Changes in mandible and masseter muscle following method of orthognathic surgery in skeletal Class III patients with facial asymmetry

Ah Kyung Cho

The Graduate School
Yonsei University
Department of Dentistry

Changes in mandible and masseter muscle following method of orthognathic surgery in skeletal Class III patients with facial asymmetry

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Ah Kyung Cho
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This certifies that the dissertation thesis of

Ah Kyung Cho is approved.

Hyung Seog Yu

Thesis Supervisor : Hyung Seog Yu

HYoung Seon Baik

Hyoung Seon Baik

Chung Ju Hwang

Sang Hwy Lee

Sang Hwy Lee

GJ Kim.

Gi Jung Kim

The Graduate School

Yonsei University

June 2015

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지금의 제가 있기까지 헌신적인 사랑으로 항상 믿고 격려해 주시는 사랑하고 존경하는 아빠, 엄마께 진심으로 감사드리고, 부족한 며느리를 언제나 아끼고 이해해주시는 시부모님과 사랑하는 가족 모두에게 깊이 감사드립니다.

마지막으로 논문이 완성될 수 있도록 항상 따뜻하게 감싸주고 도와준 사랑하는 남편, 그리고 너무도 소중한 우리 이쁜 상묵이와 영묵이에게 무한한 사랑과 감사의 마음을 전하며 이 기쁨을 함께 나누고자 합니다.

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Abstract

Changes in mandible and masseter muscle following method of orthognathic surgery in skeletal Class III patients with facial asymmetry

Ah Kyung Cho

Department of Dentistry, Graduate School, Yonsei University

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

The aim of this study was to evaluate changes of gonial angle area in skeletal Class III patients with facial asymmetry following two kinds of orthognathic surgery, sagittal split ramus osteotomy (SSRO) and intraoral vertical ramus osteotomy (IVRO). Using computed tomography (CT), one study was conducted on 20 skeletal Class III patients with facial asymmetry who had undergone SSRO orthognathic surgery at K University Hospital. Measurements from the reconstructed three-dimensional (3D) CT images were compared from T0 (before surgery) and T1 (1 year after surgery). Another longitudinal study was conducted on 17 skeletal Class III patients with facial asymmetry who had undergone IVRO orthognathic surgery at Y University Hospital. Measurements from the reconstructed 3D CT images were compared from T0 (before surgery), T1 (1 year after surgery), and T2 (4 years after surgery). The mandibular total volume, intergonial width, mandibular gonial angle area volume, the maximum cross-sectional area (MCSA) and angle of the

masseter muscle were measured from the reconstructed 3D CT images. Using 3D CT images, we evaluated this data on the deviated side and non-deviated sides. We also compared this data between SSRO group and IVRO group. The correlation between the degree of facial asymmetry and postoperative changes of mandibular gonial angle area volume and the maximum cross-sectional area of the masseter muscle were assessed and analyzed with the following results.

1. When comparing the mandibular change, during T0-T1, a significant decrease was noted in mandibular total volume, intergonial width and mandibular gonial angle area volume of non-deviated side ($P<0.01$, $P<0.05$, $P<0.01$), and no significant difference was noted in mandibular gonial angle area volume of deviated side ($P>0.05$) in SSRO group. In IVRO group during T0-T1, a significant decrease was noted in mandibular total volume and mandibular gonial angle area volume on both the deviated and non-deviated sides ($P<0.01$), and no significant difference was noted in intergonial width ($P>0.05$). Only mandibular total volume change was noted to be greater in IVRO group (10.6%) than SSRO group (3.3%) ($P<0.01$). No significant differences were noted between SSRO group and IVRO group in mandibular gonial angle area volume and intergonial width ($P>0.05$).

2. When comparing the masseter muscle change, during T0-T1, a significant increase was noted in maximum cross-sectional area of the masseter muscle on deviated side in SSRO group ($P<0.01$), and no significant difference was noted on non-deviated side ($P>0.05$). In IVRO group during T0-T1, no significant difference was noted in maximum cross sectional area of the masseter muscle ($P>0.05$). No significant difference was noted between SSRO group and IVRO group in maximum cross-sectional area of the masseter muscle ($P>0.05$). During T0-T1, a significant decrease was noted in masseter muscle angle on non-deviated side in both SSRO group and IVRO group ($P<0.05$, $P<0.01$).

3. At T1-T2, mandibular gonial angle area volume on both the deviated and non-deviated sides was noted to be smaller as the amount of menton deviation was greater in IVRO group (P<0.01, P<0.05). There was no correlation between the amount of menton deviation and postoperative changes in maximum cross-sectional area and angle of the masseter muscle (P>0.05).

As a result of this study, there was no significant difference of the change in mandibular gonial angle area volume and maximum cross-sectional area of the masseter muscle except that the mandibular total volume change of IVRO group was larger than that of SSRO group in comparison of the change between SSRO group and IVRO group during T0-T1. It is considered that further studies including expansion of study subjects and longitudinal study of SSRO group whether comparative study results of the two surgical methods depending on the degree of facial asymmetry can affect the choice of surgical method will be necessary in the future.

Key words : skeletal Class lll, facial asymmetry, SSRO, IVRO, 3D CT
mandibular volume, intergonial width, masseter muscle

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Ah Kyung Cho

Department of Dentistry, Graduate School, Yonsei University

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

I. Introduction

Skeletal Class III patients make up a large proportion of orthognathic surgery cases in our country (Kang et al., 1992). Sagittal split ramus osteotomy (SSRO) and intraoral vertical ramus osteotomy (IVRO) are the most frequently used techniques for the treatment of mandibular prognathism and facial asymmetry. IVRO procedure offers numerous advantages over SSRO for the treatment of the prognathic patient, including technical simplicity, reduced surgical time, and the ability to reposition the condyle head (Ghali et al., 2000). The greatest advantage of IVRO over SSRO is the lower incidence of injury to inferior alveolar nerve (Westermark et al., 1999; Walter et al., 1979). Also, IVRO is a treatment which shows a stable result to patients with severe mandibular asymmetry (Hall et al., 1980; Nwoku et al., 1974), and it is widely used to TMD patients with mandibular protrusion. Ueki et al reported that disc-condyle relationship has improved after IVRO and that 88% and 66.7% TMD symptom relief were shown in IVRO group and SSRO group respectively at 6 months after surgery (Ueki et al., 2002). The major advantages of SSRO are the better bony interface between osteotomized segments and the easier use of rigid fixation that minimizes the need for intermaxillary fixation (IMF) (Wolford et al., 2000). Kim et al reported IVRO and SSRO have different osteotomy design and different exposure of medullary bone, but there was no statistically significant difference in postoperative drainage of blood and exudate from bilateral mandibular osteotomy areas after IVRO and SSRO (Kim et al., 2014).

Occlusal stability, which is one of the most important factors in the prevention of postoperative relapse in orthognathic surgery, results from good dental occlusion and normal postoperative condylar position. There have been many reports describing stability following SSRO for skeletal Class III (Mobarak et al., 2000, Costa et al., 2001; Kim et al., 2002; Politi et al., 2004) including three-dimensional (3D) images (Cevidanes et al., 2007; Draenert et al., 2010; Kim et al., 2012), but there have been few reports describing stability following IVRO (Greebe et al., 1982). Several authors have reported postoperative occlusal stability after IVRO. Hall et al observed anterior dental relapse in 7% and postsurgical anterior openbite in 14.3% of 40 prognathic and 2 asymmetric patients (Hall et al., 1975). Wisth found clinical significant dental relapses in 15% of 44 prognathic patients treated 10 years previously with oblique vertical osteotomy (Wisth et al., 1981). Jung et al evaluated the postoperative stability associated with differing degrees of mandibular setback and their relations after IVRO by measuring the preoperative and postoperative lateral cephalographs to find out the degree of movement, and the vertical and horizontal positions of menton and pogonion. They reported the amount of setback has minimal effects on anterior relapse, so overcorrection was not necessary with IVRO (Jung et al., 2013).

Although the advantages and disadvantages of SSRO and IVRO for mandibular setback have been discussed frequently (Ghali et al., 2000; Wolford et al., 2000), studies comparing postoperative skeletal stability between the two surgical methods are relatively rare. Phillips et al observed that SSRO group showed a significantly greater relapse in the Sella-Nasion-B-point (SNB) angle with more anterior movement of menton and pogonion than IVRO group (Phillips et al., 1986). Yoshioka et al reported that the B-point and pogonion in IVRO group moved significantly more posteriorly and inferiorly in the early postoperative period when compared with SSRO group, but no significant difference in skeletal stability was observed between the two surgical methods 1 year after surgery (Yoshioka et al., 2008).

3D CT is useful for comparing and evaluating changes in the jaw and the associated changes in the soft tissues before and after orthognathic surgery. 3D CT images are now widely used in not only precise diagnostics and treatment planning in orthodontics but also studies on post-treatment stability (Shingo et al., 2013; Carvalho et al., 2010; Cevidanes et al., 2007). In particular, patients undergoing orthognathic surgery require 3D analysis for the precision and ability to assess changes over time although most of studies have traditionally been based on 2D images such as cephalograms and facial photos (Kitahara et al., 2009; Yoshioka et al., 2008; Chen et al., 2011).

