Postoperative stability of maxillo-mandibular complex in facial asymmetry: A three-dimensional computed tomographic study

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감사의 글

박사 논문을 마무리하며 보니 아쉽고 부족한 점이 많아 부끄러운 마음 가득합니다. 제 이름이 찍힌 논문이지만 이 결실이 결코 제 것이 아님을 잘 알고 있습니다.

먼저 논문을 완성하기까지 긴 시간 동안 따뜻한 배려와 함께 세심하며 명철한 제안을 아끼지 않으신 유형석 지도교수님께 진심으로 감사드립니다. 교수님의 관심과 가르침 덕에 부족한 저는 한걸음 더 나아갈 수 있었습니다.

귀중한 시간을 내주시어 부족한 논문을 꼼꼼히 살펴주신 백형선 교수님과 논문의 완성도를 높이기 위해 아낌없이 지도편달해 주신 김경호 교수님, 학문을 대하시는 모습을 통해 많은 깨달음을 주신 이기준 교수님, 따뜻한 조언과 격려로 힘을 북돋아주신 김기덕 교수님께 깊이 감사드립니다. 또한 부족한 논문에 관심을 갖고 조언해주신 박영철 교수님과 황충주 교수님, 차정열 교수님, 정주령 교수님, 최윤정 교수님께도 감사드립니다.
논문을 구상하고 진행하는데 많은 격려와 도움을 주신 교정과 의국 선후배님들께 이 자리를 빌어 감사의 마음을 전합니다. 통계를 도와준 예방치과 김보라 조교님께도 고마움을 전합니다.

이렇게 감사의 글을 올릴 수 있는 행복은 모두가 가족의 지지와 격려 덕분입니다. 변함없이 헌신적인 희생과 사랑으로 돌보아주시고 격려해주신 아버지, 어머니, 그리고 노심초사 항상 걱정해주시며 기도로 은총주신 장인어른과 장모님께 사랑과 깊은 감사를 드립니다.

마지막으로 임상과 연구에 지칠 때마다 저를 토닥이며 위로하고 도와준, 항상 저의 곁에서 든든한 버팀목이 되어주었던 사랑하는 아내 최은혜에게 이 박사논문을 바칩니다. 그외에 저를 아끼며 응원해준 친구들과 이 작고 소중한 기쁨을 함께 나누고자 합니다.

박사논문을 마침이 교정과 의사로서의 제 모습이 완성되었다고 생각하지 않습니다. 부족한 부분을 깨닫고 발전시키며, 하나님께서 제게 주신 능력으로 세상을 비출 수 있는 조그마한 빛이 될 수 있도록 기도하며 정진하겠습니다.

'우리가 할 수 있는 최선을 다할 때, 우리의 삶에, 아니 타인의 삶에 어떤 기적이 일어나는지 아무도 모를 것입니다. (No one knows what kind of miracle happens in our life, no, in other people's lives when we do our best.)'

헬렌켈러의 이 말처럼 환자를 위해 앞으로도 진심을 담은 열정으로, 최선을 다하는 좋은 의사가 되기 위해 노력하겠습니다. 감사합니다.

2015 년 6 월 저자 홍 재 현

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Postoperative stability of maxillo-mandibular complex in facial asymmetry: A three-dimensional computed tomographic study

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Until now, most of the studies on postoperative stability have been concerned with assessing changes during the first year after surgery. However, unlike the SSRO (Sagittal Split Ramus Osteotomy) in which proximal and distal segments are fixed through rigid fixation, the mandible's position is determined by occlusion, muscle, and the ligament's postoperative physiologic adaptation in the case of IVRO (Intraoral Vertical Ramus Osteotomy) and bone remodeling can occur gradually over a long period of time due to the discontinuity of the overlapping of both segments. Therefore, studying skeletal stability through observation for a period of one year is insufficient.

Furthermore, in order to assess the improvement of asymmetry, it is important to accurately compare and analyze skeletal changes in the gonial angle on the right and left, and if surgery was performed with the use of the IVRO, it is necessary to observe changing aspects for a sufficient period during bone remodeling with respect to the gonial angle.

This study was carried out to assess skeletal changes and to examine stability over a long period after Le Fort I osteotomy for maxilla and IVRO for the mandible was carried out on 16 patients with Class III skeletal malocclusion and facial asymmetry. For this, photographs of three-dimensional computed tomography were taken directly before surgery, one year after surgery, and about four years after surgery. Then the images were reconstructed, and the maxilla and mandible were classified in terms of deviation and non-deviation with respect to the direction of menton deviation. Then the changes in length and angle were analyzed, and postoperative three-dimensional changes in maxilla and mandible were analyzed by using a direction vector on the maxilla and mandible planes. Accordingly, the following results were obtained.

1. As a result of comparing the side were there was deviation and the side were there was no deviation one year after surgery, it was verified that in all measurement the values did not show any statistically significant differences ($p>0.05$), so the asymmetry on the deviation and non-deviation sides was resolved through a surgery.

2. When comparing the pre-surgery condition and the condition one year after surgery, on the side were there was deviation, there were statistically significant decreases ($p<0.05$) in the frontal facial line angle, frontal ramal line angle, sagittal ramal length, lateral Go vertical distance, inferior Go vertical distance, and U6 vertical distance; and on the non-deviation side, there were statistically significant increases ($P<0.05$) in the sagittal ramal line angle, sagittal Mx. occlusal line angle, frontal facial line angle, frontal Mn. body line angle, sagittal Mn. body length, and lateral Go horizontal distance. And there were statistically significant decreases ($p<0.05$) in the sagittal ramal length, lateral Go vertical distance, inferior Go vertical distance, and U6 vertical distance.
   With regard to the changes for the period from one year after surgery to four years after surgery, on the side were there was deviation, there were statistically significant increases ($P<0.05$) in the sagittal Mx. occlusal line angle, inferior Go

vertical distance; and on the non-deviation side there were statistically significant increases ($P<0.05$) in the inferior Go vertical distance and U6 vertical distance.

3. As a result of analyzing the three-dimensional skeletal changes in maxilla and mandible one year after surgery and comparing these with the condition before surgery, in the case of the maxilla, there were statistically significant differences ($p<0.05$) in pitch; and in the case of the mandible, there were statistically significant differences ($p<0.05$) in yaw, roll and pitch. But, four years after surgery, there were no statistically significant differences revealed with regard to the yaw, roll and pitch in the maxilla and mandible.

In accordance with the above results, it was verified that for a patient with Class III skeletal asymmetry, the asymmetry of the maxilla and mandible was improved after surgery, and the results were maintained for up to four years without much change except for bone remodeling in inferior gonial area.

Key words : three dimensional computed tomography(CBCT), facial asymmetry,
postoperative stability, yaw, roll, pitch

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I. Introduction

Facial asymmetry refers to the condition were there are differences between the right and left vertical dimension or the width of the face due to the fact that the center of the maxilla or mandible has deviated to either the right or left based on a craniofacial midline, or due to the fact that the facial structure on one side is not the same as that on the other side in terms of size, shape, etc.[1] Most patients with skeletal malocclusion are in need of orthognathic surgery and have facial asymmetry to a larger or small degree,[2] and the greater a facial asymmetry is, the more complicated the moving direction and quantity of the maxilla and mandible at the time of surgery becomes, and it may be necessary to perform additional surgery like genioplasty, augmentation, and differential gonial angle shaving. In order to obtain an accurate diagnosis for a patient with facial asymmetry and to establish a treatment plan and conduct a postoperative assessment, it is required to carry out a detailed and careful analysis using three-dimensional computed tomography.

A surgical method for mandibles widely used in the treatment of skeletal malocclusion includes the SSRO (Sagittal Split Ramus Osteotomy) and the IVRO (Intraoral Vertical Ramus Osteotomy). Although there have been continuous efforts to enhance postoperative stability through improved methods of surgery and the implementation of a regulation method, some postoperative recurrences continue to occur. In order to analyze this, researchers have published lots of studies on skeletal change, appearance and the causes of recurrence, etc.

Profitt et al.[3] reported that a backward movement in the pogonion appeared one year after the TOVRO (Transoral vertical oblique osteotomy) was performed on a patient with Class III skeletal malocclusion, and the degree of recurrence was approx. 11.1% (0.7 of 6.3 mm). Jeong et al.[4] reported that recurrence occurred in approx. 16% of patients with Class III skeletal malocclusion one year after IVRO surgery, and that the pogonion moved in a posterior direction. Seigo Ohba et al. reported that immediately after IVRO, the proximal segment moved in posterior or lateral directions temporarily, and that as the time passed it was re-positioned 6 months after surgery.[5]

There have also been studies by researchers focusing on postoperative changes in the front rather than on the side. According to studies by Jeong et el.[6], after surgery was performed on a patient with mandibular prognathism using IVRO, the TMW (transverse mandibular width) showed an increase (7.15 ± 4.12 mm) one month after surgery and a continuous decrease (3.35 ± 4.57 mm) until one year from surgery. Compared with the time before surgery, the TMW showed a slight increase one year after surgery (3.35 ± 4.57 mm). Also in studies by Choi et al. on skeletal changes after SSRO, immediately after surgery there were increases in both the intergonial width and proximal segment angulation, which continued to decrease time passed.[7]

Until now, most of the studies on postoperative stability have been concerned with assessing changes during the first year after surgery. However, Chen et al.[8] stated that because it was unlike the SSRO procedure, the bone healing that occurred after IVRO was performed which is based on the overlapping of proximal and distal segments without internal rigid fixation, took a longer time, so the observation period of one year after surgery might not be enough for the study of mandibular skeletal stability. Also Nihara et al.[9] pointed out that because a discontinuation between the proximal segment and distal segment occurred at the time of IVRO surgery, it was necessary to allow more time for gonial morphology to be normalized compared to the SSRO procedure.

