Comparison of transverse dental axis changes in skeletal Class III with asymmetry treated by preorthodontic orthognathic surgery and conventional surgery

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Comparison of transverse dental axis changes in skeletal Class III with asymmetry treated by preorthodontic orthognathic surgery and conventional surgery

Directed by Professor Hyung-Seog Yu

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감사의 글

이 논문이 완성되기까지 학문적 지도와 따뜻한 배려로 이끌어주신 유형석 지도교수님께 진심으로 감사 드리며, 귀중한 시간을 내주시어 부족한 논문을 세심하게 살펴주신 이기준 교수님과 차정열 교수님께 깊은 감사를 드립니다. 또한 연세대학교 치과대학 교정과학교실에서 배움의 기회를 주시고 교정의사로서 첫 발을 내딛는 데에 어려움이 없도록 인도해주신 박영철 교수님, 백형선 교수님, 황충주 교수님, 김경호 교수님, 정주령 교수님, 최윤정 교수님께 감사드립니다.

의국 생활과 교정학 공부에 큰 도움과 조언을 주시는 선배 최성환 선생님과, 서로의 버팀목이 되며 같은 길을 걷게 된 수련 동기 김수연, 서승원, 서희주, 한병희, 한송이 선생에게 감사의 마음을 전합니다.

마지막으로, 지금의 제가 있기까지 아낌없는 지원과 응원을 보내주시는 부모님과 동생에게 고마운 마음을 전합니다. 그리고 저를 믿고 도와주신 많은 분들께 감사드리며, 이 작고 소중한 기쁨을 함께 나누고자 합니다.

2016 년 6 월 저자 씀

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Abstract

Comparison of transverse dental axis changes in skeletal Class III with asymmetry treated by preorthodontic orthognathic surgery and conventional surgery

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The aim of this study was to evaluate, using 3D-CT, transverse dental axis changes in skeletal Class III patients with facial asymmetry who received 2-jaw surgery, and compare the changes between two different orthognathic surgery protocols; conventional surgery and preorthodontic orthognathic surgery.

Total 29 skeletal Class III patients (15 men, 14 women) with asymmetry (menton deviation > 4 mm) were selected. Sixteen patients (CS group, 10 men, 6 women, mean age 21.8 ± 2.2 yrs) received conventional orthognathic surgery, and thirteen

patients (POGS group, 5 men, 8 women, mean age 21.0 ± 1.7 yrs) received preorthodontic orthognathic surgery.

Orthognathic surgery was proceeded with maxillary Le Fort I osteotomy and mandibular bilateral intraoral vertical ramus osteotomy (B-IVRO). Facial 3D-CT was taken before treatment (T0), 1 month before surgery (T1), 3 days after surgery (T2) and 1 year after surgery (T3). Skeletal and dental variables were measured and compared the dental axis changes between CS and POGS groups. The results are as followings,

1. By pre-surgical orthodontic treatment in CS group, upper 1st molar and canine had shown tendency of uprighting, but there was no significant difference between CS and POGS group at 1 month before surgery (T1).

2. In POGS group, lower canine of non-deviated side and upper 1st molar of both side inclined lingually by post-surgical orthodontic treatment (T2-T3).

3. One year after the surgery (T3), skeletal and dental measurements were similar between CS and POGS groups. However, there was significant difference of buccolingual inclination of maxillary and mandibular molars between deviated and non-deviated side in POGS group.

4. Although in CS group the pre-surgical orthodontic treatment (T0-T1) was done for about 12 months, total changes of buccolingual inclination of canine and molar showed no significant difference between CS and POGS groups (T0-T3).

Preorthodontic orthognathic surgery can be an efficient method for skeletal Class III patients with facial asymmetry in the aspect of shorter treatment time and immediate improvement of facial esthetics, and lead to almost the same treatment outcome comparing to conventional surgery. However, if there is severe difference of buccolingual inclination between deviated and non-deviated posterior teeth, conventional surgery with dental decompensation prior to orthognathic surgery would be a better surgical option for a relatively stable treatment outcome.

Key words: Preorthodontic orthognathic surgery, Asymmetry, Skeletal Class III, 3D CT, Decompensation, Transverse dental axis changes

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I. Introduction

Conventional orthognathic surgery for Class III asymmetry patients is done by three steps: pre-surgical orthodontic treatment, orthognathic surgery and post-surgical orthodontic treatment (Jacobs and Sinclair, 1983; Sabri, 2006; Tompach et al., 1995). During pre-surgical orthodontic treatment, the patient's facial esthetic and functional occlusion is deteriorated by decompensation. Recently, Nagasaka (2009) and Villegas (2010) proposed the surgery-first approach for orthognathic surgery. The surgery-first approach or preorthodontic orthognathic surgery has many advantages which are immediate improvement of facial esthetics in short time and patient's psychosocial life by reducing the pre-surgical orthodontic period (Min et al., 2014; Park et al., 2015). Moreover, previous studies reported regional acceleratory phenomenon (RAP), which is the orthodontic tooth movement can be accelerated for a while after the surgery (Frost, 1989; Liou et al., 2011).

Especially in the patient with facial asymmetry, it is hard to decompensate buccolingually tilted molars because the soft tissue is adapted to skeletal discrepancy. If we position the maxilla and mandible first in the harmonious relationship, it is not anymore a difficult procedure to upright buccolingually tilted molars. However, when planning preorthodontic orthognathic surgery for the asymmetry patients, the clinicians often confront the unstable surgical occlusion and need to consider post-surgical skeletal and dental movement.

Many studies compared postoperative stability following surgery performed with and without pre-surgical orthodontic treatment (Choi et al., 2016; Ko et al., 2013; Park et al., 2016). But most of them are focusing on antero-posterior dimension on sagittal plane by using 2-dimensional lateral cephalogram.

