRB) of Yonsei University Dental Hospital (2-2019-0051).

2. Surgical and orthodontic treatment

All patients underwent conventional bimaxillary surgery, including maxillary Le Fort I osteotomy with posterior nasal spine impaction and bilateral IVRO for mandibular setback. The same protocol was applied for all surgeries, which were performed by a surgeon (Y.-S.J.). All patients also underwent pre- and postoperative orthodontic treatment at the Department of Orthodontics, Yonsei Dental Hospital, Seoul, Korea.

4 L-shaped miniplates with monocortical bone screws (2.0 mm diameter) made of self-reinforced biodegradable poly-70L/30DL-lactide (BioSorb FX; CONMED LINVATEC Biomaterials, Utica, NY, USA) were used for internal rigid fixation after complete 1-piece Le Fort I osteotomy, including pterygomaxillary disjunction of maxilla. These miniplates were placed on bilateral canine fossa and zygomatic buttress (Choi et al., 2016a). Mandibular setback surgery was done with conventional bilateral IVRO technique, which lacks rigid fixation system. Postoperative radiographs were taken at 2 days after surgery. Suture materials were removed at 7 days after surgery.

For stabilization of mandible, intermaxillary fixation (IMF) was performed just after surgery for 12-14 days using final wafers as occlusal guidance. After IMF, all patients were given instructions regarding active physical therapy (PT) protocol for rehabilitation. The PT protocol was composed of 4 cycles, each cycle containing 1 hour of mandibular movements (mouth opening, protrusion, and lateral excursion) and subsequent 2 hours of IMF. Bilateral intermaxillary elastics were applied during PT, IMF, and sleep in this period to prevent anterior open bite. If patients show stable occlusion without open bite, they reduce elastic wearing time except PT. Additionally, if maximal mouth opening of at least 30 mm was achieved, the final wafer was removed and postsurgical orthodontic treatment began (Jung et al., 2012).

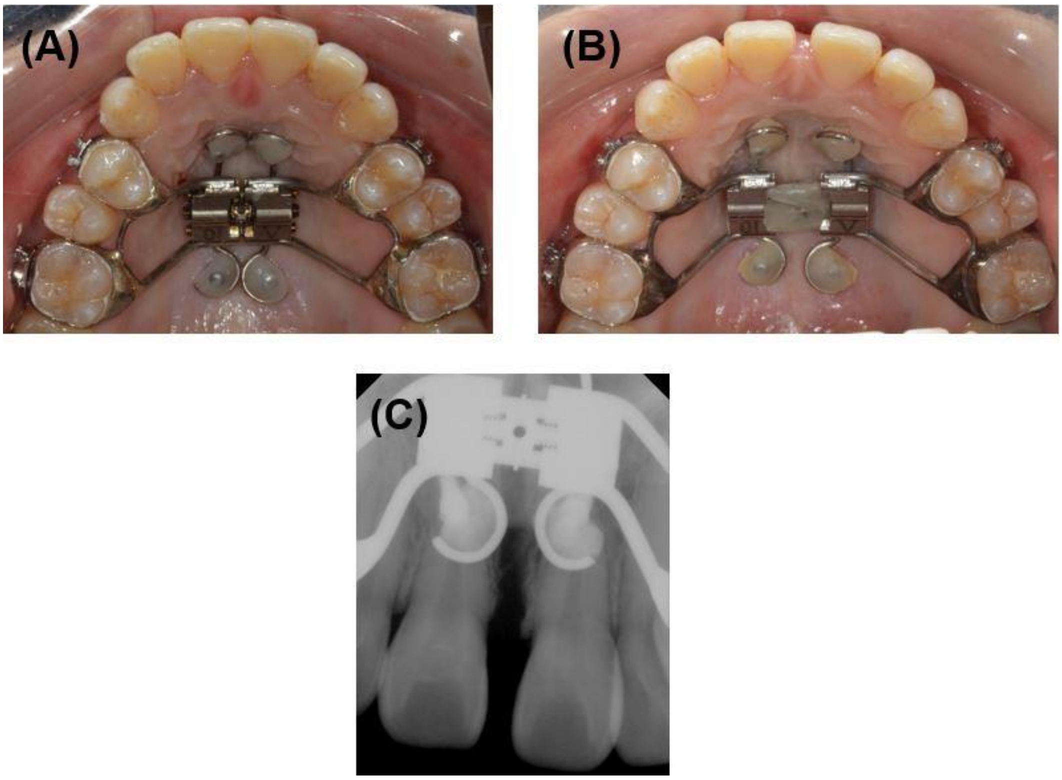

Figure 1. Nonsurgical maxillary expansion using MARPE appliance is shown. (A) after setting appliance, before expansion; (B) just after nonsurgical expansion; (C) periapical radiograph of upper incisors after expansion.

