3-Dimensional Positional Analysis of Mandibular Segments after Preorthodontic Orthognathic Surgery Using Intraoral Vertical Ramus Osteotomy in Class III Patients

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Directed by Professor Hyoung-Seon Baik

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This certifies that the Doctoral Dissertation

of Seo-Yeon Jung is approved.

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감사의 글

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이 논문이 찬란하고 즐거웠던 모교에서의 생활을 마무리할 즈음 나올 수 있게 되어 매우 기쁘게 생각합니다. 언제나 변함없는 사랑으로 격려해주시는 부모님과 시부모님, 묵묵히 곁에서 힘이 되어주는 남편에게 깊은 사랑을 전하며 이 기쁨을 나누고자 합니다.

2016년 6월

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The purpose of this study is to establish criteria on the predictability of preorthodontic orthognathic surgery (POGS) using intraoral vertical ramus osteotomy (IVRO) by measuring positional change of each bone segment immediately and 1-year after the surgery.

Thirty-eight patients of skeletal Class III malocclusion who had two-jaw orthognathic surgery by the same surgeon were included in this study. The patients had

menton deviation within 3 mm from skeletal midline, non-extraction orthodontic treatment, periodically taken multi-detector computed tomography (MD CT) data and no maxillofacial congenital abnormalities. Eight-teen patients who had orthodontic treatment prior to orthognathic surgery were included in the conventional surgery group (CS). Twenty patients who had surgery without presurgical orthodontic treatment were included in the preorthodontic orthognathic surgery group (POGS). Skeletal changes measured preoperatively (T0), two days after surgery (T1), and one year after surgery (T2) in two groups were compared using 3D CT. The results were as follows:

1. Proximal segment of mandible showed lateral (coronal, horizontal plane) and clockwise (sagittal plane) rotations, and mandibular condyle shifted in medial and anterior-inferior directions immediately after surgery. The movements returned to original positions, but not completely during the first year after the surgery. There was no significant difference between the two groups.

2. Posterior part of distal segment moved upward in the CS group, while both anterior and posterior part moved upward in the POGS group. Mandible rotated clock-wise in both groups.

3. The angle between distal segment and proximal segment 1 year after operation was greater in the CS group (9.1 ˚) compared to the POGS group (6.2 ˚). The rotation within matrix meant that POGS made the direction of the angle between two segments smaller compared to CS.

4. There was no significant difference of maxillary skeletal change between two groups. The maxillary second molars showed 1.2 mm, 1.32 mm intrusion during post-operative orthodontic treatment of POGS group.

Based on the results above, the change of proximal segment in the cases of POGS with IVRO on a patient with skeletal Class III malocclusion was not different from CS. If active physiotherapy is conducted using the conventional method, the proximal segment can be adapted in the physiological location regardless of the change in the occlusion. As POGS accompanies the movement of the distal segment itself as well as the teeth movement during the postoperative orthodontic treatment, and does not have an anterior occlusal stop, a close observation is necessary in order to prevent a formation of rotation fulcrum in an undesired location.

Keywords: Class III malocclusion, POGS, IVRO, 3-dimensional analysis, MD CT, proximal segment, distal segment

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I. Introduction

When performing orthodontic treatment accompanied by orthognathic surgery on a patient with skeletal Class III malocclusion, it has been the main method to initially form the stable postoperative occlusion through preoperative orthodontic treatment, perform the operation and complete the treatment by performing the postoperative orthodontic treatment (Jacobs and Sinclair, 1983). In this case, there is an advantage that stable occlusion can be obtained immediately after the operation. However, the disadvantages are that facial shape worsens compared to pretreatment, mastication function gets reduced due to the decompensation of teeth during the preoperative orthodontic treatment, and the total duration of treatment may increase if the tooth movement is not smooth due to occlusal interference (Dowling et al., 1999).

Due to recent advances in the diagnostic and treatment techniques, preorthodontic orthognathic surgery (POGS), which performs the operation first and then the postoperative orthodontic treatment, is preferably being conducted (Nagasaka et al., 2009). A number of advantages of POGS have been reported. POGS increases the efficiency of tooth movement by performing orthodontic treatment after correction of the skeleton, increases treatment cooperation of the patient by improving the facial shape first, and shortens total treatment duration; it has been reported in several literature that POGS receives higher satisfaction level from both the operator and orthodontist compared to the usual method of performing surgery after orthodontic treatment (Nagasaka et al., 2009). However, there are diverse opinions regarding the stability and predictability of the final occlusion and mandible location as the occlusion changes after surgery and the location of the bone segments can also change accordingly (C. S. Kim et al., 2014).

Especially, positional relationship between the bone segments could change in case of intraoral vertical ramus osteotomy (IVRO) for mandibular set-back surgery, because it does not fix the distal segment and the proximal segment, the postoperative proximal segment is located in the outer distal segment, and bone healing takes place while the direct contact is made between the cortical bones (Nihara et al., 2013). The proximal segment has an importance on recovery of normal jaw function after the surgery and postoperative stability (Jung et al., 2012; Ohba et al., 2014). Active physiotherapy takes place during the bone healing period, and in this process, remodeling takes place not only with the contact site of bony fragment but also with the surrounding structures (Bell et al., 1990). IVRO has advantages over sagittal split ramus osteotomy (SSRO) in terms of physiologic condylar position after surgery, but there are fewer researches on IVRO compared to SSRO regarding the postoperative stability.

The results of stability comparison between POGS and the conventional orthognathic surgery (CS) are being reported in a broad spectrum of literatures. However, there are not many researches on IVRO and preceding researches mostly used 2-dimensional lateral cephalometric radiographs (Jung et al., 2013). POGS differs from CS in the aspect that in POGS, the occlusal vertical dimension decreases over time from the heightened state. Also, in a research that used SSRO, it was found that, during this process, counter-clockwise rotation of the mandible takes place with the condylar head as the center (J. Lee et al., 2014).

As IVRO allows the movement of the postoperative segment, the movement pattern of the segment during the postoperative orthodontics would be different from SSRO. Therefore, the result should be predicted by analyzing the amount and direction of the locational change of each segment and this should be reflected when deciding the treatment plan. Since a 2-dimensional research has limitations in conducting this kind of analysis, 3-dimensional analysis using CT (computed tomography) is required.

Hence, this study intends to evaluate the postoperative predictability and stability by analyzing the change of each segment in 3-dimensional CT images, after performing the POGS that uses IVRO on patients with skeletal Class III malocclusion.

II. Subjects and Methods

1. Subjects

All subjects were skeletal Class III patients who had received a two-jaw surgery by the same surgeon at the department of Oral and Maxillofacial Surgery of Yonsei Dental Hospital between the years 2010 and 2014. Thirty-eight subjects were selected based on four common factors: 1) patients with menton deviation within 3mm of the midsagittal plane, 2) patients with neither cleft lip and palate, nor other severe type of maxillofacial congenital disorder, 3) patients with a history of receiving non-extraction orthodontic treatment, 4) patients with pre-surgical, immediate post-surgical and one-year post-surgical MD CT (Multi-detector CT) records.

The subjects were divided into two groups according to the time of their orthognathic surgery. 18 subjects (average age of 20.1 years old; 10 males; 8 females) had received orthodontic treatment prior to the orthognathic surgery (CS group, the control group) and their average orthodontic treatment period was 14.45 months. 20 subjects (average age of 20.3 years old; 12 males; 8 females) had no orthodontic treatment prior to the orthognathic surgery (POGS group, the experiment group).

This study followed the Declaration of Helsinki on medical protocol and ethics, and was approved by the regional Ethics Review Board of Yonsei Dental Hospital IRB (IRB No.2-2016-0004).

2. Surgical methodology

All subjects were diagnosed as skeletal Class III malocclusion. They were treated with LeFort I osteotomy and mandibular setback surgery using IVRO. Their maxillae were fixated using metal plates.