Few studies investigated the transverse skeletal and dental stability after orthognathic surgery without preorthodontic treatment, using posteroanterior (PA) cephalogram or dental cast. Wang et al. (2010) compared transverse dimensional changes in skeletal Class III patients with and without presurgical orthodontics by PA view and concluded that transverse dental changes were similar whether receiving pre-surgical orthodontics or not. Kim et al. (2014) evaluated the dental casts of the skeletal Class III patients who underwent surgery with minimal orthodontic treatment, and concluded that changes in arch width had no association with horizontal and vertical relapses of the mandible. However, we cannot precisely evaluate the buccolingual inclination of molars with the dental casts, and the assessment of transverse dental axis with PA view has many limitations of dynamic head orientation and superimposition (Lee et al., 2014). To the best of our knowledge, few studies have been reported comparing transverse dental axis in asymmetry patients between preorthodontic orthognathic surgery (POGS) and conventional orthognathic surgery (CS), using 3D-computed tomography (CT).

The aim of this study was to evaluate, using 3D-CT, transverse dental axis changes of the skeletal Class III with asymmetry patients who received 2-jaw surgery and compare the changes between two different orthognathic surgery protocols; conventional surgery and preorthodontic orthognathic surgery.

II. Material and Methods

1) Study design and subjects

This retrospective cohort study included 125 patients who were diagnosed with skeletal Class III malocclusion with facial asymmetry and underwent 2-jaw surgery using bilateral intraoral vertical ramus osteotomy (B-IVRO) from 2010 through 2015 at the Department of Oral and Maxillofacial Surgery, Yonsei Dental Hospital (Seoul, Korea). The inclusion criteria were 1) Skeletal Class III with mandible prognathism (ANB smaller than 0°), 2) Adult over 18 years of age, 3) Menton deviation greater than 4 mm from midsagittal plane, 4) 2-jaw surgery with maxillary Le Fort I and mandibular B-IVRO. Patients with previous history of orthognathic surgery, facial trauma, cleft or syndromic deformity and incomplete data were excluded.

Twenty-nine patients (15 men and 14 women) fulfilled the criteria. Sixteen patients (10 men and 6 women) received conventional orthognathic surgery (CS group, mean age 21.8 ± 2.2 yrs) and six patients in CS group had extraction of two upper bicuspids for pre-surgical orthodontic treatment. The pre-surgical orthodontic treatment time before surgery was 12.6 ± 3.5 months in average. Thirteen patients (5 men and 8 women) received preorthodontic orthognathic surgery (POGS group, mean age 21.2 ± 4.3 yrs), and no missing tooth was present in the group. Total treatment time of CS and POGS group in average was 22.9 ± 6.3 and 14.3 ± 7.3

months, respectively. Demographic characteristics of the subjects are described in Table 1.

Table 1. Sample characteristics (N = 29)

	CS n=16	POGS n=13	*p* value
Gender, n (%)			0.198[a]
Men	10 (62.5)	5 (38.5)	
Women	6 (37.5)	8 (61.5)	
Age (year)			
Mean ± SD	21.8 ± 2.2	21.2 ± 4.3	0.168[b]

Abbreviations: CS, conventional orthognathic surgery; POGS, pre-orthodontic orthognathic surgery; SD, standard deviation
a By chi square test
b By Mann-Whitney U test

2) Methods

A. Surgical and orthodontic procedure

For POGS group, the surgical arch wire with .016 × .022 or .017 × .025 inches stainless-steel wire was passively bonded directly on the teeth following band insertion on molars at 1 month before surgery. The surgeries were performed by the same surgeon (S.-H. L), and all orthodontic treatment was done by the same orthodontist (H.-S. Y).

After 1-piece Le Fort I osteotomy, the maxilla was stabilized with rigid internal fixation with 4 L-shaped titanium plates. In mandible, the osteotomy line was vertically extended from mandibular angle to sigmoid notch. Intermaxillary fixation (IMF) was removed 10 days after the surgery and physical therapy was performed for six weeks. Six to eight weeks after the surgery, surgical arch wire was removed and post-surgical orthodontic treatment was initiated by bracket bonding and wire insertion.

B. CT scanning and 3D image reconstruction

CT data were acquired before the orthodontic treatment (T0), 1 month before the surgery (T1), 3 days after the surgery (T2) and 1 year after the surgery (T3). Since only 10 patients from CS group had taken CT before the orthodontic treatment, data at T0 included CT of 10 patients. The T1 data were the same as the T0 data in POGS group, since no orthodontic movement was performed before the surgery. CT scans were obtained with the high-speed advantage CT scanner (GE Medical System Milwaukee, Wis, USA) used with high-resolution bone algorithm (200mA, 120kV). The axial images were saved as digital imaging and communication in medicine (DICOM) files and were reconstructed using Invivo ver 5.4 (Anatomage, San Jose, Calif).

C. Landmarks & Reference planes

Landmarks and reference planes are defined in Table 2 and Figure 1. Nasion (N) was set to zero point (0, 0, 0). The shifted side of menton according to midsagittal plane was defined as deviated side and the opposite side was defined as non-deviated side.

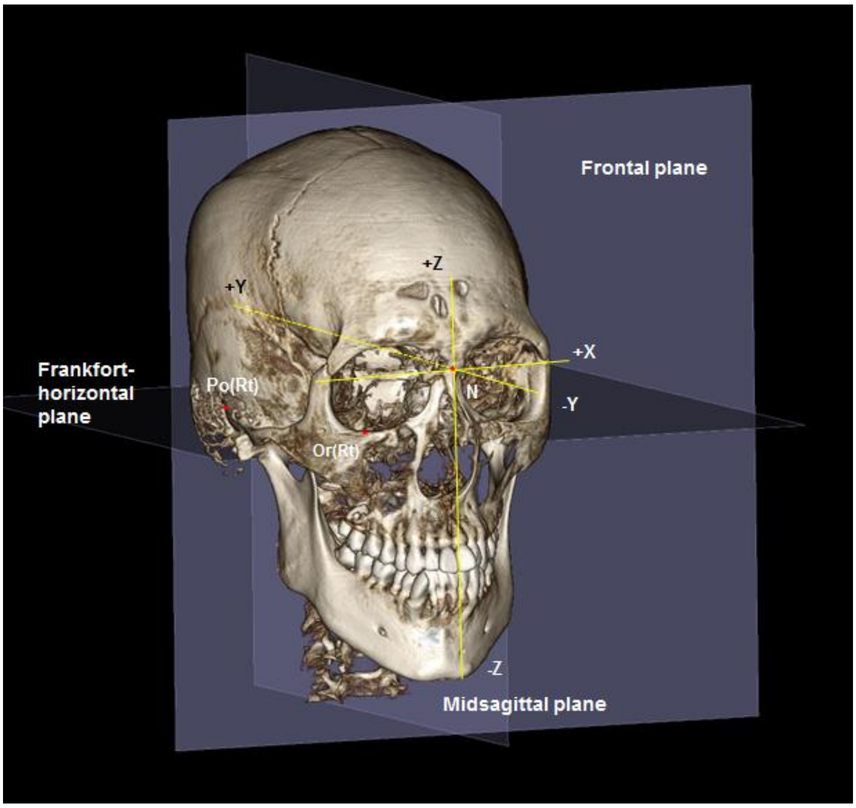

Figure 1. Reconstruction and reorientation of 3D images.
(N, nasion; Or, orbitale; Po, porion; Rt, right)