For patients included in the MARPE group, before bonding orthodonctic braces, nonsurgical rapid maxillary expansion was done using MARPE appliances. The expander design was a combined hyrax RPE (Hyrax® Click; Dentaurum, Ispringen, Germany) with four extension arms made of rigid stainless steel soldered under the body of the jackscrew for the accommodation of the miniscrews (Lee et al., 2018). Two anterior extension arms were positioned in the rugae area, and two posterior arms were positioned in para-midsagittal area. 4 orthodontic miniscrews (Orlus; Ortholution, Seoul, Korea), with a collar diameter of 1.8 mm and length of 7.0 mm, were placed in the extension arms (Fig 1). The appliance was activated at a rate of a turn per day (0.2 mm per turn) until the required expansion was achieved. The mean amount of expansion was 30.6 turns (standard deviation: 7.2; range: 17–40 turns; about 6.1 mm). After 3 months of consolidation period, MARPE appliances were removed and orthodontic braces were bonded. Presurgical orthodontic treatment including leveling and aligning teeth, relieving crowding, providing decompensation of teeth axes, and coordinating upper and lower arches, was performed at least 6 months. The patients in the control group underwent the same presurgical orthodontic procedure except MARPE expansion.

3. Lateral cephalometric analysis

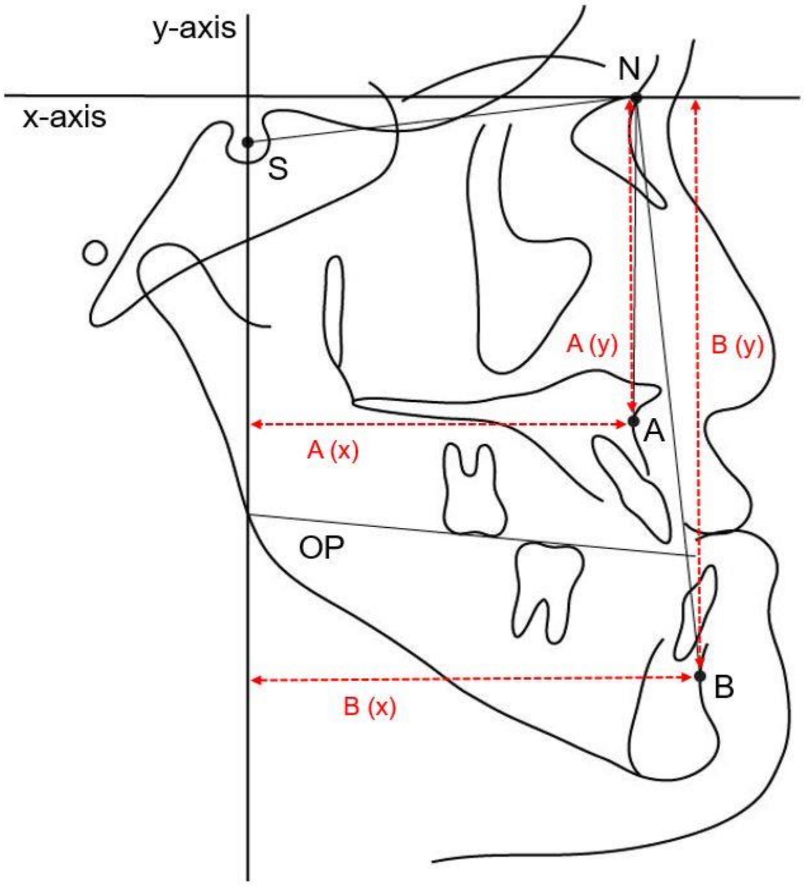

Figure 2. Skeletal landmarks used in the cephalometric analysis are shown.
S, sella; N, nasion; A, point A; B, point B; OP, occlusal plan; SN-OP, angle of the sella-nasion plane to the occlusal plane; x-axis, defined with the origin at N and forming a 7º angle upward from the SN plane; and y-axis, defined 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.

