Long-term positional changes of the mandibular proximal segment after IVRO using 3-D CT in facial asymmetry patients

Soo-Yeon Han

The Graduate School

Yonsei University

Department of Dental Science

Long-term positional changes of the mandibular proximal segment after IVRO using 3-D CT in facial asymmetry patients

A Dissertation Thesis

Submitted to the Department of Dental Science

and the Graduate School of Yonsei University

in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy of Dental Science

Soo-Yeon Han

December 2012

This certifies that the dissertation thesis

of Soo-Yeon Han is approved.

____

Thesis Supervisor: Hyung-Seog Yu

____

Hyoung-Seon Baik

____

Chung-Ju Hwang

____

Sang-Hwy Lee

____

Seong-Taek Kim

The Graduate School

Yonsei University

감사의 글

본 논문이 완성되기까지 아낌없는 배려와 함께 세심한 지도와 따뜻한 격려로 이끌어주신 유형석 지도 교수님께 진심으로 감사드립니다. 또한 많은 관심과 조언으로 논문 심사를 맡아주신 백형선 교수님, 황충주 교수님, 이상휘 교수님, 김성택 교수님께도 깊은 감사를 드리며, 제가 지금까지 교정과 의사로서 거듭날 수 있도록 가르침을 주신 유영규 교수님, 손병화 교수님, 박영철 교수님, 김경호 교수님, 이기준 교수님, 차정열 교수님께 감사드립니다.

항상 함께하며 교정과 의사로서 살아가는데 많은 도움과 용기를 주시는 임선아 선생님, 권미정 선생님, 장혜숙 선생님, 김정아 선생님, 이승호 선생님께 감사의 마음을 전하고 싶습니다. 또한 논문 완성에 많은 도움을 준 이다혜 선생님을 비롯한 교정과 의국원들에게도 감사드립니다.

지금 이순간에도 제가 꿈을 이룰 수 있도록 헌신적으로 돌봐주시는 어머니께, 또 언제나 든든하게 뒤에서 지켜주셨던 돌아가신 아버지께 한없는 사랑과 감사를 드립니다. 바쁜 며느리를 언제나 믿고 응원해주시는 시부모님께도 진심으로 감사드립니다.

마지막으로 논문이 완성될 수 있도록 물심양면으로 아낌없이 지원해준 사랑하는 남편과 소중한 우리 아이들 서영이, 보현이에게도 무한한 사랑과 감사의 마음을 전하며 이 기쁨을 함께 나누고자 합니다.

2012 년 12 월 저자씀

Table of Contents

List of Figures ii

List of Tables iv

Abstract v

I. Introduction 1

II. Subjects and Methods 5

1. Subjects 5

2. 3D CT image reconstruction 8

3. Measurements using 3D CT images 10

1) Measurements of horizontal slice images 12

2) Measurements of coronal slice images 14

3) Measurements of sagittal slice images 18

4. Statistical analysis 23

III. Results 24

IV. Discussion 38

V. Conclusion 45

VI. References 46

Abstract (Korean) 53

List of Figures

Figure 1. Facial midline on P-A cephalograms.. 6

Figure 2. Reconstruction of a three-dimensional image using OnDemand software (CyberMed Inc., Seoul, Korea). 9

Figure 3. The horizontal (A), coronal (B) and sagittal (C) slice images using OnDemand software (CyberMed Inc., Seoul, Korea) 10

Figure 4. The HCA-D (horizontal condylar angle on the deviated side) and the HCA-ND (horizontal condylar angle on the non-deviated side) on the horizontal slice image.. 13

Figure 5. The CCLA-D (coronal condylar long axis angle on the deviated side) and the CCLA-ND (coronal condylar long axis angle on the non-deviated side) on the coronal slice image. 15

Figure 6. Condylar vertical axis (cva) on the coronal slice image.............................. 16

Figure 7. The CCVA-D (coronal condylar vertical axis angle on the deviated side) and the CCVA-ND (coronal condylar vertical axis angle on the non-deviated side) on the coronal slice image. 17

Figure 8. Sagittal vertical axis (sva) on the sagittal slice image. 19

Figure 9. The SCA (sagittal condylar angle) on the sagittal slice image.. 20

Figure 10. The magnified sagittal image of condyle in midcondylar level using OnDemand software (CyberMed Inc., Seoul, Korea). 21

Figure 11. Reference points and lines in the sagittal slice images.............................. 22

Figure 12. The changes in condyle during T1–T3
at the deviated (D) and the non-deviated (ND) side. 29
Figure 13. The horizontal slice images at T1, T2, and T3 31
Figure 14. The positional changes of condyle on magnified horizontal slice images
at T1, T2, and T3 32
Figure 15. The coronal slice images at T1, T2, and T3 33
Figure 16. The sagittal slice images at T1, T2, and T3 35
Figure 17. The positional changes of condyle on magnified sagittal slice images
at T1, T2, and T3 37

List of Tables

Table 1. Description of subjects.. 7

Table 2. Comparisons of condylar measurements (Mean ± SD)

between deviated and non-deviated side 26

Table 3. Comparisons of condylar measurements (Mean ± SD) during T1-T3 27

Abstract

Long-term positional changes of the mandibular proximal segment after IVRO using 3-D CT in facial asymmetry patients

Objective: This study was to evaluate the long-term positional changes of the mandibular proximal segment including condyle in skeletal Class III patients with facial asymmetry after two-jaw orthognathic surgery (Le Fort I osteotomy + intraoral vertical ramus osteotomy) using three-dimensional computed tomography.

Subjects and Methods: The subjects were composed of 17 skeletal Class III patients with facial asymmetry. CT images were taken at T1 (before surgery), T2 (1 year after surgery), and T3 (4 years after surgery) and measurements from the reconstructed three-dimensional (3D) CT images were done.

The horizontal condylar angle (HCA) at horizontal slice image, coronal condylar long axis angle (CCLA) and coronal condylar vertical axis angle (CCVA) at coronal slice image, and sagittal condylar angle (SCA) and temporomandibular joint space distance (A-B and C-D) at sagittal slice image were measured on both deviated and non-deviated sides.

Results: When comparing the bilateral differences at T1, the horizontal, coronal, and sagittal condylar angle were significantly different ($P < .05$). At T2, there was no significant difference except the horizontal condylar angle and at T3, there was no significant difference except the horizontal condylar angle and the coronal condylar vertical axis angle ($P > .05$).

The most of measurements were significantly different during T1-T2, but there was no significant difference during T2-T3 ($P < .0167$). The horizontal condylar angle increased significantly at both sides during T1-T2, that showed outward rotation of condyle after IVRO ($P < .0167$). The coronal condylar long axis angle at non-deviated side and the coronal condylar vertical axis angle at deviated side decreased significantly during T1-T2 ($P < .0167$). The sagittal condylar angle decreased significantly at both sides during T1-T2 and the temporomandibular joint space distance (A-B and C-D) increased significantly that showed anterior-inferior movement of condyle after IVRO ($P < .0167$).

Conclusion: In skeletal Class III asymmetry patients, the mandibular asymmetry improved after IVRO, and the most of measurements of the mandibular proximal segment showed no significant difference during the 4-year follow up period.

After IVRO, three-dimensional displacement of the proximal segment represented outward rotation of condyle, medial displacement of the tip of the proximal segment on the deviated side for improving skeletal symmetry, posterior displacement of the tip of the proximal segment and anterior-inferior movement of condyle in each horizontal, coronal, and sagittal slice image. And we could observe that the mandibular proximal segments move to the more stable position while the function of the mandible recovered after surgery.

Key words: 3D CT, Proximal segment, Condyle, Orthognathic surgery, IVRO, Skeletal Class III, Facial asymmetry

Long-term positional changes of the mandibular proximal segment after IVRO using 3-D CT in facial asymmetry patients

Soo-Yeon Han, D.D.S., M.S.D.

Department of Dental Science, Graduate School, Yonsei University
(Directed by Prof. Hyung-Seog Yu, D.D.S.,M.S.D.,Ph.D.)

I. Introduction

Three-dimensional 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 diagnostics and treatment planning in orthodontics but also studies on post-treatment stability.[1,2] In particular, patients undergoing orthognathic surgery require three-dimensional 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.[3-5]

To prevent postoperative relapse, satisfactory dental occlusion and normal condylar position have been reported as key factors.[6] In particular, postoperative condylar position which is influenced by rotational movement of the distal segment, tensional balance of the surrounding muscles, fixation method, and surgeon's experience is very important factor.[7]

There have been many previous studies which reported evaluating condylar position using 2D images and Baik[8] reported about temporomandibular joint space in normal occlusion using TMJ tomogram and cephalogram. Using 3D CT, the assessment of condylar position is now possible because of its superior reliability and greater accuracy than traditional 2D images[9,10] and there have been many reports on three dimensional condylar positional changes.[11-13]

Orthognathic surgery can correct the skeletal discrepancy like mandibular prognathism and facial asymmetry. A number of surgical techniques are used to correct the mandibular prognathism, among those, intraoral vertical ramus osteotomy (IVRO) and sagittal split ramus osteotomy (SSRO) are two most frequently used techniques.

The predictable outcomes and the low complication rate of IVRO are widely known and the technique have been used for mandibular orthognathic surgery.[14-18] It offers many advantages over SSRO for the treatment of the mandibular prognathic patient, including a lower incidence of injury to the inferior alveolar nerve, technical simplicity, reduced surgical time, and the ability to reposition the condyle.[19] It also has been reported that IVRO is a suitable method in case of severe mandibular asymmetry to achieve stable mandibular results.[20,21] Previous studies have been reported that IVRO could improve the disc-condyle relationship in patients with jaw deformities and it has been used for patients with TMJ dysfunction or severe mandibular asymmetry.[22,23] IVRO has been widely applied for patients with temporomandibular dysfunction with or without jaw deformity, based on the previous reports that IVRO cause inherent displacement of the condyle, moving it away from the disc and posterior attachment, and decompressing the TMJ apparatus.[24,25]

There have been many reports[26-30] describing postoperative skeletal changes or postoperative stability after SSRO for skeletal Class III patients, including using 3D images.[31-33] However, there have been few reports on postoperative changes of the position and angle of condyle after IVRO. And most of their follow-up terms were less than 2 years.[34]

Using the 3D CT images, more precise analysis and diagnosis for the orthodontic treatment and orthognathic surgery have come to possible. Moreover, the positions and angulations of the mandibular proximal segment including condyle can be measured in horizontal, coronal, and sagittal slices with dimensional accuracy on the reconstructed 3D CT images.[35] Therefore, the purpose of this study was to evaluate the long-term postoperative changes of the mandibular proximal segment including condyle and their stability of skeletal Class III patient with facial asymmetry after IVRO. Using the 3D CT images, we evaluated the changes of condylar position on horizontal, coronal, and sagittal view in the deviated and non-deviated side.

II. Subjects and Methods

1. Subjects

This study population was composed of patients with mandibular prognathism and facial asymmetry who had undergone orthognathic surgery at Yonsei University Dental Hospital, Seoul, South Korea from 2004 to 2007. These subjects were diagnosed as skeletal Class III malocclusion using lateral cephalometric analysis. The diagnostic criteria were unilateral or bilateral Angle Class III molar key, overjet of 0mm or less, and ANB difference of 0˚ or less (average, -2.2˚). And they had mandibular menton deviation of more than 3.5 mm from the facial midline (average, 5.5mm), using posteroanterior cephalometric analysis. The facial midline was defined as a line perpendicular to the line connecting Lo and Lo' through Nc (Figure 1).[36]

Patients who did not have systemic disease or temporomandibular joint dysfunction and were treated with orthognathic surgery (Le Fort I osteotomy + bilateral intraoral vertical ramus osteotomy) to reduce facial and structural imbalance were further studied.

A total of 17 Korean patients were examined before surgery, 1 year after surgery and 4 years after surgery. The subjects were composed of 6 male and 11 female; average age, 21.7 years. All of them underwent preoperative and postoperative orthodontic treatment and two-jaw surgery (Le Fort I osteotomy + IVRO, 9 of 17 patients had genioplasty) by one surgeon.

We got informed consents on CT scan from each of the patients, and the description of the subjects was given in Table 1.