Masseter, pterygomandibular sling and medial pterygoid muscles that are attached to the mandible were extensively detached during IVRO. Intermaxillary fixation was conducted, with the cortical bone of the external area of the distal bone segment and the internal area of the proximal bone segment being in contact. All patients were subjected to 7 days of intermaxillary fixation, 5 weeks of active physiotherapy after removing the fixation, followed by post-surgical orthodontic treatment.

3. Stereoscopic image production, superimposition and segmentation

1) Reconstruction of three-dimensional (3D) model using CT images

The pre-surgical (T0), 2 days post-surgical (T1) and 1 year post-surgical (T2) CT (SOMATOM Definition AS, SIEMENS, Erlangen, Germany) images were used for the reconstruction of the 3D model. The CTs were taken under the condition of 120 mA, 100 kV, scanning time 1 sec., slice thickness 0.6 mm and field of view 24.1 mm. The image data were saved under Digital Imaging Communication In Medicine

(DICOM) form. Mimics 16.0 (Materialisen.v., Leuven, Belgium), a three-dimensional medical image program, was used to obtain 3D images of the identical craniofacial surface. The Hounsfield unit (HU) was set over 900 for a meticulous analysis of the tooth surface.

Artifacts occurred by orthodontic wire or appliance, and tooth fillings, in the CT images must be deleted for an accurate reconstruction of the tooth image. Artifacts that cannot be deleted by adjusting HU were removed by the voxel unit 'erase function' of the image program (Figure 1).

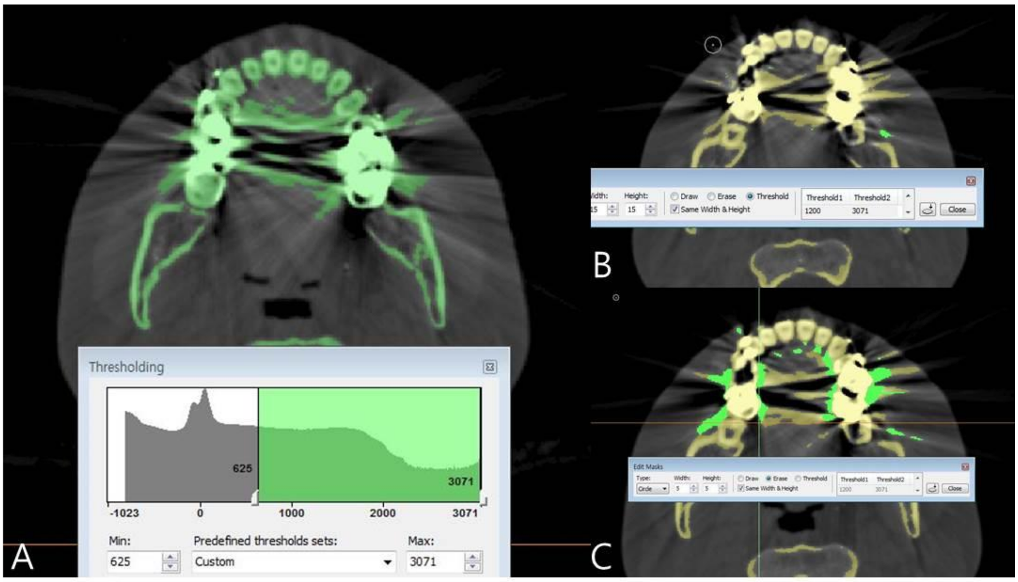

Figure 1. Thresholding for image reconstruction using Mimics 16.0 software (Materialise n.v., Leuven, Belgium)
A) Initial thresholding for bone reconstruction (minimum setting HU average, 600)
B) Thresholding for teeth reconstruction (HU above 950)
C) Erasing the artifacts by voxel units

2) Superimposition of pre-surgical (T0), 2 days post-surgical (T1) and 1 year post-surgical (T2) 3D images, and separation of the mandible from the cranial bone

Rapidform 2006 (INUS Technology, Seoul, Korea) program was used to overlap the T0, T1, T2 images of the cranial bone surface. The reference points were two supraorbital foramens (SO), two zygomaticofacial foramens (ZFF) and Lamda point (λ) of the occipital bone (Figure 2). These five points were chosen because they remain in constant position during orthognathic surgery. They were used for the overlapping process, with an error less than 0.2 mm (Figure 2-C).

Mimics 16.0 program was used to separate the mandible from the skull at T0, T1, and T2.

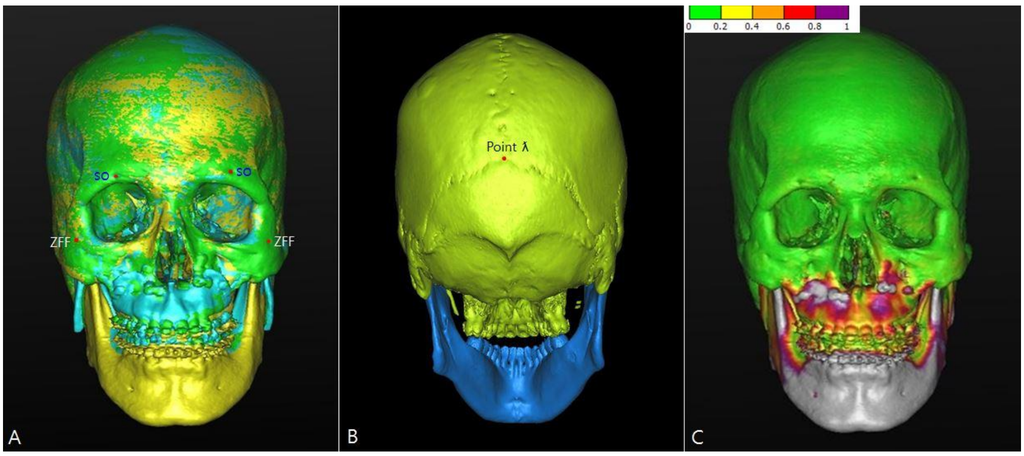

Figure 2. Superimposition of pre-surgical, 2 days post-surgical, and 1 year post-surgical 3D skull models

A) 4 Frontal points were used at different three times; pre-surgery (yellow), 2 days post-surgery (blue), 1 year post-surgery (green)

B) Point Lamda

C) Evaluation of the accuracy of superimposition using color diagram: error within 0-0.2 mm was displayed in green color and above 1.0 mm difference between objects in gray

4. Definition of reference plane, measuring points and measurement plane

Horizontal plane (FH plane) is defined as the plane passing both porion and the left orbitale. Midsagittal plane (MSP) is defined as a plane passing the Na point and P point, perpendicular to the FH plane. Coronal plane is not only perpendicular to FH plane and MSP but also passes the midpoint of both porion. The definition of each measuring points and measurement planes is as follows (Park et al., 2006).

1) Formation of the reference coordination system

a. Horizontal plane (FH plane) : the plane constructed by Right-Po, Left-Po, Left-Or

b. Midsagittal plane (MSP) : The plane constructed by Na, point P, and normal to MSP plane

c. Coronal Plane : The plane normal to MSP, FH plane passing through a point mid-Po

d. Na : The junction of the frontal nasal suture at the most posterior on the curve at the bridge of the nose

e. Point P (Prechyasmatic groove) : The vertical and transverse midpoint of prechyasmatic groove

f. Or (Orbitale) Rt & Lt : The lowest point on the infraorbital margin of each orbit (bilateral)

g. Po (Porion, anatomical) Rt & Lt : The highest midpoint on the roof of external auditory meatus