Skeletal changes and relapses were evaluated using lateral cephalograms obtained before presurgical orthodontic treatment (T0), 1 month before (T1), 2 days after (T2), and at least 6 months after surgery (T3). The mean postoperative period (T3-T2) was 9.3 months (standard deviation: 3.0;

range: 6–12 months) in the control group, and 9.4 months (standard deviation: 2.8; range: 6–12 months) in the MARPE group, respectively. The surgical change was defined as the values obtained at T2 minus those obtained at T1, and the relapse 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 T0 to T3 cephalograms based on superimposition of the sella (S)–nasion (N) plane (Fig 2).

4. Dental cast analysis

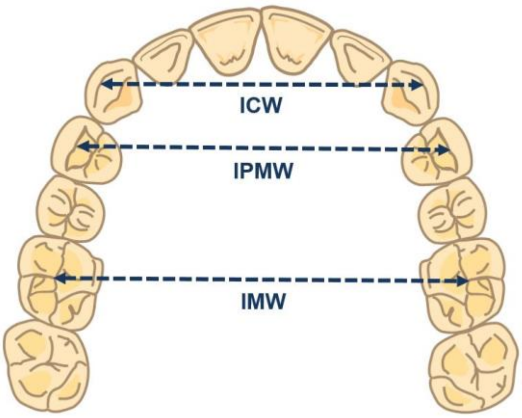

Figure 3. Measurements used in dental cast analysis are shown.
ICW, intercanine width; IPMW, interpremolar width; IMW, intermolar width.

Measurements of dental casts to evaluate changes in tooth positions were performed at T0 & T3 using a digital caliper. The intercanine widths (ICW) were measured at the cusp tip. The inter-premolar widths (IPMW) were measured at the buccal cusp tips of first premolars, and the intermolar widths (IMW) were measured at the central fossa of first molars. The maxillo-mandibular arch width difference was defined as the values obtained at maxilla minus those obtained at mandible (Fig 3).

5. Variables

Primary predictor

Nonsurgical maxillary expansion using MARPE appliance was the primary predictor variable in this study. This study sample was divided into 2 groups according to whether they got nonsurgical maxillary expansion using MARPE appliance during presurgical orthodontic treatment: the control group and the MARPE group.

Primary outcomes

3 angular and 4 linear cephalometric measurements were identified to determine skeletal relapse (Fig 2). The 3 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. The 4 linear measurements included the horizontal distances from points A and B to the y-axis and the vertical distances from points A and B to the x-axis.

6. Reliability

Two weeks after the initial cephalometric and dental cast measurements, all measurements were repeated by the same observer. The method error, calculated using Dahlberg's formula, ranged from 0.20 to 0.30 mm for linear measurements and from 0.15° to 0.30° for angular measurements.

7. Statistical analysis

All statistical analysis were performed using IBM SPSS software, version 22.0 (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 (T0, T1, T2, and T3) within each group.

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

Repeated measures analysis of variance (RMANOVA) was used to compare intraoperative and postoperative changes of angular and linear measurements in each group and between the 2 groups over time (T1, T2, and T3). If there was any significant intergroup difference, an independent *t* test with Bonferroni correction ($\alpha = 0.05/3$) followed by post-hoc tests was applied.

III. RESULTS

This study was composed of 40 patients (19 men and 21 women). The control group included 20 patients (10 men and 10 women) with a mean age of 21.1 years (SD, 2.6 years), and the MARPE group also included 20 patients (9 men and 11 women) with a mean age of 21.2 years (SD, 2.9 years). There were no significant differences in demographic characteristics between the 2 groups at the initial examination. The mean IMW difference was 6.2 mm (SD, 2.3 mm) in control group and 3.1 mm (SD, 2.1 mm) in MARPE group, which was statistically different between the 2 groups (*P* < .001). But ICW & IPMW differences were not statistically different between the 2 groups at initial examination (Table 1).