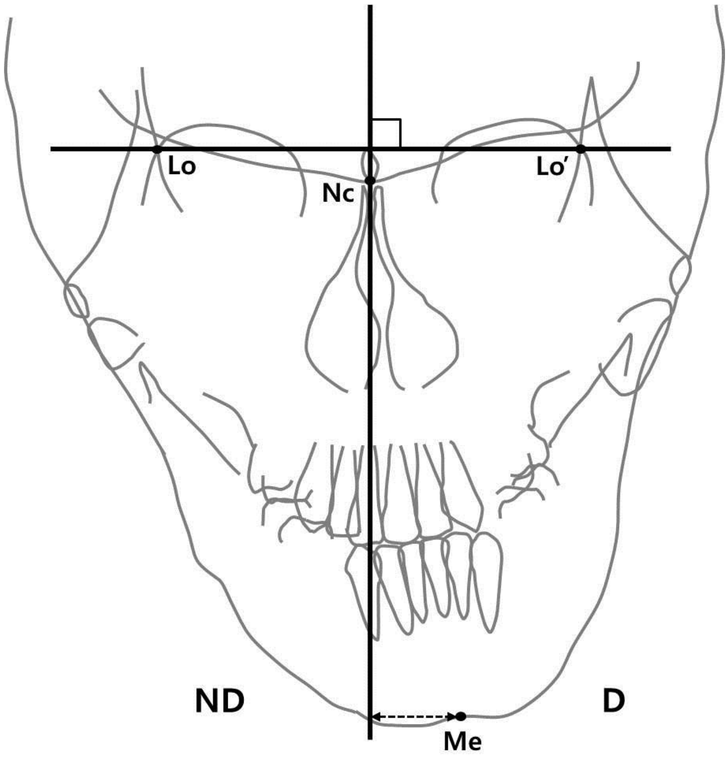


Figure 1. Facial midline on P-A cephalograms.

*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. Description of subjects

	Subjects
N	17
Gender	6 males and 11 females
Race	Korean
Average age	21.7 y
Inclusion criteria	Skeletal/dental Class III with mandibular prognathism
	Chin deviation of more than 3.5 mm from the facial midline
Orthodontic treatment	Preoperative and postoperative orthodontic treatment
Surgery	Le Fort I osteotomy + IVRO
	9 of 17 patients had genioplasty
TMD	No remarkable pain, crepitus or degenerative joint disease

* N indicates number of total subjects; IVRO, intraoral vertical ramus osteotomy; TMD, temporomandibular joint disorder.

2. 3D CT image reconstruction

Stereoscopic images were created for each patient based on the 3D CT taken before surgery (T1), one year after surgery (T2), and approximately 4 years after surgery (T3). The CT images were taken using a CT Hispeed Advantage (GE Medical System, Milwaukee, Wis, USA).

The Frankfort Horizontal plane (FH plane) of the patient was adjusted perpendicular to the ground, and the middle line and major axis were placed in the same position.

The thickness of the axial image was 1 mm, and images were taken at a table speed of 6 mm per second. The axial images taken were sent out as Digital Imaging & Communication in Medicine (DICOM) files, and were restructured into a 3D model with OnDemand program (CyberMed Inc., Seoul, Korea; Figure 2).

The horizontal reference plane was established parallel to the FH plane, which was constructed on both sides of porion and left of orbitale, passing through nasion. And the sagittal reference plane was drawn perpendicular to the FH plane passing through nasion and prechiasmatic groove. The shifted side of menton for the sagittal reference plane was defined as the deviated side, and the other side was defined as non-deviated side. The coronal reference plane was drawn perpendicular to the horizontal and sagittal reference plane passing through nasion . [37]

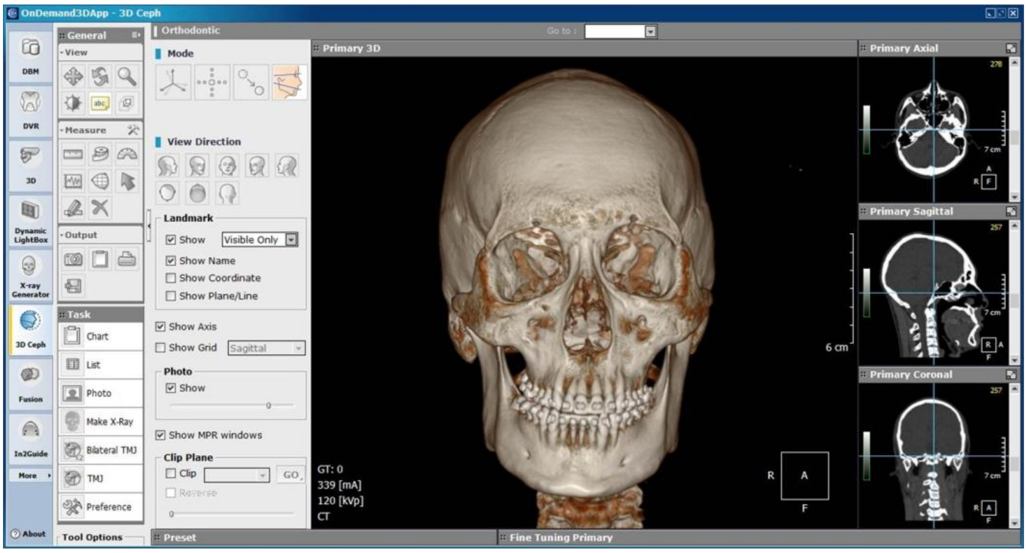


Figure 2. Reconstruction of a three-dimensional image using OnDemand software (CyberMed Inc., Seoul, Korea).

3. Measurements using 3D CT images

Under the MPR (Multiplanar reconstruction) mode of software, we assessed the three-dimensional condylar positional changes after IVRO on horizontal, coronal, and sagittal slice images with the reconstructed three-dimensional images (Figure 3).

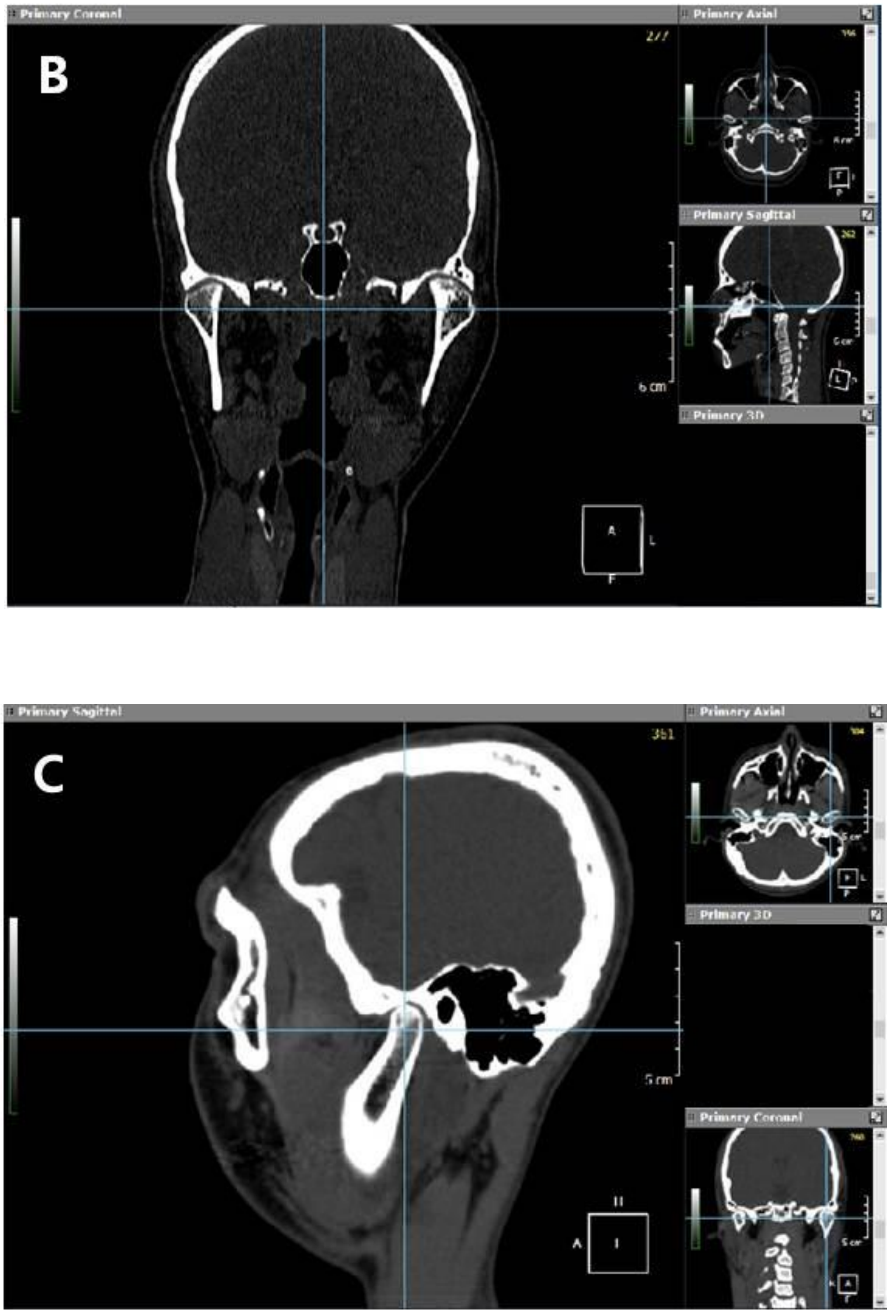


Figure 3. The horizontal (A), coronal (B) and sagittal (C) slice images using OnDemand software (CyberMed Inc., Seoul, Korea).

The horizontal condylar angle (HCA) on horizontal slice image, coronal condylar long axis angle (CCLA) and coronal condylar vertical axis angle (CCVA) on coronal slice image, and sagittal condylar angle (SCA) and temporomandibular joint space distance (A-B and C-D) on sagittal slice image were measured on both the deviated and non-deviated side using the reconstructed 3D CT images of T1, T2, and T3.

1) Measurements of horizontal slice images

The horizontal slice image parallel to the FH plane where two condyles could be recognized at including medial and lateral poles of the condyle was selected to measure the horizontal condylar angle.

When both sides of the condyle were not appeared in one horizontal slice image, we measured the horizontal condylar angle separately in deviated and non-deviated side.

Horizontal condylar angle was measured as the angle between condylar long axis and sagittal reference plane (Figure 4).

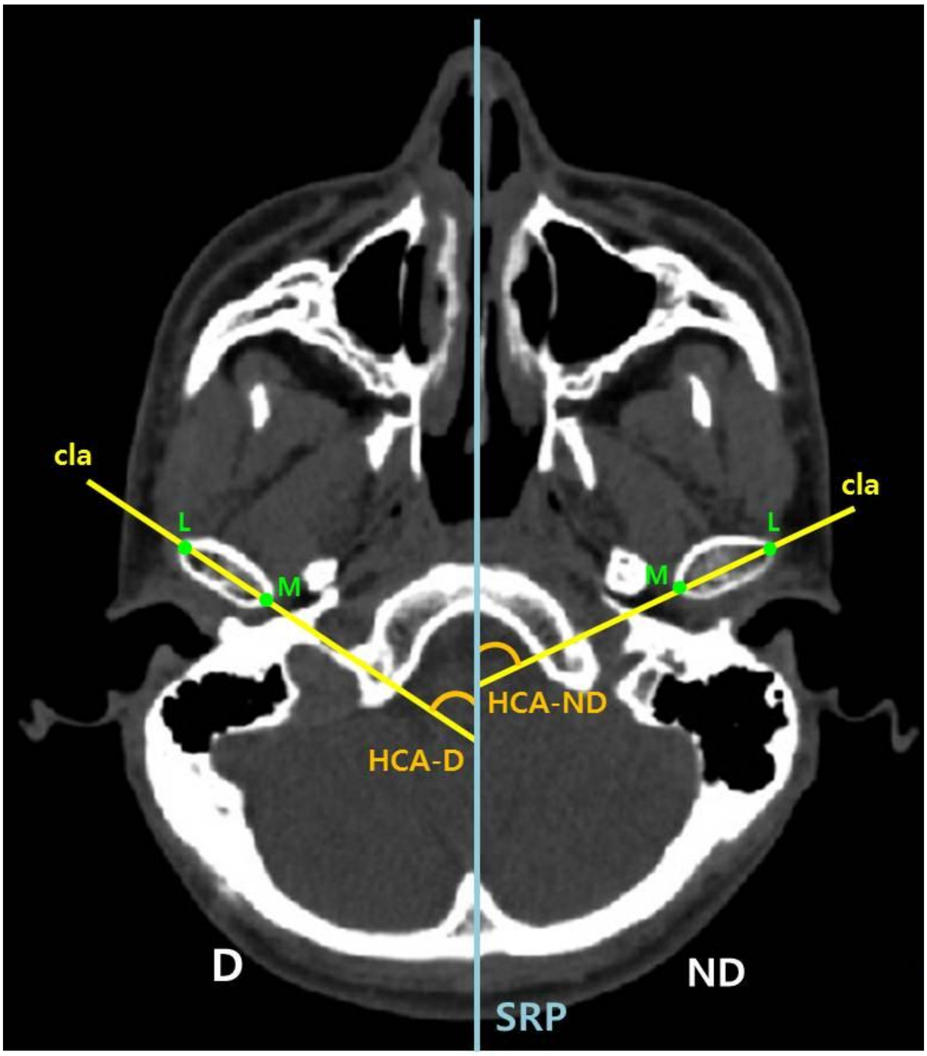


Figure 4. The HCA-D (horizontal condylar angle on the deviated side) and the HCA-ND (horizontal condylar angle on the non-deviated side) on the horizontal slice image. *SRP indicates sagittal reference plane; M, medial pole of condyle; L, lateral pole of condyle; cla (condylar long axis), the line passed M and L; D, deviated side; ND, non-deviated side.