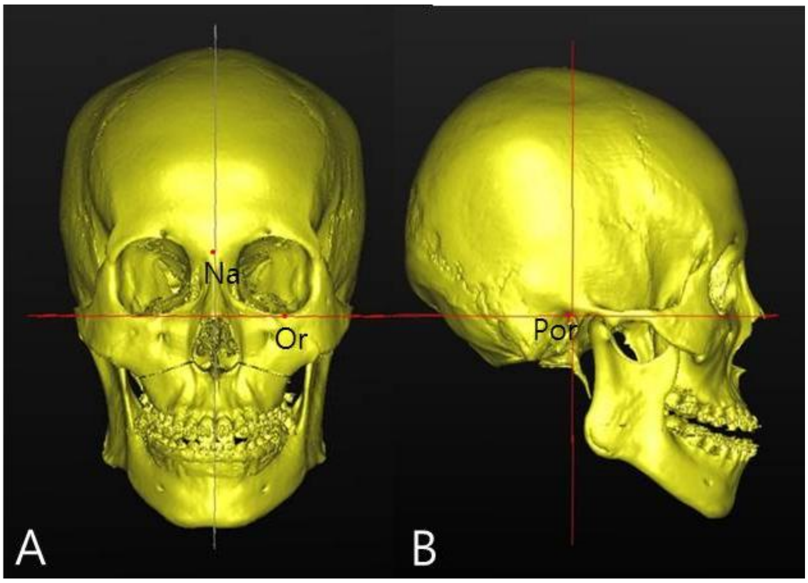

Figure 3. Construction of co-ordination system

A) Horizontal plane (FH) and midsagittal plane (MSP)

B) Coronal plane and FH plane

2) Definition and measurement of landmarks

(1) Maxilla landmarks

a. A point : Innermost curvature from maxillary anterior nasal spine to crest of alveolar process

b. PNS : Posterior nasal spine

c. U1 : The midpoint of incisal tip of the right upper incisor

d, e. #16, 26 : The mesiobuccal cusp tip of the first molar, Rt & Lt

f, g. #17, 27 : The palatal cusp of the second molar, Rt & Lt

(2) Distal segment of mandible landmarks (Figure 4)

a. B point : Innermost curvature from chin to alveolar bone junction

b, c. Mental foramen (MF) Rt & Lt : A foramen which transmits the terminal branches of the inferior alveolar nerve and vessels. The most anterior point of mental foramen is defined as MF

d, e. Mandibular foramen (F) Rt & Lt : A foramen passing through the mandibular nerve and vessels. The most inferior point of mandibular foramen is defined as F

f. mid-MF : The midpoint of both MFs.

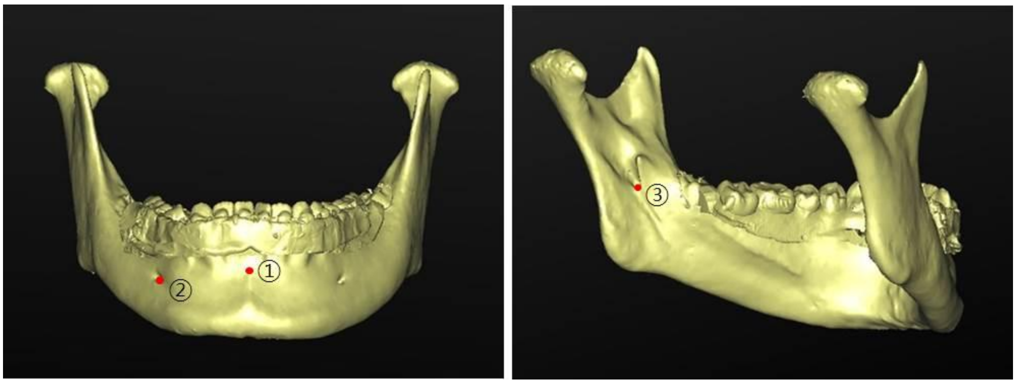

Figure 4. Reference points for distal segment

① B point, ② Mental foramen (MF), ③ Mandibular foramen (F)

(3) Proximal segment of mandible landmarks (Figure 5)

a, b. MCP Rt & Lt : The most medial point of the condylar head

c, d. LCP Rt & Lt : The most lateral point of the condylar head

e, f. Cp Rt & Lt : The most prominent posterior point of condyle

g, h. Go-post Rt & Lt : The most prominent posterior point of ramus posterior border

i, j. CON Rt & Lt : The most superior point of condylar head

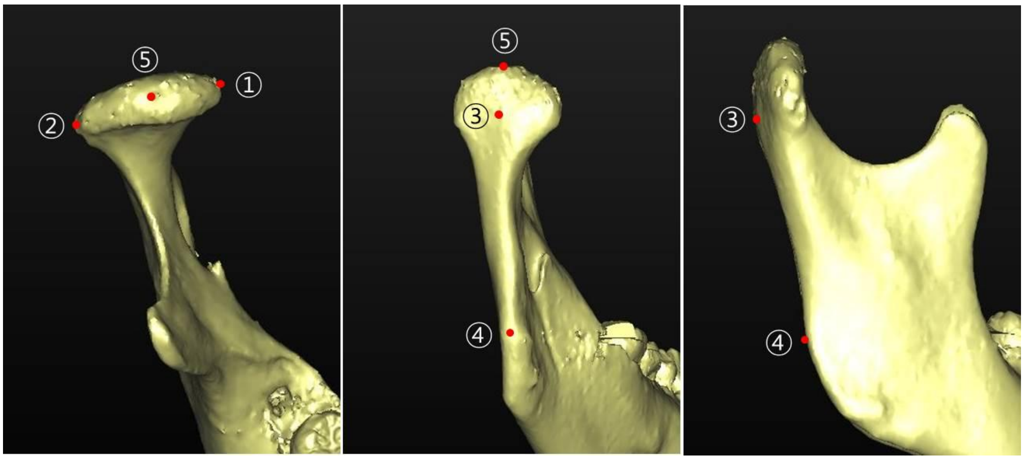

Figure 5. Reference points for proximal segment
① MCP, ② LCP, ③ Cp, ④ Go-post, ⑤ CON

(4) Definition of planes (Figure 6)

a. Palatal plane (PP) : A plane through point ANS, PNS and normal to MSP

b. Occlusal plane (OP) : A plane through point #16, 26 and U1

c. Mandibular plane (MP) : A plane through point R F, L F and mid-MF

d. Proximal segment plane (PxP) : A plane through point Cp, Go-post and normal to MSP

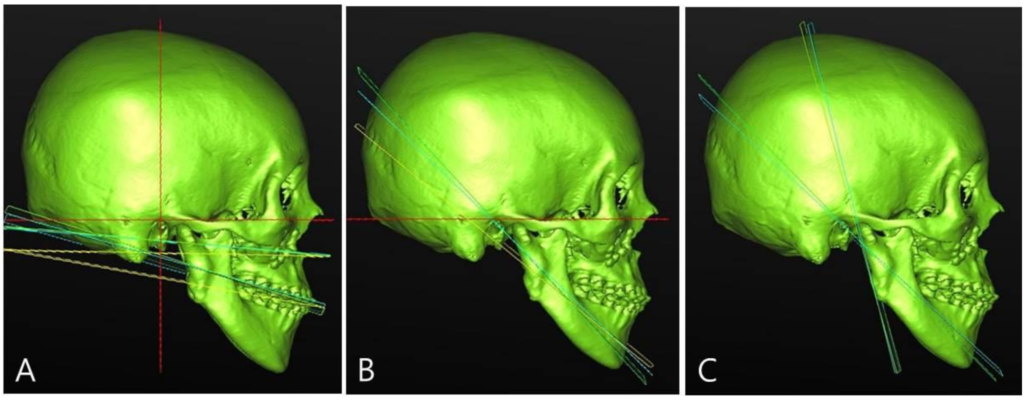

Figure 6. Reference planes

A) Palatal plane (PP) and occlusal plane (OP)
B) Mandibular plane (MP)
C) Proximal plane (PxP)

Pre-surgery (yellow), 2 days post-surgery (blue), 1 year post-surgery (green)

5. Measurement of positional change of the maxilla and mandibular distal segments

1) 2D measurement

① SNA : An angle between Sella-Nasion line and Nasion-A point line

② SNB : An angle between Sella-Nasion line and Nasion-B point line

③ ANB : The difference between SNA and SNB

④ Wits appraisal

⑤ SN-U1 : An angle between Sella-Nasion line and Apex-Incisal tip of upper incisor

⑥ IMPA :An angle between mandibular plane and Apex-Incisal tip of lower incisor

⑦ OJ : overjet

⑧ OB : overbite

2) Surgical movements (T1-T0) of maxilla-mandibular complex (T1-T0)

The difference between CS and POGS groups in change of the mandible and maxilla caused by the surgery was verified. The transverse displacement was not measured because the subjects did not have asymmetry. The 3D cranial models were superimposed at T0, T1, T2, and by sharing common reference points, all measurements were taken using common reference plane. Vertical change was measured vertical to the FH plane and the anterior-posterior (A-P) displacement was measured by using the coronal plane which passes the Po point. The measurement points were distributed in the same direction of the reference plane, thus, all the negative and positive values were of the same direction.