Table 1. Sample characteristics (N = 40)

Variable	Control (n = 20)	MARPE (n = 20)	*P* value
Sex, n (%)			1.000[a]
Men	10 (50.0)	9 (45.0)	
Women	10 (50.0)	11 (45.0)	
Age (year)			
Mean ± SD	21.1 ± 2.6	21.2 ± 2.9	0.925[b]
Maxillo-mandibular arch width difference (mm)			
ICW difference	8.0 ± 2.0	6.7 ± 2.6	0.089[c]
IPMW difference	8.0 ± 2.4	7.4 ± 3.8	0.608[c]
IMW difference	6.2 ± 2.3	3.1 ± 2.1	< 0.001[c]

MARPE, miniscrew-assisted rapid palatal expansion group; SD, standard deviation; ICW, intercanine width; IPMW, interpremolar width; IMW, intermolar width.
[a] *P* value calculated with chi-squared test. [b] *P* value calculated with Mann-Whitney *U* test. [c] *P* value calculated with the independent *t* test.

Table 2 shows that all linear transverse measurement changes (T3-T0) from maxillary dental casts were significantly different between 2 groups (*P* < .001). In the MARPE group, all maxillary transverse linear measurements increased, but maintained or even decreased in the control group.

Table 2. Comparison of the maxillary arch width changes (T3-T0) with or without MARPE

Variable	Control	MARPE	*P* value
ICW (mm)	0.4 ± 1.5	2.7 ± 2.1	< 0.001
IPMW (mm)	0.2 ± 1.2	3.6 ± 2.4	< 0.001
IMW (mm)	-0.6 ± 1.2	2.0 ± 1.3	< 0.001

P value calculated with the independent *t* test.
MARPE, miniscrew-assisted rapid palatal expansion group; T0, before pre-surgical orthodontics; T3, at least 6 months after surgery; ICW, intercanine width; IPMW, interpremolar width; IMW, intermolar width.

1. Observation at 2 days after surgery

Table 3 shows that 3 angular measurements and 4 linear measurements were not statistically different between the 2 groups over time. The mean surgical movement of point A was forward and upward, but not statistically meaningful in both 2 groups. The mean surgical change of point B was 10.9 mm (SD, 3.7 mm) posterior (*P* < .001) and 1.5 mm (SD, 2.3 mm) superior in the control group and was 10.3 mm (SD, 5.2 mm) posterior (*P* < .001) and 3.9 mm (SD, 3.5 mm) superior (*P* < .001) in the MARPE group . SN-OP angle increased 4.6° (SD, 3.6°) (*P* < .001) in the control group and 5.4° (SD, 3.1°) (*P* < .001) in the MARPE group, respectively. However, there were no statistically significant differences in all measurements in surgical changes (T2-T1) between the 2 groups over time (Table 4).

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

Outcome variable	Time	Control	MARPE	Time x group *P* value
SNA	T1	82.0 ± 3.0^{BA}	79.8 ± 3.3^{BA}	
	T2	82.3 ± 3.4^{B}	80.6 ± 3.1^{B}	0.271
	T3	81.5 ± 3.5^{A}	80.0 ± 3.4^{A}	
SNB	T1	84.4 ± 3.6^{C}	81.4 ± 4.9^{B}	
	T2	79.0 ± 3.6^{B}	76.3 ± 3.4^{A}	0.633
	T3	78.2 ± 3.2^{A}	75.7 ± 3.7^{A}	
SN-OP	T1	16.8 ± 3.4^{A}	19.7 ± 5.4^{A}	
	T2	21.4 ± 5.5^{B}	25.1 ± 3.8^{B}	0.583
	T3	22.3 ± 4.8^{B}	26.2 ± 4.1^{B}	
A(x)	T1	69.5 ± 5.5^{BA}	67.3 ± 4.7^{A}	
	T2	69.8 ± 6.1^{B}	68.0 ± 4.8^{A}	0.263
	T3	68.8 ± 6.1^{A}	67.4 ± 5.1^{A}	
B(x)	T1	73.7 ± 9.4^{C}	67.7 ± 10.4^{B}	
	T2	62.7 ± 9.2^{B}	57.4 ± 7.4^{A}	0.553
	T3	61.2 ± 8.6^{A}	56.5 ± 8.5^{A}	
A(y)	T1	68.9 ± 3.7^{B}	68.5 ± 5.1^{A}	
	T2	67.6 ± 4.7^{BA}	68.3 ± 5.3^{A}	0.181
	T3	67.0 ± 3.9^{A}	67.5 ± 4.7^{A}	
B(y)	T1	116.9 ± 7.4^{B}	117.0 ± 8.9^{C}	
	T2	115.6 ± 6.1^{BA}	114.4 ± 8.0^{B}	0.086
	T3	114.5 ± 6.6^{A}	113.0 ± 7.4^{A}	