In this study, the mandibular volume change and maximum cross-sectional area of the masseter muscle change depending on SSRO and IVRO orthognathic surgery was to be investigated by measurement of mandibular total volume, mandibular gonial angle area volume, intergonial width, masseter muscle angle and maximum cross-sectional area of the masseter muscle using the reconstructed 3D CT images in order to compare the change from gonial angle area remodeling in each two surgical methods, since soft tissue change tends to look larger macroscopically more after IVRO surgery than after SSRO surgery.

II. Subjects and Methods

1. Subjects

This study was carried out in two groups of patients diagnosed with mandibular prognathism and facial asymmetry. One group (SSRO group) underwent SSRO orthognathic surgery at K University Hospital form 2012 to 2013. The other group (IVRO group) underwent IVRO orthognathic surgery at Y University Hospital from 2004 to 2007. These subjects were diagnosed as skeletal Class lll malocclusion using lateral cephalometric analysis. The diagnostic criteria of two groups were unilateral or bilateral Angle Class lll molar key, overjet of 0 mm or less, and ANB (A-point-Nasion-B-point) angle difference of 0° or less (average, -2.0°). And they had mandibular menton deviation of more than 3.5 mm from the facial midline (average, 5.5 mm), using posteroanterior cephalometric analysis. The facial midline was defined as a line perpendicular to the line connecting Lo and Lo’ through Nc (Figure 1) (Haraguchi et al., 2002). Patients with systemic disease were excluded from the study.

SSRO group was composed of 20 patients who underwent preoperative and postoperative orthodontic treatment and two-jaw surgery (Le Fort I osteotomy + bilateral sagittal split ramus osteotomy, 12 of 20 patients had genioplasty) by one surgical team and who agreed on additional CT examinations at 1 year after surgery (11 male and 9 female; average age, 24.0 years). IVRO group was composed of 17 patients who underwent preoperative and postoperative orthodontic treatment and two-jaw surgery (Le Fort I osteotomy + bilateral intraoral vertical ramus osteotomy, 9 of 17 patients had genioplasty) by one surgical team and who agreed on additional CT examinations at 4 years after surgery (6 male and 11 female; average age, 21.7 years) (Table 1). In IVRO treatment, effort was made to preserve the gonial angle by positioning the bone cutting line superiorly, and in

SSRO treatment, masseter muscle separation was done to a minimum, but in IVRO treatment, masseter muscle and medial pterygoid muscle were separated widely. The studygroup was divided into two sub-groups based on the amount of menton deviation (Table 2).

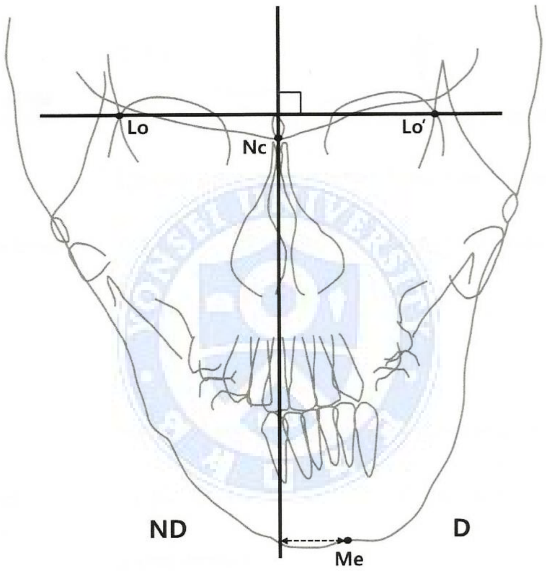

Figure 1. Facial midline on P-A cephalograms.

* Lo and Lo' indicate bilateral intersection of the oblique orbital line with the lateral contour of the right and left side orbits; Nc, neck of crista galli; Me, menton; D, deviated side; ND, non-deviated side

Table 1. Classification of subjects

	SSRO group	IVRO group
N	20	17
Gender	11 Male and 9 Female	6 Male and 11 Female
Average age	24.0 years	21.7 years
Surgery	Le Fort I osteotomy + SSRO	Le Fort I osteotomy + IVRO
	12 of 20 patients had genioplasty	9 of 17 patients had genioplasty

N indicates Number of subjects; SSRO, sagittal split ramus osteotomy;

IVRO, intraoral vertical ramus osteotomy.

Table 2. Classification of sub-groups in each groups

Group	Sub-groups		N	Total
SSRO	SSRO-1	Dev ≥ 5mm	8	20
	SSRO-2	Dev < 5mm	12	
IVRO	IVRO-1	Dev ≥ 5mm	9	17
	IVRO-2	Dev < 5mm	8	
Total				37

N indicates Number of subjects; Dev, the amount of menton deviation

2. Methods

A. CT scanning & 3D images reconstruction

Each patient of SSRO group underwent 3D CT examinations at before surgery (T0) and 1 year after surgery (T1). A spiral CT scanner (GE Medical System, Milwaukee, Wis, USA) was used for CT scans under conditions of 120 kV and 175 mA. Each patient of IVRO group underwent 3D CT examinations at before surgery (T0), 1 year after surgery (T1), and 4 years after surgery (T2). A spiral CT scanner (GE Medical System, Milwaukee, Wis, USA) was used for CT scans under conditions of 100 kV and 150 mA. The Frankfort Horizontal plane (FH plane) of the patient was adjusted perpendicular to the ground, and the middle line was aligned with the major axis of the machine.

The thickness of the axial image was 1 mm, and the table speed was 6 mm per second. The axial images taking were sent out as digital imaging and communication in medicine (DICOM) images, and were reconstructed into 3D images using OnDemand^{TM} software (CyberMed Inc, Seoul, Korea) (Figure 2). The Frankfort Horizontal plane (FH plane), which was constructed on both sides of porion and left of orbitale was used as a horizontal reference plane, and the midsagittal plane was drawn perpendicular to the FH plane passing through nasion (Park et al., 2006). The shifted side of menton for the midsagittal plane was defined as the deviated side, and the other side was defined as non-deviated side.

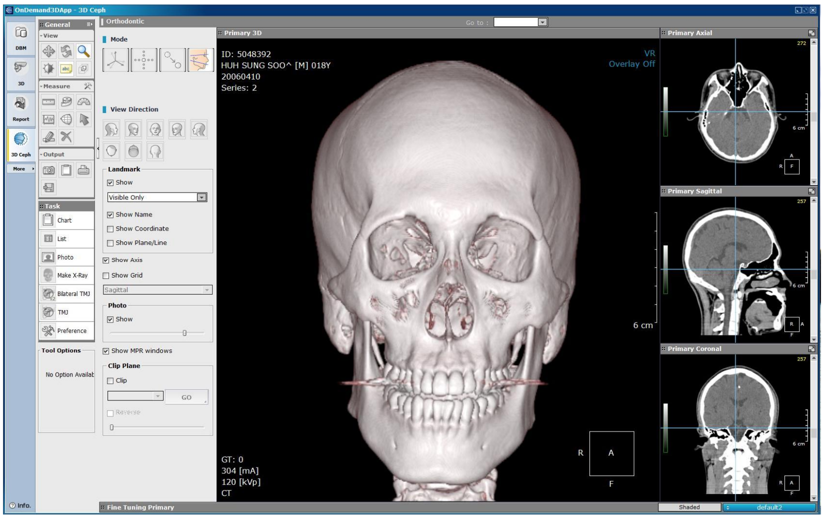

Figure 2. Reconstruction of a three-dimensional image using OnDemand™ software (CyberMed Inc., Seoul, Korea).

B. Measurements with reconstructed 3D CT images

Under 3D mode of OnDemand™ software, we assessed mandibular total volume, mandibular gonial angle area volume and maximum cross-sectional area of the masseter muscle with the reconstructed 3D CT images. Under 3D Ceph mode of OnDemand™ software, we assessed intergonial width and the masseter muscle angle with the reconstructed 3D CT images.

(1) Measurement of mandibular total volume

Under 3D mode of OnDemand™ software, we assessed mandibular total volume after separating the mandible using Segmentation funtion.

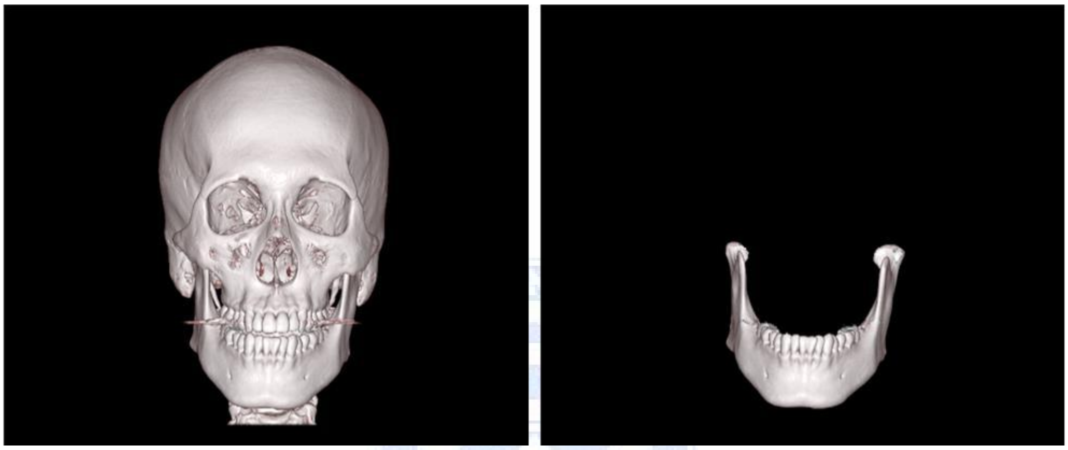

Figure 3. Measurement of mandibular total volume.