The most important thing with regard to the postoperative assessment of a patient with facial asymmetry will be whether or not an improvement is has occurred in facial contour asymmetry based on the sentiments of the patient. Lee et al.[10] stated that with regard to facial asymmetry, a menton deviation was the most influential factor, and that in addition to this, with regard to the symmetry of the mandibular gonial angle, lip line canting was another important factor when considering asymmetry. Therefore, in order to assess improvements with regard to asymmetry, it is important to accurately compare and analyze skeletal changes in the gonial angle on the right and left, and if a surgery was performed utilizing the IVRO procedure, it is necessary to observe changing aspects for a sufficiently long period of time while bone remodeling takes place in the gonial angle.

The aim of this study was to assess the aspects of asymmetry postoperative improvement with regard to the sides on which there was deviation and no deviation and three-dimensional direction changes in the maxilla and mandible were examined with the use of three-dimensional computed tomography at the time points before surgery, one year after surgery and four years after surgery for patients with Class III skeletal malocclusion and stability was analyzed over a long period of time.

II. Subject and method of study

1. Subject of study

Among the adult patients with Class III skeletal malocclusion who came to Severance Dental Hospital of Yonsei University, patients with facial asymmetry having a 4 mm or more menton deviation against a reference line linking the crista galli (Cg) and anterior nasal spine (ANS) in a frontal cephalogram were selected.[11] Among them, the patients with cleft lip and palate or other syndromes were excluded, and the patients with temporomandibular pain, crepitus or degenerative arthropathia were also excluded. As a result, 16 patients in total (6 males, 10 females) were selected, and the mean age of the patients for the first medical examination was 21.7 years (Table 1, 2). For the treatment of facial asymmetry and Class III skeletal malocclusion, Le Fort I osteotomy was performed for the maxilla, and a differential set-back surgery for the mandible using the IVRO procedure was performed, and for 9 patients a genioplasty was performed together at the time of surgery. The surgery was performed all by one oral surgeon, and for all patients, after orthodontic treatment, the surgery was performed, and then the treatment was completed through postoperative finishing orthodontic treatment.

Table 1. Mean and standard deviation of angular measurements in subjects

(unit : °)	Female	Male
Gonial angle(①)	127.5 ± 7.3	124.4 ± 10.9
Bjork sum (①+②+③)	397.6 ± 5.9	399.3 ± 4.0
Mn. plane angle (④)	37.6 ± 5.9	39.3 ± 4.0
FMA (⑤)	28.4 ± 5.9	31.6 ± 6.8
Occl. plane angle (⑥)	19.6 ± 5.0	19.1 ± 4.5
ANB (⑦)	-2.9 ± 3.3	-0.7 ± 2.0

(Mn. : mandible, FMA : Frankfort mandibular plane angle, Occl. : occlusal)

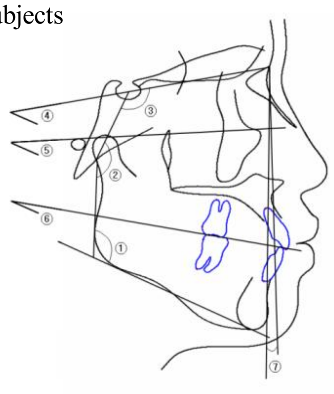


Fig 1. Angular measurements

Table 2. Mean and standard deviation of linear measurements in subjects

(unit : mm)	Female	Male
Ramal height(①)	53.4 ± 4.2	53.1 ± 7.6
Post. facial height(②)	83.9 ± 4.3	90.1 ± 9.5
Ant. facial height(③)	134.1 ± 5.4	145.0 ± 9.5
Post./Ant. facial height ratio (② / ③) x 100	62.7 ± 4.5	62.1 ± 3.6
Wits appraisal(④)	-12.4 ± 4.9	-9.8 ± 3.3
Mn. body length(⑤)	83.7 ± 4.1	88.5 ± 4.1

(Post. : posterior, Ant. : Anterior, Mn. : mandible)

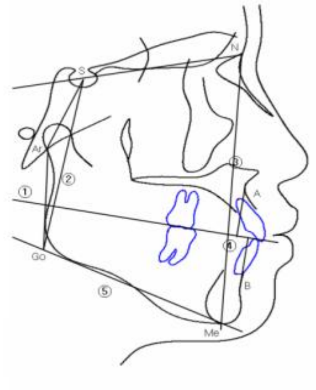
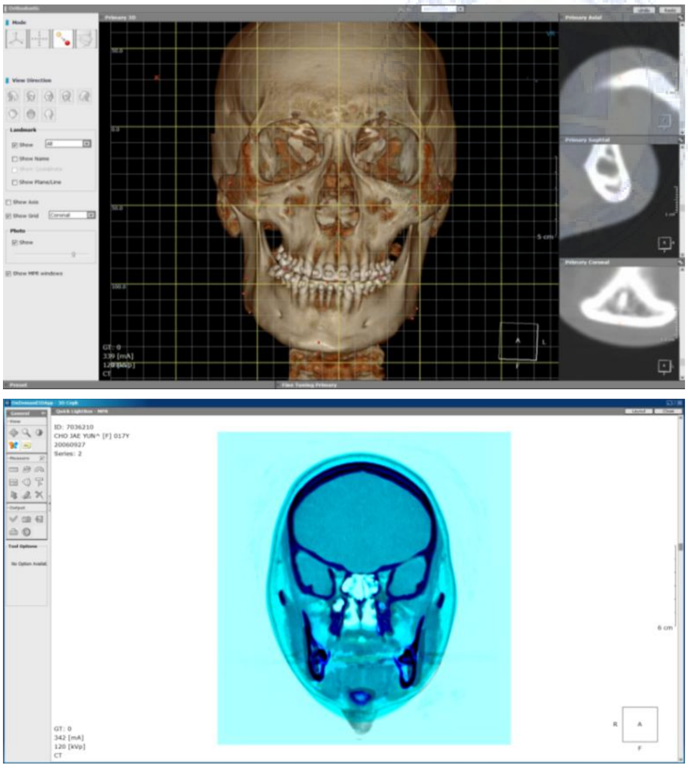


Fig 2. Linear measurements

2. Method of study

A. Photographing of a three-dimensional computed tomography image and reconstruction of image

For the assessment on the aspects of skeletal changes before/after surgery and postoperative stability, a photograph of a three-dimensional computed tomography image was taken at the time points before surgery (T1), one year after surgery (T2), and after four years after surgery (3.25~5.33 years, T3) (CT Hispeed Advantage, GE Medical System, Milwaukee, Wis, USA). The data obtained from the photography were converted to DICOM (Digital Imaging and Communication in Medicine) files and saved, and then by use of OnDemand® 3D software (Cybermed Inc., Seoul, Korea), the data were reconstructed in three-dimensional images (Fig 3).



A

B

Fig 3. Three dimensional image reconstruction

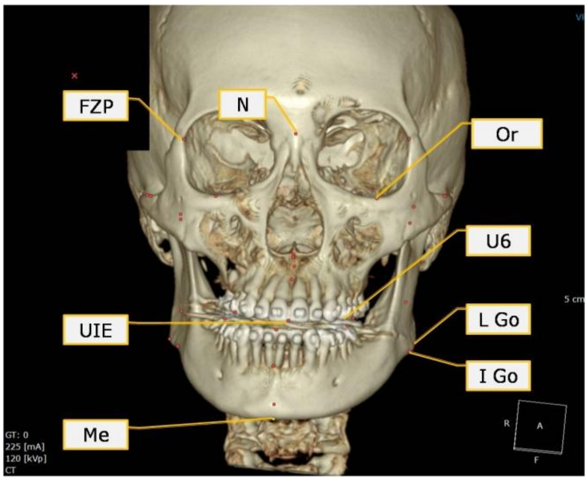
A: Preoperative three dimensional image, B: Pre and Postoperative superimposition

B. Landmark

The definitions of landmarks used in the study are as follows. (Table 3, Fig 4)

Table 3. Definitions of the 3D landmarks used in the study

FZP (Frontozygomatic point)	the intersection of the frontozygomatic suture and the inner rim of the orbit in the frontal plane
TFP (Temporal fossa point)	the most superior point of the inferior zygomatic arch border, above the condylar head as seen from the sagittal perspective; the most lateral landmark in the submental-vertex view
Po (Porion)	the most superior point of the external auditory meatus
Or (Orbitale)	the most inferior point of the orbital rim in the frontal plane
P CP (Posterior condylar point)	the most posterior point of the condyle in the sagittal plane
P Go (Posterior gonion)	the most posterior point of the gonial area in the sagittal plane
L Go (Lateral gonion)	the most lateral point of the gonial area in the frontal plane
I Go (Inferior gonion)	the most inferior point of the gonial area in the sagittal plane
U6 (U6 mesiobuccal cusp)	the tip of the mesiobuccal cusp of the maxillary first molar crown
N (Nasion)	the middle point of the frontonasal suture in the frontal plane
Me (Menton)	the most inferior point in the middle of the mandibular chin in the frontal plane; the deepest point in the mental depression in the submental-vertex view
UIE (U1 incisal embrasure)	the middle point of the RL U1 incisal edge



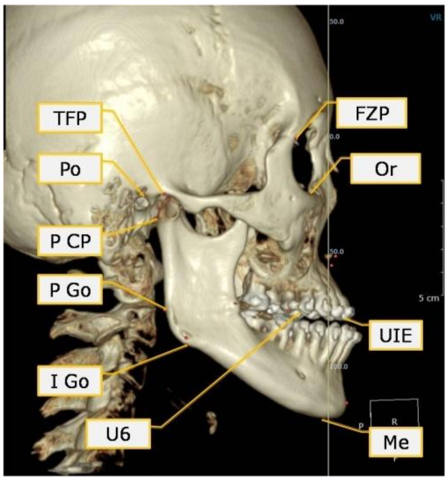


Fig 4. 3D landmarks used in the study

C. Setting of reference plane

Using the coordinate values of 4 landmarks; right/left FZP, right Or, right Po in a three-dimensional space based on X, Y, Z axes, the roll (canting), yaw and pitch of a three-dimensional image were modified, respectively, and after the orientation was determined, a reference plane with the origin (0,0,0) of Nasion was set (Fig 5,6). In other words, the roll was modified after an image was rotated for each value of Z in the right/left FZP to be identical to each other, and the yaw was modified after an image was rotated for each value of Y in the right/left FZP to be identical to each other, and finally the pitch was modified after an image was rotated for each value of Z in the right Po and Or to be identical to each other. This process was conducted through a program after 5 landmarks were selected using OnDemand 3D® software. Through this process of orientation, a reference plane was set which consists of