P value calculated with repeated measures analysis of variance with Bonferroni correction.
Within each column, significant differences are represented by uppercase letters.
MARPE, miniscrew-assisted rapid palatal expansion group; T1, 1 month before surgery; T2, 2 days after surgery; T3, at least 6 months 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; A(y), vertical position of point A; B(y), vertical position of point B.

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

T2-T1	Control		MARPE		Between groups
	Difference	*P* value[a]	Difference	*P* value[a]	
SNA	0.2 ± 1.6	1.000	0.7 ± 1.2	0.052	0.286
SNB	-5.4 ± 1.9	< 0.001	-5.0 ± 2.7	< 0.001	0.614
SN-OP	4.6 ± 3.6	< 0.001	5.4 ± 3.1	< 0.001	0.502
A(x)	0.2 ± 1.6	1.000	0.7 ± 1.7	0.264	0.405
B(x)	-10.9 ± 3.7	< 0.001	-10.3 ± 5.2	< 0.001	0.647
A(y)	-1.3 ± 2.4	0.076	-0.1 ± 2.0	1.000	0.113
B(y)	-1.5 ± 2.3	0.319	-3.9 ± 3.5	< 0.001	0.125

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.
MARPE, miniscrew-assisted rapid palatal expansion group; T1, 1 month before surgery; T2, 2 days 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; A(y), vertical position of point A; B(y), vertical position of point B.

2. Observation at least 6 months after surgery

The mean postoperative period (T3-T2) was 9.3 months (standard deviation: 3.0; range: 6−12 months) in the control group, and 9.2 months (standard deviation: 2.8; range: 6−12 months) in the MARPE group. There was no significant difference in postoperative period length between the 2 groups.

During the postoperative period, SNA and SNB decreased significantly in both 2 groups (control group, P = .001 for SNA, P = .002 for SNB; MARPE group, P = .029 for SNA), but this changes were not statistically different between the 2 groups over time. SN-OP angle increased 0.8° (SD, 2.3°) in the control group and 1.0° (SD, 2.0°) in the MARPE group, but this angular change also did not show statistically significant in each group nor between the 2 groups (Table 5). Point B moved 1.5 mm (SD, 1.7 mm) backward (P = .003) and 1.0 mm (SD, 2.1 mm) upward in the control group, and 0.8 mm (SD, 2.0 mm) backward and 1.3 mm (SD, 1.6 mm) upward (P = .004) in the MARPE group. However, there was no statistically significant difference in the postoperative changes of all measurements between the 2 groups over time (Fig 4).

In both 2 groups at least 6 months after surgery, the amount of postoperative mandibular upward movement (B[Y] at T3-T2) decreased as the amount of surgical mandibular upward change (B[Y] at T2-T1) increased (r = -0.330; P = 0.038). However, the amount of horizontal and vertical mandibular change in surgery (B[X]; B[Y] at T2-T1) and maxillary arch width expansion during overall treatment (ICW; IPMW; IMW at T3-T0) were not significantly correlated with postoperative relapse of mandibular setback surgery (Table 6).

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

T3-T2	Control		MARPE		Between groups
	Difference	*P* value[a]	Difference	*P* value[a]	
SNA	-0.7 ± 0.7	0.001	-0.5 ± 0.9	0.029	0.475
SNB	-0.7 ± 0.8	0.002	-0.5 ± 1.1	0.133	0.485
SN-OP	0.8 ± 2.3	0.342	1.0 ± 2.0	0.103	0.780
A(x)	-0.9 ± 1.0	0.002	-0.5 ± 1.0	0.075	0.256
B(x)	-1.5 ±1.7	0.003	-0.8 ± 2.0	0.215	0.268
A(y)	-0.5 ± 1.8	0.698	-0.8 ± 1.5	0.096	0.584
B(y)	-1.0 ± 2.1	0.116	-1.3 ± 1.6	0.004	0.622

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.
MARPE, miniscrew-assisted rapid palatal expansion group; T2, 2 days after surgery; T3, at least 6 months 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; A(y), vertical position of point A; B(y), vertical position of point B.