2) Measurements of coronal slice images

The coronal slice images parallel to the coronal reference plane passed through the condyle were selected for measurement.

Coronal condylar long axis angle was measured as the angle between condylar long axis and horizontal reference plane on the coronal slice image to evaluate the degree of tilting of the condyle (Figure 5).

And coronal condylar vertical axis angle was measured as the angle between horizontal reference plane on the coronal slice image and condylar vertical axis, a line bisecting the medial and lateral border of the proximal segment (Figure 6, 7).

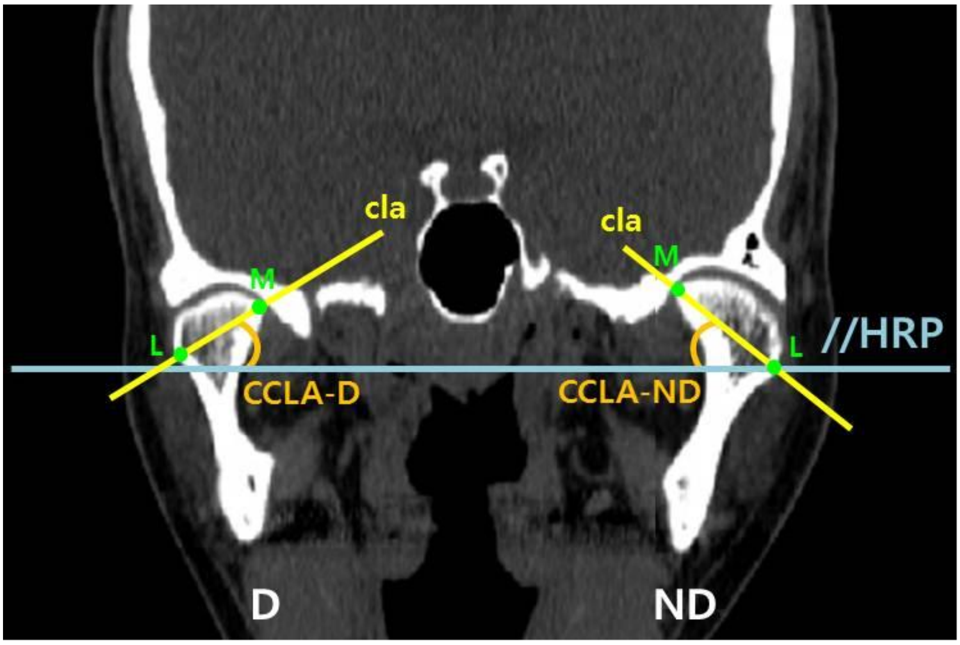


Figure 5. The CCLA-D (coronal condylar long axis angle on the deviated side) and the CCLA-ND (coronal condylar long axis angle on the non-deviated side) on the coronal slice image.

*//HRP indicates parallel plane to the horizontal reference plane; M, medial pole of condyle; L, lateral pole of condyle; cla, condylar long axis; D, deviated side; ND, non-deviated side.

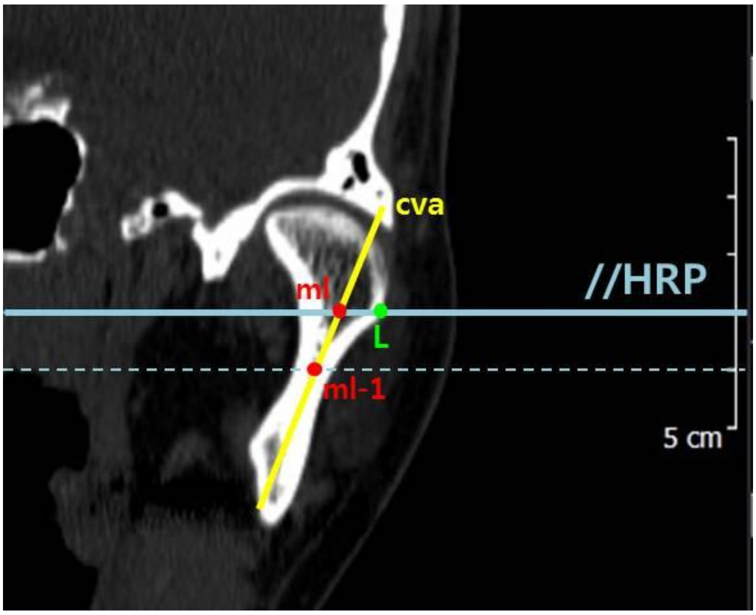


Figure 6. Condylar vertical axis (cva) on the coronal slice image.

*//HRP indicates parallel plane to the horizontal reference plane; L, lateral pole of condyle; ml, midpoint between medial and lateral border of the proximal segment at the level of lateral pole on the //HRP; ml-1, midpoint between medial and lateral border of the proximal segment at the 1cm lower level from the lateral pole parallel to HRP; cva (condylar vertical axis), the line passed ml and ml-1.

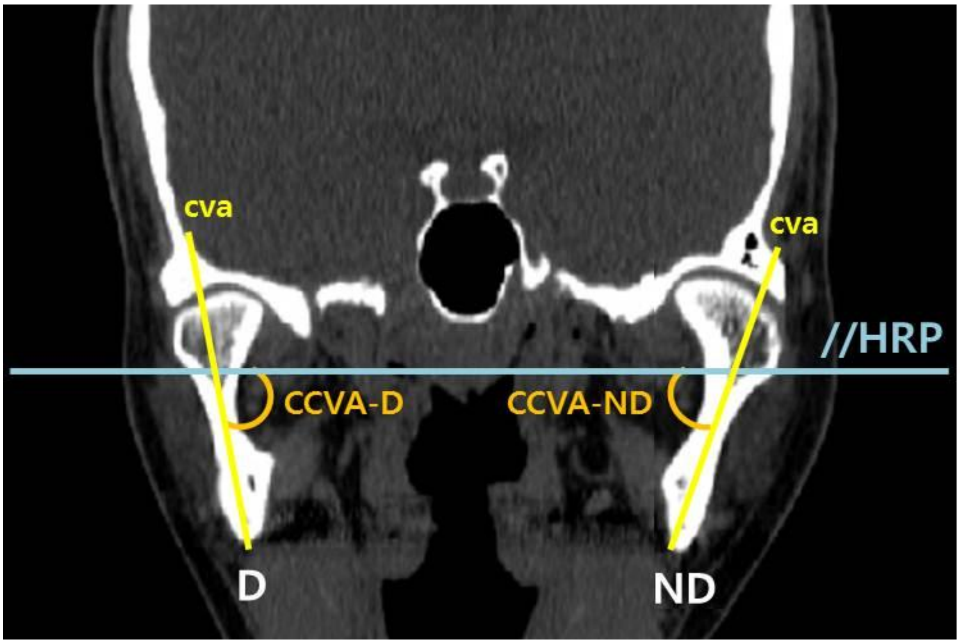


Figure 7. The CCVA-D (coronal condylar vertical axis angle on the deviated side) and the CCVA-ND (coronal condylar vertical axis angle on the non-deviated side) on the coronal slice image.

*//HRP indicates parallel plane to the horizontal reference plane; cva, condylar vertical axis; D, deviated side; ND, non-deviated side.

3) Measurements of sagittal slice images

The sagittal slice images parallel to the sagittal reference plane including the condylar head were selected for measurement.

Sagittal condylar angle was measured as the angle between sagittal vertical axis, a line bisecting the anterior and posterior border of the proximal segment and coronal reference plane on the sagittal slice image (Figure 8,9).

The temporomandibular joint space distance (A-B and C-D) was measured as midline of the condylar head which shown on the coronal slice image to assess the position of condyle (Figure 10). In the magnified sagittal slice images, some reference points and lines were selected to evaluate the position of condyle (Figure 11).

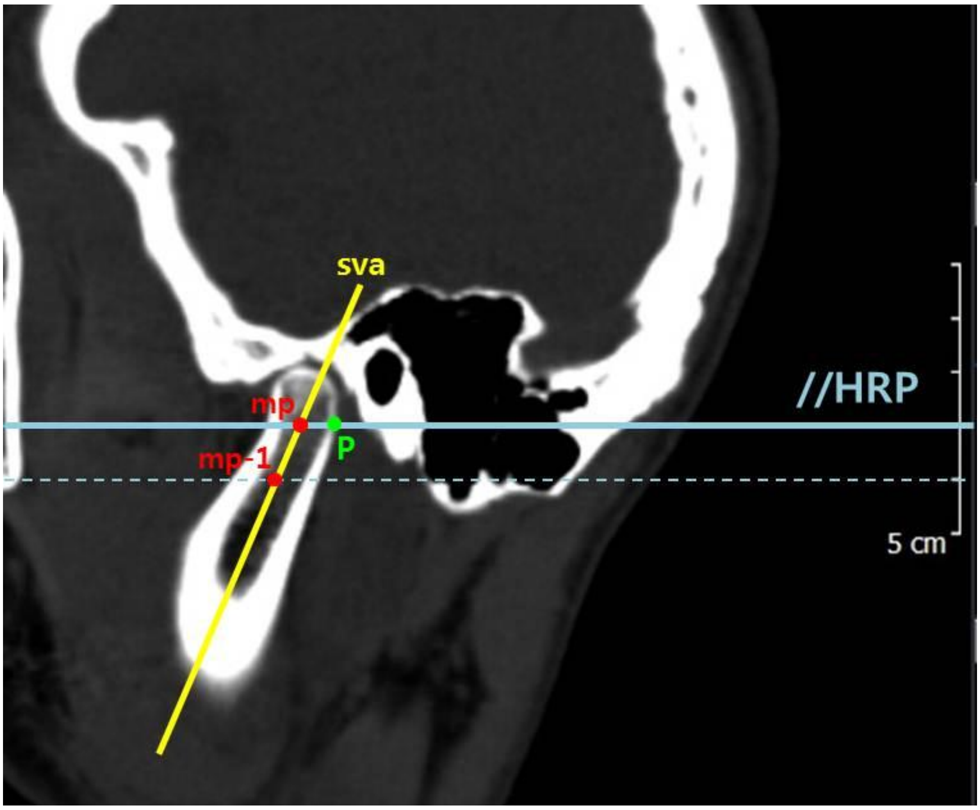


Figure 8. Sagittal vertical axis (sva) on the sagittal slice image.

*//HRP indicates parallel plane to the horizontal reference plane; P, posterior pole of condyle; mp, midpoint between anterior and posterior border of the proximal segment at the level of posterior pole on the //HRP; mp-1, midpoint between anterior and posterior border of the proximal segment at the 1cm lower level from the posterior pole parallel to HRP; sva (sagittal vertical axis), the line passed mp and mp-1.