Table 2. Definition of landmarks and reference planes

Landmarks	Definition
N (Nasion)	The junction of the frontal nasal suture at the most posterior on the curve at the bridge of the nose
S (Sella)	The center of the pituitary fossa of the sphenoid bone
Or (Orbitale) Rt. & Lt.	The lowest point in the inferior margin of the orbit
Po (Porion) Rt. & Lt.	The point located at the most superior point of the external auditory meatus
J (Jugale) Rt. & Lt.	The point show maximum concavity on contour of maxilla around molars and lower contour of maxillozygomatic process
Co (Condylion) Rt. & Lt.	The most upper and posterior aspect of condyle
Me (Menton)	The most inferior point on the symphyseal outline
Go (Gonion) Rt. & Lt.	The midpoint of inferior and posterior border of mandibular angle
Canine tip Rt. & Lt.	The uppermost point of canine tip
Canine apex Rt. & Lt.	The point of canine apex of the root
1st molar central groove Rt. & Lt.	The point of the 1st molar central groove between the buccal and palatal cusps
1st molar furcation Rt. & Lt.	The point of the 1st molar furcation of the roots
Reference planes	
FHP (Frankfort horizontal plane)	The plane passing through right Porion, left Porion and right Orbitale
MSP (Midsagittal plane)	The plane perpendicular to FHP, passing through Nasion and Sella
FP (Frontal plane)	The plane perpendicular to FHP and MSP, passing through Nasion

D. Measurements on reconstructed 3D images

Skeletal and dental measurements are defined in Table 3 and Figure 2.

Table 3. Definition of skeletal and dental measurements

Skeletal	**Definition**
Maxillary canting	The angle between the line connecting Rt & Lt Jugale and FH plane projected on the frontal plane
Ramal inclination Rt. & Lt	The angle between the line connecting Co & Go and FH plane projected on the frontal plane
Ramal length Rt. & Lt.	Distance between Co & Go
Mandibular body length Rt. & Lt.	Distance between Go & Me
Asymmetry	Distance from Me to Midsagittal plane
Dental	
Canine inclination Rt. & Lt.	The angle between the line connecting the cusp tip and the apex and FH plane projected on the frontal plane
1^{st} molar inclination Rt. & Lt.	The angle between the line connecting the central groove and the furcation and FH plane projected on the frontal plane

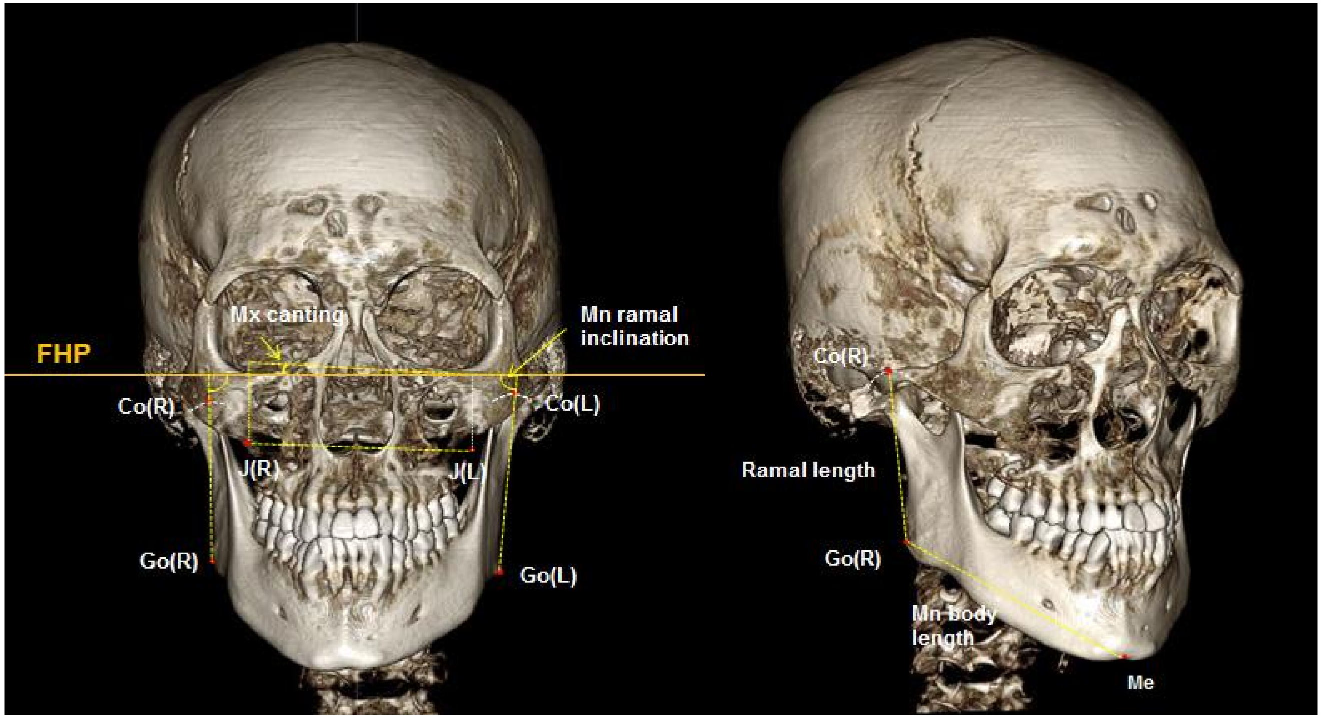

Figure 2. Landmarks and skeletal measurements. (FHP, Frankfort horizontal plane; J, jugale; Co, condylion; Go, gonion; Me, menton; Mx, maxilla; Mn, mandible; R, right; L, left)