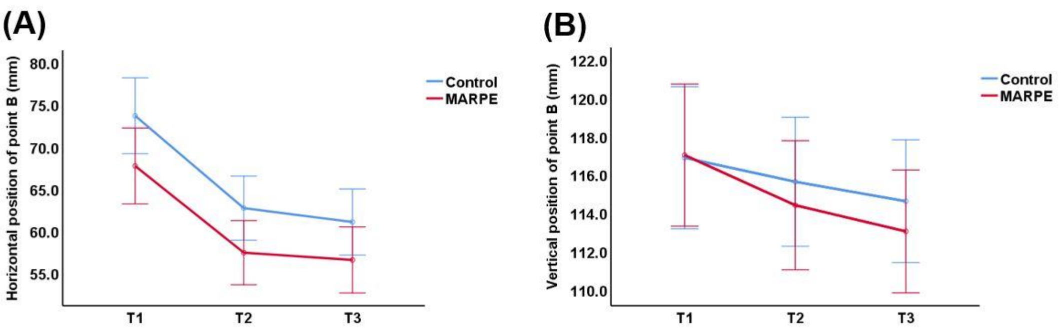

Figure 4. (A) Horizontal distances between point B and the y-axis [B(x)] and (B) vertical distances between point B and the x-axis [B(y)] in the 2 groups at different time points are shown.
Control, the control group; MARPE, the MARPE group; T1, 1 month before surgery; T2, 2 days after surgery; and T3, at least 6 months after surgery; error bar, standard deviation.

Table 6. Correlations of maxillary arch width changes (T3–T0) and surgical changes (T2–T1) with postoperative changes (T3–T2) in patients who underwent bimaxillary surgery with (MARPE group) or without (control group) presurgical MARPE

	Postsurgical change 6 months after surgery (T3-T2)			
	B(x)		B(y)	
	r	*P* value	*r*	*P* value
ICW (T3-T0)	0.185	0.254	-0.155	0.339
IPMW (T3-T0)	0.120	0.460	0.032	0.845
IMW (T3-T0)	-0.068	0.677	0.208	0.198
B(x) (T2-T1)	-0.221	0.170	0.193	0.233
B(y) (T2-T1)	-0.027	0.868	-0.330	0.038

r : pearson correlation coefficient.

ICW, intercanine width; IPMW, interpremolar width; IMW, intermolar width; T0, before pre-surgical orthodontics; T1, 1 month before surgery; T2, 2 days after surgery; T3, at least 6 months after surgery; B(x), horizontal position of point B; B(y), vertical position of point B.

IV. DISCUSSION

The purpose of this study was to investigate the association between the relapse after bimaxillary surgery, especially IVRO for mandibular setback, and nonsurgical maxillary expansion using MARPE appliance during presurgical orthodontic treatment. The author hypothesized that nonsurgical maxillary expansion would have significant effect on the skeletal relapse after IVRO. To verify this hypothesis, the author assessed linear and angular outcome variables in patients with skeletal Class III malocclusion using serial lateral cephalograms and dental casts. Then, these patients were divided into 2 groups according to nonsurgical maxillary expansion during presurgical orthodontics. Additionally, correlations between the amount of maxillary expansion, intraoperative mandibular change, and mandibular relapse were evaluated. The results showed no clinically or statistically meaningful intergroup differences nor correlation between maxillary expansion and surgical relapse, though the amount of postoperative superior movement of the mandible decreased with the increase in the amount of intraoperative surperior displacement of the mandible.