(2) Measurement of mandibular gonial angle area volume in SSRO

Under 3D mode of OnDemand™ software, in order to include the surgical site, mandible was sectioned based on the line 10mm above the occlusal plane which was reported to be highly correlated with the volume of the masseter muscle, and the line vertical to mandibular occlusal plane passing the proximal surface of the first and second premolars as a fiducial line, and then mandibular gonial angle area volume was measured on both the deviated side and non-deviated side respectively (Xu et al., 1994; Hong et al., 2006).

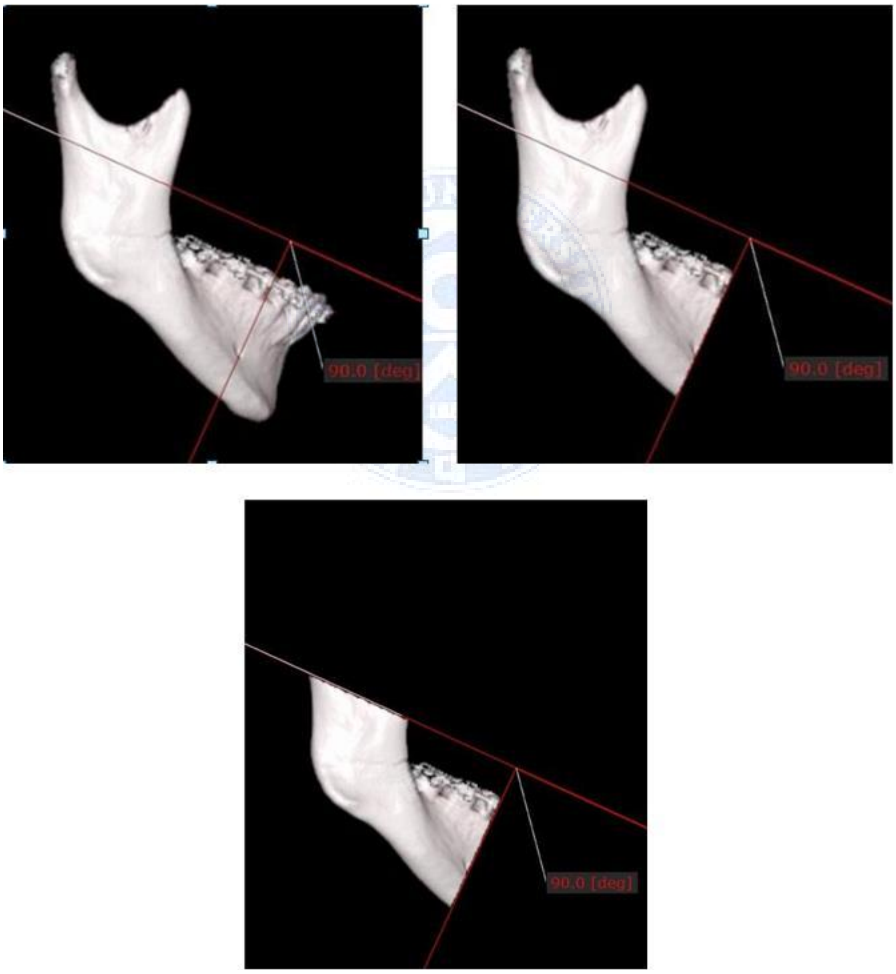

Figure 4. Measurement of mandibular gonial angle area volume in SSRO

(3) Measurement of mandibular gonial angle area volume in IVRO

Under 3D mode of OnDemand™ software, in order to include the surgical site, mandible was sectioned based on the line 10mm above the occlusal plane which was reported to be highly correlated with the volume of the masseter muscle, and the line connecting from the anterior surface of ramus to the distal surface of the most posterior lower molar tooth as a fiducial line, and then mandibular gonial angle area volume was measured on both the deviated side and non-deviated side respectively (Xu et al., 1994; Hong et al., 2006).

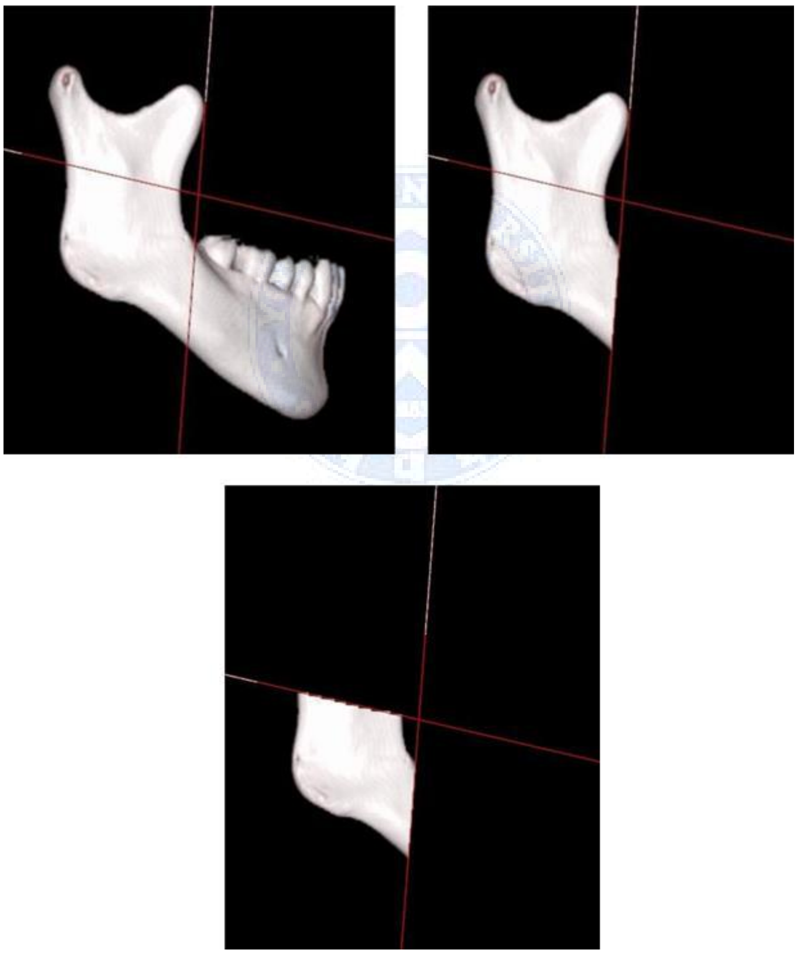

Figure 5. Measurement of mandibular gonial angle area volume in IVRO

(4) Measurement of intergonial width

Under 3D mode of OnDemand™ software, by drawing an extension line of the posterior border of ramus and the one of the inferior border of mandible, R Go and L Go were designated in two-dimensional space where two lines emerged, and R Go and L Go on 3D image were designating by moving Go in three-dimensional space (sagittal, axial, coronal), the distance between two dots was measured (Figure 6, Figure 7).