- X axis : a line passing N in parallel with right/left FZP line
- Y axis : a line passing N in parallel with Po ~ Or lines
- Z axis : a line passing N vertical to X,Y axes

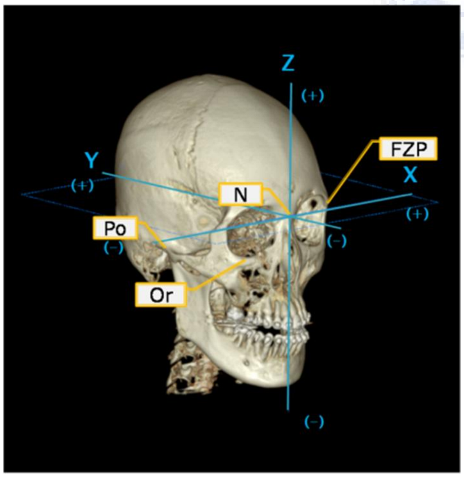


Fig 5. Reference planes

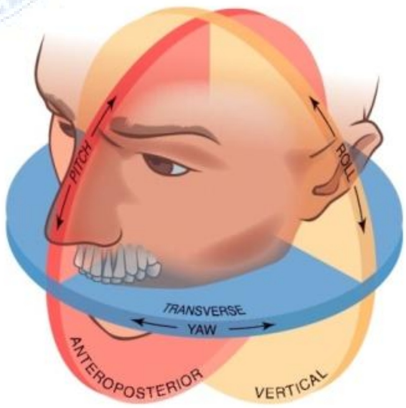


Fig 6. Illustration of yaw, roll, pitch (Orthodontics. Current Principles and Techniques, 5th edition, Xubair et al, p26)

D. Postoperative assessment on the improvement in maxillo-mandibular asymmetry (assessment on size, shape and position)

In order to analyze the postoperative improvement in asymmetry and the postoperative stability for a patient with facial asymmetry, the length and angle of each portion were measured after being distinguishing into the deviation side and non-deviation side based on the displacement direction of the menton.

Through the changes in length and distance, the changes in size and position of each structure on the deviation side and non-deviation side were assessed, and through the changes in angle, the shape of each structure was assessed. In the case of the gonial portion where bone remodeling is expected to occur most actively after the IVRO surgery, the changes in a lower facial contour were assessed for accurate analysis by use of 3 landmarks; L Go, I Go, P Go.

(1) Angle (Fig 7)

[Sagittal plane]

① Sagittal ramal line angle on deviation and non-deviation sides: angle between a line P CP ~ P Go and a reference plane (X-Y plane)

② Sagittal gonial angle on deviation and non-deviation sides: angle between a line P CP ~ P Go and a line I Go ~ Me

③ Sagittal Mx. occlusal line angle on deviation and non-deviation sides: angle between a line UIE ~ U6 and a reference plane (X-Y plane)

[Frontal plane]

④ Frontal facial line angle on deviation and non-deviation sides: angle between a line TFP ~ L Go and a reference plane (X-Y plane)

⑤ Frontal ramal line angle on deviation and non-deviation sides: angle between a line P CP ~ I Go and a reference plane (X-Y plane)

⑥ Frontal Mn. body line angle on deviation and non-deviation sides: angle between a line I Go ~ Me and a reference plane (X-Y plane)

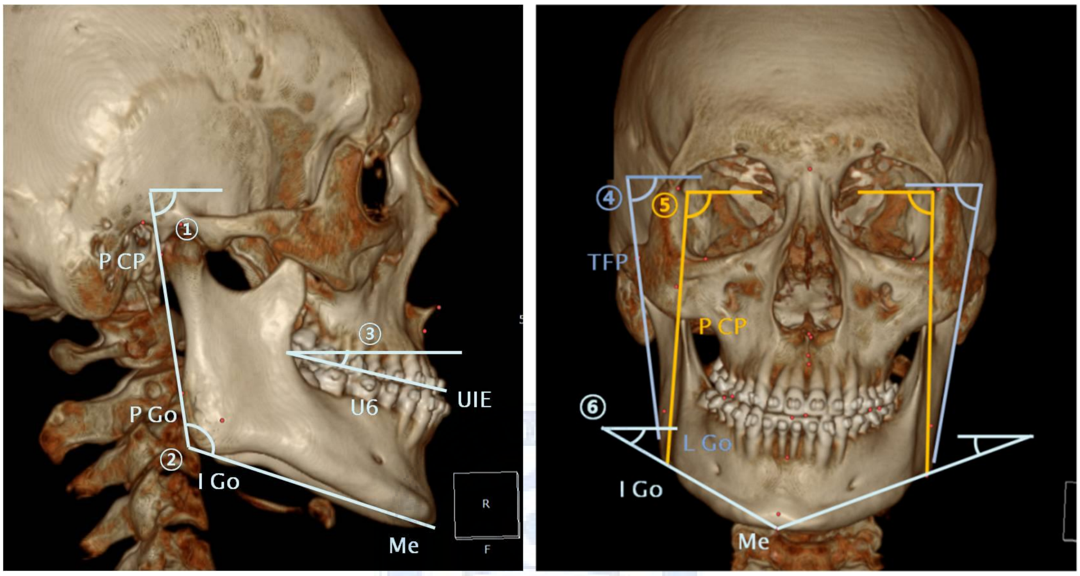


Fig 7. Angular measurements in 3D CT

① sagittal ramal line angle; ② sagittal gonial angle; ③ sagittal Mx. occlusal line angle; ④ frontal facial line angle; ⑤ frontal ramal line angle; ⑥ frontal Mn. body line angle

(2) Length, distance (Fig 8)

[Sagittal plane]

① Ramal length on deviation and non-deviation sides: length between P CP ~ P Go

② Mn. body length on deviation and non-deviation sides: length between I Go ~ Me

[Frontal plane]

③ L Go vertical distance on deviation and non-deviation sides: distance from L Go to a reference plane (X-Y plane)

④ I Go vertical distance on deviation and non-deviation sides: distance from I Go to a reference plane (X-Y plane)

⑤ U6 vertical distance on deviation and non-deviation sides: distance from U6 to a reference plane (X-Y plane)

⑥ L Go horizontal distance on deviation and non-deviation sides: distance from L Go to a reference plane (Y-Z plane)

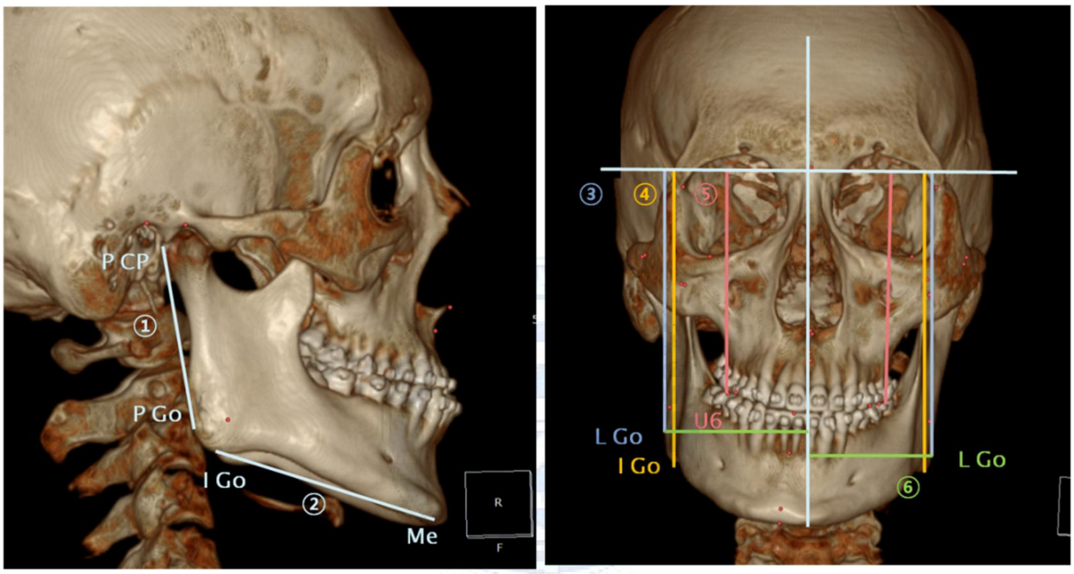
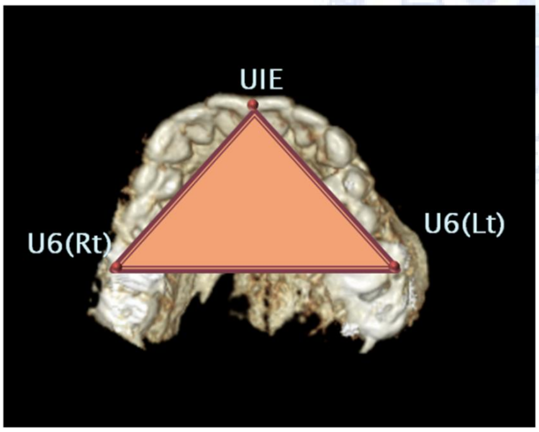


Fig 8. Linear measurements in 3D CT

① Ramal length; ② Mn. body length; ③ L Go vertical distance; ④ I Go vertical distance; ⑤ U6 vertical distance; ⑥ L Go horizontal distance

E. Plane setting and X', Y', Z' axes setting for maxilla and mandible (Fig 9)

- Maxilla: Using 3 landmarks of UIE and mesiobuccal cusps of the right/left maxillary first molars, a plane was made and a normal vector vertical to this plane was set as Z' axis, and the rest were set as Y', X' axes. In other words, a line passing the point bisecting the mesiobuccal cusp of right/left maxillary first molars from the UIE was set as Y' axis, and a line vertical to the rest Y', Z' axes from the UIE was set as X' axis, and thereby a direction vector indicating the direction of the maxilla was set.[12]
- Mandible: Using 3 landmarks of Me and right/left I Go, a plane was made and a normal vector vertical to this plane was set as Z' axis, and the rest were set as Y', X' axes. In other words, a line passing Me from the point bisecting the right/left I Go on the basis of Me was set as Y' axis, and a line vertical to the rest Y', Z' axes on the basis of Me was set as X' axis, and thereby a direction vector indicating the direction of the mandible was set.