Nonsurgical maxillary expansion was reported to show pyramidal pattern in circummaxillary structures, whose rotation center is located near frontonasal surture (Park et al., 2017). Lim et al. (Lim et al., 2017), who investigated stability after 1 year of MARPE expansion, reported that more than half of expansion was dentoalveolar portion, whose patterns were mainly buccal tipping. And the expansion percentage of MARPE showed less skeletal and more dentoalveolar expansion compared to those of SARPE (Asscherickx et al., 2016). Hong (Hong, 2019) reported that the axial angulation of the maxillary first molar in adults increased by 2.29 ± 8.09° upon removal of the fixed orthodontic appliance after completion of nonsurgical orthodontic treatment with MARPE; this indicated that the maxillary molar is slightly buccally inclined after orthodontic treatment. Due to its tipping nature of expansion, including dentition and alveolus, the relapse of expanded molars and alveolar bone after MARPE could cause occlusal interference in postoperative period. Kor et al. (Kor et al., 2014) reported that, after mandibular setback surgery by SSRO, containing rigid fixation with medullary contact bone healing, distal segment showed counterclockwise rotation in postoperative period regardless of direction of mandibular rotation in surgery. Likewise, Liao et al. (Liao et al., 2010) reported that SSRO procedure was favorable for preventing postsurgical open bite due to postoperative superior movement of mandible. Differing from SSRO technique, IVRO needs cortex-to-cortex bone healing between proximal and distal segments without rigid fixation system. Then, some investigators stated that there were posterior and inferior relapse and clockwise rotation of mandible after setback surgery using IVRO (Nihara et al., 2013; Yoshioka et al., 2008). By above-mentioned 2 factors, relapse of MARPE expansion and mandibular vertical instability of IVRO technique, the author has been doubtful on the results of mandibular setback by IVRO with nonsurgical MARPE expansion in skeletal Class III patients with transverse discrepancy.

At the initial examination, the MARPE group showed more severe transverse discrepancy than the control group in molar region (Table 1). From T0 to T3, maxillary transverse arch widths were significantly more expanded in the MARPE group than the control group (Table 2). The mean amount of expansion by MARPE appliance was about 6 mm (30 turns times 0.2 mm per turn), but remained amount of expansion at T3 was about 2 mm in molar region. Uysal et al. (Uysal et al., 2005) reported that maxillomandibular intermolar width difference was around 5 mm in normal occlusion. And Ballanti et al. (Ballanti et al., 2009) reported that anterior open bite was deeply associated with skeletal and dentoalveolar transverse discrepancy. Therefore, in the present study, the subjects in the MARPE group had transverse discrepancy, morphologically associated to vertical dimension as well as sagittal discrepancy unlike those in the control group. It can be questionable for small amount of transverse discrepancy at initial state of the MARPE group. Handelman et al. (Handelman et al., 2000) stated that SARPE should be applied when the required expansion of intermolar width exceeds 8 mm. So, nonsurgical expansion of the subjects in MARPE group can be justified due to their moderate amount of transverse discrepancy. Milder cases could be treated by transpalatal arch (TPA) or archwire, while more severe cases could be treated by SARPE. Cost-effectiveness evaluation should be considered for treatment planning according to patients' degree of transverse discrepancy which can be evaluated by repositioning dental casts into Class I molar relationship (Jacobs et al., 1980).

2 days after surgery, there were no significant intergroup differences in amount of surgical change of B-point in any direction (Table 4). Thereafter, at least 6 months after surgery, skeletal relapses of mandibles were not statistically different between 2 groups (Table 5). In the present study, both groups showed backward and upward mandibular movement intraoperatively, and same direction changes postoperatively, though some of latter changes were not statistically significant. This posterior relapse pattern accords with some previous studies on IVRO technique, (Jung et al., 2013; Yoshioka et al., 2008) but disaccords with other studies (Chen et al., 2011; Nihara et al., 2013) which reported anterior relapse after IVRO. Postoperative upward movement of B point may be due to physiologic condylar repositioning by early mobilization and vertical vectors derived from intermaxillary elastics at active PT (Choi et al., 2016a). Besides, there was no meaningful correlation between the amount of maxillary expansion and skeletal relapse of mandible (Table 6).

In several previous studies, (Han et al., 2014; Park et al., 2016; Souza Pinto et al., 2019) skeletal tissues have been reported to be stable at 6 months after orthognathic surgery. Normally, debonding in cases undergoing postsurgical orthodontic treatment is performed within 6 months of surgery. Accordingly, we also followed our cases for 6 months after surgery. Point A did not show significant anteroposterior or vertical movement at T1, T2, and T3 in the MARPE group. Hong (Hong, 2019) reported that maxillary expansion using MARPE in adults induced forward and downward movement of the maxilla, with no change in the tilt of the palatal plane relative to the cranial base. This displaced maxillary position is reportedly maintained after debonding. In the present study, forward and downward movements of the maxilla may have occurred during presurgical orthodontic treatment with MARPE; however, the position of point A was relatively stable between 2 days and 6 months after orthognathic surgery. This indicates that the maxilla was anteroposteriorly and vertically stable after the surgery.