In the maxilla, the anterior representative points were U1 and A point, the posterior was PNS, thus allowing the measurement of the vertical and A-P displacement caused by the surgery. During the mandible set-back surgery using IVRO, the final position of the mandible was determined by the final occlusion of the lower teeth and upper teeth after the LeFort I osteotomy. The amount of mandibular displacement was measured using the anterior representative point mid-MF, as well as posterior representative points, Rt. F and Lt. F. These points were meaningful because they are unchangeable structures and are highly reproducible points.

(A) Maxilla

a. U1 : Vertical and antero-posterior change

b. A point : Vertical and antero-posterior change

c. PNS : Vertical and antero-posterior change

(B) Distal segment of mandible

a. mid-MF : Vertical and antero-posterior change

b. B point : Vertical and antero-posterior change

c. Rt./Lt. F : Vertical and antero-posterior change

(C) Angular changes after surgery

a. PP angle : Angle between FH plane and palatal plane

b. OP angle : Angle between FH plane and occlusal plane

c. MP angle : Angle between FH plane and mandibular plane

(D) Changes of OJ, OB

3) Change of maxillary landmarks between T1 and T2 (T2-T1)

A. Skeletal change: Vertical and A-P displacement of A point and PNS

B. Dental change: Vertical displacement of U1, #16, #26, #17, #27

C. Intrusion or extrusion of the tooth (⊿Dental) : Distance measurement of U1, #16, #26 on palatal plane

4) **Change of mandibular distal segment landmarks between T1 and T2 (T2-T1)**

A. Skeletal change:

Vertical and A-P displacement of mid-MF, B point, Rt. F, Lt. F

B. Measurement of change in angle and direction of FH-MP

6. Measurement of positional change of mandibular proximal segment at T0, T1 and T2

1) **Measurement of proximal segment change**

The proximal bone segment change was analyzed on three planes (the coronal, sagittal and horizontal) at T0, T1, and T2. To measure the proximal bone segment displacement on the coronal plane, a line passing through the right and left Cp and Go-post was projected onto the coronal plane. The angle between the projected line and the line created by the horizontal plane being projected on the coronal plane was then measured. To measure the change on the sagittal plane, the line passing through the right and left Cp and Go-post was projected onto the sagittal plane. The angle between the projected line and the line created by the horizontal plane being projected on the sagittal plane was then measured. To measure the change on the horizontal plane, the line passing through MCP and LCP of both condyles was projected onto the horizontal plane. The angle between the projected line and the line created by the sagittal plane being projected on the horizontal plane was then measured. For all three planes, the difference was measured between T1-T0 and T2-T1.

A positive value was given when proximal segment rotates laterally from the coronal plane, when it rotates clockwise from the sagittal plane, and when it rotates outward from the horizontal plane (Figure 7).

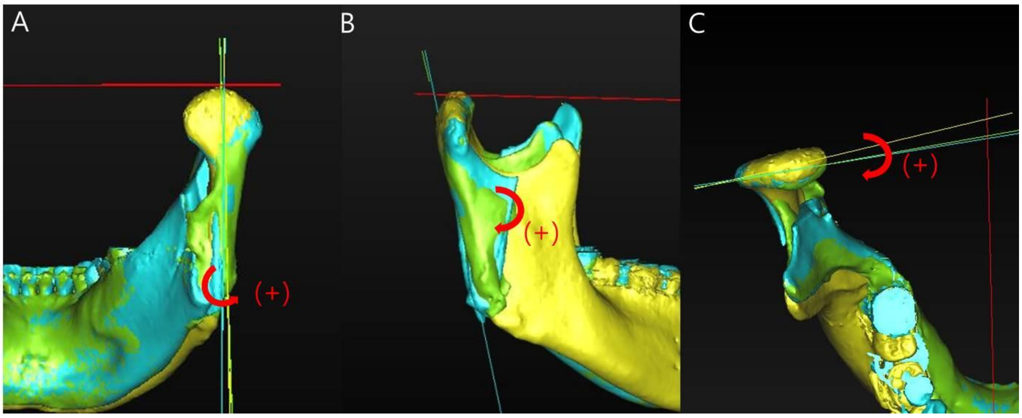

Figure 7. Positionsal change of proximal segment

A) Coronal change (COR), (+); Lateral flaring
B) Sagittal change (SAG), (+); Clock-wise rotation
C) Horizontal change (HOR), (+); Outward rotation

Pre-surgery (yellow), 2 days post-surgery (blue), 1 year post-surgery (green)

2) Change of the uppermost point of the condyle

The mandible condyle's uppermost point (CON) displacement was measured on the x, y, and z-axes at T0, T1 and T2. External and internal, upper and lower, anterior and posterior displacements of the condyle were evaluated.

7. Statistical analysis

1) All measurements were performed twice by one trained observer at one week interval. According to the paired t-test, there was no significant difference between measurements at the two time points.
2) Statistical analysis was carried out by using the PASW (Predictive Analytics Software) 18.0 (SPSS Inc., Illinois, U.S.A) program and p-values below 0.05 were judged as being statistically significant.
3) The comparison of the pre-surgical measurements (T0) between control group (CS) and treatment group (POGS) : Independent t-test
4) Statistical significance verification of the skeletal measurements between CS group and POGS group at (T1-T0) and (T2-T1) : Paired t-test
5) Statistical significance verification of the change in skeletal measurements between CS and POGS group at (T1-T0) and (T2-T1) : Independent t-test
6) Statistical significance verification of change in mandibular proximal segment between CS and POGS group at (T1-T0) and (T2-T1): repeated measures ANOVA, t-test

III. Results

1. Initial subject characteristics of POGS group and CS group (Table 1)

We measured the initial skeletal and dental characteristics on the lateral cephalograms for both groups. There was no significant difference between the groups except Wits appraisal.

The initial IMPA of group CS has mean 80.33 ˚ (S.D 3.99), the overjet was -2.03 mm (S.D 2.25), and the overbite was -0.77 mm (S.D 2.21). After the decompensation of lower anterior teeth, there was a statistically significant increase of IMPA and negative overjet by 4.96 ˚ and -1.69 mm (p=0.02), respectively, resulting in IMPA of 85.29 ˚ (S.D 4.55), overjet of -3.72 mm (S.D 3.53), and overbite of -0.43 mm (S.D 2.53).

Table 1. Initial cephalometric characteristics in CS and POGS groups

	CS group (n=18)		POGS group (n=20)		between groups
	Mean	**S.D.**	**Mean**	**S.D.**	**P***
Lateral Cephalometric variables					
SNA (°)	80.01	2.95	79.20	3.57	NS
SNB (°)	82.33	3.22	83.0	2.94	NS
ANB (°)	-2.32	1.19	-3.01	1.67	NS
Wits (mm)	-9.88	3.4	-13.04	1.94	*
FH-PP (°)	3.02	1.78	2.5	1.70	NS
FH-OP (°)	9.90	4.28	9.36	2.51	NS
FH-MP (°)	38.10	5.81	36.57	5.58	NS
U1 to SN (°)	108.2	7.44	108.76	5.33	NS
IMPA (°)	80.33	3.99	80.30	4.26	NS
Overjet (mm)	-2.03	2.25	-2.97	2.97	NS
Overbite (mm)	-0.77	2.21	-0.27	2.08	NS

CS group; Conventional surgery, POGS group: Orthognathic surgery without presurgical orthodontic treatment
*P<0.05, NS: not significant by independent t-test

2. Surgical movements (T1-T0) of maxilla-mandibular complex (Table 2)

The horizontal reference plane was above all measurement points and the vertical plane was posteriorly positioned than all points. Hence, a positive value represented an extrusive movement, and a negative value represented an intrusive movement in the vertical direction. As for the antero-posterior direction, a positive value represented a forward movement and a negative value represented backward movement.