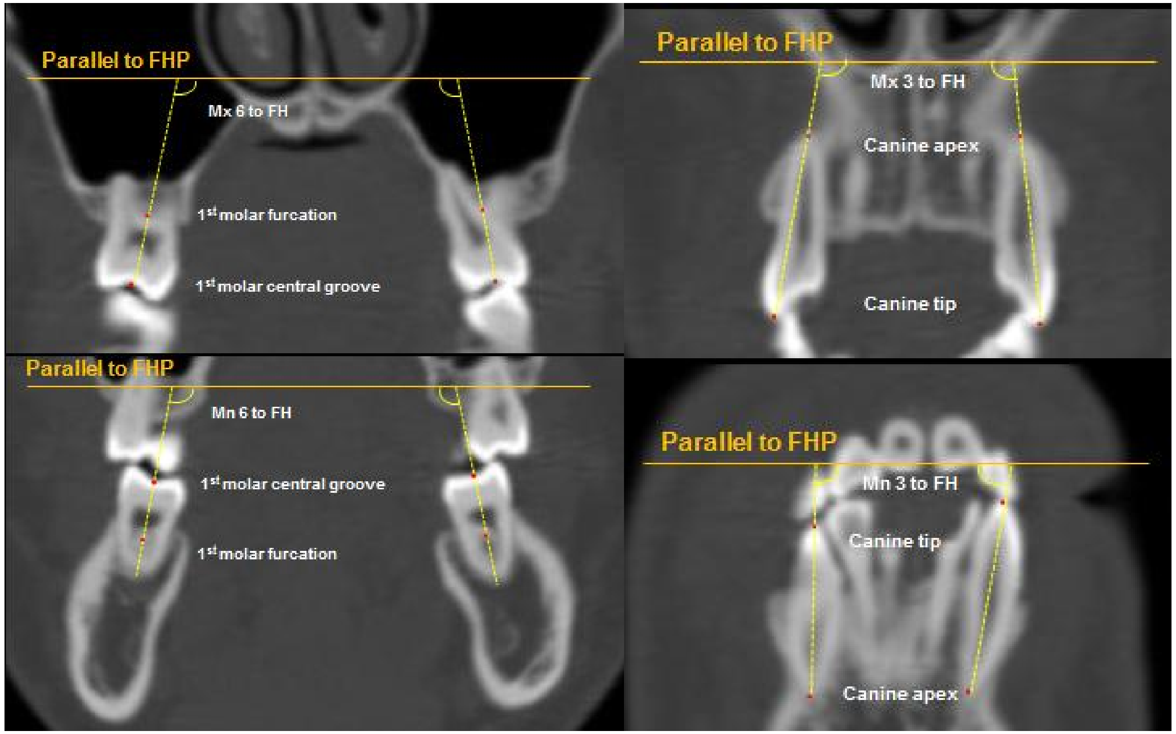

Figure 3. Landmarks and dental measurements. (FHP, Frankfort horizontal plane; Mx 3, maxillary canine; Mx 6, maxillary 1st molar; Mn 3, mandibular canine; Mn 6, mandibular 1st molar)

3) Statistical analysis

All variables were measured by one author and repeated after 2 week interval of 20 randomly selected patients.

① Differences in initial skeletal variables between CS and POGS groups (Independent t-test).

② Comparison of differences of measurements between CS and POGS groups at T1 (Independent t-test), and examination of difference in measurements between deviated and non-deviated side in each group at T1 (Paired t-test).

③ Comparison of surgical changes (T2 – T1) between CS and POGS groups (Independent t-test) and examination of difference of surgical changes (T2 – T1) in each group (Paired t-test).

④ Comparison of post-surgical changes (T3 – T2) between CS and POGS groups (Independent t-test), and examination of difference of post-surgical changes (T3 – T2) in each group (Paired t-test).

⑤ Differences in measurements between CS and POGS groups at T3 (Independent t-test), and examination of difference in measurements between deviated and non-deviated side in each group at T3 (Paired t-test).

All statistical analyses were performed with SPSS 20.0 (SPSS Inc. Illinois, USA) and p value less than 0.05 was regarded to be statistically significant. To verify the normality of samples, the Shapiro-Wilk test was conducted.

III. Results

1. Error of the method

The intra-examiner reproducibility was assessed by the intraclass correlation coefficient for repeated measurements. It showed high reliability with range from 0.994 to 0.999 (p<0.001).

2. Comparison of initial skeletal variables at T0 (Table 4).

Lateral cephalogram was used to evaluate antero-posterior skeletal variables between CS and POGS groups. Mean menton deviation was 8.3 ± 3.6 mm in CS group and 7.4 ± 5.6 mm in POGS group, which was not different significantly.

Table 4. Skeletal variables at initial (T0)

	CS	POGS	*p* value
SNA (°)	80.7 ± 3.8	80.2 ± 3.0	0.713
SNB (°)	83.0 ± 4.0	84.0 ± 3.6	0.457
SN-MP (°)	35.5 ± 6.7	34.9 ± 5.9	0.806
Me deviation (mm)	8.3 ± 3.6	7.4 ± 5.6	0.622

Abbreviations: CS, conventional orthognathic surgery; POGS, pre-orthodontic orthognathic surgery; A, point A; B, point B; S, sella; N, nasion; MP, mandibular plane; Me, menton
Group comparisons were tested with the independent t-test

3. Comparison of skeletal and dental variables at T1 (Table 5).

One month before surgery (T1), there was significant difference between deviated and non-deviated side of ramal inclination ($p<0.001$), mandibular body length ($p<0.001$) in both groups.

In CS group, from T0 to T1, upper canine and 1st molar were inclined lingually, and lower canine and 1st molar were inclined buccally on the deviated side. Buccolingual inclination of the maxillary and mandibular 1st molar was significantly different between deviated and non-deviated side in both groups ($p<0.01$). However, there was no significant difference of skeletal and dental variables between CS and POGS groups at T1.