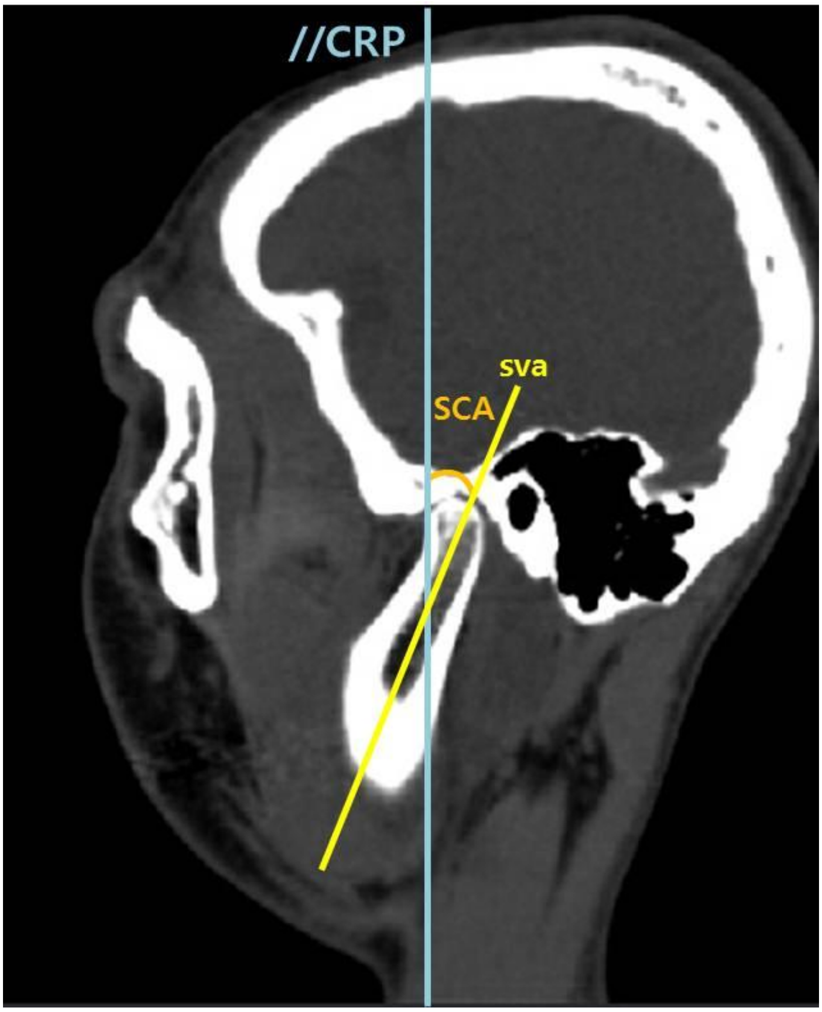


Figure 9. The SCA (sagittal condylar angle) on the sagittal slice image.

*//CRP indicates parallel plane to the coronal reference plane; sva, sagittal vertical axis.

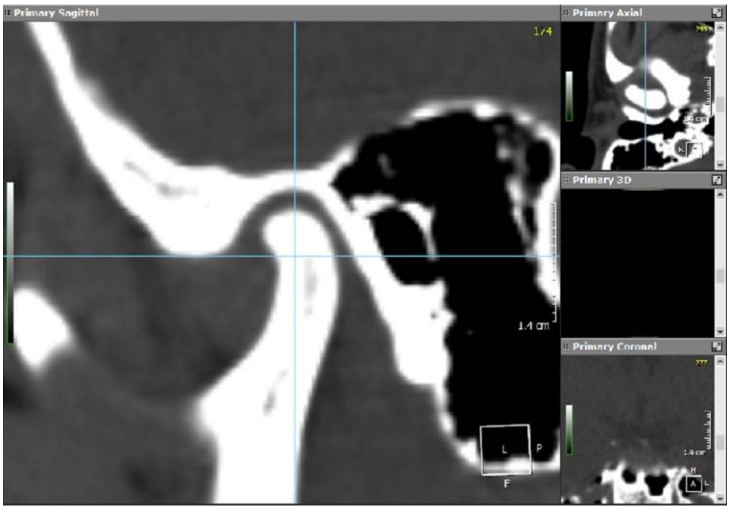


Figure 10. The magnified sagittal image of condyle in midcondylar level using OnDemand software (CyberMed Inc., Seoul, Korea).

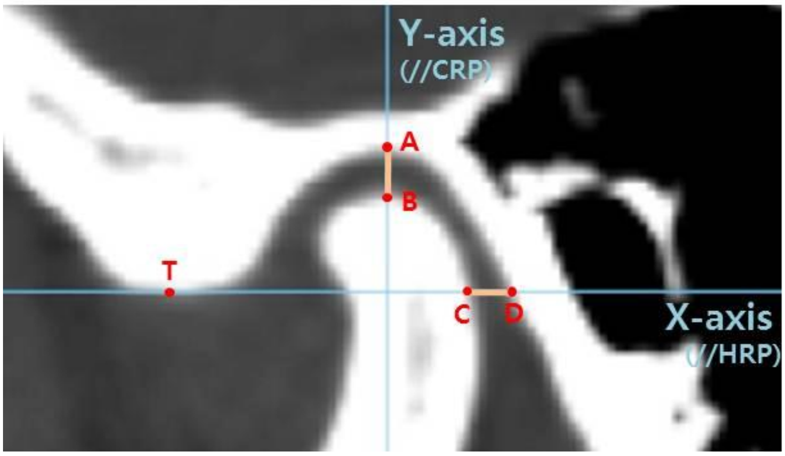


Figure 11. Reference points and lines in the sagittal slice images.

A, the most cranial point on curvature of glenoid fossa; **T**, the inferior point of tuberculum; **Y-axis**, the plane parallel with CRP (coronal reference plane) through the A point; **B**, intersection between the superior curvature of condyle and Y-axis; **X-axis**, the plane parallel with HRP (horizontal reference plane) through the T point; **C**, intersection between the posterior curvature of condyle and X-axis; **D**, intersection between the posterior border on glenoid fossa and X-axis.

4. Statistical Analysis

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

Paired t-test was used to compare the differences between the deviated and non-deviated sides and the differences were considered significant at $p < .05$.

Paired t-test was used to compare the changes of condylar measurements over the period during T1–T3 and the differences were considered significant at $p < .0167$ which was adjusted by Bonferroni correction.

All statistical evaluations were performed with SAS version 9.2 (SAS Inc, Cary, NC).

III. Results

The intraexaminer error was found to be statistically insignificant ($P < .05$), and the intraclass correlation coefficients were within acceptable value (mean of .97, with a range of .96–.99).

The comparison of condylar measurements between the deviated and non-deviated side are shown in Table 2. When comparing the bilateral differences at T1, horizontal, coronal, and sagittal condylar angle were significantly different. At T2, there was no significant difference except horizontal condylar angle and at T3, there was no significant difference except the horizontal condylar angle and the coronal condylar vertical axis angle ($P > .05$).

The changes in condyle during T1-T3 are shown in Table 3 and Figure 12. The most of measurements were significantly different during T1-T2, but there was no significant difference during T2-T3 ($P < .0167$).

In horizontal slice image, the horizontal condylar angle increased significantly at both sides during T1-T2, that showed outward rotation of condyle after IVRO ($P < .0167$).

In coronal slice image, the coronal condylar long axis angle at non-deviated side and the coronal condylar vertical axis angle at deviated side decreased significantly during T1-T2 ($P < .0167$).

In sagittal slice image, the sagittal condylar angle decreased significantly at both sides during T1-T2 and the temporomandibular joint space distance (A-B and C-D) increased significantly that showed anterior-inferior movement of condyle after IVRO ($P < .0167$).

The changes in condyle during T1-T3 of each slice images are shown in Figure 13-17.

Table 2. Comparisons of condylar measurements (Mean ± SD) between deviated and non-deviated side.

	T1-D	T1-ND	T2-D	T2-ND	T3-D	T3-ND
Horizontal Condylar Angle, °	68.7 ± 7.9	76.5 ± 5.9	76.1 ± 9.4	82.3 ± 7.3	76.5 ± 9.9	82.0 ± 8.0
Sig	*		*		*	
Coronal Condylar Long axis Angle, °	14.2 ± 5.2	18.4 ± 6.6	15.0 ± 6.4	15.1 ± 7.1	15.8 ± 4.9	16.6 ± 6.9
Sig	*		NS		NS	
Coronal Condylar Vertical axis Angle, °	82.8 ± 4.4	78.4 ± 3.5	80.3 ± 4.9	79.0 ± 5.5	79.9 ± 5.3	77.8 ± 4.9
Sig	*		NS		*	
Sagittal Condylar Angle, °	14.2 ± 5.4	17.1 ± 6.3	11.0 ± 5.3	11.7 ± 5.4	10.5 ± 4.9	12.4 ± 5.2
Sig	*		NS		NS	
A-B, mm	1.9 ± 0.9	1.7 ± 0.8	2.9 ± 1.6	2.6 ± 0.8	2.8 ± 1.3	2.2 ± 0.7
Sig	NS		NS		NS	
C-D, mm	2.9 ± 1.2	2.8 ± 1.0	3.8 ± 1.8	3.8 ± 1.1	3.6 ± 1.5	3.2 ± 0.7
Sig	NS		NS		NS	

Sig : comparison between deviated and non-deviated side.

D indicates deviated side; ND, non-deviated side; NS, not significant; Sig, significance; SD, standard deviation.

* $P < .05$

Table 3. Comparisons of condylar measurements (Mean ± SD) during T1-T3.

	Deviated side			Non-deviated side		
	T1	T2	T3	T1	T2	T3
Horizontal Condylar Angle, °	68.7 ± 7.9	76.1 ± 9.4	76.5 ± 9.9	76.5 ± 5.9	82.3 ± 7.3	82.0 ± 8.0
Sig 1	*			*		
Sig 2			NS			NS
Sig 3		*			*	
Coronal Condylar Long axis Angle, °	14.2 ± 5.2	15.0 ± 6.4	15.8 ± 4.9	18.4 ± 6.6	15.1 ± 7.1	16.6 ± 6.9
Sig 1	NS			*		
Sig 2			NS			NS
Sig 3		NS			NS	
Coronal Condylar Vertical axis Angle, °	82.8 ± 4.4	80.3 ± 4.9	79.9 ± 5.3	78.4 ± 3.5	79.0 ± 5.5	77.8 ± 4.9
Sig 1	*			NS		
Sig 2			NS			NS
Sig 3		*			NS	
Sagittal Condylar Angle, °	14.2 ± 5.4	11.0 ± 5.3	10.5 ± 4.9	17.1 ± 6.3	11.7 ± 5.4	12.4 ± 5.2
Sig 1	*			*		
Sig 2			NS			NS
Sig 3		*			*	

	Deviated side			Non-deviated side		
	T1	T2	T3	T1	T2	T3
A-B, mm	1.9 ± 0.9	2.9 ± 1.6	2.8 ± 1.3	1.7 ± 0.8	2.6 ± 0.8	2.2 ± 0.7
Sig 1		*			*	
Sig 2			NS			NS
Sig 3		*			NS	
C-D, mm	2.9 ± 1.2	3.8 ± 1.8	3.6 ± 1.5	2.8 ± 1.0	3.8 ± 1.1	3.2 ± 0.7
Sig 1		*			*	
Sig 2			NS			NS
Sig 3		NS			NS	

Sig 1: comparison between T1 and T2; Sig 2: comparison between T2 and T3;

Sig 3: comparison between T1 and T3.

NS indicates not significant; Sig, significance; SD, standard deviation.

* *P* < .0167, adjusted alpha = 0.0167 (by Bonferroni correction)