CS group and POGS group demonstrated 0.39 mm, 0.38 mm anterior impaction, 4.5 mm, 3.95 mm posterior impaction, and 0.44 mm, 0.54 mm maxillary set-back, which were measured from the tip of right central incisors, respectively. The mean values of the amount of mandibular setback at the B point were 7.39 mm, 7.61 mm respectively. In the case of mandible, horizontal movement was greater than the vertical movement at the anterior portion. However, according to the maxillary posterior impaction, the vertical movement was dominant at the posterior portion which was represented by point F.

In the case of CS group, the right F point had moved 6.34 mm superiorly and the left F point had moved 6.93 mm superiorly. In the POGS group, the right F point had moved 5.67 mm and the left F point had moved 5.0 mm superiorly. The movement of the left F point was significantly different between that of CS and POGS group. According to the clock-wise rotation of the maxilla-mandibular complex, palatal plane angle, occlusal plane angle, mandibular plane were all increased.

Table 2. Comparison of 3D measurements between the landmarks of maxilla and mandible between pre and post-surgery (T1-T0)

Variables		CS group		POGS group		between groups
		Mean	**S.D.**	**Mean**	**S.D.**	**P***
Anteroposterior movement(mm)						
Maxilla	**U1**	-0.44	1.54	-0.54	2.63	NS
	A point	1.20	1.46	1.29	2.95	NS
	PNS	-0.93	1.81	-1.31	1.12	NS
Mandible	**mid-MF**	-7.9	3.86	-8.02	4.19	NS
	B point	-7.39	3.76	-7.61	4.03	NS
	Rt. F	-5.29	4.46	-6.37	4.25	NS
	Lt. F	-5.64	3.58	-6.39	4.43	NS
	OJ	4.97	4.03	6.22	3.73	NS
Vertical movement(mm)						
Maxilla	**U1**	-0.39	1.71	-0.38	1.43	NS
	A point	-0.93	1.81	-1.31	1.12	NS
	PNS	-4.50	2.01	-3.95	1.64	NS
Mandible	**mid-MF**	-3.98	1.72	-3.06	2.56	NS
	B point	-3.00	2.45	-2.83	2.92	NS
	Rt. F	-6.34	3.17	-5.67	2.81	NS
	Lt. F	-6.93	3.17	-5.00	2.58	*
	OB	1.64	2.60	0.51	2.05	NS
Angular changes(˚)						
	PP angle	2.26	2.99	3.37	2.65	NS
	OP angle	6.29	4.55	5.19	1.94	NS
	MP angle	3.15	4.05	2.67	4.29	NS

*P<0.05, NS, not significant by independent t-test
(+); Downward movement, (-); Upward movement

3. Change of maxillary landmarks at T2-T1 (Table 3)

From immediate post-operation time to 1-year after the operation, both CS group and POGS group demonstrated backward movement of A point; 1.13 mm and 1.33 mm respectively. CS group demonstrated 0.4 mm superior movement of A point which is statistically significant, whereas no significant vertical movement of PNS was observed in both groups.

In a case of skeletal Class III malocclusion patients, the rearmost teeth of maxilla are often extruded due to the absence of the occluding teeth and posterior downing rotation of the occlusal plane. Since POGS group did not undergo orthodontic treatment before the operation, the vertical occlusal dimension was heightened intra-operatively. Intrusion of the rearmost teeth by intrusive mechanics or the continuous action of masticatory muscle tends to achieve the proper vertical height. For this reason, we measured the vertical change of the palatal cusp of maxillary second molars and statistically significant difference was observed between two groups. In the case of POGS group, mean value for the intrusion of #17, 27 teeth were 1.2 mm, 1.32 mm, respectively.

Table 3. Comparison of 3D measurements between the landmarks of maxilla between 2 days post-surgery and 1 year post-surgery (T2-T1) (mm)

			CS group			POGS group			between groups
			Mean	S.D	P†	Mean	S.D	P†	P*
Skeletal	**A point**	**ver**	-0.4	0.62	††	0.02	0.7	NS	*
		AP	-1.13	0.77	†††	-1.33	0.86	†††	NS
	PNS	**ver**	0.1	0.67	NS	-0.13	0.58	NS	NS
		AP	-0.65	1.7	NS	-0.39	1.01	NS	NS
Dental	**U1**		-0.19	0.53	NS	0.24	0.56	NS	*
Vertical mov.(mm)	**#16**		0.26	0.61	NS	0.1	0.59	NS	NS
	#17		0.13	0.69	NS	-1.2	0.6	†††	***
	#26		0.03	0.54	NS	-0.67	1.30	NS	*
	#27		-0.19	0.58	NS	-1.32	0.52	†††	***
Δ Dental	**PP-U1**		-0.6	1.32	NS	0.1	0.53	NS	NS
	PP-16		-0.08	0.85	NS	0.14	0.33	NS	NS
	PP-26		-0.33	0.75	NS	-0.67	1.21	†	NS

PP-U1, the distance from palatal plane to U1; PP-16, the distance form palatal plane to #16 mesiobuccal cusp tip; PP-26, the distance from palatal plane to #26 mesiobuccal cusp tip
*P<0.05, **P<0.01, ***P<0.001, NS, not significant by independent t-test
†P<0.05, ††P<0.01, †††P<0.001, NS, not significant by paired t-test

4. Change of mandibular landmarks at T2-T1 (Table 4)

From immediate post-operation time to 1-year after the operation, mandibular foramens (F), which represent the posterior area of the mandible, had moved superiorly in both groups. In case of POGS group, mid-MF point, representing the anterior portion of the mandible, demonstrated 0.93 mm upward movement, showing bodily upward movement compared to that of the CS group. Since the upward movement of the posterior portion was greater than that of the anterior portion, mandible plane demonstrated the tendency of clock-wise rotation. The degree of clock-wise rotation of the mandible plane was 1.91 ˚ for the CS group and 1.48 ˚ for the POGS group. For both CS and POGS group, overbite increased significantly, and for the POGS group, overjet decreased significantly by 0.9 mm. Although there was no significant antero-posterior change of mid-MF point, B point demonstrated 0.79 mm and 0.93 mm posterior movement on CS group, POGS group, respectively.

Table 4. Comparison of 3D measurements between the landmarks of mandible between 2 days post-surgery and 1 year post-surgery (T2-T1)

		CS group			POGS group			between groups
		Mean	**S.D**	**P†**	**Mean**	**S.D**	**P†**	**P***
AP(mm)	**mid-MF**	-0.59	1.47	NS	-0.51	1.5	NS	NS
	Rt. F	0.71	2.22	NS	0.9	2.47	NS	NS
	Lt. F	0.33	2.25	NS	1.33	2.34	†	NS
	B point	-0.79	1.33	†	-0.93	1.3	††	NS
	OJ	0.06	1.05	NS	-0.9	1.27	†	*
Ver(mm)	**mid-MF**	-0.53	1.17	NS	-0.93	0.97	†	*
	Rt. F	-1.51	1.70	††	-1.84	1.93	†††	NS
	Lt. F	-1.4	1.5	†††	-2.22	2.63	††	NS
	B point	-0.35	0.95	NS	-0.3	1.24	NS	NS
	OB	0.41	0.56	††	1.52	0.84	†	*
Angular(°)	**FH-MP**	1.91	2.8	††	1.48	2.57	†	NS
	PxP-MP	9.1	4.45	†††	6.19	5.24	†††	*

*P<0.05, **P<0.01, ***P<0.001, NS, not significant by independent t-test
†P<0.05, ††P<0.01, †††P<0.001, NS, not significant by paired t-test

5. Change of proximal segments and the uppermost point of the condyle at T1-T0, and T2-T1 (Table 5, 6, Figure 8)

In both groups, proximal segments showed lateral flaring from the mid-sagittal plane, and clockwise rotation at sagittal view, outward rotation at horizontal view immediately after the surgery. After 1 year of surgery, there was a tendency of recovery to pre-surgical position, which showed statistically significant change using repeated measures ANOVA test. Statistical analysis didn't meet Mauchly's sphericity, resulted in use of Greenhouse-Geisser coefficient. There was no difference between two groups, at each time point.