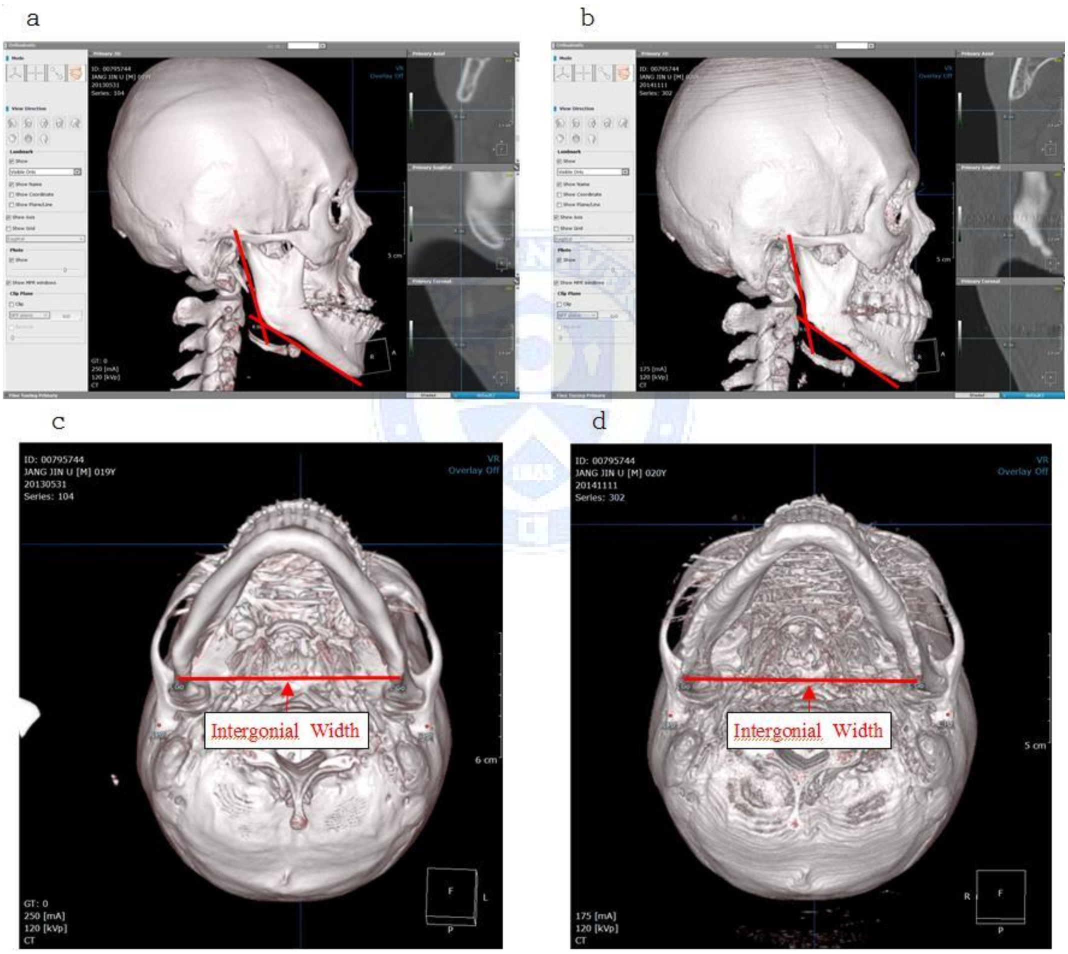

Figure 6. Measurement of intergonial width in SSRO

(a) preoperative CT sagittal image (b) postoperative CT sagittal image

(c) preoperative CT submentovertex image (d) postoperative CT submentovertex image

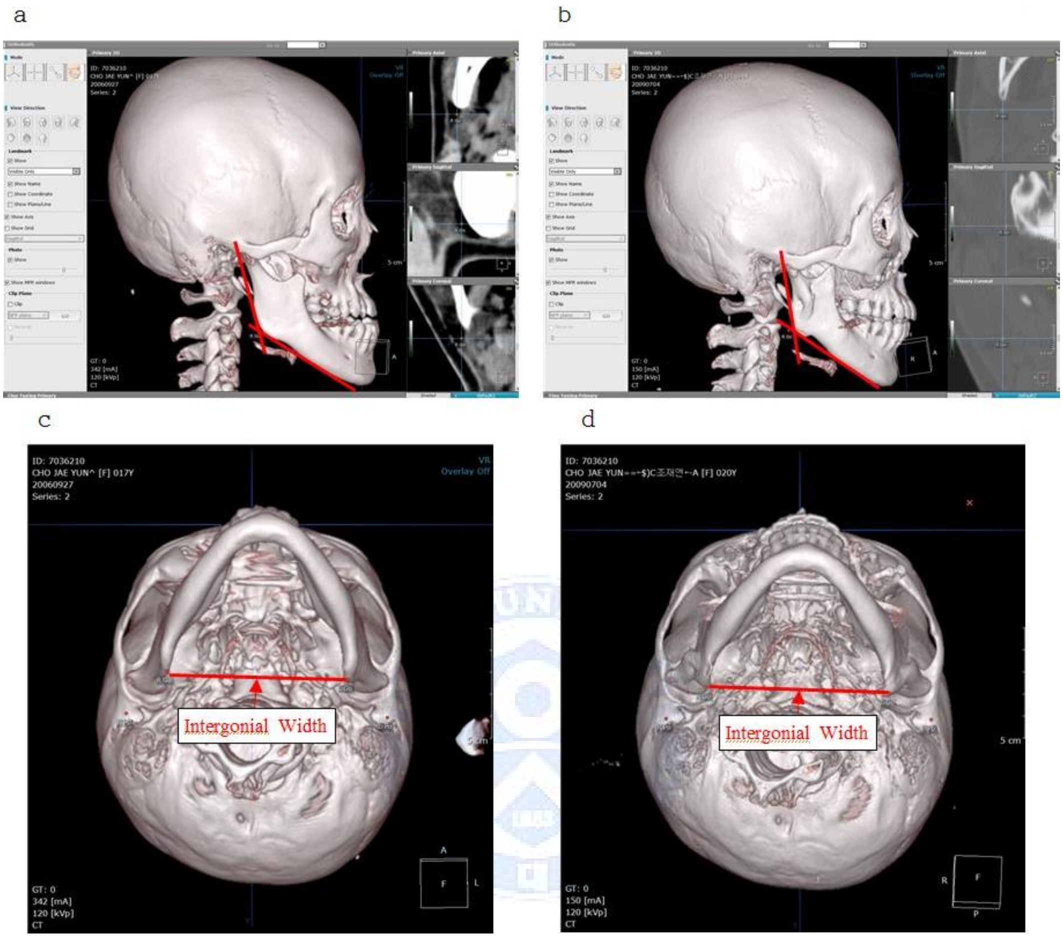

Figure 7. Measurement of intergonial width in IVRO

(a) preoperative CT sagittal image (b) postoperative CT sagittal image

(c) preoperative CT submentovertex image (d) postoperative CT submentovertex image

(5) Measurement of masseter muscle angle

Under 3D Ceph mode of OnDemand™ software, the masseter muscle angle was measured as the angle between the FH plane and the anterior border of masseter muscle, which was clearly defined on the lateral view of reconstructed 3D CT images. To observe the clear outline of masseter muscle, the images were processed with the software by adjusting the density range, color assignment, opacity value using Fine tuning (Figure 8).

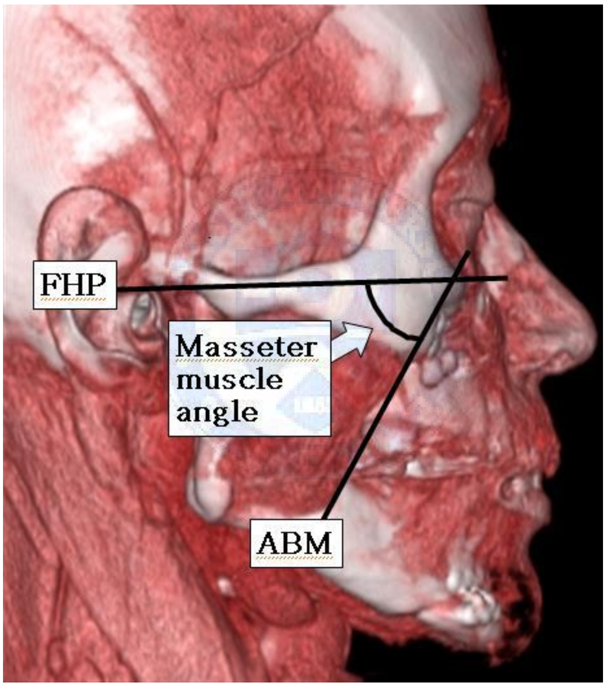

Figure 8. Measurement of masseter muscle angle
Masseter muscle angle was defined as the angle between Frankfort Horizontal plane (FHP) and anterior border of masseter muscle (ABM).

(6) Measurement of maximum cross-sectional area of masseter muscle

Under 3D mode of OnDemand™ software, the maximum cross-sectional area (MCSA) of the masseter muscle was measured on both the deviated and the non-deviated side, using the reconstructed 3D CT axial images. To observe the clear outline of masseter muscle, the images were processed with the software by adjusting the window level, contrast, and density ranges. The MCSA of the masseter muscle was measured a level 10 mm above the occlusal plane of the maxillary second molar on the reconstructed 3D CT images. The scanning level for the measurements was chosen so that metal artifacts from brackets and wires were avoided and corresponded to the roots of the maxillary teeth. Furthermore, previous reports showed that the measured values were relatively stable and highly correlated with the volume of the masseter muscle at the level of the scan (Ariji et al., 2000; Xu et al., 1994; Hong et al., 2006) (Figure 9).

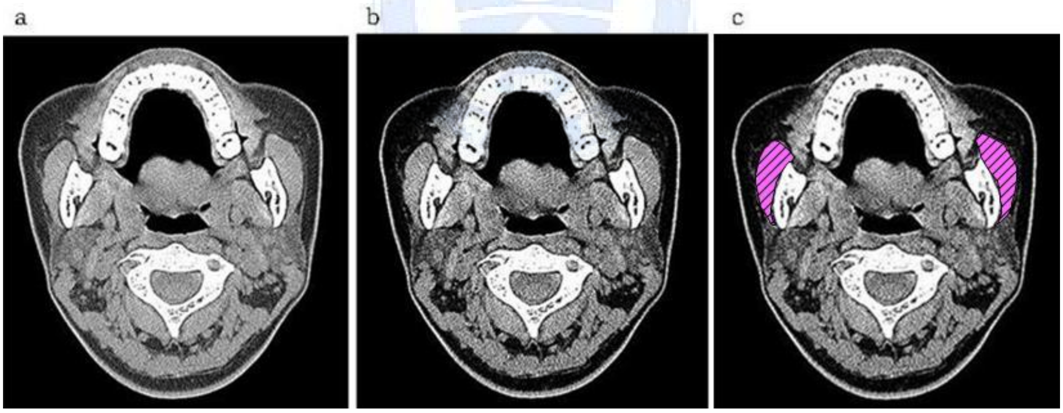

Figure 9. CT images of masseter muscle area

(a) Original axial image

(b) After adjusting window level to allow visualization of masseter muscle

(c) Delineation of masseter muscle area

(7) Calculation of maximum cross-sectional area of masseter muscle

To obtain the MCSA of masseter muscle perpendicular to the muscle direction, the maximum area of masseter muscle (a) was calculated by multiplying the cross-sectional area measured on the axial image (a_0) by Cos Θ (the angle between the axial image and the section perpendicular to the muscle image) (Figure 10).