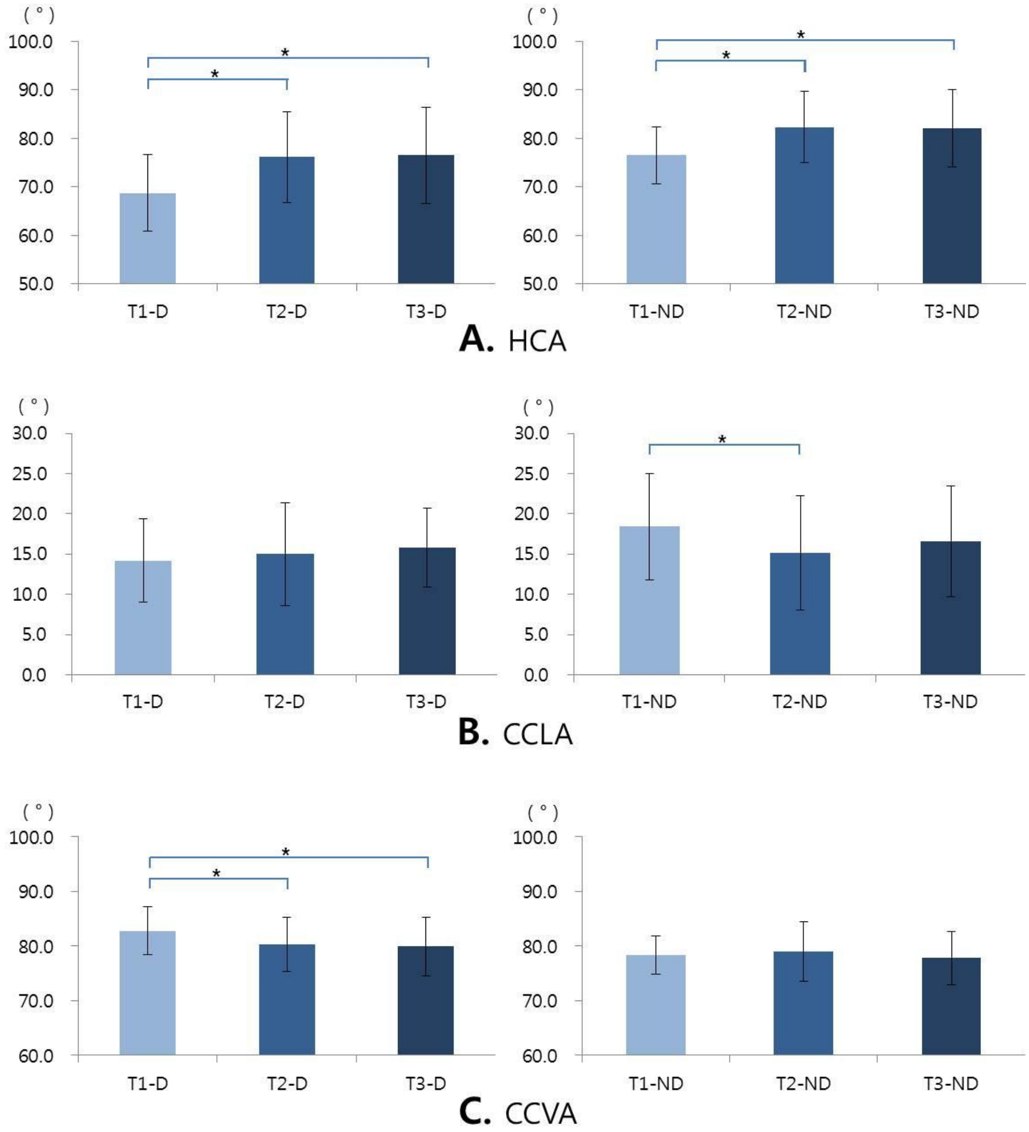


Figure 12. The changes in condyle during T1–T3 at the deviated (D) and the non-deviated (ND) side. **A**. HCA, the horizontal condylar angle; **B**. CCLA, the coronal condylar long axis angle; **C**. CCVA, the coronal condylar vertical axis angle;

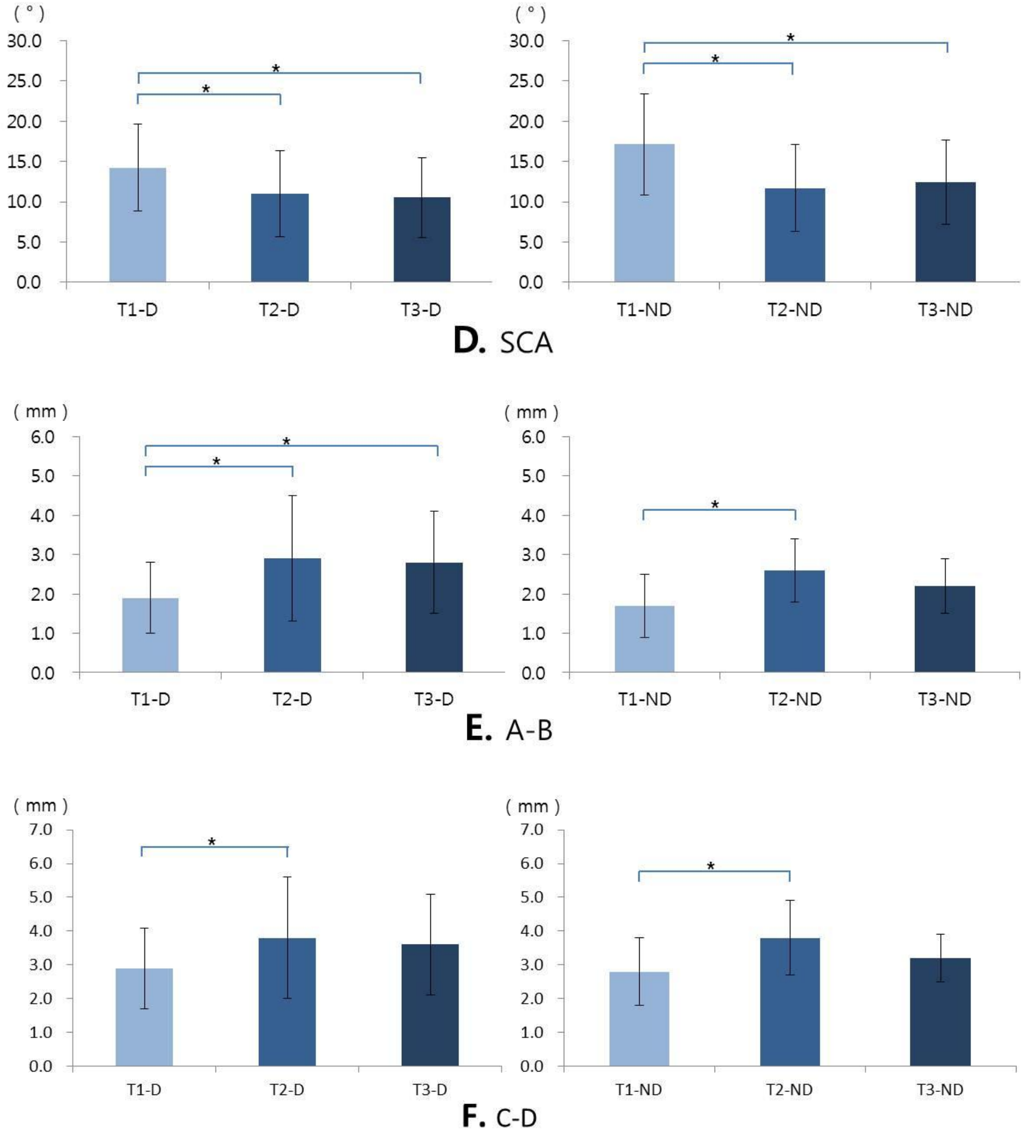


Figure 12, cont'd. D. SCA, the sagittal condylar angle; **E**. A-B, the distance of the A and B points in the sagittal slice image; **F**. C-D, the distance of the C and D points in the sagittal slice image.

* $P < .0167$

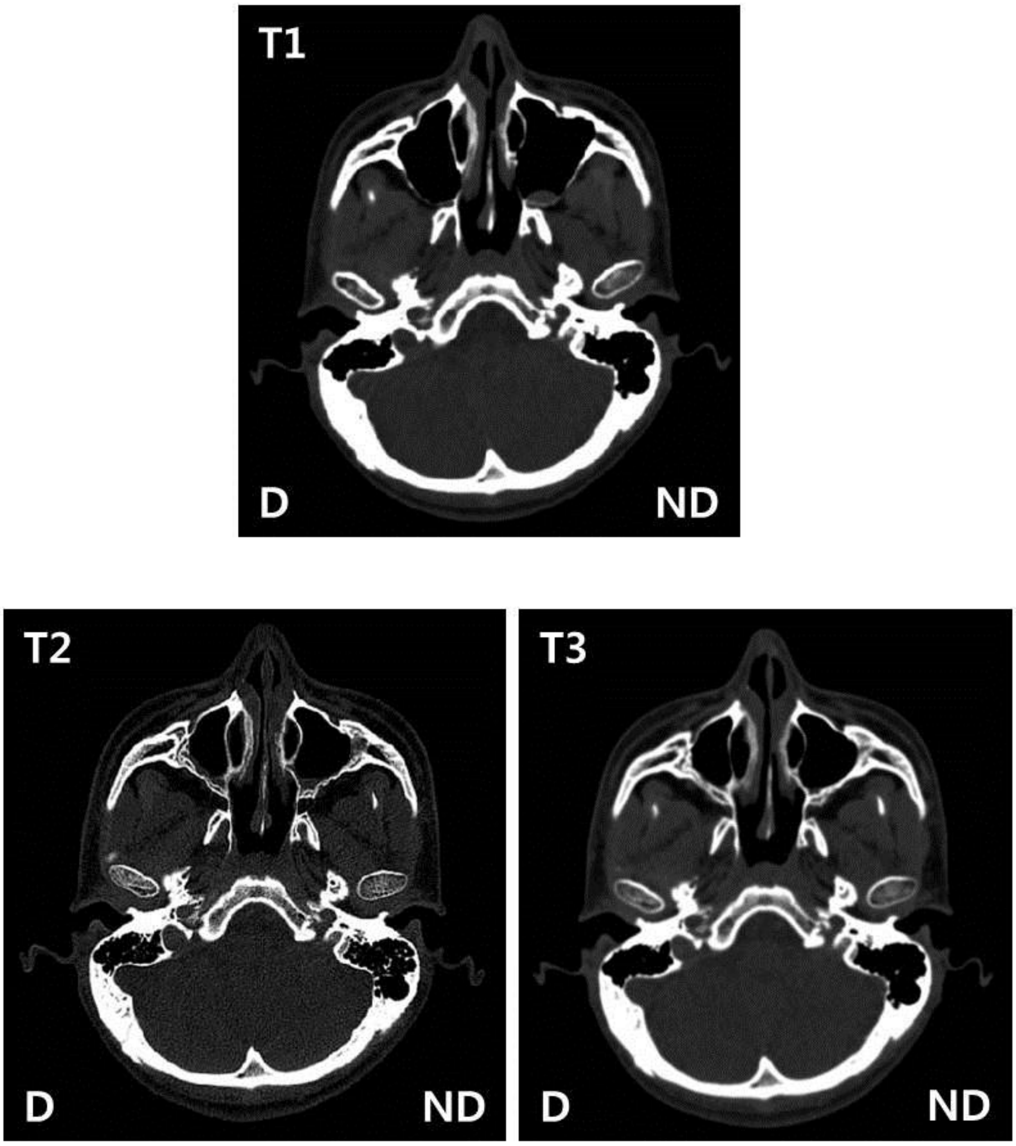


Figure 13. The horizontal slice images at T1, T2, and T3. *D indicates deviated side; ND, non-deviated side.