On the coronal plane, the line passing through Cp and Go-post showed lateral flaring tendency after surgery, by 6.1 ˚ (S.D 3.56) on CS group and by 6.53 ˚ (S.D 3.85) on POGS group. After 1 year from surgery, the line showed a tendency of recovery by 1.69 ˚ (S.D2.11) and 2.05 ˚ (S.D 2.25) medially, on CS and POGS group respectively, without any significant difference.

On the sagittal plane, the line passing through Cp and G-Post showed clockwise rotation after surgery by 8.19 ˚ (S.D 4.38) and 8.79 ˚ (S.D 3.61) on CS group and POGS group, respectively. The line rotated to counter-clockwise direction by 5.66 ˚ (S.D 4.8) and 5.79 ˚ (S.D 3.84) on CS and POGS group, respectively, during the postoperative 1 year.

On the horizontal plane, the line passing through MCP and LCP rotated outward from mid-sagittal plane by 9.36 ˚ (S.D 5.42) and 10.45 ˚ (S.D 6.04), and recovered to opposite direction by 4.06 ˚ (S.D 3.17) and 3.13 ˚ (S.D.4.46) in CS and POGS groups, respectively, within 1 year of the surgery.

Since mandibular condyle may affect post-operative stability and TMD, we measured the movement of the uppermost point of the condyle at each plane. The tendency of condylar movement was similar in both groups, showing 0.6 mm of medial movement at T1, and 0.2-0.3 mm of recovery at T2. There was a significant difference of antero-posterior movement; 1.09 mm (S.D 1.29) anterior movement on CS group and 1.78 mm (S.D 1.49) on POGS group. One year after surgery, it was recovered backward by 0.49 mm (S.D 0.86) on CS group, and 1.01 mm (S.D 0.91) on POGS group. Both groups showed vertical movement of 2.5 mm to the downward direction at T1 and recovered about 2.1 mm during T2-T1. The final position of the mandibular condyle was 0.4 mm medial, 0.6 mm anterior, and 0.52 mm inferior to the original position in the CS group, and 0.31 mm medial, 0.77 mm anterior, 0.32 mm inferior in the POGS group, but all of these differences were statistically insignificant.

Table 5. Angular changes of proximal segment between 2 days post-surgery and 1 year post-surgery (T2-T1) (˚)

		CS group			POGS group			between groups	
		Mean	**S.D**	**P†**	**Mean**	**S.D**	**P†**	**P***	**Prm**
COR	**T1-T0**	6.10	3.56	†††	6.53	3.85	†††	NS	0.94
	T2-T1	-1.69	2.11	†††	-2.05	2.25	†††	NS	
	T2-T0	4.41	3.21	†††	4.47	3.12	†††	NS	
SAG	**T1-T0**	8.19	4.38	†††	8.79	3.61	†††	NS	0.68
	T2-T1	-5.66	4.80	†††	-5.79	3.84	†††	NS	
	T2-T0	2.53	4.52	†††	3.03	4.29	†††	NS	
HOR	**T1-T0**	9.36	5.42	†††	10.45	6.04	†††	NS	0.08
	T2-T1	-4.06	3.17	†††	-3.13	4.46	†††	NS	
	T2-T0	5.31	4.35	†††	7.32	4.13	†††	NS	

COR, angular changes of proximal segments at coronal view, (+) lateral flaring away from MSP, (-) medial flaring form MSP
SAG, angular changes at sagittal view, (+) clock-wise rotation, (-) counter-clockwise rotation
HOR, angular changes at horizontal view, (+) outward rotation, (-) inward rotation
*P<0.05, NS, not significant by paried t-test
†P<0.05, ††P<0.01, †††P<0.001, NS, not significant by paired t-test
Prm<0.05,NS, not significant by repeated measures ANOVA test (p-value)

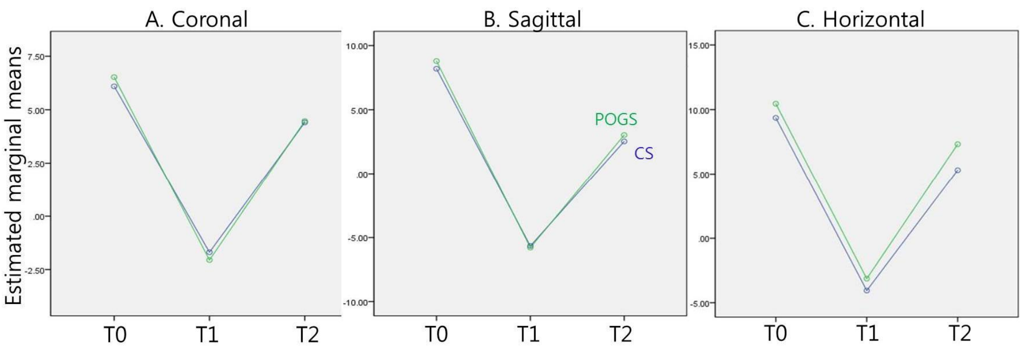

Figure 8. Results of repeated measures ANOVA test; variables are time interval and groups

A) Coronal change (COR), B) Sagittal change (SAG), C) Horizontal change (HOR)

Table 6. Comparison of 3D measurements of CON between 2 days post-surgery and 1 year post-surgery (T2-T1) (mm)

		CS group		POGS group		between groups
		Mean	**S.D**	**Mean**	**S.D**	**P***
CON(x)	**T1-T0**	-0.61	0.87	-0.63	0.77	NS
	T2-T1	0.22	0.63	0.32	0.51	NS
	T2-T0	-0.40	1.01	-0.31	0.77	NS
CON(y)	**T1-T0**	1.09	1.29	1.78	1.49	*
	T2-T1	-0.49	0.86	-1.01	0.91	*
	T2-T0	0.60	1.32	0.77	1.1	NS
CON(z)	**T1-T0**	2.59	1.34	2.54	1.43	NS
	T2-T1	-2.07	0.90	-2.21	1.07	NS
	T2-T0	0.52	1.02	0.32	1.03	NS

CON(x), external/internal movement to MSP, (-) internal, (+) external
CON(y), antero-posterior movement, (-) postero-movement, (+) antero-movement
CON(z),vertical movement, (-) superior, (+) inferior
*P<0.05, NS, not significant by paried t-test

IV. Discussion

The introduction of 3-dimensional computed tomography (3D CT) for the analysis of complex craniofacial structure has improved the research accuracy and reproducibility (Cevidanes et al., 2011; T. Y. Lee et al., 2014). The traditional 2-dimensional (2D) analysis with lateral cephalograms often resulted in inaccurate measurements and distorted representation of anatomic structures (Baumrind et al., 1976; Lagravere et al., 2010). Especially when evaluating the serial surgical changes of the condyles, magnification, distortion, reproducibility of the projection, direction of the beam and accurate superimposition methods were all limited (Athanasiou and Mavreas, 1991). Accurate measurement of few structures like condylar head was difficult using previous method due to accessibility. However, with 3D CT data, the accurate treatment planning and measurement of all structures became possible, as the structure can be separated and superimposed through the use of a program that reconstructs single-layer image as well as 3D image (Kang et al., 2015; Uribe et al., 2013). 3D analysis can produce more accurate measurement of distance and angle between points and lines compared to 2D analysis, the reference plane and measurement point, line and plane should be set carefully. When comparing the 3D models of three time points as per this research, it is more effective to make the measurement by superimposing the 3D images and sharing one coordination system compared to setting the reference planes for each plane image.