Table 5. Comparison of variables at T1

		CS at T0	CS	*p* value	POGS	*p* value	Between groups
Skeletal							
Angular measurement (°)							
Mx canting			1.7 ± 0.9		1.6 ± 1.0		0.816
Ramal inclination	D		89.4 ± 2.1		90.0 ± 2.7		0.522
	ND		85.6 ± 2.5		85.6 ± 3.7		0.978
	diff.		3.8***	<0.001	4.4***	<0.001	
Linear measurement (mm)							
Ramal length (Co-Go)	D		61.6 ± 7.2		60.9 ± 6.4		0.781
	ND		64.6 ± 5.2		63.2 ± 4.8		0.479
	diff.		3.0*	0.019	2.3	0.053	
Mn body length (Go-Me)	D		89.8 ± 6.5		89.8 ± 3.7		0.969
	ND		93.6 ± 5.3		93.7 ± 2.9		0.962
	diff.		3.8***	<0.001	3.9***	<0.001	
Dental							
Angular measurement (°)							
Mx 3 to FH	D	101.8 ± 3.9	99.5 ± 5.7		100.3 ± 4.1		0.665
	ND	94.5 ± 5.2	95.0 ± 3.6		96.4 ± 5.8		0.441
	diff.	7.3	4.5**	0.008	3.9	0.063	
Mn 3 to FH	D	93.2 ± 5.5	91.8 ± 4.1		92.6 ± 5.7		0.685
	ND	82.2 ± 8.9	85.6 ± 4.8		84.3 ± 5.4		0.477
	diff.	11.0	6.2**	0.001	8.3**	0.002	
Mx 6 to FH	D	102.4 ± 2.9	98.1 ± 6.6		102.3 ± 5.7		0.080
	ND	92.7 ± 6.2	92.2 ± 5.2		94.8 ± 6.0		0.225
	diff.	9.7	5.9**	0.006	7.5**	0.004	
Mn 6 to FH	D	108.9 ± 6.4	107.9 ± 7.1		109.5 ± 7.3		0.544
	ND	101.1 ± 5.0	101.0 ± 5.6		99.6 ± 5.3		0.491
	diff.	7.8	6.9**	0.004	9.9**	0.005	

* $p<0.05$; ** $p<0.01$; *** $p<0.001$

Abbreviations: Go, gonion; Co, Condylion; Mx 3, maxillary canine; Mn 3 mandibular canine; Mx 6, maxillary first molar; Mn 6, mandibular first molar; FH, Frankfort horizontal plane; D, deviated; ND, non-deviated; CS, conventional surgery; POGS; preorthodontic orthognathic surgery

Group comparison were tested with the independent t-test

4. Comparison of surgical changes between two groups (Table 6).

Skeletal and dental measurements are improved by surgical correction of the asymmetry. Ramal length of non-deviated side was significantly decreased in CS and POGS group (-8.6 ± 3.6 mm, -8.5 ± 2.8 mm, respectively, $p<0.001$). Also mandibular body length of non-deviated side was significantly decreased in CS and POGS group (-2.0 ± 2.6 mm, -3.1 ± 3.0 mm, respectively, $p<0.05$). In both groups, upper 1^{st} molar on the deviated side and lower 1^{st} molar on the non-deviated side inclined lingually ($p<0.05$), while upper 1^{st} molar on the non-deviated side and lower 1^{st} molar on the deviated side inclined buccally ($p<0.05$). Also it was similar in upper and lower canine, but the surgical change was only significant in the deviated side of lower canine ($p<0.01$). There was no significant difference of skeletal, dental changes between two groups.

Table 6. Comparison of surgical changes between two groups (T2 vs T1)

T2 vs T1		CS		POGS		Between groups
		Difference	*p* value	Difference	*p* value	
Skeletal						
Angular measurement (°)						
Maxilla canting [a]		-1.2 ± 1.1***	<0.001	-1.6 ± 1.4**	0.001	0.414
Ramal inclination [b]	D	-1.7 ± 2.4*	0.010	-2.0 ± 3.4	0.061	0.838
	ND	2.4 ± 2.7**	0.003	1.3 ± 2.6	0.097	0.288
Linear measurement (mm) [c]						
Ramal length (Co-Go)	D	-5.1 ± 5.0**	0.001	-8.6 ± 5.2**	0.002	0.838
	ND	-8.6 ± 3.6***	<0.001	-8.5 ± 2.8***	<0.001	0.981
	diff.	3.5		0.1		
Mn body length (Go-Me)	D	-1.6 ± 3.4	0.083	-2.3 ± 3.1*	0.021	0.565
	ND	-2.0 ± 2.6**	0.007	-3.1 ± 3.0**	0.002	0.268
	diff.	0.4		0.8		
Dental						
Angular measurement (°)						
Mx 3 to FH [d]	D	-1.2 ± 3.9	0.240	-0.8 ± 3.3	0.381	0.783
	ND	1.5 ± 3.1	0.072	0.2 ± 3.3	0.804	0.298
Mn 3 to FH [e]	D	-0.8 ± 2.6	0.260	-0.4 ± 3.1	0.676	0.714
	ND	2.1 ± 2.4**	0.003	1.0 ± 3.3	0.315	0.290
Mx 6 to FH [d]	D	-3.6 ± 2.8***	<0.001	-2.9 ± 2.8**	0.002	0.545
	ND	2.3 ± 3.7*	0.027	2.8 ± 3.3*	0.010	0.678
Mn 6 to FH [e]	D	-3.2 ± 3.9**	0.005	-4.5 ± 3.9**	0.001	0.378
	ND	2.6 ± 3.3**	0.007	1.9 ± 3.1*	0.046	0.561

* $p<0.05$; ** $p<0.01$; *** $p<0.001$
Abbreviations: Go, gonion; Co, Condylion; Mx 3, maxillary canine; Mn 3 mandibular canine; Mx 6, maxillary first molar; Mn 6, mandibular first molar; FH, Frankfort horizontal plane; D, deviated; ND, non-deviated; CS, conventional surgery; POGS; preorthodontic orthognathic surgery
Group comparison were tested with the independent t-test
a: positive and negative values indicate deterioration and improvement of maxilla canting, respectively
b: positive and negative values indicate lateral and mesial movement of ramus, respectively
c: positive and negative values indicate increase and decrease of measurements, respectively
d: positive and negative values indicate buccally and lingually inclined, respectively
e: positive and negative values indicate lingually and buccally inclined, respectively

5. Comparison of post-surgical changes between two groups (Table 7).

In CS group, ramal length decreased 1.8 ± 2.3 mm on deviated side (*p*=0.007), and mandibular body length decreased 1.3 ± 1.9 mm on non-deviated side (*p*=0.021). The changes in ramal length and mandibular body length of CS group were greater than those of POGS group, however the difference showed no significance.