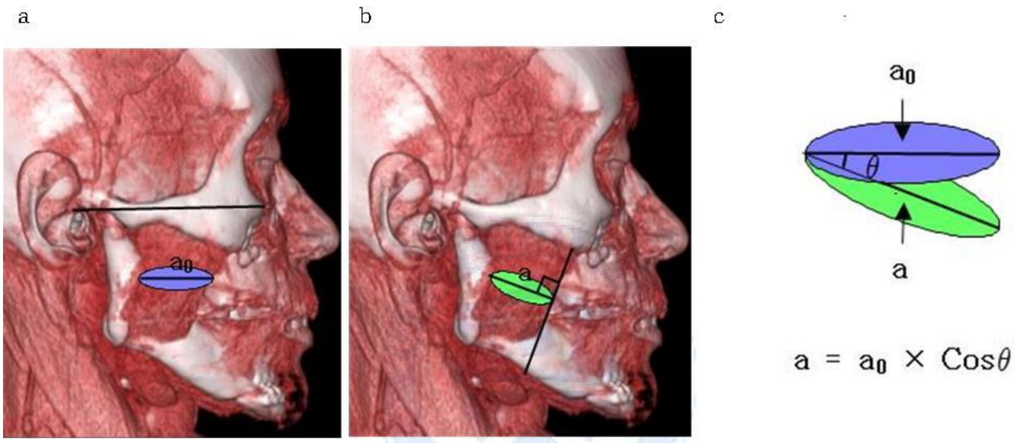

Figure 10. Measurement of cross-sectional area of the masseter muscle.
(a) The cross-sectional area measured on an axial slice of the CT images.
(b) The adjusted cross-sectional area perpendicular to the muscle direction.
(c) Methods for calculating the area (a) from (a_0).

C. Statistical Analysis

All measurements were performed by one author. Measurements were repeated after 2 weeks by the same author, and the second measurement was used for the statistical analysis. The intra-examiner error between the two measurements was determined by means of R. version 3.1.1, and the intra-class correlation coefficient was calculated.

Wilcoxon signed rank test was used to compare the changes of measurements over the period during T0-T1 in each two groups and during T1-T2 in IVRO group. Mann-Whitney U test was used to compare differences between SSRO group and IVRO group, SSRO-1 group and SSRO-2 group, IVRO-1 group and IVRO-2 group.

Spearman correlation analysis was used to determine the correlation between the amount of menton deviation and the changes of mandibular gonial angle area volume, masseter muscle measurements over the period from T0-T1.

All statistical evaluations were performed with SPSS version 20.0 (Statistical Package for the Social Science Inc., Chicago, IL, U.S.A.).

III. Results

The intra-examiner error was found to be statistically insignificant (P<0.05), and the intra-class correlation coefficient was within acceptable value (mean of 0.96, with a range of 0.94 − 0.97).

1. Comparison of mandibular volume in SSRO and IVRO

In SSRO group, mandibular measurements except mandibular gonial angle area volume on deviated side decreased significantly during T0-T1 (P<0.05). In IVRO group, mandibular measurements except intergonial width decreased significantly during T0-T1 (P<0.001). At T1-T2, no significant differences were found on all measurements in IVRO group (P>0.05). When comparing mandibular measurements between SSRO group and IVRO group at T0-T1, only mandibular total volume showed the differences, which was more smaller significantly in SSRO group than in IVRO group (P<0.001). At T0-T1, mandibular gonial angle area volume on deviated side more increased in IVRO group than SSRO group, but there was no significant differences between SSRO group and IVRO group (Table 3).

Table 3. Comparison of mandible changes (Mean ± SD)

Variables	SSRO			IVRO					
	T0-T1			T0-T1			T1-T2		
	Mean	SD	Sig	Mean	SD	Sig	Mean	SD	Sig
Mandible									
Mand Total Volume (cc)	-2.83	3.20	**	-10.12	6.09	**	-0.25	2.61	
Sig #				**					
Intergonial Width (mm)	-2.23	3.81	*	-0.73	2.27		0.34	1.85	
Sig #									
Mand Gonial angle area Vol - D (cc)	-0.60	1.49		-1.51	1.49	**	0.38	0.89	
Sig #									
Mand Gonial angle area Vol - ND (cc)	-1.40	1.59	**	-1.70	1.75	**	-0.04	0.86	
Sig #									

Sig # : comparison between SSRO (T0-T1) group and IVRO (T0-T1) group

Mand indicates Mandible; Vol, Volume; D, Deviated side; ND, Non-deviated side; SD, Standard deviation; Sig, Significance; SSRO, sagittal split ramus osteotomy; IVRO, intraoral vertical ramus osteotomy.

* $P < 0.05$; ** $P < 0.01$.

2. Comparison of maximum cross-sectional area and angle of masseter muscle in SSRO and IVRO

In SSRO group, there was significant decrease in the masseter muscle angle on non-deviated side (P<0.05) and there was no significant difference in the masseter muscle angle on deviated side during T0-T1 (P>0.05). In SSRO group, there was significant increase in maximum cross-sectional area of the masseter muscle on deviated side (P<0.01) and there was no significant difference in maximum cross-sectional area of the masseter muscle on non-deviated side during T0-T1 (P>0.05) (Table 4). In IVRO group, there was significant decrease in the masseter muscle angle on non-deviated side (P<0.01) and there was no significant difference in the masseter muscle angle on deviated side during T0-T1 (P>0.05). In IVRO group, there was no significant difference in maximum cross-sectional area of the masseter muscle on both the deviated and non-deviated side (P>0.05). There was a little increase in the masseter muscle angle on deviated side during T1-T2 but there was no significant difference (Table 4).

Table 4. Comparison of masseter muscle changes (Mean ± SD)

Variables	SSRO			IVRO					
	T0-T1			T0-T1			T1-T2		
	Mean	SD	Sig	Mean	SD	Sig	Mean	SD	Sig
Masseter muscle									
Angle-D (°)	-1.42	5.51		-3.41	7.80		1.12	5.84	
Sig #									
Angle-ND (°)	-2.82	5.28	*	-5.36	6.95	**	-1.85	9.44	
Sig #									
MCSA-D (mm^2)	39.26	59.78	**	3.39	75.44		35.64	69.34	
Sig #									
MCSA-ND (mm^2)	16.38	52.75		2.71	64.05		23.34	53.14	
Sig #									

Sig # : comparison between SSRO (T0-T1) group and IVRO (T0-T1) group

Angle indicates Masseter muscle Angle; MCSA, maximum cross-sectional area; D, Deviated side; ND, Non-deviated side; SD, Standard deviation; Sig, Significance; SSRO, sagittal split ramus osteotomy; IVRO, intraoral vertical ramus osteotomy.

* P < 0.05; ** P < 0.01.

3. Correlation between menton deviation and the other variables

A. Correlation between menton deviation and mandibular gonial angle area volume

In SSRO-1 (Dev≥5mm) group and SSRO-2 (Dev<5mm) group, IVRO-1 (Dev≥5mm) group and IVRO-2 (Dev<5mm) group, there was no significant difference in mandibular gonial angle area volume both the deviated side and non-deviated side during T0-T1 (P>0.05). When comparing SSRO-1 group and SSRO-2 group, IVRO-1 group and IVRO-2 group, there was no significant difference in mandibular gonial angle area volume (P>0.05). The mandibular gonial angle area volume in IVRO-1 (Dev≥5mm) group showed smaller decrease than in IVRO-2 (Dev<5mm) group during T1-T2 but there was no significant difference (Table 5). Spearman correlation analysis was used to find out the relationship between the amount of menton deviation and T0-T1, and T1-T2 changes of mandibular gonial angle area volume on the deviated side and non-deviated side. In SSRO group, there was no statistical relationship between the amount of menton deviation and the change of mandibular gonial angle area volume. In IVRO group, as the amount of menton deviation became larger, the changes of T1-T2 decreased with significant difference on both the deviated side and non-deviated side (P<0.01, P<0.05) (Table 6).

Table 5. Comparison of mandibular gonial angle area volume changes (cc) (Mean ± SD)

	SSRO-1 (Dev≥5mm)	SSRO-2 (Dev<5mm)	Sig	IVRO-1 (Dev≥5mm)	IVRO-2 (Dev<5mm)	Sig
Dev. side						
T0-T1	-0.40 ± 1.42	-0.73 ± 1.58	NS	-1.41 ± 1.35	-1.61 ± 1.73	NS
T1-T2				-0.01 ± 0.99	0.76 ± 0.62	NS
Non-Dev. side						
T0-T1	-1.46 ± 1.82	-1.36 ± 1.50	NS	-1.71 ± 1.38	-1.69 ± 2.20	NS
T1-T2				-0.34 ± 0.52	0.27 ± 1.04	NS
Sig #						
T0-T1	NS	NS		NS	NS	
T1-T2				NS	NS	

Sig # : comparison between the deviated side and non-deviated side

Dev indicates Deviated; NS, Not significant; SD, Standard deviation; Sig, Significance

* P < 0.05; ** P < 0.01.