The point, surface and voxel can be used when superimposing the solid models (Baik and Kim, 2010). The superimpositions using surface and voxel are the most widely used methods and it has been reported that there is no difference in accuracy between the two methods (Almukhtar et al., 2014). The surface superimposition was performed in this study using the structure of the upper part of LeFort I osteotomy line that was not changed by the operation, and the measurement was made after confirming that the error of superimposition was below 0.2 mm.

Inappropriate condylar position after orthognathic surgery could induce idiopathic condylar resorption, functional limitation, pain and postoperative relapse (Costa et al., 2008; Jung et al., 2015; Rebellato et al., 1999). Positional changes of condyles after IVRO and SSRO have been reported in several clinical and experimental studies (Bell et al., 1990; Feinerman and Piecuch, 1995; Ueki et al., 2002). In case of IVRO, among the several advantages of the procedure, physiologic placement of the proximal segments with postoperative physiotherapy is clinically important (Jung et al., 2012). It had been reported that the proximal segment rotated outward immediately after the surgery, but the degree of recovery tendency and displacement of the condylar head were variant (Kawamata et al., 1998; Ohba et al., 2014; Ueki et al., 2005). Choi et al studied the change of the proximal segment in the horizontal plane after IVRO using SMV X-ray and reported that the location of the center of condylar head was not changed while the proximal segment rotated by 15.05 ° outward and decreased to 4.53 ° one year after the surgery (Choi et al., 2013). Zhao et al reported antero-inferior displacement and lateral tilting of the proximal segments after IVRO in monkeys (Zhao et al., 2007). In this experimental study, they suggested that the antero-inferior condylar displacement induced fibrous cartilage to enter an activated state and articular cartilage and bone tissue were increased histologically, which meant favorable alteration of the disc-condyle relationship (Zhao et al., 2007).

In this study, we did not find the evidence of difference in the change pattern of the proximal segments in coronal, sagittal and horizontal planes and the locational change of the uppermost point of the condylar head (CON) between POGS group and CS group. When observed in the coronal plane, the long axis of proximal segment underwent lateral flaring by 6.1 ˚ and 6.53 ˚ in CS and POGS group with respect to the MSP, and was restored to original orientation by 27.7% and 31.3% respectively for one year after surgery. Compared to the previous studies, the rate of recovery was low, potentially due to the difference of the amount of mandibular set-back. When observed in the sagittal plane, it rotated clockwise by 8.19 ˚ and 8.79 ˚ right after the operation, and was restored by 69.1% and 65.9% on CS and POGS group; this seemed to be the rotation by the action of masseter and medial pterygoid muscle during physiotherapy. There was no significant change of ramal inclination during post-operative orthodontic treatment in POGS group. When observed in the horizontal plane, the front of condylar head rotated outward by 9.36 ˚ and 10.45 ˚, and was restored by 43.4% and 30.0%, respectively. Since the distal segment moved backward and overlapped with the proximal segment, it was not able to be completely restored to the original position. It is thought that subperiosteal, cortical bone derived, and endosseous callus got formed, remodeled during physiotherapy, and adapted at the new position. The final CON point position was seen inward, forward and downward by 0.4 mm, 0.6 mm and 0.52 mm, respectively for the CS group, and 0.31 mm, 0.77 mm and 0.32 mm, respectively for the POGS group. This result demonstrated that the condyles were set in the physiologic position regardless of the postsurgical occlusal change in IVRO.

In cases of POGS, the change in occlusal vertical dimension is accompanied during the postoperative orthodontic treatment (Alsafadi et al., 2016; J. Lee et al., 2014). Evidences suggested that intrusion of molars using skeletal anchorage systems can cause mandibular counter-clockwise rotation about 2.3 ° to 3.9 ° (Alsafadi et al., 2016). Also, there have been reports on the aspect of counter-clockwise mandibular autorotation taking place with a center of rotation on the condylar head as the occlusal interference settled, which was presented as a change of ramal inclination after POGS using SSRO (Baek et al., 2010; Ko et al., 2013). However, there has been no report on what kind of change occurs when IVRO is performed without the fixation of proximal and distal segment.

There have been many studies on the relapse and stability of mandible after setback surgery (Chen et al., 2011; Costa et al., 2001). The factors that affect the stability of maxilla-mandibular complex include the stretching of soft tissue, neuromuscular adaptation and muscle orientation. Proffit et al have stated that forward movement of 2.7 mm takes place at B point one year after the surgery and many other studies after also showed anterior relapse of about 25-38% (Proffit et al., 2012).

In the case of IVRO procedure, the results on stability are different by the time of measurement and by research, and there is a lack of research compared to SSRO. IVRO differs from SSRO or other fracture in healing aspect; the healing takes place as the contact occurs between unfixed cortical bones (Arimoto et al., 2013). The stability of IVRO is determined by the healing process of the two overlapped segments and ongoing repositioning of the condyles through postoperative early mobilization (Ghali and Sikes, 2000). Some studies have reported that the backward movement of about 0.5~1.2 mm takes place at the pogonion point one year after the surgery (Ayoub et al., 2000; Greebe and Tuinzing, 1982; Jung et al., 2013; Yoshioka et al., 2008) and in the study by Kitahara et al, the pogonion and menton moved backward and upward (Kitahara et al., 2009). However, Chen et al have reported the anterior relapse of 1.3 mm after two years (Chen et al., 2011) and Nihara et al have reported that the mental region rotated in the postero-inferior direction immediately after removing the intermaxillary fixation until 3 months after the operation; however after 3 months, there was forward movement when making long- term observation of about 2 years (Nihara et al., 2013).

In this study, using the advantage of CT superimposition, mental foramen and mandibular foramen were selected representing the front portion and rear portion of the mandible that were not changed after surgery and highly reproducible. Since they were not the most anterior point of the mandible, B point was also included in the measurement. There was a backward movement of B point in both groups 1 year after surgery and showed results of 0.79 mm for CS group and 0.93 mm for POGS group, which is similar to the result of previous study by Jung et al (Jung et al., 2013). Vertically, both groups had upward movement of about 1.4-2.2 mm on Rt. F and Lt. F, and in the case of POGS group, the mid-MF point showed significant upward movement by 0.93 mm. As there was a larger amount of vertical movement of the posterior portion compared to the anterior portion, both groups showed clock-wise rotation of 1.91° and 1.48°, respectively. The FH-MP angle was measured by the plane without remodeling after surgery, representing that intrinsic rotation took place rather than the remodeling of gonial area.

The proximal plane angle increased by 9.1 °, 6.19 ° on CS group and POGS group, respectively, during 1 year after surgery with a significant difference between groups. In the POGS group, it appeared that the adaptation took place in the direction in which the front portion of the distal segment moved upwards and the intra-matrix rotation became smaller than CS group.

The previous studies about the positional change of mandible after POGS have reported increased anterior relapse than CS due to postoperative occlusal instability (Baek et al., 2010; Leelasinjaroen et al., 2012). Ko et al have stated that the overbite is the predictor of the vertical movement of mandible after POGS (Ko et al., 2013), and Lee et al have reported that for POGS, a plan must be set in consideration of the increased occlusal vertical dimension (J. Lee et al., 2014). However, most of the existing studies were the ones that used SSRO and as stated above, there is a difference in procedure between SSRO and IVRO. Hence, more research is needed on the stability of POGS using IVRO.