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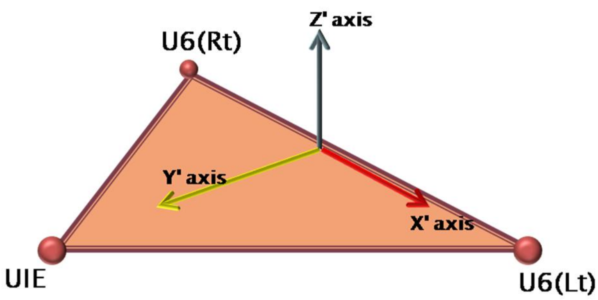

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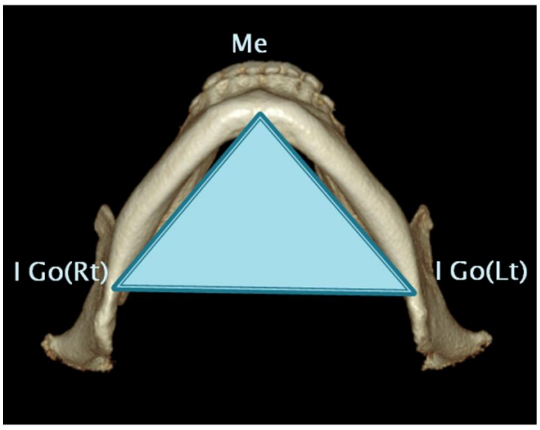

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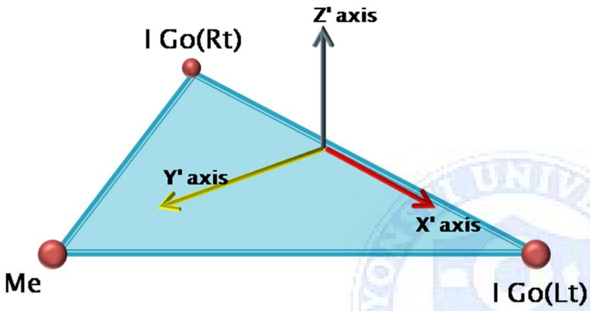


D

Fig 9. X', Y', Z' axes configuration on the maxilla and mandible

A,B: maxilla, C,D: mandible, UIE: U1 incisal embrasure; U6: U6 mesiobuccal cusp; Me: menton; I Go: Inferior gonion

F. Postoperative assessment on the maxillo-mandibular three-dimensional orientation

Through the comparison between the direction of vectors on X, Y, Z axes of a reference plane with the origin of nasion and the direction of vectors on X', Y', Z' axes of a maxilla/mandible plane, the yaw, roll and pitch in the maxilla and mandible at the time points before surgery, one year after surgery and four years after surgery were measured (Fig 10, Fig 11).

(1) Measurement of yaw in the maxilla and mandible
Through the comparison between the direction of Y axis on a reference plane with the origin of nasion and the direction of Y' axis in the maxilla and mandible, the yaw in the maxilla and mandible was measured (Fig 10-ⓐ, Fig 11-ⓐ).

(2) Measurement of roll in the maxilla and mandible
After the measurement of the yaw in the maxilla and mandible, the yaw was removed from the direction vector in the maxilla and mandible (Fig 10-ⓑ, Fig 11-ⓑ: rotate the maxilla and mandible in conformity to Y axis on a reference plane), and thereafter through the comparison between X axis on a reference plane and X' axis in the maxilla and mandible, the roll was measured (Fig 10-ⓒ, Fig 11-ⓒ).

(3) Measurement of pitch in the maxilla and mandible
After the measurement of the roll in the maxilla and mandible, the roll was removed from the direction vector in the maxilla and mandible (Fig 10-ⓓ, Fig 11-ⓓ: rotate the maxilla and mandible in conformity to X axis on a reference plane) following the removal of the yaw, and thereafter through the comparison between Z axis on a reference plane and Z' axis in the maxilla and mandible, the pitch was measured (Fig 10-ⓔ, Fig 11-ⓔ).

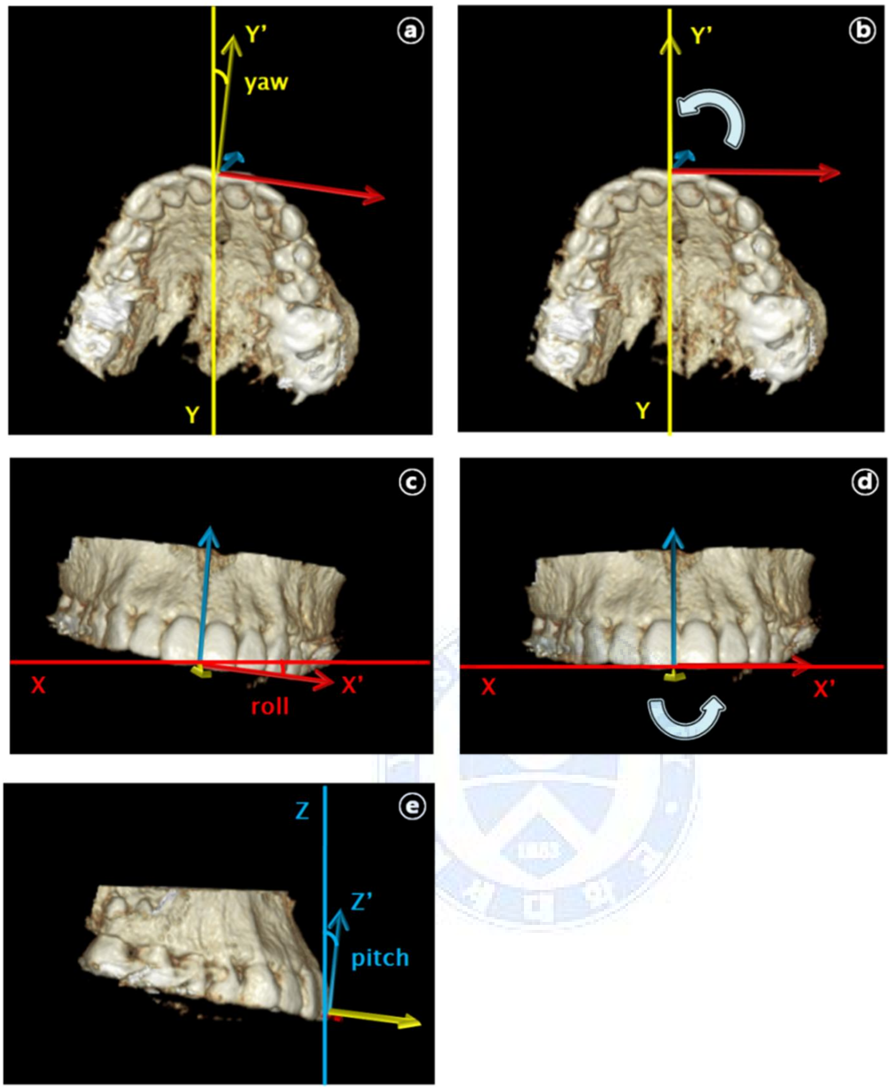


Fig 10. Measurements of yaw, roll, pitch in the maxilla

ⓐ yaw measured in maxilla: comparison between Y and Y', ⓑ rotate maxilla in conformity to Y axis, ⓒ roll measured: comparison between X and X', ⓓ rotate maxilla in conformity to X axis, ⓔ pitch measured: comparison between Z and Z'

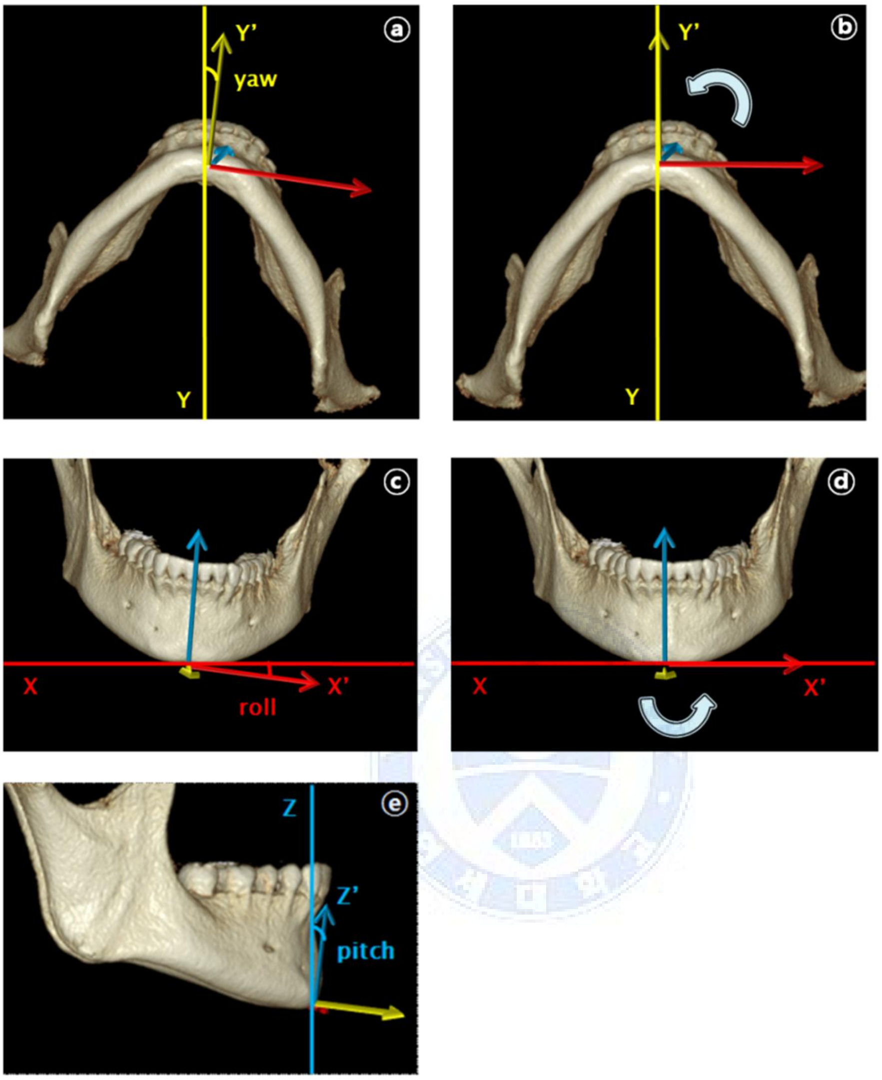


Fig 11. Measurements of yaw, roll, pitch in the mandible

ⓐ yaw measured in mandible: comparison between Y and Y', ⓑ rotate mandible in conformity to Y axis, ⓒ roll measured: comparison between X and X', ⓓ rotate mandible in conformity to X axis, ⓔ pitch measured: comparison between Z and Z'

3. Statistical analysis

All analyses were performed at a significance level (α=0.05) using the SPSS statistics program (IBM® SPSS® Statistic ver. 20, IBM, Armonk, NY, USA). To verify the normality of samples, the Shapiro-Wilk test was conducted.