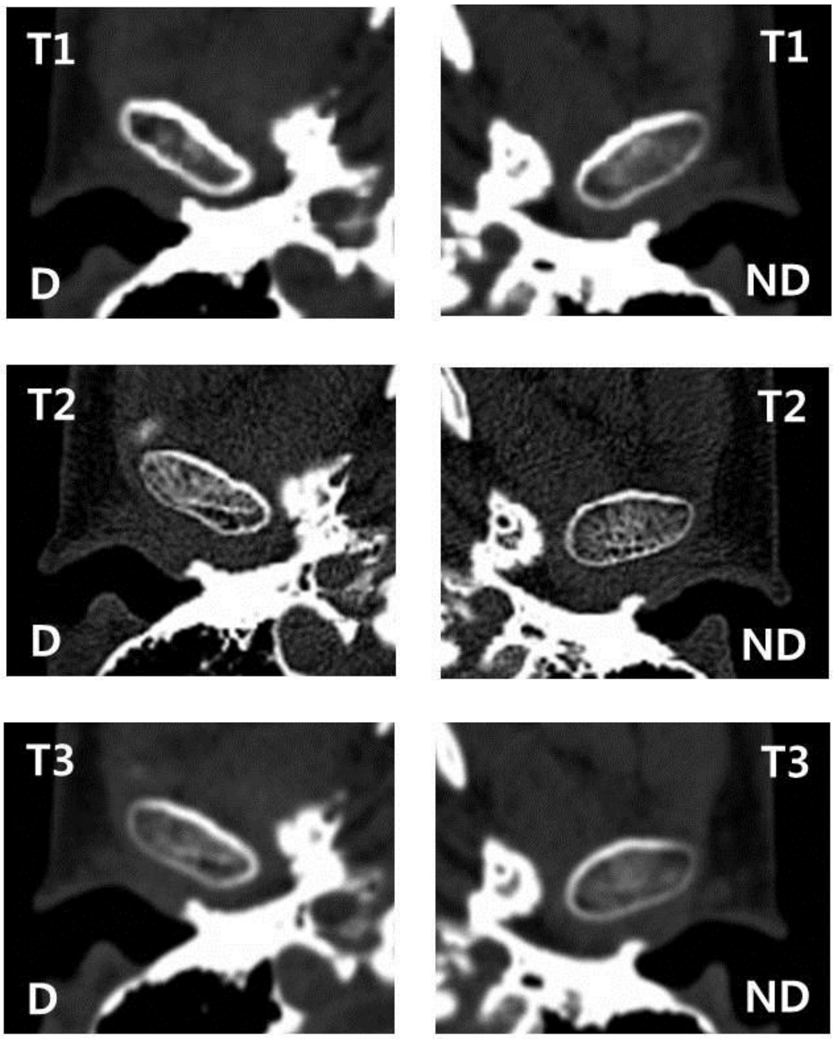
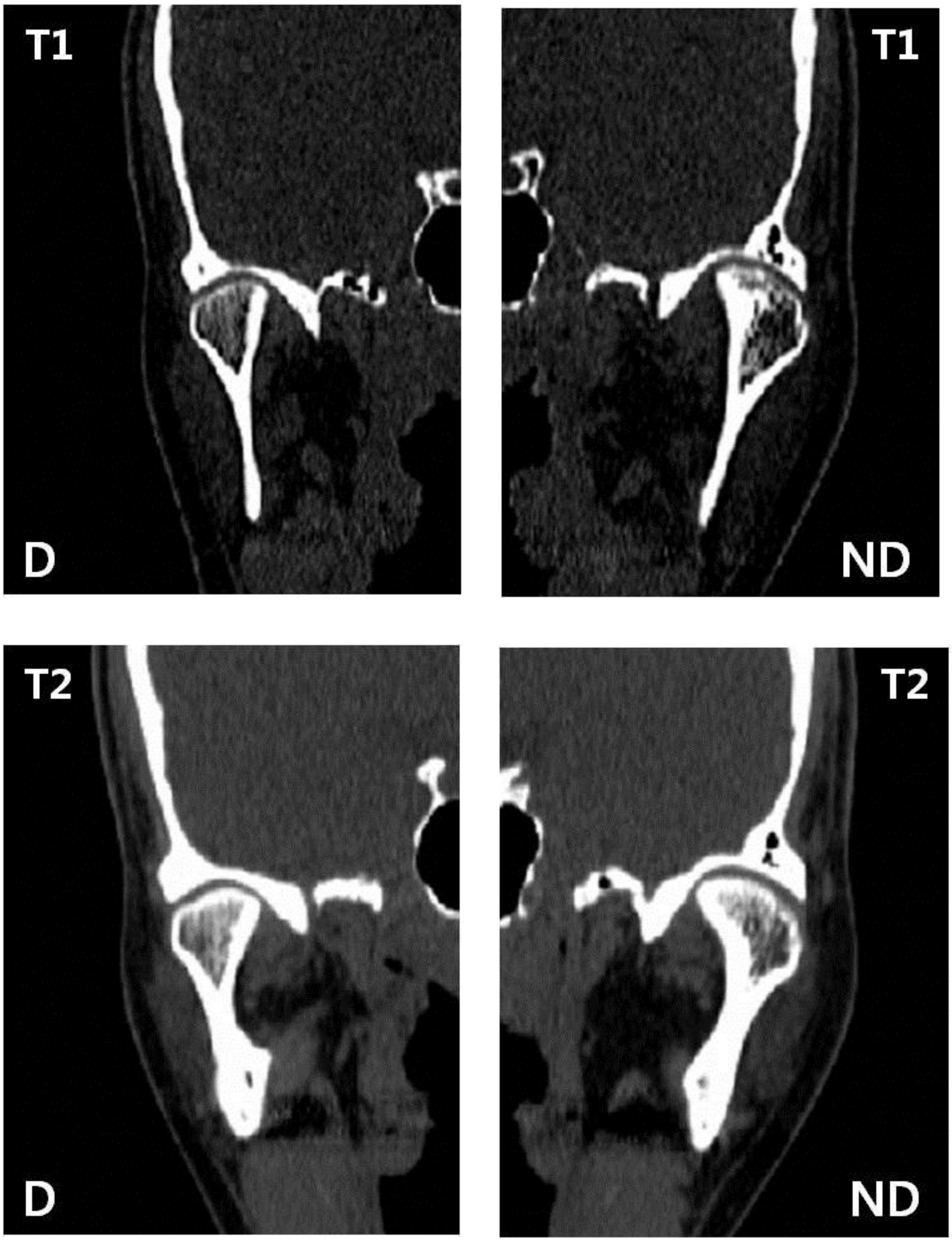


Figure 14. The positional changes of condyle on magnified horizontal slice images at T1, T2, and T3. *D indicates deviated side; ND, non-deviated side.


T1
T1
D
ND
T2
T2
D
ND

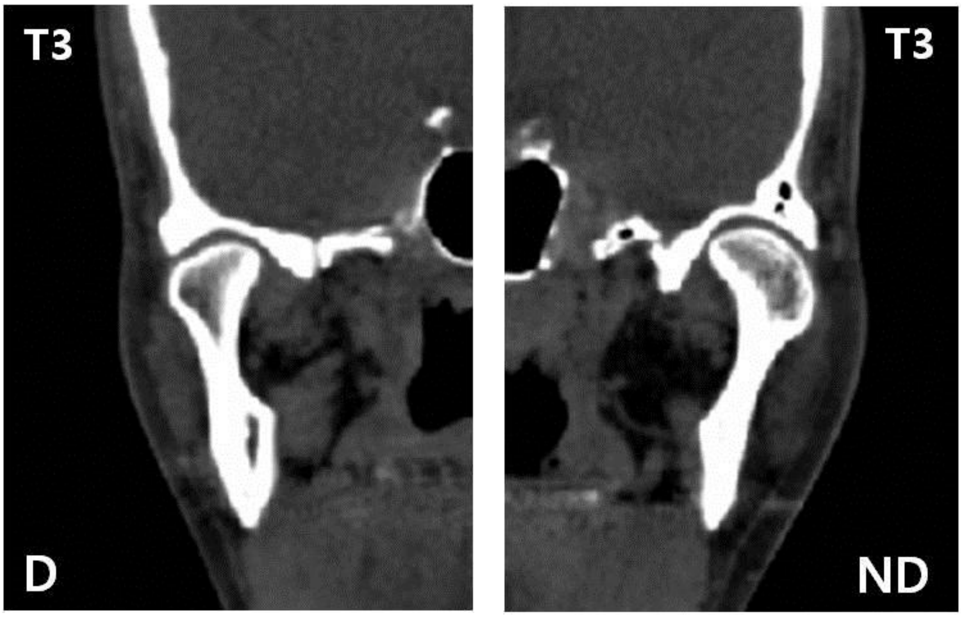
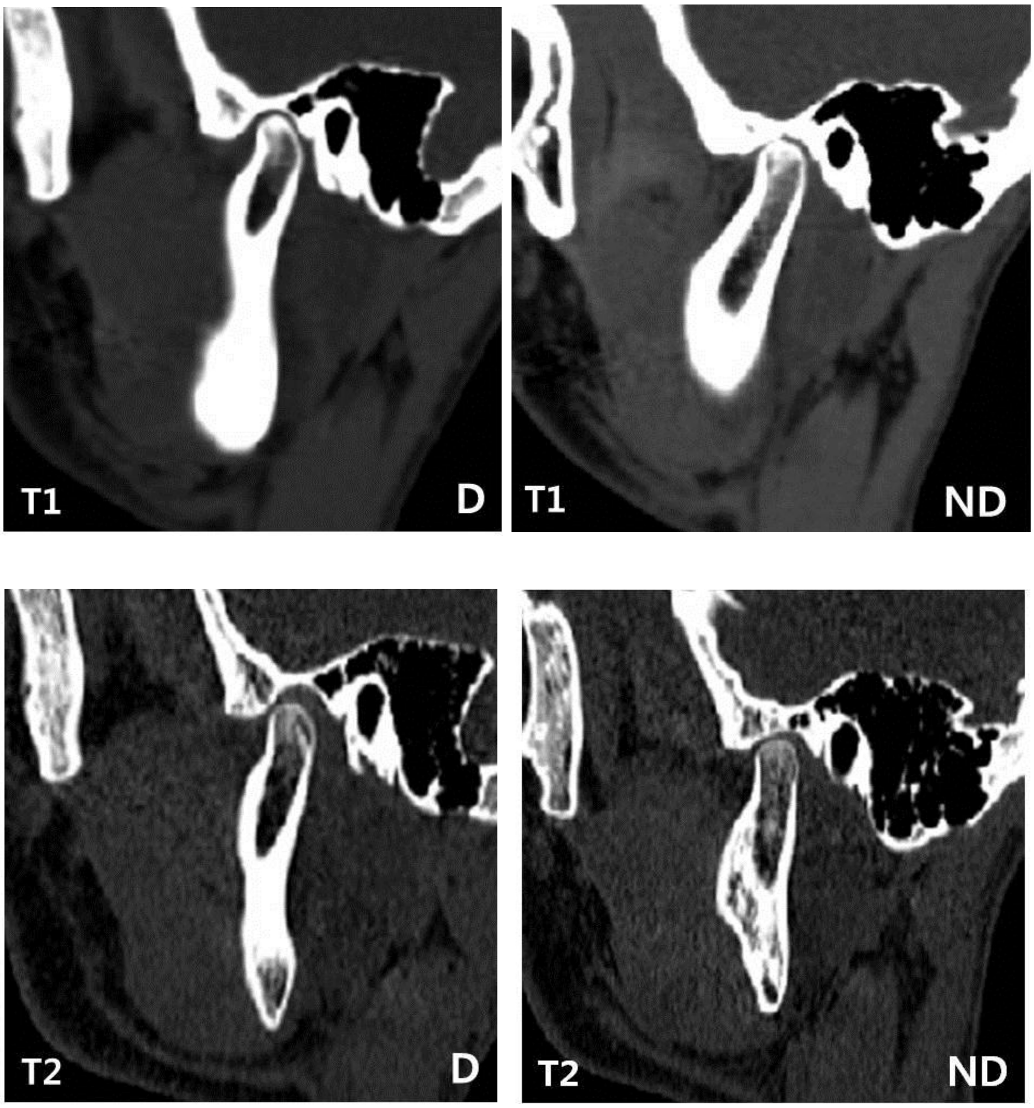


Figure 15. The coronal slice images at T1, T2, and T3. *D indicates deviated side; ND, non-deviated side.


T1
D
T1
ND
T2
D
T2
ND

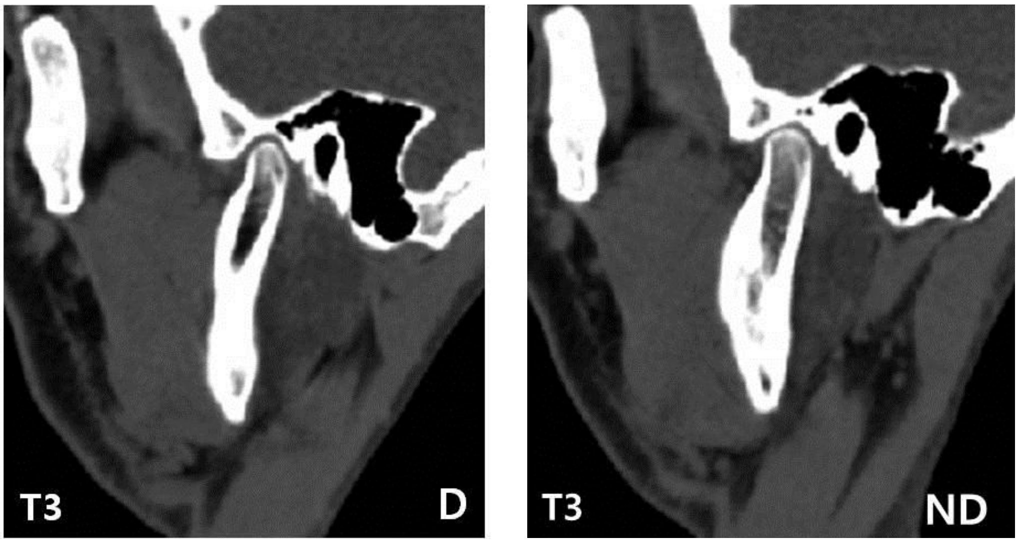


Figure 16. The sagittal slice images at T1, T2, and T3. *D indicates deviated side; ND, non-deviated side.