To the best of our knowledge, this is the first study to compare the relapse pattern after IVRO in patients with skeletal Class III whether they undergone nonsurgical maxillary expansion using MARPE. This study has its limitations such as absence of records just after expansion, two-dimensional analysis, retrospective design, and short postoperative retention period. Many previous studies on maxillary expansion analyzed posteroanterior cephalograms to evaluate its skeletal effects. But in the present study, it was difficult to detect transverse maxillary landmarks due to haziness in nasal cavity, discontinuity at lateral walls of maxilla after Le Fort I osteotomy. 3 subjects in the MARPE group failed to separate midpalatal suture. However, due to small number of samples, it was difficult to analyze or further interpret statistically. Well-organized long-term prospective studies, comparing the effectiveness and stability of nonsurgical and surgical maxillary expansion in bimaxillary surgery patients according to their degree of transverse discrepancy, are warranted in future. Additionally, It will be helpful to investigate that how failure of separation in nonsurgical maxillary expansion affect results of bimaxillary surgery.

V. CONCLUSION

Null hypothesis is rejected. Skeletal relapse at least 6 months after two-jaw surgery including mandibular setback by IVRO did not differ significantly according to whether a maxilla was expanded nonsurgically using MARPE appliance. This finding legitimizes the use of nonsurgical maxillary expansion and IVRO technique in patients with skeletal Class III and moderate transverse discrepancy.

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국문 요약

악교정수술 전 비수술적 상악골 확장치료 여부에 따른 골격성 III급 환자의 양악수술 후 안정성에 관한 연구

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안 윤 수

본 후향적 연구는 골격성 III급 성인 환자들에서 악교정수술 전 미니스크류 보강형 급속 구개 확장장치(Miniscrew-assisted rapid palatal expansion; MARPE)를 이용한 비수술적 상악골 확장치료 여부에 따른 구내 하악지 수직 골절단술(Intraoral vertical ramus osteotomy; IVRO)을 이용한 악교정수술의 안정성을 평가하였다.

이를 위해 골격성 III급 부정교합으로 진단받고 악교정수술을 받은 40명의 성인 환자들을 각각 20명의 MARPE군(평균 나이, 21.2 ± 2.9 세)과 대조군(평균 나이, 21.1 ± 2.6 세)으로 나누었다. 수술 1 달 전, 수술 2 일 후, 그리고 수술 최소 6 개월 후에 촬영한 측모두부계측방사선사진(Lateral cephalogram)과 교정치료 전과 수술 최소 6 개월 후에 채득한 치아 모형(Dental cast)을 계측하여 상악골의

비수술적 확장치료 여부 및 그 양이 악교정수술 후의 안정성에 미치는 영향에 관하여 분석하였다.

본 연구의 결과, 두 군은 초진 시에 나이와 성별 분포에는 차이가 없었으며, 악궁의 횡적 부조화에서만 통계적으로 유의한 차이를 보였다. 수술적 변화와 수술 후 재발(B점의 전후방 및 수직적 이동)은 두 군 사이에서 통계적으로 유의한 차이가 없었으며, MARPE군에서 상악 치열궁의 확장량과 악교정수술 후의 전후방 및 수직적 재발량 사이에도 유의미한 상관관계를 보이지 않았다. 다만, 수술 과정에서의 하악골의 상방이동량과 하악골의 술후 상방이동량 사이에만 음의 상관관계를 보였다(r = −0.330; P = 0.038).

결과적으로, 수술 전 MARPE에 의한 상악골 확장 여부와 그 양이 IVRO 이후 하악골의 위치변화에 통계적으로 유의한 영향을 미치지 않았다. 따라서 악교정수술이 필요하며, 동시에 상악골의 횡적 결핍이 있는 골격성 III급 환자들에서 MARPE를 이용한 비수술적 상악골 확장치료가 유용하고 안정적인 선택이 될 수 있다.

핵심 되는 말: 비수술적 상악골 확장, 양악수술, 수술 후 안정성, 미니스크류 보강형 급속 구개 확장 (MARPE), 구내 하악지 수직 골절단술 (IVRO), 골격성 III급 부정교합.