(1) The reliability level of a measurer was assessed by using an intraclass correlation coefficient (ICC).

(2) For the postoperative assessment of asymmetry improvement, the differences between the deviation and non-deviation sides at the time points before surgery and one year after surgery were verified by performing a paired t-test.

(3) The mean and standard deviation on the deviation and non-deviation sides at the time points before surgery, one year after surgery and four years after surgery were calculated, and for the analysis of changes on the deviation and non-deviation sides between not only the period from before surgery to one year after surgery but also the period from one year after surgery to four years after surgery, a paired t-test was performed, respectively.

(4) By measuring the yaw, roll and pitch in the maxilla and mandible, the mean and standard deviation at the time points before surgery, one year after surgery and four years after surgery were calculated, and for the analysis of changes on the deviation and non-deviation sides between not only the period from before surgery to one year after surgery but also the period from one year after surgery to four years after surgery, a paired t-test was performed, respectively.

III. Result

1. Reliability level within an examiner

As a result of analysis on recurrence within an examiner, the intraclass correlation coefficient (ICC) was shown very high as 0.976 (95% C.I. 0.973–0.979).

Table 4. Intraclass Correlation Coefficient of single examiner

	Intraclass correlation coefficient	95% Confidence interval		P-value
		Lower bound	Upper bound	
Single examiner	0.976	0.973	0.979	<0.001

2. Postoperative assessment on asymmetry improvement level on deviation and non-deviation sides

Table 5. Comparison between deviation and non-deviation sides at the time of T1, T2

Variables	T1		P^*	T2		$P^\dagger$
	Dev.	Non-dev.		Dev.	Non-dev.	
Angle(°)						
SRla	84.04 (4.78)	81.71 (4.27)	*0.007	85.41 (4.27)	84.32 (4.79)	0.261
SGa	126.02 (9.02)	127.74 (8.39)	0.238	127.53 (6.46)	129.46 (7.26)	0.129
SMOla	11.89 (7.13)	8.47 (7.68)	*0.020	13.46 (5.13)	13.78 (4.77)	0.794
FFla	80.12 (2.77)	76.59 (2.31)	*<0.001	78.56 (3.96)	78.17 (4.49)	0.742
FRla	88.88 (4.04)	85.28 (2.99)	*0.001	87.05 (4.90)	85.42 (2.65)	0.148
FMBla	37.99 (5.04)	31.49 (5.53)	*<0.001	39.06 (2.98)	37.32 (4.63)	0.153
Distance, length(mm)						
SRl	43.39 (4.57)	47.09 (5.39)	*0.001	38.92 (6.30)	40.43 (5.92)	0.103
SMBl	66.76 (5.55)	64.22 (4.03)	*0.014	66.10 (4.70)	66.59 (4.46)	0.631
LGVd	87.83 (7.63)	90.98 (8.07)	*0.015	79.35 (10.31)	76.78 (8.92)	0.099
LGHd	52.22 (3.76)	46.71 (3.79)	*<0.001	51.78 (4.45)	51.75 (5.10)	0.980
IGVd	93.96 (8.47)	95.36 (8.72)	0.108	87.36 (9.59)	85.92 (10.42)	0.124
UVd	77.82 (5.52)	79.17 (5.82)	*0.031	76.27 (5.54)	76.00 (5.95)	0.588

All values are means (standard deviations).
Dev. means deviation, and Non-dev. means non-deviation.
P-values are obtained by paired t-test.
* P-value means statistically significant difference between deviation and non-deviation values at T1 (α=0.05).

† P-value means statistically significant difference between deviation and non-deviation values at T2 (α=0.05).

T1, pre-op; T2, post-op 1yr; SRla, Sagittal ramal line angle; SGa, Sagittal gonial angle; SMOla, Sagittal Mx. occlusal line angle; FFla, Frontal facial line angle; FRla, Frontal ramal line angle; FMBla, Frontal Mn. body line angle; SRl, Sagittal ramal length; SMBl, Sagittal Mn. body length; LGVd, Lateral Go vertical distance; LGHd, Lateral Go horizontal distance ; IGVd, Inferior Go vertical distance; UVd, U6 vertical distance.

For the postoperative assessment of asymmetry improvement for a patient with facial asymmetry, the differences on the deviation and non-deviation sides at the time points before surgery and one year after surgery were analyzed. In order to verify the symmetry, the angle and length of a structure on both sides, not a single structure like the menton, were compared. (Table 5)

As a result of the preoperative performance of a paired t-test for the differences on the deviation and non-deviation sides, all measurement values excluding sagittal gonial angle and inferior Go vertical distance were shown as statistically significant differences ($P<0.05$), and thereby it was verified that a condition of asymmetry existed in various areas. On the other hand, in comparison between the deviation and non-deviation sides one year after surgery, all measurement values revealed the non-existence of statistically significant differences ($P>0.05$), and thereby it was verified that the asymmetry condition had been resolved.

3. Means and standard deviation of each landmark on deviation side for T1, T2 and T3 and changes in T2 - T1 and T3 - T2

Table 6. Measured difference of angle, length, and distance on deviation side at the time of T1, T2, and T3

Variables	T1	T2	T3	T2-T1	P^*	T3-T2	$P^\dagger$
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)		Mean (S.D.)	
Angle(°)							
SRla	84.04 (4.78)	85.41 (4.27)	85.43 (4.52)	1.37 (3.20)	0.108	0.02 (2.39)	0.976
SGa	126.02 (9.02)	127.53 (6.46)	127.44 (6.17)	1.51 (4.37)	0.187	-0.10 (1.21)	0.754
SMOla	11.89 (7.13)	13.46 (5.13)	14.42 (5.18)	1.57 (6.17)	0.341	0.95 (1.53)	†**0.030**
FFla	80.12 (2.77)	78.56 (3.96)	78.50 (3.77)	-1.56 (2.34)	*__0.018__	-0.07 (1.01)	0.797
FRla	88.88 (4.04)	87.05 (4.90)	86.82 (4.96)	-1.83 (2.38)	*__0.008__	-0.23 (1.19)	0.451
FMBla	37.99 (5.04)	39.06 (2.98)	38.36 (4.13)	1.07 (4.24)	0.329	-0.71 (2.30)	0.238
Distance, length(mm)							
SRl	43.39 (4.57)	38.92 (6.30)	39.30 (6.36)	-4.48 (5.29)	*__0.004__	0.38 (2.54)	0.554
SMBl	66.76 (5.55)	66.10 (4.70)	65.08 (4.71)	-0.66 (4.24)	0.541	-1.01 (2.37)	0.108
LGVd	87.83 (7.63)	79.35 (10.31)	79.81 (10.71)	-8.48 (7.01)	*__<0.001__	0.46 (2.08)	0.405
LGHd	52.22 (3.76)	51.78 (4.45)	51.44 (4.68)	-0.44 (2.95)	0.561	-0.34 (1.10)	0.237
IGVd	93.96 (8.47)	87.36 (9.59)	88.49 (10.05)	-6.60 (4.71)	*__<0.001__	1.13 (1.83)	†**0.032**
UVd	77.82 (5.52)	76.27 (5.54)	76.28 (5.41)	-1.55 (2.27)	*__0.019__	0.02 (0.71)	0.926

S.D. means standard deviation

* P-value means a statistically significant difference between T1 value and T2 value.

† P-value means a statistically significant difference between T2 value and T3 value.

T1, pre-op; T2, post-op 1yr; T3, post-op 4yrs; SRla, Sagittal ramal line angle; SGa, Sagittal gonial angle; SMOla, Sagittal Mx. occlusal line angle; FFla, Frontal facial line angle; FRla, Frontal ramal line angle; FMBla, Frontal Mn. body line angle; SRl, Sagittal ramal length; SMBl, Sagittal Mn. body length; LGVd, Lateral Go vertical distance; LGHd, Lateral Go horizontal distance ; IGVd, Inferior Go vertical distance; UVd, U6 vertical distance.

In order to examine the changes in shape, size and position on the deviation side and non-deviation side at the time points before surgery, one year after surgery and four years after surgery, the mean and standard deviation at each time point and the means and standard deviation of changes were calculated. (Table 6, 7)

With regard to changes for the period from before surgery to one year after surgery, the sagittal ramal line angle, sagittal gonial angle, sagittal Mx. occlusal line angle, and frontal Mn. body line angle increased while all the other measurement values revealed a decrease. Among these, the measurement values with statistically significant differences were the frontal facial line angle and frontal ramal line angle in the case of angles, and there were statistically significant differences for the sagittal ramal length, lateral Go vertical distance, inferior Go vertical distance, and U6 vertical distance in the case of lengths and distances, so that all 6 measurement values significantly decreased one year after surgery statistically ($p<0.05$).