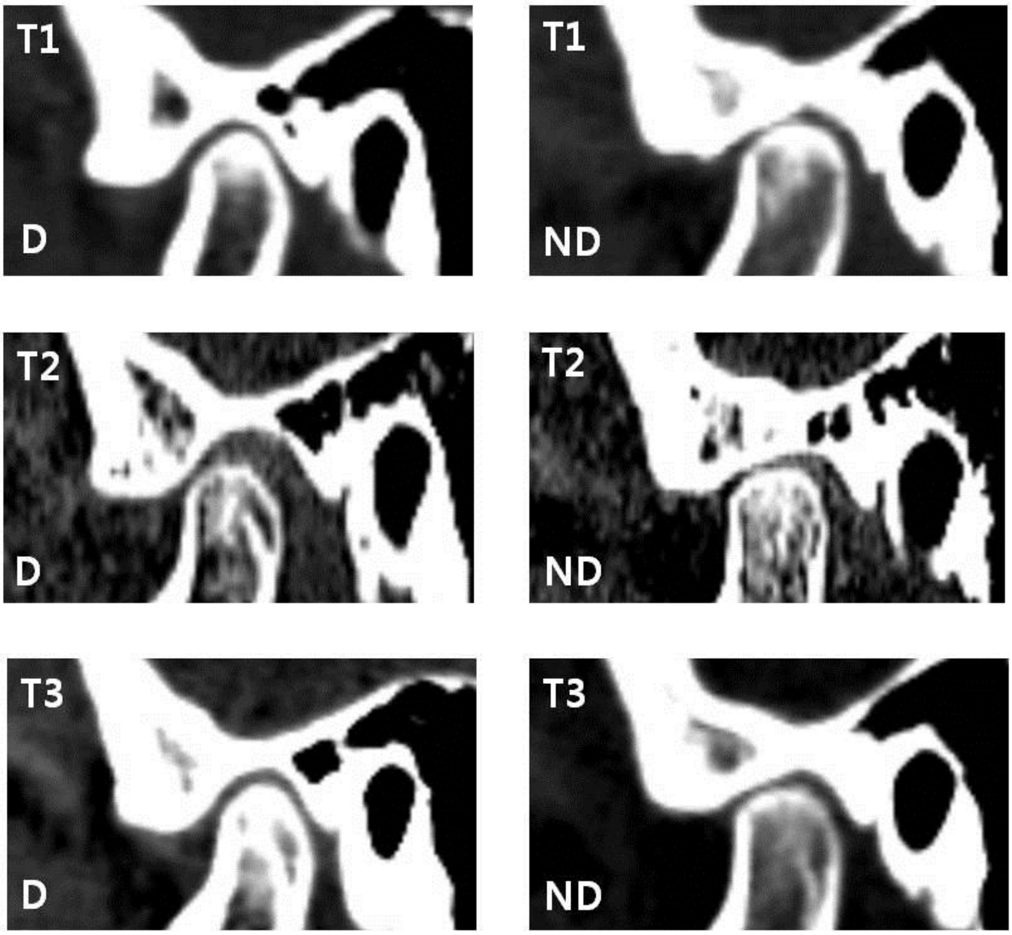


Figure 17. The positional changes of condyle on magnified sagittal slice images at T1, T2, and T3. *D indicates deviated side; ND, non-deviated side.

IV. Discussion

The purpose of this study was to assess the positional changes of the mandibular proximal segment of skeletal Class III patients with facial asymmetry who underwent orthognathic surgery (Le Fort I osteotomy + IVRO) using the 3-D CT images of before surgery, 1 year after surgery and 4 years after surgery.

Proffit et al[38] have suggested that the changes after orthognathic surgery do not have a normal distribution, and only a few patients show considerable changes. Most of previous studies[4,5] about the long term stability after IVRO reported reliable postoperative stability. Tuinzing and Greebe[39] reported that IVRO was a sound procedure with predictable results when used properly.

The long-term evaluation of the movement of the mandibular proximal segment including condyle after IVRO was useful to assess the improvement and stability following surgery. In this study, the horizontal, coronal, and sagittal condylar angle showed significant difference between the deviated side and non-deviated side at T1 and this was thought to be characteristics of asymmetric patients. In T2, The skeletal asymmetry improved and there was no significant bilateral difference except horizontal condylar angle. In T3, all of the measurements except horizontal condylar angle and coronal condylar vertical axis angle showed no significant differences, which means stable postoperative improvements. The horizontal condylar angle was significantly larger in the non-deviated side than deviated side during T1-T3 and the bilateral difference decreased from T1 to T3. The bilateral difference of coronal condylar vertical axis angle was non-significant at T2 and significant at T3. As Lee and Yu[40] have reported that postoperative muscle recovery needed more than 1 year, it seems that soft tissue recovery is related to postopeative muscle changes. Further evaluation of myofunctional adaptation after surgery with larger study population is necessary in the future study.

Previous studies[39,41] about postoperative stability using 2D images such as lateral cephalograms or posterior-anterior cephalograms have reported that mandibular height, width and position were stable after IVRO.

In this study, most of the measurements showed significant differences during T1-T2 and they were maintained during T2-T3, showing no significant differences.

The horizontal condylar angle significantly increased on both side after surgery, showing outward rotation in the horizontal slice image (Figure 13,14). The horizontal condylar angle increased after surgery, as shown in previous studies[22,23,42] and the horizontal condylar angle tended to rotate inward after SSRO and rotated outward after IVRO.[43] It has been reported that surgically induced inward rotation in the horizontal condylar angle correlates with an increase in the side range and incisor path angle.[44] The change in the horizontal condylar angle is important for the postoperative chewing path, and the preoperative angle of the condylar long axis is not always adequate postoperatively.[42]

There have been several studies which focused on condylar long axis in the horizontal plane, which is very important for evaluation of temporomandibular dysfunction and positional changes in the proximal segment after SSRO or IVRO. After IVRO, the condylar long axis in the horizontal plane showed outward rotation. To sum up, after IVRO, the condyle not only moved in an anterior-inferior direction in the sagittal plane, but also rotated outward in the horizontal plane.[45]

Westesson et al[46] studied 200 patients with clinical signs and symptoms of TMJ internal derangement using magnetic resonance images. They reported that as the condyle moves outward, the disc is in normal superior disc position and as the condyle moves inward, the disk is in displacement or in degenerative joint disease state. Sanroman et al[47] found that a more inward rotation in horizontal condylar angle can be an etiologic factor in disc displacement and degenerative joint disease.

Therefore, in our study, outward rotation of the horizontal condylar angle represent that the horizontal condylar change after IVRO may induce more favorable results in TMJ treatment.

In this study, the coronal condylar long axis angle which measured on the coronal slice images (Figure 15) increased but showed no significant postoperative differences on the deviated side and showed significant decrease on the non-deviated side. The coronal condylar vertical axis angle on the deviated side decreased significantly during T1-T2 and on the non-deviated side, increased during T1-T2 and decreased during T2-T3, however, there was no significant difference.

Ueki et al[42] reported that the postoperative coronal condylar angle was significantly increased on the deviated side and there was no significant change in coronal ramus angle.

The tip of the proximal segment on the deviated side tended towards medial displacement after IVRO. The surgical procedure reduced the preoperative difference in the bilateral coronal condylar vertical axis angle, suggesting that the medial displacement in the tip of the proximal segment on the deviated side could decrease the coronal condylar vertical axis angle and correct facial asymmetry.

The sagittal condylar angle which was measured on sagittal slice decreased significantly on both deviated side and non-deviated side during T1-T2. And the temporomandibular joint space distance (A-B and C-D) was measured to assess condylar position in the fossa more precisely and they showed significant increase during T1-T2, implicating anterior-inferior displacement of the condyle (Figure 16,17).

The sagittal condylar angle was smaller postoperatively, indicating posterior displacement in the tip of the proximal segment. The postoperative displacement of the proximal segment incorporates anterior-inferior displacement as well as position and angle changes in the horizontal, coronal, and sagittal planes. As the position of anteriorly displaced disc moves to a superior-posterior position, it also allows better condylar positioning in the glenoid fossa.[42]

A number of studies have reported similar result as our study that the condyles were displaced anterior-inferiorly after IVRO.[43,48-51] Detachment of the masseter, temporalis, and a portion of the medial pterygoid muscle allow the condyle to move in an anterior-inferior direction under the influence of the lateral pterygoid muscle.[52] Hu et al[53] posited that anterior-inferior movement of the condyle is to be expected from the direction of the lateral pterygoid muscle and the pterygomasseteric sling to the proximal segment in IVRO.

IVRO has been reported to be favorable to the temporomandibular joint because of anterior-inferior repositioning of the condyle and the increase of the joint space, with a chance of improved symptoms of the joint.[54,55]

Anterior-inferior displacement of the condyle which induced a significant adaptive remodeling in the TMJ was noted in the monkey that underwent IVRO with IMF. The animals that received SSRO with rigid fixation showed no obvious positional and histological changes in the condyle. This experimental study suggested that both SSRO and IVRO can be biologically sound procedures for correction of mandibular prognathism, but IVRO could be considered as a preferred surgical treatment for those patients with preoperative TMJ disorders.[48]

In this study, condylar head displaced anterior-inferiorly at T2 and returned to approximately original position at T3. Lee & Yu[40] reported that the masseter muscle measurements gradually increased during postoperative follow-up period and approached control values at 4 years after surgery. According to their study, the surrounding muscle takes more than 1 year to recover the function after surgery and that explains the postoperative movement of condylar head in this study.

In the present study, we evaluated the positional changes of the mandibular proximal segment including condyle of skeletal Class III with asymmetry patient after

IVRO using each cross-sectional image of 3D CT. In conclusion, the skeletal asymmetry improved and the result was stable during the follow-up period and after IVRO, three-dimensional displacement of the proximal segment represented outward rotation of condyle, medial displacement of the tip of the proximal segment on the deviated side for improving skeletal symmetry, posterior displacement of the tip of the proximal segment and anterior-inferior movement of condyle in each horizontal, coronal, and sagittal slice image.

IVRO can cause less rotational displacement of the proximal segment in asymmetric patients and it seems that the IVRO procedure is favorable for asymmetric patients.[19,56] And the altered condylar position was favorable to the TMJ because of the anterior-inferior repositioning of the condyle and the increase in joint space, with a chance of improved symptoms of the joint.

Further evaluation of the long-term effects of orthognathic surgery and myofunctional adaptation with larger study population using 3D CT is necessary in the future study.

V. Conclusion

In skeletal Class III asymmetry patients, the mandibular asymmetry improved after IVRO, and the most of measurements of the mandibular proximal segment showed no significant difference within the 4-year follow up period.

After IVRO, three-dimensional displacement of the proximal segment represented outward rotation of condyle, medial displacement of the tip of the proximal segment on the deviated side for improving skeletal symmetry, posterior displacement of the tip of the proximal segment and anterior-inferior movement of condyle in each horizontal, coronal, and sagittal slice image.

And we could observe that the mandibular proximal segments move to the more stable position while the function of the mandible recovered after surgery.

VI. References

1. Carvalho F, Cevidanes L, Motta A, et al. Three-dimensional assessment of mandibular advancement 1 year after surgery. Am J Orthod Dentofacial Orthop 137:S53.e1-S53.e12, 2010
2. Cevidanes L, Bailey L, Tucker S, et al. Three-dimensional cone-beam computed tomography for assessment of mandibular changes after orthognathic surgery. Am J Orthod Dentofacial Orthop 131:44-50, 2007
3. Kitahara T, Nakasima A, Kurahara S, et al. Hard and soft tissue stability of orthognathicsurgery. Angle Orthod 79:158–165, 2009
4. Chen CM, Lai ST, Wang CH, et al. The Stability of Intraoral Vertical Ramus Osteotomy and Factors Related to Skeletal Relapse. Aesth Plast Surg 35:192–197, 2011
5. Yoshioka I, Khanal A, Tominaga K, et al. Vertical Ramus Versus Sagittal Split Osteotomies: Comparison of Stability After Mandibular Setback. American Association of Oral and Maxillofacial Surgeons J Oral Maxillofac Surg 66:1138-1144, 2008
6. Landes CA, Sterz M. Proximal segment positioning in bilateral sagittal split osteotomy: Intraoperative controlled positioning by a positioning splint. J Oral Maxillofac Surg 61:1423-1431, 2003
7. Lee W, Park JU. Three-dimensional evaluation of positional change of the condyle after mandibular setback by means of bilateral sagittal split ramus osteotomy. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 94:305-309, 2002
8. Baik HS. A study of the temporomandibular joint in normal occlusion using T.M.J. tomogram and cephalogram. Korean J Orthod 16:85-106, 1986