There was no significant dental change during 1 year after the surgery in CS group. In POGS group, the upper 1st molar on both side inclined lingually (deviated side -1.8 ± 2.8°, *p*=0.044; non-deviated side -3.7 ± 3.3°, *p*=0.001). Also lower canine on non-deviated side inclined lingually (4.0 ± 5.4°, *p*=0.022) during post-surgical orthodontic treatment.

6. Comparison of skeletal and dental variables at T3 (Table 8).

There was no significant difference of skeletal variables and buccolingual dental axis between CS and POGS groups. However, there was significant difference of buccolingual dental axis of upper and lower 1st molar between deviated and non-deviated side in POGS group ($p<0.05$).

Table 7. Comparison of post-surgical changes between two groups (T3 vs T2).

T3 vs T2		CS		POGS		Between groups
		Difference	*p* value	Difference	*p* value	
Skeletal						
Angular measurement (°)						
Maxilla canting [a]		0.1 ± 0.7	0.899	0.3 ± 0.6	0.074	0.215
Ramal inclination [b]	D	-0.5 ± 1.8	0.885	0.6 ± 2.5	0.438	0.435
	ND	0.1 ± 1.9	0.912	0.3 ± 1.4	0.487	0.787
Linear measurement (mm) [c]						
Ramal length (Co-Go)	D	-1.8 ± 2.3**	0.007	-1.2 ± 2.7	0.140	0.518
	ND	-0.6 ± 5.9	0.358	-0.4 ± 2.2	0.549	0.821
	diff.	1.2		0.8		
Mn body length (Go-Me)	D	-0.6 ± 2.7	0.381	0.1 ± 3.1	0.958	0.549
	ND	-1.3 ± 1.9*	0.021	-0.8 ± 1.8	0.167	0.486
	diff.	0.7		0.9		
Dental						
Angular measurement (°)						
Mx 3 to FH [d]	D	-0.7 ± 1.6	0.097	-0.6 ± 3.6	0.588	0.878
	ND	0.1 ± 2.8	0.937	0.5 ± 3.5	0.635	0.724
Mn 3 to FH [e]	D	1.3 ± 3.0	0.096	-0.1 ± 3.6	0.963	0.265
	ND	1.1 ± 2.6	0.103	4.0 ± 5.4*	0.022	0.074
Mx 6 to FH [d]	D	0.1 ± 3.3	0.937	-1.8 ± 2.8*	0.044	0.116
	ND	-0.2 ± 2.5	0.286	-3.7 ± 3.3**	0.001	0.012
Mn 6 to FH [e]	D	1.1 ± 3.7	0.857	0.5 ± 4.3	0.689	0.674
	ND	0.1 ± 3.2	0.440	0.6 ± 3.1	0.515	0.316

* $p<0.05$; ** $p<0.01$
Abbreviations: Go, gonion; Co, Condylion; Mx 3, maxillary canine; Mn 3 mandibular canine; Mx 6, maxillary first molar; Mn 6, mandibular first molar; FH, Frankfort horizontal plane; D, deviated; ND, non-deviated; CS, conventional surgery; POGS; preorthodontic orthognathic surgery
Group comparison were tested with the independent t-test
a: positive and negative values indicate deterioration and improvement of maxilla canting, respectively
b: positive and negative values indicate lateral and mesial movement of ramus, respectively
c: positive and negative values indicate increase and decrease of measurements, respectively
d: positive and negative values indicate buccally and lingually inclined, respectively
e: positive and negative values indicate lingually and buccally inclined, respectively

Table 8. Comparison of variables at T3

		CS		POGS		Between groups
			p value		*p* value	
Skeletal						
Angular measurement (°)						
Mx canting		0.4 ± 0.8		0.3 ± 0.4		0.588
Mn ramal inclination	D	87.6 ± 3.8		88.6 ± 4.2		0.519
	ND	88.1 ± 3.2		87.2 ± 2.4		0.437
	diff.	0.5	0.575	1.4	0.218	
Linear measurement (mm)						
Ramal length (Co-Go)	D	54.7 ± 5.9		54.2 ± 5.9		0.821
	ND	55.4 ± 5.5		54.3 ± 5.3		0.583
	diff.	0.7	0.433	0.1	0.851	
Mn body length (Go-Me)	D	87.7 ± 5.2		87.6 ± 4.5		0.939
	ND	90.4 ± 5.6		89.8 ± 2.9		0.742
	diff.	2.7***	<0.001	2.2	0.053	
Dental						
Angular measurement (°)						
Mx 3 to FH	D	97.6 ± 4.7		98.9 ± 4.8		0.447
	ND	96.5 ± 3.1		97.1 ± 4.0		0.684
	diff.	1.1	0.472	1.8	0.167	
Mn 3 to FH	D	92.4 ± 4.0		92.2 ± 4.3		0.870
	ND	88.9 ± 3.7		89.2 ± 4.9		0.825
	diff.	3.5	0.028	3.0	0.037	
Mx 6 to FH	D	94.4 ± 7.1		97.6 ± 4.4		0.180
	ND	93.7 ± 3.7		93.8 ± 4.6		0.926
	diff.	0.7	0.677	3.8*	0.012	
Mn 6 to FH	D	104.4 ± 5.7		105.5 ± 3.5		0.576
	ND	103.0 ± 5.4		102.1 ± 3.5		0.631
	diff.	1.4	0.403	3.4**	0.009	

* $p<0.05$; ** $p<0.01$; *** $p<0.001$

Abbreviations: Go, gonion; Co, Condylion; Mx 3, maxillary canine; Mn 3 mandibular canine; Mx 6, maxillary first molar; Mn 6, mandibular first molar; FH, Frankfort horizontal plane; D, deviated; ND, non-deviated; CS, conventional surgery; POGS; preorthodontic orthognathic surgery
Group comparison were tested by the independent t-test

7. Comparison of total changes between two groups (Table 9).

There was no significant difference of total changes of buccolingual inclination between CS and POGS groups.