With regard to the changes for the period from one year after surgery to four years after surgery, the results showed that stability had been maintained with the average within 1° in the case of angles, and the average within 1mm in the case of lengths and distances, excluding increases in the sagittal Mx. occlusal line angle and inferior Go vertical distance, which showed statistically significant differences ($p<0.05$).

4. Means and standard deviation of each landmark on non-deviation side for T1, T2 and T3 and changes in T2 - T1 and T3 - T2

Table 7. Measured difference of angle, length, and distance on non-deviation side at the time of T1, T2, and T3

Variables	T1	T2	T3	T2-T1	P^*	T3-T2	$P^\dagger$
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)		Mean (S.D.)	
Angle(°)							
SRla	81.71 (4.27)	84.32 (4.79)	84.41 (4.61)	2.61 (4.26)	***0.027**	0.09 (2.14)	0.870
SGa	127.74 (8.39)	129.46 (7.26)	128.87 (6.73)	1.72 (5.70)	0.246	-0.59 (1.98)	0.253
SMOla	8.47 (7.68)	13.78 (4.77)	13.98 (5.10)	5.31 (5.88)	***0.004**	0.20 (1.61)	0.633
FFla	76.59 (2.31)	78.17 (4.49)	77.92 (4.18)	1.58 (2.61)	***0.029**	-0.26 (1.19)	0.401
FRla	85.28 (2.99)	85.42 (2.65)	85.55 (3.30)	0.14 (2.17)	0.801	0.13 (1.23)	0.679
FMBla	31.49 (5.53)	37.32 (4.63)	36.61 (5.49)	5.84 (3.55)	***<0.001**	-0.72 (2.11)	0.193
Distance, length(mm)							
SRl	47.09 (5.39)	40.43 (5.92)	40.78 (6.21)	-6.66 (4.67)	***<0.001**	0.35 (2.07)	0.505
SMBl	64.22 (4.03)	66.59 (4.46)	65.78 (4.66)	2.37 (3.34)	***0.013**	-0.82 (2.82)	0.265
LGVd	90.98 (8.07)	76.78 (8.92)	77.44 (9.54)	-14.20 (5.30)	***<0.001**	0.66 (1.87)	0.194
LGHd	46.71 (3.79)	51.75 (5.10)	51.35 (5.31)	5.04 (3.24)	***<0.001**	-0.40 (1.28)	0.230
IGVd	95.36 (8.72)	85.92 (10.42)	87.12 (11.27)	-9.44 (3.68)	***<0.001**	1.21 (1.90)	**†0.028**
UVd	79.17 (5.82)	76.00 (5.95)	76.47 (5.81)	-3.18 (2.08)	***<0.001**	0.47 (0.71)	**†0.022**

S.D. means standard deviation

* P-value means statistically significant difference between T1 value and T2 value.

† P-value means statistically significant difference between T2 value and T3 value.

T1, pre-op; T2, post-op 1yr; T3, post-op 4yrs; SRla, Sagittal ramal line angle; SGa, Sagittal gonial angle; SMOla, Sagittal Mx. occlusal line angle; FFla, Frontal facial line angle; FRla, Frontal ramal line angle; FMBla, Frontal Mn. body line angle; SRl, Sagittal ramal length; SMBl, Sagittal Mn. body length; LGVd, Lateral Go vertical distance; LGHd, Lateral Go horizontal distance ; IGVd, Inferior Go vertical distance; UVd, U6 vertical distance.

When examining changes one year after surgery on the non-deviation side, all measurement values related to angle increased, and among the measurement values related to length and distance, the values of the sagittal Mn. body length and lateral Go horizontal distance increased while all the other values were shown as decreasing. Among these, statistically significant differences ($p<0.05$) were indicated in the measurement values: with regard to angles, there were increases in the sagittal ramal line angle, sagittal Mx. occlusal line angle, frontal facial line angle, and frontal Mn. body line angle; and in the case of lengths and distances, there were decreases in the sagittal ramal length, lateral Go vertical distance, inferior Go vertical distance and U6 vertical distance but increases in the sagittal Mn. body length and lateral Go horizontal distance. On the other hand, with respect to the period from one year after surgery to four years after surgery, there were statistically significant differences in the inferior Go vertical distance and U6 vertical distance ($p<0.05$) and it was verified that all the other measurement values were maintained stably without any changes.

5. Postoperative assessment on the three-dimensional orientation of maxilla and mandible

In order to assess the changes in the three-dimensional orientation of the maxilla and mandible before/after surgery, the means and standard deviation of the yaw, roll and pitch in the maxilla and mandible measured at the time points before surgery, one year after surgery and four years after surgery, respectively were obtained, and the changes for the period from before surgery to one year after surgery and the changes for the period from one year after surgery to four years after surgery were verified through a t-test. Because the orientation should be excluded for the analysis of changes, the analysis was performed using absolute values, not the original values. As a result, in the case of changes for the period from before surgery to one year after surgery, the pitch in the maxilla and the yaw, roll and pitch in the mandible were verified and showed statistically significant differences ($p<0.05$), and in the case of changes for the period from one year after surgery to four years after surgery, all were verified and did not show any statistically significant differences (Table 8, 9, Fig 12).

Table 8. Means and standard deviation of yaw, roll, and pitch's absolute value measured in maxilla at the time of T1, T2, and T3

Maxillary variables	∣T1∣	∣T2∣	∣T3∣	Δ(T2-T1)	P^*	Δ(T3-T2)	$P^\dagger$
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)		Mean (S.D.)	
Yaw(°)	2.68 (2.25)	2.68 (2.36)	3.10 (2.37)	2.59 (3.07)	0.998	1.42 (1.38)	0.286
Roll(°)	2.41 (1.56)	2.02 (1.64)	1.99 (1.49)	2.33 (2.19)	0.383	0.53 (0.41)	0.789
Pitch(°)	10.31 (6.01)	13.86 (4.36)	14.34 (4.38)	4.86 (3.53)	*0.006	1.07 (0.85)	0.161

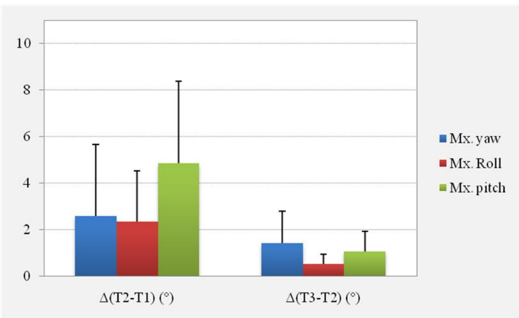
Δ(T2-T1) means a postsurgical change between T1 and T2.
Δ(T3-T2) means a postsurgical change between T2 and T3.

S.D. means the standard deviation.
*P-value means a statistically significant difference between T1 value and T2 value.
†P-value means a statistically significant difference between T2 value and T3 value.
T1, pre-op; T2, post-op 1yr; T3, post-op 4yrs.

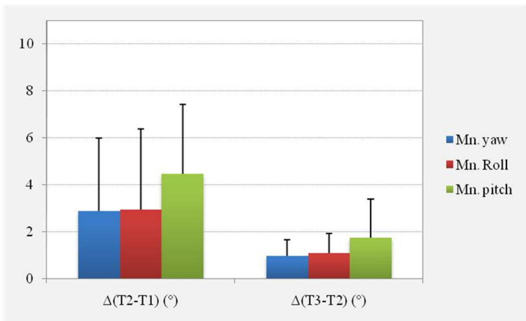
Table 9. Means and standard deviation of yaw, roll, and pitch's absolute value measured in mandible at the time of T1, T2, and T3

Mandibular variables	∣T1∣ Mean (S.D.)	∣T2∣ Mean (S.D.)	∣T3∣ Mean (S.D.)	Δ(T2-T1) Mean (S.D.)	P^*	Δ(T3-T2) Mean (S.D.)	$P^†$
Yaw(°)	5.00 (2.86)	2.66 (1.84)	2.42 (1.80)	2.89 (3.09)	*0.004	0.95 (0.69)	0.417
Roll(°)	3.65 (3.75)	2.29 (1.83)	2.20 (1.52)	2.93 (3.46)	*0.040	1.09 (0.83)	0.789
Pitch(°)	29.57 (6.24)	33.34 (4.98)	33.07 (5.48)	4.45 (2.98)	*0.001	1.74 (1.66)	0.664

Δ(T2-T1) means a postsurgical change between T1 and T2.
Δ(T3-T2) means a postsurgical change between T2 and T3.
S.D. means the standard deviation.
*P-value means a statistically significant difference between T1 value and T2 value.
† P-value means a statistically significant difference between T2 value and T3 value.
T1, pre-op; T2, post-op 1yr; T3, post-op 4yrs.



A



B

Fig 12. Pre-op and post-op 1yr's change(ΔT2-T1), post-op 1yr and post-op 4yrs' change(ΔT3-T2) of yaw, roll, pitch (A : maxilla, B : mandible)

IV. Discussion

- Necessity of using a three-dimensional image and method of analysis for a patient with facial asymmetry

The image of a three-dimensional computed tomography shows a structure in a three-dimensional space as it is without any distortion, so it has advantages over 2D cephalograms for the measurement of landmarks, actual length and angle.[13,14] Through the studies of existing researchers, various methods of analysis used for analysis were presented together with proposals for landmarks regarding the analysis of a three-dimensional image and considerations regarding repetitious reappearance.[15,16] However, the reason why this method has not been widely used until now, despite its accuracy, is because it takes lots of time and effort to analyze these images compared to the existing lateral/frontal cephalograms in use -not to mention the expense and increase in radiation exposure. If a measurement is taken from a three-dimensional image, we know that it not only takes lots of time to identify the landmark positions but also there is an effect on the repetitious reappearance of landmarks due to the fact that the landmark positions are identified through the continuous rotation of the image. In particular, in the case of a patient with facial asymmetry, it is necessary to accurately analyze the differences in shape, size and position of right/left structures, so such difficulties may be even greater.