Table 6. Correlation coefficients between menton deviation and mandibular gonial angle area volume

				Menton Deviation
Mandibular gonial angle area volume (cc)				
	SSRO	T0-T1	Deviated side	
			Non-Deviated side	
	IVRO	T0-T1	Deviated side	
			Non-Deviated side	
		T1-T2	Deviated side	**
			Non-Deviated side	*

* P < 0.05; ** P < 0.01.

B. Correlation between menton deviation and masseter muscle angle

In SSRO group, there was no significant difference in the masseter muscle angle on both the deviated side and non-deviated side ($P>0.05$). The masseter muscle angle on the deviated side showed more greater decrease in IVRO-1 (Dev≥5mm) group compared to IVRO-2 (Dev<5mm) group ($P<0.05$). There was no significant difference in the masseter muscle angle between SSRO group and IVRO group on both the deviated side and non-deviated side ($P>0.05$). The masseter muscle angle in IVRO-2 group showed greater decrease than in SSRO-2 group but there was no significant difference. When comparing SSRO-1 group and SSRO-2 group, IVRO-1 group and IVRO-2 group, there was no significant difference in mandibular gonial angle area volume during T0-T1, and T1-T2 on both the deviated side and non-deviated side ($P>0.05$) (Table 7). Spearman correlation analysis was used to find out the relationship between the amount of menton deviation and T0-T1, and T1-T2 changes of masseter muscle angle on the deviated side and non-deviated side. In both SSRO group and IVRO group, there was no statistical relationship between the amount of menton deviation and the changes of masseter muscle angle on both the deviated side and non-deviated side ($P>0.05$).

Table 7. Comparison of masseter muscle angle changes (°) (Mean ± SD)

	SSRO-1 (Dev≥5mm)	SSRO-2 (Dev<5mm)	Sig	IVRO-1 (Dev≥5mm)	IVRO-2 (Dev<5mm)	Sig
Dev. side						
T0-T1	-1.12 ± 3.91	-1.62 ± 6.54	NS	0.62 ± 6.25	-7.95 ± 7.08	**
Sig 1	NS			NS		
Sig 2		NS			NS	
Sig 3	NS	NS		NS	NS	
T1-T2				0.79 ± 3.99	1.45 ± 7.54	
Sig 3				NS	NS	
Non-Dev. side						
T0-T1	-1.91 ± 4.62	-3.42 ± 5.79	NS	-2.87 ± 6.13	-8.18 ± 7.11	NS
Sig 1	NS			NS		
Sig 2		NS			NS	
Sig 3	NS	NS		NS	NS	
T1-T2				-0.77 ± 9.76	4.46 ± 7.71	
Sig 3				NS	NS	

Sig 1: comparison between SSRO-1 and IVRO-1 group

Sig 2: comparison between SSRO-2 and IVRO-2 group

Sig 3: comparison between deviated side and non-deviated side

Dev indicates Deviated; NS, Not significant; SD, Standard deviation; Sig, Significance

* $P < 0.05$; ** $P < 0.01$.

C. Correlation between menton deviation and maximum cross-sectional area of the masseter muscle

There was no significant difference in maximum cross-sectional area of the masseter muscle between the deviated side and non-deviated side, SSRO group and IVRO group (P>0.05). The maximum cross-sectional area of the masseter muscle on deviated side showed greater decrease than on non-deviated side in SSRO-2 group, but there was no significant difference (Table 8). Spearman correlation analysis was used to find out the relationship between the amount of menton deviation and T0-T1, and T1-T2 changes of maximum cross-sectional area of the masseter muscle on the deviated side and non-deviated side. In both SSRO group and IVRO group, there was no statistical relationship between the amount of menton deviation and the changes of maximum cross-sectional area of the masseter muscle on both the deviated side and non-deviated side (P>0.05).

Table 8. Comparison of maximum cross-sectional area changes of the masseter muscle (mm^2) (Mean ± SD)

	SSRO-1 (Dev≥5mm)	SSRO-2 (Dev<5mm)	Sig	IVRO-1 (Dev≥5mm)	IVRO-2 (Dev<5mm)	Sig
Dev. side						
T0-T1	41.26 ± 66.21	37.93 ± 58.11	NS	14.96 ± 73.65	-9.78 ± 80.26	NS
Sig 1	NS			NS		
Sig 2		NS			NS	
Sig 3	NS	NS		NS	NS	
T1-T2				21.24 ± 64.52	50.03 ± 75.36	
Sig 3				NS	NS	
Non-Dev. side						
T0-T1	10.33 ± 47.63	20.42 ± 57.60	NS	8.20 ± 65.27	-9.99 ± 64.51	NS
Sig 1	NS			NS		
Sig 2		NS			NS	
Sig 3	NS	NS		NS	NS	
T1-T2				8.20 ± 33.30	38.48 ± 66.48	
Sig 3				NS	NS	

Sig 1: comparison between SSRO-1 and IVRO-1 group

Sig 2: comparison between SSRO-2 and IVRO-2 group

Sig 3: comparison between deviated side and non-deviated side

Dev indicates Deviated; NS, Not significant; SD, Standard deviation; Sig, Significance

* P < 0.05; ** P < 0.01.

IV. Discussion

Facial asymmetry is a relatively common feature in patients with maxillomandibular deformities about to undergo orthognathic surgery. Facial asymmetry is a condition in which the center of the maxilla or mandible is deviated from the midline, or when there is a discrepancy in facial height or width (Peck et al., 1970). Most images used to analyse and diagnose abnormalities of the craniofacial complex are x-rays, particularly lateral and panoramic views. It is, therefore, somewhat problematic to distinguish between the various anatomical points of right and left sides. Furthermore, two-dimensional x-rays have inherent limitations, such as elongation or distortion of the image, which may lead to a wrong diagnosis. Grummons et al used frontal analyses to study asymmetry and found that the cephalometric measurements were subject to distortion as a result of the projection technique, and could not be used for either quantitative or comparative purposes (Grummons et al., 1987). Given that a quantitative measurement is critical to a diagnosis of asymmetry, the use of two-dimensional x-rays should clearly not be regarded as valid. Analysing the craniofacial complex has improved recently with the development of three-dimensional (3D) image technology (Park et al., 2009), since the 3D images obtained from computed tomography enable us to observe any one of the craniofacial bones from different angles. The accuracy of 3D CT reconstruction is sufficiently high for the linear measurements (Christiansen et al., 1986; Cavalcanti et al., 1999). The use of 3D CT analysis in the diagnosis and treatment of patients with facial asymmetry requiring surgical correction is now widely employed, and considered indispensible.

3D CT images are widely used in a number of studies. Three months after the two surgical methods, SSRO and IVRO, the lateral and frontal width of the pharyngeal airway had decreased significantly in comparison with the preoperative width. The diminished airway did not recover by either 6 months or 1 year after surgery in most cases. And there were no significant differences between the two surgical methods, SSRO and IVRO

(Kawamata et al., 2000). In bilateral SSRO for the correction of asymmetry of the mandible, Park et al used 3D CT imaging to evaluate the changes in bone volume after remodeling, bone union of the unfixed bone fragments after distal cutting (osteotomy of the posterior part of the distal segment). Distal cutting minimized yawing movement of the distal segment which could displace the proximal segment (Park et al., 2014). The positional changes of the maxilla and the mandible in three dimensions following orthognathic surgery have been reported using surface meshes of hard tissue. Following cone-beam CT scanning of each surgical simulations, the actual surgical movement was compared to the analysis based on surface model movement (Jabar et al., 2015). The three-dimensional changes in hard tissue position following orthognathic surgery have been reported using 3D cephalometry, changes in volume, principal component analysis, and changes based on the surface model of hard tissue.

Sforza et al reported seven women all with skeletal Class III and facial asymmetry, were assessed both 2 months before and 10.7 months after surgery (Le Fort I osteotomy and SSRO) and surgery reduced mandibular volume (approximately, a significant, average 10% reduction), but it also reduced maxillary volume (an average 13% reduction), and nasal volume (Sforza et al., 2006). In this study, it was shown that the decrease amount of mandibular total volume after orthognathic surgery could differ depending on the surgical method, and the decrease amount was 10.6% and 3.3% in IVRO group and SSRO group respectively. IVRO group showed a larger mandibular volume change than that of SSRO group with significant difference ($P<0.01$). The mandibular gonial angle area volume was the only measurement whose relatedness to the amount of menton deviation was shown after IVRO surgery. The larger the amount of menton deviation was, the smaller the change of mandibular gonial angle area volume became on both the deviated side and non-deviated side during T1-T2 (Table 6). It could be said that this is a result showing that the remodeling of Gonion area occurs gradually for up to 4 years after IVRO surgery and that it is more stable from a long term perspective as the degree of facial asymmetry was severer after IVRO surgery.