Table 9. Comparison of total changes between two groups (T3 vs T0)

T3 vs T0		CS		POGS		Group difference
		difference	*p* value	difference	*p* value	
Dental						
Angular measurement(°)						
Mx 3 to FH [a]	D	-3.4 ± 5.6	0.085	-1.4 ± 2.6	0.079	0.257
	ND	2.3 ± 5.0	0.187	0.7 ± 5.1	0.625	0.473
Mn 3 to FH [b]	D	-1.6 ± 6.2	0.437	-0.4 ± 4.8	0.759	0.625
	ND	5.9 ± 6.9*	0.024	4.9 ± 5.9*	0.010	0.722
Mx 6 to FH [a]	D	-6.0 ± 8.6	0.055	-4.7 ± 4.6**	0.003	0.670
	ND	1.1 ± 6.3	0.608	-0.9 ± 3.7	0.376	0.388
Mn 6 to FH [b]	D	-3.6 ± 4.0*	0.020	-4.1 ± 6.0*	0.031	0.828
	ND	3.2 ± 3.4*	0.015	2.5 ± 3.4*	0.020	0.316

*$p<0.05$, ** $p<0.01$,
Group comparison were tested with the independent t-test
a: positive and negative values indicate buccally and lingually inclined, respectively
b: positive and negative values indicate lingually and buccally inclined, respectively

IV. Discussion

The preorthodontic orthognathic surgery (POGS) has many advantages; decrease of total treatment time, avoid deterioration of facial esthetics and functional occlusion which can be present during pre-surgical orthodontic treatment (Liou et al., 2011; Min et al., 2014). However, without pre-surgical orthodontic treatment, surgical occlusion can be unstable and it is hard to predict post-surgical stability and maintain successful occlusion. Various reports have been published on skeletal and dental stability of POGS (Choi et al., 2016; Ko et al., 2013; Park et al., 2016). Most of them used lateral cephalogram for the assessment, and recently 3-dimensional studies using CT or CBCT are reported. However, few studies had compared transverse changes between conventional surgery (CS) and preorthodontic orthognathic surgery (POGS) with 3-dimensional images. This study evaluated progressive transverse dental axis changes with two different orthognathic surgery protocols (CS and POGS), and compared the changes between groups using 3D-CT.

Several studies had evaluated transverse analysis of skeletal Class III patients with CT or CBCT (Baek et al., 2012; Tyan et al., 2015). For the assessment of buccolingual inclination of maxillary and mandibular dentition in 3D-CT, we used the plane parallel to Frankfort horizontal plane, because the occlusal plane and mandibular plane can change during surgical procedure.

In CS group, buccolingually inclined teeth were uprighted during pre-surgical orthodontic treatment. However, there was no significant difference of buccolingual inclination between POGS and CS groups after pre-surgical orthodontic treatment (T1, Table 5). There still exists significant difference of buccolingual inclination between deviated and non-deviated in both groups due to skeletal asymmetry.

In both groups, during surgical correction, there was improvement of skeletal measurement including canting of maxilla, ramal length and mandibular body length which were the cause of the asymmetry. Also there were significant changes in buccolingual inclination of posterior teeth following surgical correction of skeletal discrepancy. Upper 1st molar on deviated side and lower 1st molar on non-deviated side inclined lingually, while lower 1st molar on deviated side and upper 1st molar on non-deviated side inclined buccally. The change was similar in canine but significant movement was observed on lower canine of deviated side in CS group. Due to the shape of mandible, smaller movement occurred in anterior segment by surgical correction of maxillomandibular complex, and this might appear to be the cause of the insignificant changes in canine.

This study demonstrates that, despite the pre-surgical orthodontic treatment was done for about 12 months in CS groups, total changes (T0 – T3) of buccolingual axis of canine and 1st molars showed no significant difference between CS and POGS groups (Table 9). This result is similar to the previous study (Wang et al., 2010). Considering the longer treatment time in CS group, preorthodontic orthognathic surgery might be an efficient treatment method for transverse control.

One year after the surgery, there was no significant difference of skeletal, dental measurements between CS and POGS groups. However, in POGS group, there exists significant difference of buccolingual inclination of posterior teeth between deviated and non-deviated side. During preorthodontic orthognathic surgery, it is hard to predict the amount of transverse decompensation when constructing surgical occlusion. In order to secure stability after the surgery, clinicians might tend to fabricate final wafer bite with more occlusal contacts. The iatrogenic factor such as insufficient prediction of the decompensation might lead to the difference of dental axis between deviation and non-deviation side. It is important to consider post-surgical dental axis change, when fabricating final wafer bite in preorthodontic orthognathic surgery. In the severely compensated case, we suggest that the pre-surgical orthodontic treatment with decompensation of the posterior teeth might be helpful for achieving satisfactory occlusion at the end of treatment. Except for the severe cases, with appropriate fabrication of final wafer bite, preorthodontic orthognathic surgery can achieve treatment goal in shorter time with fast improvement of facial esthetic.

The patients enrolled in this study received 2-jaw surgery with Le Fort I and intraoral vertical ramus osteotomy (IVRO). Since there is no rigid fixation in mandible, the distal segment shows tendency to move backward in CS group by post-operative change. In comparison with CS group, distal segment in POGS group moved superiorly due to elimination of occlusal interference. In this study, during post-surgical period (T2 - T3) mandibular body length decreased. The amount of decrease was greater in CS group although there was no significance between groups. This finding coincides with the previous studies (Choi et al., 2016; J. Y. Kim et al., 2014) that the distal segment moved backward in CS group, and moved superiorly in POGS group by post-surgical orthodontic treatment.

The asymmetry is affected by maxilla canting, ramus length, mandibular body length, ramal inclination, chin prominence and chin height (Baek et al., 2012; Hwang et al., 2007; Park et al., 2006). Tyan et al. (2015) reported that the roll type (similar in mandibular body length, different in ramus length with maxilla canting) showed greater transverse compensation and vertical height difference in maxillary molar compared with the translation type (similar in ramus length, mandibular body length without maxilla canting). It would be better to consider pre-surgical orthodontic treatment before surgery on roll type cases with severely tilted posterior teeth. In the present study, we did not subdivide asymmetry samples into more detailed type, but ramal inclination and mandibular body length were significantly different between deviated and non-deviated side in CS and POGS groups at initial. Further studies involving subdivision of asymmetry are indicated.