Therefore, in order to solve these problems, it is required to simplify the analysis in a manner similar to 2D cephalograms, and the first step is the setting of reference plane and orientation. In other words, in the same manner as a 2D cephalogram, a reference is set by using NHP (natural head position) or head posture aligner, a reference plane should be set and an image should be aligned by use of landmarks of a stable structure that does not change much. In this study, among various landmarks for the setting of reference plane, the landmarks of N (nasion), right/left FZP (Frontozygomatic point), right Or (orbitale) and right Po (Porion) were used. If 5 landmarks are selected, X, Y, Z axes are set and aligned automatically through the OnDemand® software program based on a reference point of N for the head position. This function is not different from the past method of using a widget in the In-Vivo® program, but the process is performed automatically in this program, which is very convenient.

If a landmark position is selected in a CT image after this orientation process is completed, the applicable positions are displayed in the coronal, sagittal and axial slide view on the right of the screen. If an operator moves a mouse scroll on this image, pre/post slide view of each slide view is displayed, and through this, the accurate position of landmarks may be examined by comparing pre/post slides. Therefore it is not necessary to examine landmarks by rotating the CT image up/down/right/left, so this method has advantages not only in terms of the reliability of landmarks but also in saving time. For example, if the orientation of an image is not set when intending to measure the lateral gonion, the position of lateral gonion may be changed a little according to the rotation of CT image, but if the orientation is set, because a coronal plane (X-Z plane) is determined based on a reference for the nasion, the operator has only to select a point that protrudes the most to the exterior in the gonion portion as a lateral gonion in an image on a coronal plane. Through this, the repetitious appearance of landmarks can be enhanced. It is difficult to specify one point in a gentle curve, but not an inflection or a protruded point. In this case, the accuracy of measurement may be improved by the addition or supplementation of other references. For example, as it was difficult to measure the lateral gonion in this study, the measurement was performed by adding a reference of an examiner that a landmark should be positioned at the lower direction of the occlusion plane in addition to the original definition of a landmark, and as a result, greater reliability within an inspection could be obtained.

As for other difficulties, if the position of a landmark used in the orientation is not symmetrical between right and left, the result of other measurements may be inaccurate because the orientation cannot be set accurately. For example, in the case of a patient with facial asymmetry shown not only in the maxilla and mandible but also in the entire head, if the orientation is set based on a reference point by use of right/left heights of FZP, Or and Po, the asymmetry of the lower face may be exaggerated or distorted because their heights are not the same on the right and left. So, in this case, an alternative method to assess the asymmetry may be used in a manner that like a 2D cephalogram, and the photograph of an image is taken either by use of the NHP or a head posture aligner, and then a line bisecting a face to right/left in the front is set as Z axis, and a line vertical to Z axis by bisecting from lateral to up-down directions based on portion is set as Y axis, and a line vertical to Z, Y axes is set as X axis.

- Postoperative assessment on improved portion and improvement level for asymmetry

In current studies on postoperative changes, most of the studies have focused on changes in the position and direction of condyle, evaluated postoperative changes regarding the proximal segment, and researched changes in the distal segment through an assessment on the pogonion and menton.[17-19] In the front, an assessment on changes in intergonial width or changes in ramal angulation was made for the purpose of assessing skeletal changes and/or stability.[20,21] However, it was hard to find studies on patients with asymmetry which compared postoperative changes regarding the deviation and non-deviation sides and that investigated stability. In particular, unlike SSRO in the case of IVRO surgery, since not only does overlapping occur in the distal segment and proximal segment but also the inferior border of the proximal segment is mostly trimmed at the time of surgery, changes in the shape of the gonial portion are unavoidable.[22] Therefore, for postsurgical assessment on changes in shape, size, position and recovery of symmetry with the use of the IVRO, it is required to mutually compare each length and angle on the deviation and non-deviation sides.

First, in this study, for the assessment of the asymmetry improvement level for a patient with facial asymmetry before/after surgery, an analysis was conducted on the differences on the deviation and non-deviation sides at the time points before surgery and one year after surgery. According to studies by Baek et al. on patients with facial asymmetry,[23] the ramal height on the deviation side was shown to be smaller than that on the non-deviation side, and the inclination of the ramus on the non-deviation was shown to be larger than that on the deviation side. With regard to the results for preoperative comparisons between the deviation and non-deviation sides in this study, with respect to angles all measurement values were shown as smaller except for the sagittal gonial angle, and with respect to lengths all measurement values were shown as larger while the sagittal Mn. body length and lateral Go horizontal distance had small values. With regard to the results for statistical analysis, all measurement values excluding the sagittal gonial angle and inferior Go vertical distance showed statistically significant differences.

The measurements for one year after surgery showed such differences between the deviation and non-deviation sides had disappeared. That is to say, statistically significant differences did not exist for all landmarks, and it was verified that the asymmetry had been resolved surgery. According to studies by Ahn et al.[24], the right/left differences that may be used as reference values for asymmetry diagnosis were shown to be as relatively small as 1.0~3.0mm in the case of the distance landmark, 1.0~3.0° scope in the case of the angle landmark. The results of this study also revealed that on the deviation and non-deviation sides the postsurgical measurement values regarding length were 0.03~2.57mm in terms of differences, and the measurement values regarding angles revealed differences of 0.32~1.93°.

Analysis on skeletal changes on the deviation and non-deviation sides before/after surgery

Next, the means and standard deviation on the deviation and non-deviation sides at the time points before surgery, one year after surgery and four years after surgery were obtained, and then the changes among the time points were analyzed, and finally an assessment on skeletal changes and stability for a long period before/after surgery was made.

When examining aspects of one year after surgery compared to pre-surgery, the sagittal ramal line angle, sagittal gonial angle, sagittal Mx. occlusal line angle, and frontal Mn. body line angle showed increases on both the deviation and non-deviation sides, and the sagittal ramal length, lateral Go vertical distance, inferior Go vertical distance, and U6 vertical distance showed decreases on both the deviation and non-deviation sides. This may be understood as reflecting the changes caused by maxilla impaction and mandible set-back at the time of surgery for a patient with Class III skeletal malocclusion. In addition, the changes in the frontal facial line angle, frontal ramal line angle, sagittal Mn. body length, and lateral Go horizontal distance were shown to be opposite on the deviation and non-deviation sides, so the changes in these measurement values may be inferred as being influenced by facial asymmetry surgery. For example, the changes before/after surgery in the frontal facial line angle showed a 1.56° decrease on the deviation side, representing 78.56° one year after surgery, and a 1.58° increase on the non-deviation side, representing 78.17° one year after surgery, which showed that the asymmetry had been resolved (Fig 13).

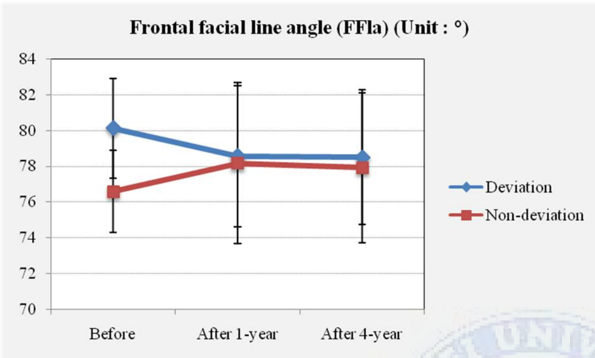


Fig 13. Postsurgical change of frontal facial line angle

Regarding the results on the analysis on changes for the period from one year after surgery to four years after surgery, the sagittal Mx. occlusal line angle and inferior Go vertical distance showed statistically significant differences on the deviation side, and the inferior Go vertical distance and U6 vertical distance showed statistically significant differences on the non-deviation side, and all the other landmarks were maintained stably. In the case of the Mx. occlusal line angle and U6 vertical distance, because the landmark is teeth, the changes in teeth occlusion rather than postoperative skeletal changes may be considered, and we know that the changes are not great as 1° and 1mm or so, respectively. However, in the case of the inferior Go vertical distance, increases of 1~3mm or so were revealed on both the deviation and non-deviation sides, so we can know that partial bone remodeling continues up to four years after surgery.

- Analysis on postoperative changes in a three-dimensional orientation after maxillo-mandibular complex (yaw, roll, pitch)

In this study, an assessment was made on postoperative three-dimensional skeletal changes in the maxilla and mandible. For this, an assessment was made in a way where the planes for maxilla and mandible were set, and a direction vector was obtained, and then the angles of X, Y, Z axes on a reference plane were measured. Since the angles of direction vectors in the maxilla and mandible in a three-dimensional space area combination of the yaw, roll and pitch, unlike the angle in a two-dimensional plane, each component should be calculated in order for the measurement of these angles.[12] For this, the yaw was calculated after an angle between Y axis on a reference plane and Y' axis on the maxilla and mandible planes was obtained, and then aligned to Y axis on a reference plane after rotating the maxilla and mandible planes as much as the angle, and finally the roll was measured. After the measurement of the roll, after rotating again in conformity to X axis, then the pitch was measured through a comparison between Z axis on a reference plane and Z' axis in maxilla and mandible.

As a result, one year after surgery compared to pre-surgery, statistically significant changes were shown in the pitch in the case of the maxilla, and the yaw, roll and pitch in the case of the mandible. In the case of the yaw and roll in the maxilla, postoperative changes compared to pre-surgery were not so great because a facial asymmetry exists to a great extent in the mandible compared to the maxilla and the surgical changes are proportional thereto. Therefore we can understand that at the time of surgery for a patient with Class III skeletal malocclusion and facial asymmetry, there occurred changes in the pitch in the maxilla due to posterior impaction, and there occurred significant changes in the yaw, roll and pitch in the mandible due to movement to conform with the differential set back and changes in the maxilla. On the other hand, the changes in the yaw, roll and pitch in the maxilla and mandible for the period from one year after surgery to four years after surgery did not show any statistically significant differences, and therefore the positions of the maxilla and mandible can be assessed to have been maintained stably for that period.