9. Honey OB, Scarfe WC, Hilgers MJ, et al. Accuracy of cone-beam computed tomography imaging of the temporomandibular joint: Comparisons with panoramic radiology and linear tomography. Am J Orthod Dentofacial Orthop 132:429-438, 2007
10. Hilgers ML, Scarfe WC, Scheetz JP, et al. Accuracy of linear temporomandibular joint measurements with cone beam computed tomography and digital cephalometric radiography. Am J Orthod Dentofacial Orthop 128:803-811, 2005
11. Endo M, Terajima M, Goto TK, et al. Three-dimensional analysis of the temporomandibular joint and fossa-condyle relationship. Orthodontics (Chic) 12:210-221, 2011
12. Yáñez-Vico RM, Iglesias-Linares A, Torres-Lagares D, et al. Association between condylar asymmetry and temporomandibular disorders using 3d-ct. Med Oral Patol Oral Cir Bucal. doi:10.4317/medoral.17786, 2011
13. Katsumata A, Nojiri M, Fujishita M, et al. Condylar head remodeling following mandibular setback osteotomy for prognathism: A comparative study of different imaging modalities. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 101:505-514, 2006
14. Bell WH. Mandibular prognathism. In: Modern Practice in Orthognathic and Reconstructive Surgery. Philsdelphia, PA: Saunders, pp 61, 2111-2137, 1992
15. Boyne PJ. Osseous healing after oblique osteotomy of the mandibular ramus. J Oral Surg 24: 125-133, 1966
16. Quinn PD, Wedell D. Complications from intraoral vertical subsigmoid osteotomy: Review of the literature and report of two cases. Int J Adult Orthod Orthognath Surg 3: 189-196, 1988
17. Rosenquist B. Medial displacement of proximal segment. Int J Oral Maxillofac Surg 19: 226-229, 1990

18. Tuinzing DB, Greebe RB. Complications relating to the intraoral vertical ramus osteotomy. Int J Oral Surg 14: 319-324, 1985
19. Ghali GE, Sikes JW. Intraoral vertical ramus osteotomy as the preferred treatment for mandibular prognathism. J Oral Maxillofac Surg 58:313, 2000
20. Hall DH. Intraoral vertical ramus osteotomy. In: BELL WH, ed: Surgical Correction of Dentofacial Deformities, II. Philadelphia: Saunders 890-895, 1980
21. Nwoku AL, Palomero-Rodriguez R, Horch HH. The problems of correction of asymmetric mandibular prognathism. Int J Oral Surg 3: 229-233, 1974
22. Ueki K, Marukawa K, Nakagawa K, et al. Condylar and temporo-mandibular joint disc positions after mandibular osteotomy for prognathism. J Oral Maxillofac Surg 60: 1424-1432, 2002
23. Ueki K, Marukawa K, Shimada M, et al. Condylar and disc positions after intraoral vertical ramus osteotomy with and with-out a Le Fort I osteotomy. Int J Oral Maxillofac Surg 36: 207-213, 2007
24. Bell WH, Walker RV. The treatment of mandibular dysfunction by intraoral vertical ramus osteotomy. J Dent Res 67:207, 1988
25. Nickerson JW, Veaco NS. Condylotomy in surgery of the TMJ. Disorders of the TMJ Ⅱ: Arthrotomy. Oral Maxillofac Surg Clin North Am 1:303, 1989
26. Politi M, Costa F, Cian R, et al. Stability of skeletal Class Ⅲ malocclusion after combined maxillary and mandibular procedures: Rigid internal fixation versus wire osteosynthesis of the mandible. J Oral Maxillofac Surg 62:169-181, 2004
27. Costa F, Robiony M, Sembronio S, et al. Stability of skeletal Class III malocclusion after combined maxillary and mandibular procedures. Int J Adult Orthodont Orthognath Surg 16:179-192, 2001
28. Kim MJ, Kim SG, Park YW. Positional stability following intentional posterior ostectomy of the distal segment in bilateral sagittal split ramus osteotomy for correction of mandibular prognathism. J Craniomaxillofac Surg 30:35-40, 2002

29. Costa F, Robiony M, Politi M. Stability of sagittal split ramus osteotomy used to correct Class III malocclusion: Review of the literature. Int J Adult Orthodont Orthognath Surg 16:121-129, 2001

30. Mobarak KA, Krogstad O, Espeland L, et al. Long-term stability of mandibular setback surgery: A follow-up of 80 bilateral sagittal split osteotomy patients. Int J Adult Orthodont Orthognath Surg 15:83-95, 2000

31. Draenert FG, Erbe C, Zenglein V, et al. 3D analysis of condylar position after sagittal split osteotomy of the mandible in mono-and bimaxillary orthognathic surgery—A methodology study in 18 patients. J Orofac Orthop 71:421-429, 2010

32. Cevidanes LH, Bailey LJ, Tucker SF, et al. Three-dimensional cone-beam computed tomography for assessment of mandibular changes after orthognathic surgery. Am J Orthod Dentofacial Orthop 131:44-50, 2007

33. Kim YJ, Oh KM, Hong JS, et al. Do Patients Treated With Bimaxillary Surgery Have More Stable Condylar Positions Than Those Who Have Undergone Single-Jaw Surgery? J Oral Maxillofac Surg 70: 2143-2152, 2012

34. Greebe RB, Tuinzing DB. Overcorrection and relapse after the intraoral vertical ramus osteotomy. A one-year postoperative review of thirty-five patients. Oral Surg Oral Med Oral Pathol 54:382-384, 1982

35. Baek SH, Kim K, Choi JY. Evaluation of treatment modality for skeletal Class III malocclusion with labioversed upper incisors and/or protrusive maxilla: Surgical movement and stability of rotational maxillary setback procedure. J Craniofac Surg 20:2049-2054, 2009

36. Haraguchi S, Takada K, Yasuda Y. Facial asymmetry in subjects with skeletal Class Ⅲ deformity. Angle Orthod. 72: 28-35, 2002

37. Park SH, Yu HS, Kim KD, et al. A proposal for a new analysis of craniofacial morphology by 3-dimensional computed tomography. Am J Orthod Dentofacial Orthop. 129: e623-e634, 2006

38. Proffit WR, Turvey TA, Phillips C. The hierarchy of stability and predictability in orthognathic surgery with rigid fixation: An update and extension. Head Face Med 3:21, 2007

39. Tuinzing DB, Greebe RB. Complications related to the intraoral vertical ramus osteotomy. Int J Oral Surg 14: 319-324, 1985

40. Lee DH, Yu HS. Masseter muscle changes following orthognathic surgery. A long-term three-dimensional computed tomography follow-up. Angle Orthod. 82:792–798, 2012

41. Gunaid TA, Yamada K, Takagi R, et al. Postoperative stability of bimaxillary surgery in Class Ⅲ Patients with mandibular protrusion and mandibular deviation: a frontal cephalometric study. Int. J. Oral Maxillofac. Surg 37: 992-998, 2008

42. Ueki K, Hashiba Y, Marukawa K, et al. The effects of changing position and angle of the proximal segment after intraoral vertical ramus osteotomy. Int J Oral Maxillofac Surg 38: 1041-1047, 2009

43. Ueki K, Marukawa K, Nakagawa K, et al. Condylar and temporomandibular joint disc positions after mandibular osteotomy for prognathism. J Oral Maxillofac Surg 60:1424-1432, 2002

44. Ueki K, Marukawa K, Shimada M, et al. Changes in the chewing path of patients in skeletal class III with and without asymmetry before and after orthognathic surgery. J Oral Maxillofac Surg 63: 442-448, 2005

45. Ueki K, Marukawa K, Shimada M, et al. Change in condylar long axis and skeletal stability following sagittal split ramus osteotomy and intraoral vertical ramus osteotomy for mancibular prognathia. J Oral Maxillofac. Surg 63: 1494-1499, 2005

46. Westesson PL, Bifano JA, Tallents RH, et al. Increased horizontal angle of the mandibular condyle in abnormal temporomandibular joints. Oral Surg Oral Med Oral Pathol 72:359-363, 1991

47. Sanroman JF, Gomez JM, Alonso J. Morphometric and morphological changes in the temporomandibular joint after orthognathic surgery: a magnetic resonance imaging and computed tomography prospective study. J Craniomaxillofac Surg 25:139-148, 1997

48. Zhao Q, Hu J, Wang D, et al. Changes in the temporomandibular joint after mandibular setback surgery in monkeys: intraoral vertical versus sagittal split ramus osteotomy. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 104:329-337, 2007

49. Wisth PJ, Tornes K. Radiographic changes in the temporomandibular joint subsequent to vertical ramus osteotomy. Int J Oral Surg 4:242-250, 1975

50. Sund G, Eckerdal O, Astrrand P. Changes in the temporomandibular joint after oblique sliding osteotomy of the mandibular rami. J Maxillofac Surg 11:87-91, 1983

51. Rotskoff KS, Herbosa EG, Nickels B. Correction of condylar displacement following intraoral vertical ramus osteotomy. J Oral Maxillofac Surg 49:366-372, 1991

52. Ghali GE, Sikes JW Jr. Intraoral vertical ramus osteotomy as the preferred treatment for mandibular prognathism. J Oral Maxillofac Surg 58:313–315, 2000

53. Hu J, Wang D, Zou S. Effects of mandibular setback on the temporomandibular joint: A comparison of oblique and sagittal split ramus osteotomy. J Oral Maxillofac Surg 58:375-380, 2000

54. Bell WH, Yamaguchi Y, Poor MR. Treatment of temporomandibular joint dysfunction by intraoral vertical ramus osteotomy. Int J Adult Orthod Orthognath Surg 5:9-27, 1990

55. Bell WH, Yamaguchi Y. Condyle position and mobility before and after intraoral vertical ramus osteotomies and neuromuscular rehabilitation. Int J Adult Orthod Orthognath Surg 6:97-104, 1991

56. Kawamura H, Sugawara J, Nagasawa H. Surgical correction of mandibular asymmetry by unilateral sagittal split ramus osteotomy combined with contra-lateral vertical ramus osteotomy. Jpn J Jaw Deform 2: 139-149, 1992

국문요약

3 차원 CT 영상을 이용한 비대칭을 동반한 골격성 제 III 급 악교정 수술 환자의 하악 근심 골편 위치의 장기적 변화

(지도교수 유형석)

연세대학교 대학원 치의학과

한 수 연

이 연구는 비대칭을 동반한 골격성 제 III 급 부정교합 환자의 악교정 수술 (Le Fort I osteotomy 와 intraoral vertical ramus osteotomy) 전 후의 턱관절을 포함한 하악 근심 골편의 위치 변화를 3 차원적으로 평가하는 것이다.

17 명의 비대칭을 동반한 골격성 제 III 급 부정교합 환자를 술전 (T1), 술후 1 년 (T2), 그리고 술후 4 년 (T3)에 각각 3 차원 CT 영상을 촬영하여 horizontal, coronal, sagittal 각 단면에서 하악 근심 골편의 위치 변화를 측정하였다.

Horizontal 단면에서는 horizontal condylar angle (HCA), coronal 단면에서는 coronal condylar long axis angle (CCLA)과 coronal condylar vertical axis angle (CCVA), 그리고 sagittal 단면에서는 sagittal condylar angle (SCA)과 temporomandibular joint space distance (A-B and C-D)를 편위측과 비편위측에서 각각 측정하였다.

T1 에서 양측을 비교하였을 때, 모든 단면에서 편위측과 비편위측이 통계적으로 유의차가 있었으며 (P < .05), T2, T3 에서는 대부분의 측정치가 유의차 없이 비대칭이 개선된 상태로 유지되었다 (P > .05).

T1-T2 동안 대부분의 측정치가 유의차 있는 변화가 있었으며 (P < .0167), 유지 기간인 T2-T3 동안에는 유의차 없이 수술 이후의 상태가 잘 유지되었다 (P > .0167).

Horizontal 단면에서 T1-T2 기간 동안 horizontal condylar angle 은 양측 모두 유의차 있게 증가하였으며, 이는 IVRO 수술 이후 턱관절의 outward 회전 양상을 보여주었다 (P < .0167).

Coronal 단면에서 비편위측의 coronal condylar long axis angle 과 편위측의 coronal condylar vertical axis angle 은 T1-T2 기간 동안 유의차 있게 감소하였다 (P < .0167).

Sagittal 단면에서 sagittal condylar angle 은 양측 모두 T1-T2 동안 유의차 있게 감소하였고, temporomandibular joint space distance (A-B and C-D)는 유의차 있게 증가하여 턱관절의 전하방 이동 양상을 보여주었다 (*P* < .0167).

이상을 종합하면 비대칭을 동반한 골격성 제 III 급 부정교합 환자의 악교정 수술 (IVRO) 이후 양측의 비대칭이 개선되었으며, 대부분의 하악 근심 골편의 위치 변화의 측정치는 4 년 간의 수술 후 기간 동안 비교적 안정적으로 유지되었다. 또한 수술 후 하악의 기능이 회복되면서 하악 근심 골편이 좀 더 안정적인 위치로 이동하는 양상을 관찰 할 수 있었다.

핵심되는 말: 3 차원 CT, 근심 골편, 턱관절, 악교정 수술, IVRO, 골격성 제 III 급, 비대칭