Making complete surgical occlusion generates predictable post-operative skeletal stability. However, it is time consuming and challenging procedure to decompensate buccolingually tilted dentition against physiologically adapted soft tissue. If we correct the skeletal discrepancy first, tooth movement of resolving compensated dentition becomes much easier and faster. In this study, duration of pre-surgical orthodontic treatment was approximately 12 months, and this is similar with previous studies (Dowling et al., 1999; Luther et al., 2003). Many studies reported that, by removing pre-surgical orthodontic treatment with preorthodontic orthognathic surgery, the entire treatment time can be reduced (Baek et al., 2010; Liou et al., 2011). With cautious case selection and precise treatment planning, preorthodontic orthognathic surgery can benefit the patient with skeletal discrepancy.

There are limitations in this study. First, some of the patients in POGS group still had orthodontic treatment at 1 year after the surgery. Second, the sample size was too small. Only twenty-nine patients enrolled in this study (CS group, n = 16; POGS group, n = 13). During 2-jaw surgery, the maxillomandibular complex rotates in 3-dimensional direction, which is not only rolling, but also pitch and yaw (Kim et al., 2015). To analyze transverse dental axis and progressive changes between intervals, we set the reference plane (Frankfort horizontal plane) and observed the dental axis in 2-dimension by projecting on frontal plane. If we subdivide the asymmetry case into roll type and translation type, it would be available to find detailed correlation between surgical changes and dental axis correction in 3-dimensional direction. As previously mentioned, due to small sample, we did not subdivide asymmetry in detail type. More samples with longer follow-up period would be indicated for further investigation.

V. Conclusion

Transverse dental axis changes of skeletal Class III patients with facial asymmetry who underwent orthognathic surgery were evaluated and were compared between conventional surgery group (CS group) and preorthodontic orthognathic surgery group (POGS group). The findings were as followings,

1. By pre-surgical orthodontic treatment in CS group, upper 1st molar and canine had shown tendency of uprighting, but there was no significant difference between CS and POGS group at 1 month before surgery (T1).

2. In POGS group, lower canine of non-deviated side and upper 1st molar of both side inclined lingually by post-surgical orthodontic treatment (T2-T3).

3. One year after the surgery (T3), skeletal and dental measurements were similar between CS and POGS groups. However, there was significant difference of buccolingual inclination of maxillary and mandibular molars between deviated and non-deviated side in POGS group.

4. Although in CS group the pre-surgical orthodontic treatment (T0-T1) was done for about 12 months, total changes of buccolingual inclination of canine and molar showed no significant difference between CS and POGS groups (T0-T3).

We concluded that, preorthodontic orthognathic surgery can be an efficient method for skeletal Class III patients with facial asymmetry in the aspect of shorter treatment time and immediate improvement of facial esthetics, and lead to almost the same treatment outcome comparing to conventional surgery. However, if there is severe difference of buccolingual inclination between deviated and non-deviated posterior teeth, conventional surgery with dental decompensation prior to orthognathic surgery would be a better surgical option for a relatively stable treatment outcome.

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국문 요약

비대칭을 동반한 골격성 III급의 술전교정 유무에 따른 횡적 치축 변화

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본 연구에서는 비대칭을 동반한 골격성 III급의 수술 전과 후의 횡적 치축 변화를 3차원 CT를 통해 분석하고, 선수술과 통상적인 악교정수술 간에 변화양상을 비교하였다.

총 29명의 골격성 III급 부정교합 환자 (남 : 15명, 여 : 14명) 가 선정되었으며, 이 중 16명 (남 : 10명, 여 : 6명, 평균나이 21.8 ± 2.2세) 은 통상적인 악교정수술로, 13명 (남 : 5명, 여 : 8명, 평균나이 21.0 ± 1.7세) 은 선수술로 치료받았다.

상하악 악교정수술은 상악은 Le Fort I osteotomy, 하악은 bilateral intraoral vertical ramus osteotomy (B-IVRO) 로 진행하였으며, 치료 시작 전 (T0), 수술 1달 전 (T1), 수술 3일 후 (T2), 수술 1년 후 (T3) 3차원 CT를 촬영하여 골격 및 치아계측 항목의 횡적 변화량을 분석한 결과 다음과 같은 결론을 얻었다.

1. 통상적 수술군에서 술전교정에 의해 (T0-T1) 상악 제1대구치와 견치는 직립되었으나, 술전교정을 했음에도 불구하고 수술직전 (T1) 통상적 수술군과 선수술군 간 상하악 치아의 협설측 치축경사에는 유의미한 차이가 없었다.

2. 수술 후 1년 동안 (T2-T3) 선수술군에서 좌우측 상악 제1대구치와 비편위측 하악 견치는 설측경사를 보였다.

3. 수술 1년 후 (T3), 술전교정 유무에 따른 상하악 견치와 제1대구치의 협설측 치축 경사의 유의할 만한 차이는 없었으나, 선수술군의 편위측-비편위측 제1대구치의 치축 경사는 차이가 다소 잔존하였다.

4. 통상적인 수술군의 술전교정 기간은 (T0-T1) 평균 12개월이었으나, 치료 전과 수술 1년 후의 (T0-T3) 상하악 견치와 제1대구치의

횡적인 치축변화는 통상적인 수술군과 선수술군 간 유의한 차이가 없었다.

안모비대칭을 동반한 골격성 III급에서, 선수술은 통상적인 악교정수술과 횡적인 치축 분석에서 비슷한 치료결과를 보이며, 치료기간의 단축 및 즉각적인 심미개선의 측면에서 효율적인 치료로 볼 수 있다. 하지만 편위-비편위측간의 협설 치축 경사 차이가 매우 심한 경우, 보다 안정적인 구치부 교합관계를 위하여 술전교정으로 decompensation을 어느 정도 시행한 후 악교정수술을 시행하는 것을 고려해볼 수 있겠다.

핵심 되는 말: 선수술, 비대칭, 골격성 III급, 3차원 CT, Decompensation, 횡적 치축 변화