Orthognathic surgery affects the postoperative position of the condyle within the glenoid fossa and often results in condylar displacement. Studies using tomographic radiographic and stereometric methods have shown that condylar displacement is frequent after mandibular setback surgery (Rosenquist et al., 1988; Athanasiou et al., 1991). Transverse proximal segment displacement has been studied using different types of orthognathic surgery by means of various methods, and this has led to different results (Alder et al., 1999; Becktor et al., 2002; Becktor et al., 2008; Harris et al., 1999; Schultes et al., 1998; Stroster et al., 1994). Schendel et al found that control of the proximal segment was the most significant aspect in stability and prevention of relapse (Schendel et al., 1980). In the present study, Gonion (Go), defined as the most inferolateral point of the ramal outline at the mandibular angle, was used as a landmark in P-A cephalometrics. Major et al presented the landmark identification errors in P-A cephalometrics and reported that there was a considerable range in the magnitude of error with different horizontal and vertical values (Major et al., 1994). They recommended that landmarks with identification errors greater than 1.5 mm should probably be avoided and landmarks with identification errors greater than 2.5 mm are inappropriate. Landmarks with a large horizontal identification error should be avoided in transverse measurements. Similarly, landmarks with large vertical identification errors should be avoided in measuring vertical structural relationships. According to their study, landmark Gonion (Go) may be very useful in transverse measurements because Gonion had the smallest intra-examiner errors in the horizontal dimension (Major et al., 1994). In the three-dimensional evaluation of craniofacial asymmetry using computed tomography, Menton (Me), Orbitale (Or), Porion (Po), Gonion (Go), Condylion (Co), Sella (S), Anterior nasal spine (ANS), Coronoid process (Cop), Nasion (N) were used for anatomical landmarks. Using the proposed asymmetric index method with 3D reconstructions, the Gonion emerged as the most asymmetrical landmark in all subjects (Yáñez-Vico et al., 2011). Choi et al reported all 42 patients had an increased intergonial width and the both ramus angles with statistical significance between T0 (preoperatively) and T1 (early postoperatively). Most patients had a decrease in their intergonial width late postoperatively. It means some relapse in their transverse dimension changes. However, the magnitude of the changes was small, and it is still uncertain as to whether these changes are of any clinical significance (Choi et al., 2005). These results show that the transverse relapse or cortical surface remodeling, is occurring at gonial angle and the proximal segments following SSRO surgery. Angle et al reported all 25 SSRO patients showed an increase in intergonial width and the angulations of the proximal segments increased, mandibular length (Ar-B) increased, B point moved anteriorly, T1(early postoperatively) - T0 (preoperatively). During T2 (after orthodontic treatment completion) - T1 (early postoperatively), intergonial width decreased, angulation of the right and left proximal segments decreased and condylion moved superiorly (Angle et al., 2007). Bayat et al suggested that the intraoral vertico-sagittal ramus osteotomy (IVSRO) leads to an increase in intergonial width, both ramus angles, inter-ramus width, and outward angulation of the condylar fragment after 1 month after surgery (Bayat et al., 2011). IVSRO was first introduced by Choung to correct mandibular prognathism (Choung et al., 1992). Ko et al reported that 27 patients showed a decrease of 2.2 mm in intergonial width from T1 (after surgery) to T2 (at completion of orthodontic treatment). The mild decrease of the intergonial width in the postoperative period indicated extensive remodeling changes of the mandibular gonial angle in both sides (Ko et al., 2009). Reduction of the intergonial distance and remodeling of the gonial angle is more esthetically pleasing in Asian culture than an increase in facial width (Hajeer et al., 2004). There was a decrease in intergonial width which reported the increase from preoperative to early postoperative in previous studies, because intergonial width was compared between T0 (before surgery) and T1 (1 year after surgery) in our study. There was a decrease of 2.2 mm and 0.7 mm in intergonial width from T0 to T1 in SSRO group and IVRO group respectively. IVRO group had an increased intergonial width between T1 and T2 (4 years after surgery) in our study. However, the magnitude of the changes was small and there was no significant difference. It indicated extensive remodeling changes of the mandibular gonial angle were maintained during postoperative period.

Soft tissue analysis should be considered in the diagnosis of facial asymmetry patients because soft tissue reflects the skeletal components. The function of the jaw musculature is considered to be a determinant of craniofacial growth (van Spronsen et al., 1997) and development and a significant relationship has been found between the masticatory muscles and facial morphology in normal subjects (van Spronsen et al., 1997; van Spronsen et al., 1991; Weijs et al., 1984; Weijs et al., 1989). The masseter muscle is considered to generate biting or chewing force and is one of the structures that is most altered by orthognathic surgery. Functional activity and bite force have been shown to differ significantly from normal subjects in patients with mandibular prognathism (Bakke et al., 1991; Kayukawa et al., 1992; Ueda et al., 1998; Bakke et al., 1992; Sasaki et al., 1989; Hannam et al., 1989; van Spronsen et al., 1989; Ingervall et al., 1997). These factors are also reported to be altered after orthognathic surgery (Hirose et al., 1990; Zarrinkelk et al., 1995; Harper et al., 1997; Iwase et al., 1998). Orthognathic surgery can alter not only morphological aspects of the masticatory apparatus, but also functional aspects. It's postoperative status may influence the patient's physical appearance as well as masticatory function (Katsumata et al., 2004). Muscle morphology could also be a significant parameter to consider in planning surgery and predicting the outcome. In previous study the cross-sectional area and thickness of masticatory muscle is highly correlated with masticatory force and the patient's physical appearance as a measure of functoinal capacity (Throckmorton et al., 2000; Sassouni et al., 1969; Ringqvist et al., 1973; Ingervall et al., 1976; Proffit et al., 1983; Ingervall et al., 1987). CT has made it possible to measure the cross-sectional area of the upper arm muscles and the jaw muscles in living subjects (Weijs et al., 1984; Xu et al., 1994). The cross-sectional area has been used frequently as a parameter of muscle size because it is highly correlated with muscle volume (van Spronsen et al., 1989; Bakke et al., 1992).

Various methods have been described for measuring muscle morphology (van Spronsen et al., 1989; Bakke et al., 1992). The direction and cross-sectional area of the masseter muscle have frequently been measured from cross-sectional images obtained by CT

(Computed tomography) and MRI (Magnetic resonance imaging) (van Spronsen et al., 1991; Weijs et al., 1984; Xu et al., 1994). The cross-sectional images are usually obtained by scanning parallel to the horizontal or occlusal plane. Wejis et al have asserted the importance of obtaining images perpendicular to the muscle fibers and proposed scanning at 30° to the Frankfurt Horizontal plane (FH plane) for the masseter and medial pterygoid muscles (Weijs et al., 1984). However, this technique cannot be applied to patients with mandibular prognathism, since the direction of the masseter muscle in patients with mandibular prognathism is considerably different from normal (Weijs et al., 1989; Sasaki et al., 1989; Hannam et al., 1989; van Spronsen et al., 1996). In this study, the maximum cross-sectional area of the masseter muscle was measured at a level approximately 10 mm above the occlusal plane from the maxilliary second molar and the scanning level for the measurements was chosen so that metal artifacts from brackets and wires were avoided and corresponded to the roots of the maxillary teeth (Ariji et al., 2000). Previous study reported that the measured values were relatively stable and highly correlated with the volume of the masseter muscle at the level of the scan (Xu et al., 1994; Hong et al., 2006).

CT evaluation of the masseter muscle has shown that the morphology of the masseter muscle in patients with mandibular prognathism is significantly different from that in normal subjects (Ariji et al., 2000). A significant reduction in the cross-sectional area of the masseter muscle has been seen, and a tendency to revert back to the normal dimension was seen between 6 months and 1 year postoperation (Katsumata et al., 2004). In the previous study, no significant difference in the area of the masseter muscle was found between the symmetry and asymmetry groups (Ueki et al., 2006). No statistically significant difference in the area of the masseter muscle was found between the deviated side and the non-deviated side (Ueki et al., 2006). And there was no significant difference in the masseter area preoperatively and 1-year postoperatively, similar to the previous study. However, there were significant differences between right and left in ramus length, ramus width, masseter length, and masseter width preoperatively and ramus length, masseter length, masseter width and condylar area postoperatively, although the reason was still unclear (Ueki et al., 2009).

In our study, there was an increase in maximum cross-sectional area of the masseter muscle during T0-T1 on both SSRO group and IVRO group. But there was significant difference only on the deviated side in IVRO group. In IVRO group, maximum cross-sectional area of the masseter muscle showed a smaller increase compared to SSRO group during T0-T1, but there was no significant difference of maximum cross-sectional area of the masseter muscle between SSRO group and IVRO group. In IVRO group, maximum cross-sectional area of the masseter muscle during T1-T2 showd significant increase in the ten more times than during T0-T1. Maximum cross-sectional area of the masseter muscle during T1-T2 in IVRO group showed an increase similarly to that during T0-T1 in SSRO group. It indicates maximum cross-sectional area of the masseter muscle has increased over 4 years in IVRO group. In the study measuring the cross-sectional area of masseter muscle with CT for mandibular prognathism patients after SSRO, Katsumata et al performed preoperative and postoperative CT examinations on 17 prognathic patients treated by SSRO with rigid osteosynthesis and 13 patients treated by IVRO without osteosynthesis. They found that a significant reduction was seen 3 months postoperatively and a tendency to revert back between 6 months and 1 year postoperatively. The results of this study suggest the masseter muscle may undergo reversible atrophy after mandibular setback osteotomy (Katsumata et al., 2004). However, masseter muscle length was unchanged and they concluded that temporary atrophy was observed immediately after SSRO, but recovered within 1 year after surgery. No significant difference was noted between the two surgical methods (Katsumata et al., 2004). The study by Ohkura et al suggested that occlusal force 3 years after SSRO reached the highest recorded value at the end of follow-up (3 years after surgery) (Ohkura et al., 2001). Perhaps the masseter muscle area was not stable and had not completely adapted to the new occlusion and skeletal morphology 1 year after surgery ; however, it might increase at 2 to 3 years after surgery. Therefore, they reported further investigation for long follow-up will be necessary.