In this study, when selecting the landmarks for the setting of the maxilla plane, embrasures between maxillary incisors and the mesiobuccal cusp of the maxillary molar were selected instead of selecting skeletal landmarks such as the maxillare. The reason for this was that, due to the use of a plate and screw for the fixation of the maxilla at the time of surgery, it was difficult to make a repetitious reappearance measurement on

skeletal landmarks in postoperative images of three-dimensional computed tomography. Furthermore, if the right/left maxillary molars are not positioned symmetrical to the center of the maxilla in anterior and posterior directions, the direction of a vector on a maxillary plane using the maxillary incisors and molars may be different from the actual direction of a vector in the maxilla. In other words, although the differences between anterior and posterior positions have a relatively small impact on the measurement of the roll and pitch, in the case of the yaw great differences between anterior and posterior positions in the maxillary molars on both sides may result in differences of the actual yaw in the maxilla. Accordingly, in this study, for the yaw, it is desirable to analyze the differences between the period from before surgery to one year after surgery and the period from one year after surgery to four years after surgery and assess the changes and stability rather than its own numerical value.
To assess the malocclusion and establish a treatment plan by use of the above method, a plane may be set based on a landmark of teeth and when intending to analyze a three-dimensional direction, the values of roll and pitch may be used as they are, and for the yaw the degree of displacement (mm) of maxillary and mandibular incisors, Pog and Me, etc. or the angle (°) of ANS~PNS line on a frontal plane may be used together in auxiliary manner.

Until now, many researchers have reviewed the causes for the movement of the mandible after IVRO surgery. The mechanism for the movement of the proximal segment after the IVRO has not yet been clearly defined; Rosenquist et al.[25] presented the possibilities of mandibular gravity, soft tissue or muscular action as the causes for mandibular posterior movement after the IVRO; and Seigo Ohba et al.[5] suggested the disappearance of traction force in the temporalis after osteotomy, or traction force in the stylomandibular ligament, etc. as factors affecting the postoperative movement of the proximal segment, and explained that the recovery of muscular function occurs through jaw exercise that influences the physiological position of the proximal segment. In a study regarding IVRO, Nihara et al. [9] studied changes up to two years after surgery by dividing changes into the 'adaptive rotation' process during which a clockwise rotation occurs by muscle action around the mandible up to 3 months after a surgery, and the 'continuous period' thereafter during which bone remodeling occurs around the portion where surgery has been performed. As can be seen from the above, unlike the SSRO method of surgery by which the proximal segment and distal segment are fixed through rigid fixation at the time of surgery, in the case of the IVRO, the position of the mandible is determined through adaptation to a new environment without rigid fixation after surgery on occlusion, muscles and ligament tissue, and due to the discontinuity of overlapping parts between the two segments and the trimming of the lower margin of the proximal segment at the time of surgery. Accordingly, bone remodeling may occur on steady basis for a long period.

The stability of asymmetry surgery for maxilla may differ depending on the movement direction of the maxilla. Bailey et al.[26] classified the movement of the maxilla at the time of surgery into three categories: movement in an upward direction as very stable, frontal movement as stable, and downward movement as problematic. At the time of surgery for Class III asymmetry patients, in order to solve the occlusal canting in the maxilla, one side should be moved upward (perhaps the other side downward) and the surgery for the mandible is to be performed thereby. If the movement direction and movement quantity differ on the right and left sides, this may have an impact on postoperative stability.

In this study, in order to observe the possibility of skeletal changes over a long period of time, not initial changes in the maxilla and mandible after a surgery, aspects of change in maxillo-mandibular asymmetry and stability were examined by using images at the time points one year after surgery and four years after surgery. As a result of this study, in the case of a patient with Class III skeletal facial asymmetry, it was verified that the maxillo-mandibular asymmetry was resolved after Le Fort I osteotomy and the IVRO surgery, and the state after one year after surgery was mostly maintained stably up to four years, and in the case of the inferior Go, the occurrence of bone remodeling was verified.

V. Conclusion

This study was performed to assess skeletal changes and to examine stability for a long period of time after Le Fort I osteotomy for the maxilla and the IVRO for the mandible was performed on 16 patients with Class III skeletal malocclusion and facial asymmetry. For this, photographs of three-dimensional computed tomography were taken before and after surgery. Then the images were reconstructed, and the maxilla and mandible were classified into the deviation and non-deviation sides depending on the direction of menton deviation. Then the changes in length and angle were analyzed, and postoperative three-dimensional changes in the maxilla and mandible were analyzed by using direction vectors on the maxilla and mandible planes. Then the following results were obtained.

1. As a result of comparing the deviation and non-deviation sides one year after surgery, it was verified that in all measurement values there were not shown to be any statistically significant differences ($p>0.05$), so the asymmetry on the deviation and non-deviation sides had been resolved through surgery.

2. In comparing the conditions before surgery and the time point one year after surgery, on the deviation side, there were statistically significant decreases ($p<0.05$) in the frontal facial line angle, frontal ramal line angle, sagittal ramal length, lateral Go vertical distance, inferior Go vertical distance, and U6 vertical distance; and on the non-deviation side, there were statistically significant increases ($P<0.05$) in the sagittal ramal line angle, sagittal Mx. occlusal line angle, frontal facial line angle, frontal Mn. body line angle, sagittal Mn. body length, and lateral Go horizontal distance. And there were statistically significant decreases ($p<0.05$) in the sagittal ramal length, lateral Go vertical distance, inferior Go vertical distance, and U6 vertical distance.
   Regarding the changes for the period from one year after surgery to four years after surgery, on the deviation side, there were statistically significant increases ($P<0.05$) in the sagittal Mx. occlusal line angle, inferior Go vertical distance; and

on the non-deviation side there were statistically significant increases ($P<0.05$) in the inferior Go vertical distance and U6 vertical distance.

3. As a result of analyzing three-dimensional skeletal changes in the maxilla and mandible one year after surgery compared to before surgery, in the case of the maxilla, there were statistically significant differences ($p<0.05$) in the pitch; and in the case of the mandible, there were statistically significant differences ($p<0.05$) in the yaw, roll and pitch. But, four years after surgery, there were no statistically significant differences regarding the yaw, roll and pitch in the maxilla and mandible.

As a result of this study, it was verified that for a patient with Class III skeletal asymmetry, the asymmetry of the maxilla and mandible had been improved after surgery, and that one year after surgery the results were maintained up to four years without much change except for bone remodeling in the inferior gonial area.

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국문요약

3차원 전산화 단층사진을 이용한 안면비대칭 환자의 수술 후 상하악 골격안정성

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이제까지 수술 후 안정성에 관한 연구들은 수술 후 1년 동안의 변화를 평가한 경우가 대부분이었다. 그러나 수직골절단술(Intraoral Vertical Ramus Osteotomy, IVRO)의 경우 강성고정(rigid fixation)을 통해 근심골편과 원심골편이 고정되는 시상분할골절단술(Sagittal Split Ramus Osteotomy, SSRO)과는 달리 교합, 근육, 인대의 수술 후 생리적 적응을 통해 하악의 위치가 결정되고, 두 골편 사이 겹쳐진 부위의 불연속성으로 인해 장기간 동안 점진적으로 골개조가 일어날 수 있으므로 1년의 수술 후 관찰로는 골격안정성을 연구하는 데에 충분하지 않을 수 있다. 또한 비대칭의 개선을 평가하기 위해서는 좌우 우각부위의 골격 변화를 정확히 비교 분석하는 것이 중요하므로, 안면비대칭 환자를 수직골절단술을 이용해 수술을 한 경우, 우각부위의 골개조가 일어나는 충분한 기간 동안의 변화양상을 관찰하는 것이 필요하다.

본 연구는 16명의 안면비대칭을 가진 골격성 제 III급 부정교합 환자를 대상으로, 상악은 Le Fort I 골절단술, 하악은 수직골절단술을 시행한 후, 골격변화를 평가하고 장기간 안정성을 살펴보고자 하였다. 이를 위해 수술 전, 수술 1년 후, 수술 4년 후의 3차원 전산화 단층사진을 촬영하여 영상을 재구성한 뒤 상하악골을 이부편위 방향에 따라 편위측, 비편위측으로 분류하여 길이, 각도를 측정하여 변화를 분석하고, 상하악 평면의 방향벡터를 이용하여 수술 후 상하악골의 삼차원적인 변화를 분석하여 다음과 같은 결과를 얻었다.

1. 수술 1년 후 편위측과 비편위측을 비교한 결과 모든 계측치에서 통계적 유의차를 나타내지 않아 ($p>0.05$), 수술을 통해 편위측과 비편위측의 비대칭이 해소됨을 확인하였다.

2. 수술 전과 수술 1년 후의 비교에서, 편위측은 frontal facial line angle, frontal ramal line angle, sagittal ramal length, lateral Go vertical distance, inferior Go vertical distance, U6 vertical distance가 통계적으로 유의하게 감소하였고 ($p<0.05$), 비편위측은 sagittal ramal line angle, sagittal Mx. occlusal line angle, frontal facial line angle, frontal Mn. body line angle, sagittal Mn. body length, lateral Go horizontal distance는 통계적으로 유의하게 증가 ($P<0.05$), sagittal ramal length, lateral Go vertical distance, inferior Go vertical distance, U6 vertical distance는 통계적으로 유의하게 감소하였다 ($p<0.05$). 수술 1년 후와 수술 4년 후 사이의 변화에서는 편위측에서는 sagittal Mx. occlusal line angle, inferior Go vertical distance가 통계적으로 유의하게

증가하였고 ($p<0.05$), 비편위측에서는 inferior Go vertical distance, U6 vertical distance가 통계적으로 유의하게 증가하였다 ($p<0.05$).

3. 수술 전에 비해 수술 1년 후의 상악과 하악의 삼차원적인 골격변화를 분석한 결과 상악은 pitch, 하악은 yaw, roll, pitch에서 통계적 유의차를 나타내었고 ($p<0.05$), 수술 4년 후에는 상하악의 yaw, roll, pitch 모두 통계적 유의차를 나타내지 않았다.

이상의 연구결과, 골격성 제 III급 안면비대칭환자의 수술 후 상, 하악의 비대칭이 개선되었었고, 수술 1년 후 결과가 inferior gonion부위의 골개조를 제외하고 큰 변화없이 4년까지 유지됨을 확인하였다.

핵심되는 말: 3차원 전산화 단층촬영영상, 안면비대칭, 수술 후 장기적안정성, yaw, roll, pitch