Kim et al have reported the stability after POGS by studying the cases of 37 patients with skeletal Class III malocclusion who received POGS using IVRO, reporting the anterior relapse of 0.6 mm and superior relapse of 2.9 mm after 1 year but no remarkable difference in CS in 2D study (J. Y. Kim et al., 2014). Choi et al compared the stability of CS and POGS group after IVRO surgery and reported that the distal segment moved upward by 1.9 mm at 1 year post-surgery in POGS group, and horizontal and vertical changes were linearly correlated with the amount of set-back (Choi et al., 2016). In this 3D study, the upward movement of 0.93 mm of the front portion of mandibular distal segment occurred in the POGS group, and this difference, as well as ones in previous studies, is thought to have been caused by the difference in the degree of instability of the preoperative occlusion. Although there was a statistically significant difference in superior displacement of the anterior portion of mandible between CS and POGS group, the degree of difference was within the range that could normally occur after IVRO surgery (Jung et al., 2013). As this study used the data at two days and one year after surgery, it was difficult to analyze the exact point in time when the displacement took place. However, in existing studies that measured the shorter interval by lateral cephalograms, it has been reported the segment movements take place within 6 months of the operation (Arimoto et al., 2013; J. Y. Kim et al., 2014; Ohba et al., 2014). It was supposed that the major dental change took place within 6 month after the surgery, due to the regional acceleration phenomenon (RAP) resulting in a decrease of vertical dimension, and the movement of distal segment also took place in this period (Wilcko et al., 2009; Wilcko et al., 2001).

In Class III malocclusion, extrusion of the maxillary second molars is relatively common due to the absence of occluding mandibular dentition. In POGS group, the vertical dimension is heightened while setting the surgical occlusion, usually because of these rearmost maxillary molars as well as other occlusal interferences. After surgery, the occlusal dimension is getting reduced by direct intrusive mechanics or muscle force (J. Lee et al., 2014). Among 20 patients in POGS group in this study, direct intrusion was conducted on 10 patients (50%) with the skeletal anchorage system on the maxillary second molar, while a reverse curve of Spee was given to orthodontic wire and MEAW was used for 3 patients (15%). For one patient (5%), step down bend was given to the maxillary first and second molars on both sides.

This study showed no difference in the displacement aspect of proximal segment and the final location of the condylar head between POGS and CS groups, verifying that POGS can also be used for treatment stably with IVRO and implying the difference between IVRO and SSRO in change of ramal inclination during occlusal change. The upward movement of the anterior portion of distal segment in the POGS group was noted, which demonstrated the bodily movement of distal segment as well as the teeth movement during the postoperative orthodontic period. Although the degree of movement was not significant, surgeons should consider such superior relapse tendency when planning treatment for POGS, and orthodontists should observe whether the rotation fulcrum of the distal segment takes place at an unintended location during postsurgical orthodontic phase. As this study is limited to 1 year after surgery, a longer-term follow-up study is required. Additionally, a more detailed classification of the degree of vertical dimensional change with a larger sample would serve as a valuable further study on the stability of POGS.

V. Conclusion

This study compared the positional change of bone segments after POGS to CS using IVRO. All the subjects were skeletal Class III patients who had received a two-jaw surgery, and were divided into two groups according to the time of their surgery. 18 subjects (average age of 20.1 years old; 10 males; 8 females) had orthodontic treatment prior to the surgery (CS group, the control group) and 20 subjects (average age of 20.3 years old; 12 males; 8 females) had no orthodontic treatment prior to the surgery (POGS group, the treatment group). The pre-surgical (T0), 2 days post-surgical (T1) and 1 year post-surgical (T2) MD CT images were used to measure the change of each bone segment.

1. Proximal segment of mandible showed lateral (coronal, horizontal plane) and clock-wise (sagittal plane) rotations, and mandibular condyle shifted in medial and anterior-inferior directions immediately after surgery. The movements returned to original positions, but not completely during the first year after the surgery. There was no significant difference between the two groups.

2. Posterior part of distal segment moved upward in the CS group, while both anterior and posterior part moved upward in the POGS group. Mandible rotated clock-wise in both groups.

3. The angle between distal segment and proximal segment 1 year after operation was greater in the CS group (9.1 °) compared to the POGS group (6.2 °). The rotation within matrix meant that POGS made the direction of the angle between two segments smaller compared to CS.

4. There was no significant difference of maxillary skeletal change between two groups. The maxillary second molars showed 1.2 mm, 1.32 mm intrusion during post-operative orthodontic treatment of POGS group.

Based on the results above, the change of proximal segment in the cases of POGS with IVRO on a patient with skeletal Class III malocclusion was not different from CS. Also, if active physiotherapy is conducted using the conventional method, the proximal segment can be adapted in the physiological location regardless of the change in the occlusion. As POGS accompanies the movement of the distal segment itself as well as the teeth movement during the postoperative orthodontic treatment, and does not have an anterior occlusal stop, a close observation is necessary in order to prevent a formation of rotation fulcrum in an undesired location.

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국문요약

구강내 수직 골절단술을 이용한 골격성 제 III급 부정교합의 선수술 후 하악골 골편 변위의 3차원적 분석

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정 서 연

본 연구에서는 골격성 제 III급 부정교합 환자에서 IVRO를 이용하여 선수술을 시행했을 시 수술 직후와 수술 1년 후 사이의 하악골 골편의 변화 양상을 측정하여 결과의 예측성에 대한 기준을 마련하고자 하였다.

동일한 술자에 의해 양악을 동시에 악교정 수술을 시행받은 골격성 제 III급 부정교합 환자 중, 안모중심선에 대하여 이부의 변위가 3 mm 이내이며 비발치로 교정 치료를 시행하고, 기타 악안면의 성장 발육 부전을 동반하지 않으며, 일정한 간격으로 MD CT를 시행한 자료가 있는 환자 38명을 연구대상으로 하였다. 이중, 술전 교정치료를 시행한 후 악교정 수술을 시행한 환자 18명을 통상의 악교정 수술군 (Conventional surgery, CS)으로, 수술전 교정 치료를 시행하지 않은 환자 20명을 선수술군 (Preorthodontic orthognathic surgery, POGS)으로 구분하여 술전 (T0), 수술 2일 후 (T1), 수술 1년 후 (T2)에 촬영한 CT 자료를 이용하

여 골격적 변화를 계측한 후 두 군을 비교하여 다음과 같은 결과를 얻었다.

1. 하악골 근심 골편은 술직후 외측(관상, 수평 평면), 시계방향(시상 평면)으로 회전하고 하악 과두는 전,내,하방으로 이동하며 술후 1년 동안 원래의 방향으로 회복하나 완전히 회복하지는 못하며, 이는 두 군 사이의 차이가 없었다.
2. 하악골 원심 골편은 수술 후 1년 동안 CS군에서는 후방부가 상방 이동하고, POGS 군에서는 전, 후방부가 모두 상방 이동하며, 두 군 모두 하악골은 시계방향으로 회전하였으며 이부는 후방으로 이동하였다.
3. 수술 1년 후 하악골의 매트릭스 내 회전은 두 골편이 벌어지는 방향으로 발생하였으며, 원심 골편과 근심 골편 사이의 각도 차이는 CS군(9.1˚)이 POGS군(6.2˚)보다 유의하게 컸다 (p=0.01).
4. 수술 1년 후 상악골의 골격적 계측점의 변화는 두 군 사이의 유의한 차이가 없었다. POGS군에서는 술후 교정치료 진행 중 상악 양측 제2대구치의 1.2 mm, 1.32mm 함입이 발생하였다.

이상의 결과를 바탕으로 IVRO를 이용한 골격성 제 III급 부정교합 환자의 선수술시 근심 골편의 변화는 술전 안정적인 최종 교합을 형성한 후 수술을 시행하는 방법과 차이가 없으며, 통상의 방법대로 활성적 물리치료를 시행한다면 근심 골편은 교합의 변화와 관계없이 생리적인 위치에서 적응될 수 있음을 알 수 있었

다. 또한 POGS는 술후 교정치료 중 치아의 이동과 함께 원심 골편 자체의 이동이 동반되고, 전방부 교합 접촉이 없으므로, 원심 골편의 회전축이 원하지 않는 곳에 형성되지 않도록 술후 교정치료 중 면밀한 관찰이 필요하다.

핵심단어 : 골격성 제 III급 부정교합, 선수술, 구강내 수직 골절단술, 근심 골편, 원심 골편, 3차원 분석