In our study, SSRO group showed an increase in maximum cross-sectional area of the masseter muscle on both the deviated and non-deviated sides during T0-T1. IVRO-1 group (Dev≥5mm) showed an increase in maximum cross-sectional area of the masseter muscle during T0-T1, IVRO-2 group (Dev<5mm) showed a decrease. However, we found that a significant reduction was seen 1 year postoperatively and a tendency to significant increase back between 1 year and 4 years postoperatively in IVRO-2 group (Dev<5mm). The results of our study suggested the masseter muscle may undergo reversible atrophy 1 year after mandibular setback osteotomy in IVRO-2 group (Dev<5mm). Since it turns out that the change of maximum cross-sectional area of the masseter muscle undergoes long-term influence more after IVRO than after SSRO depending on the degree of facial asymmetry, it is considered that further studies including expansion of study subjects and longitudinal study of SSRO group whether comparative study results of the two surgical methods depending on the degree of facial asymmetry can affect the choice of surgical method will be necessary in the future.

V. Conclusion

The aim of this study was to evaluate changes of gonial angle area in skeletal Class III patients with facial asymmetry following two kinds of orthognathic surgery, sagittal split ramus osteotomy (SSRO) and intraoral vertical ramus osteotomy (IVRO) using computed tomography (CT). The mandibular total volume, intergonial width, mandibular gonial angle area volume, the maximum cross-sectional area (MCSA) and angle of the masseter muscle were measured from the reconstructed three-dimensional (3D) CT images. Using 3D CT images, we evaluated this data on the deviated side and non-deviated sides. We also compared this data between SSRO group and IVRO group. The correlation between the degree of facial asymmetry and postoperative changes of mandibular gonial angle area volume and the maximum cross-sectional area of the masseter muscle were assessed and analyzed with the following results.

1. When comparing the mandibular change, during T0 (before surgery) - T1 (1 year after surgery), a significant decrease was noted in mandibular total volume, intergonial width and mandibular gonial angle area volume of non-deviated side ($P<0.01$, $P<0.05$, $P<0.01$), no significant difference was noted in mandibular gonial angle area volume of deviated side ($P>0.05$) in SSRO group. In IVRO group during T0-T1, a significant decrease was noted in mandibular total volume and mandibular gonial angle area volume on both the deviated and non-deviated sides ($P<0.01$), no significant difference was noted in intergonial width ($P>0.05$). Only mandibular total volume change was noted to be greater on IVRO group (10.6%) than SSRO group (3.3%) ($P<0.01$), no significant differences were noted between SSRO group and IVRO group in mandibular gonial angle area volume and intergonial width ($P>0.05$).

2. When comparing the masseter muscle change, during T0-T1, a significant increase was noted in maximum cross-sectional area of the masseter muscle on deviated side

in SSRO group (*P*<0.01), no significant difference was noted on non-deviated side (*P*>0.05). In IVRO group during T0-T1, no significant difference was noted in maximum cross sectional area of the masseter muscle (*P*>0.05). No significant difference was noted between SSRO group and IVRO group in maximum cross-sectional area of the masseter muscle (*P*>0.05). During T0-T1, a significant decrease was noted in masseter muscle angle on non-deviated side in both SSRO group and IVRO group (*P*<0.05, *P*<0.01).

3. At T1 (1 year after surgery) - T2 (4 years after surgery), mandibular gonial angle area volume on both the deviated and non-deviated sides was noted to be smaller as the amount of menton deviation was greater in IVRO group (*P*<0.01, *P*<0.05). There was no correlation between the amount of menton deviation and postoperative changes in the maximum cross-sectional area and angle of the masseter muscle (*P*>0.05).

As a result of this study, there was no significant difference of the change in mandibular gonial angle area volume and maximum cross-sectional area of the masseter muscle except that the mandibular total volume change of IVRO group was larger than that of SSRO group in comparison of the change between SSRO group and IVRO group during T0-T1. It is considered that further studies including expansion of study subjects and longitudinal study of SSRO group whether comparative study results of the two surgical methods depending on the degree of facial asymmetry can affect the choice of surgical method will be necessary in the future.

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국 문 요 약

골격성 제 III급 안면 비대칭 환자의 악교정 수술방법에 따른 하악골과 교근의 변화에 대한 고찰

(지도교수 유형석)

연세대학교 대학원 치의학과

조 아 경

본 연구에서는 골격성 제 III급 안면 비대칭 환자의 구내 시상 분할 골절단술 (Sagittal Split Ramus Osteotomy, SSRO)와 구내 상행지 수직 골절단술 (Intraoral Vertical Ramus Osteotomy, IVRO) 두 악교정 술식에 따른 Gonial angle 부위의 변화를 알아보고자, 하악골의 전돌과 비대칭으로 K대학교 병원에서 SSRO 수술을 받은 20명의 환자를 대상으로 수술 전 (T0), 수술 후 1년 (T1)에 CT 촬영을 시행하였고, Y대학교 병원에서 IVRO 수술을 받은 17명을 대상으로 수술 전 (T0), 수술 후 1년 (T1)과 수술 후 4년 (T2)에 CT 촬영을 시행하였다. 3D CT 영상을 재구성하여 하악골의 전체 부피, 하악골의 Gonial angle 부위 부피 및 intergonial width, 교근의 주행 각도와 최대 단면적을 측정하여, SSRO와 IVRO 술식 간 비교와 각 술식 내 편위측과 비편위측의 비교를 하였다. 또한 비대칭의 정도에 따른 편위측과 비편위측의 하악골의 Gonial angle 부위 부피와 교근의 최대 단면적의 술후 변화량와의 상관성을 알아보아 다음과 같은 결과를 얻었다.

1. 하악골의 부피 변화를 비교해보면, SSRO 군에서 하악골의 전체부피와 intergonial width, 비편위측 하악골의 Gonial angle 부위 부피는 수술 후 1년에 모두 감소하였고 (각각 $P<0.01$, $P<0.05$, $P<0.01$), 편위측 하악골의 Gonial angle 부위 부피는 유의한 변화가 없었다 ($P>0.05$). IVRO 군에서는 하악골의 전체 및 양측 Gonial angle 부위 부피는 수술 후 1년에 모두 감소하였고 ($P<0.01$), intergonial width는 유의한 변화가 없었다 ($P>0.05$). SSRO 군과 IVRO 군의 술후 변화량을 비교해보면 하악골의 전체 부피만 IVRO 군이 SSRO 군보다 감소량이 컸고 ($P<0.01$), 하악골의 Gonial angle 부위 부피와 intergonial width의 변화량간 유의한 차이는 없었다 ($P>0.05$).

2. 교근의 최대 단면적 변화를 비교해보면, SSRO 군에서 편위측의 교근의 최대 단면적은 수술 후 1년에 수술 전보다 증가하였고 ($P<0.01$), 비편위측의 교근의 최대 단면적은 수술 전과 수술 후 1년에 유의한 변화가 없었다 ($P>0.05$). IVRO 군에서의 교근의 최대 단면적은 수술 전과 수술 후 1년에 유의한 변화가 없었다 ($P>0.05$). SSRO 군과 IVRO 군 간의 교근의 최대 단면적의 술후 변화량의 차이는 없었다 ($P>0.05$). 교근의 주행 각도는 SSRO 군과 IVRO 군 모두 비편위측에서 수술 전보다 수술 1년 후에 감소하였다 ($P<0.05$, $P<0.01$).

3. 하악골의 Gonial angle 부위 부피, 교근의 주행 각도와 최대 단면적과 menton deviation과의 상관성을 살펴보면, IVRO 군에서 하악골의 편위측과 비편위측 Gonial angle 부위 부피의 수술 후 4년과 수술 후 1년간의 변화량이 menton deviation의 양이 클수록 줄었고 ($P<0.01$, $P<0.05$), 교근의 주행 각도와 교근의 최대 단면적의 술후 변화량은 menton deviation의 양과 상관성이 없었다 ($P>0.05$).

이상의 연구 결과, SSRO 군과 IVRO 군의 수술 후 1년의 변화를 비교를 해보면 하악골의 전체 부피의 변화가 IVRO 군이 SSRO 군보다 더 큰 것을 제외하고는

하악골의 Gonial angle 부위 부피나, 교근의 최대 단면적의 수술 후 1년의 변화량에 유의차가 없었다. 비대칭의 정도에 따른 두 술식의 비교 연구 결과가 수술 방법의 선택에 영향을 줄 수 있을지 추후 향후 연구대상의 확대 및 SSRO 군의 종적인 연구를 포함한 심화 연구가 필요하리라 생각된다.

핵심되는 말 : 골격성 제 lll 급 부정교합, 안면 비대칭, SSRO, IVRO, 3차원 CT,
하악골의 부피, intergonial width, 교근