Three-dimensional analysis of soft and hard tissue changes after simultaneous 2-Jaw surgery in Class III patients: 1-year follow-up

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Three-dimensional analysis of soft and hard tissue changes after simultaneous 2-Jaw surgery in Class III patients: 1-year follow-up

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2017년 6월

서 승 원

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ABSTRACT

Three-dimensional analysis of soft and hard tissue changes after simultaneous 2-Jaw surgery in Class III patients: 1-year follow-up

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Department of Dentistry
(Directed by Professor Kee-Joon Lee, D.D.S., M.S., Ph.D.)

Introduction: This study investigated the correlation between the three–dimensional changes in facial soft tissues, including the midfacial parasagittal area and maxilla–mandible complex, after Le Fort I osteotomy with maxillary posterior impaction and bilateral intraoral vertical ramus osteotomy (B-IVRO), using cone-beam computed tomography (CBCT).

Material and Methods: This retrospective study included 22 skeletal Class III patients who underwent orthognathic surgery. Three–dimensional CBCT images taken before and

1–year after surgery were superimposed based on the cranial base. Midfacial soft tissues, including those in the parasagittal area and midsagittal areas of the face, were evaluated using reconstructed CBCT images. The study variables were analyzed using paired *t*-tests and Pearson's correlation coefficient, and the ratios between soft tissue and hard tissue movement were calculated.

Results: After surgery, the paranasal area moved forward with a ratio of 0.5, according to vertical movement of B. The upper lip and M U1 showed correlation in the sagittal axis with a ratio of 0.8. The lower lip and M L1 were correlated in the sagittal and vertical axis in a ratio of 1.12 and 0.84, respectively. B′, Pog′, Me′ had a ratio of 0.8–1.1 with their paired hard tissue landmarks for all axes.

Conclusion: Orthognathic surgery using Le Fort I maxillary posterior impaction with B-IVRO mandibular setback results in forward movement of midfacial soft tissues, even though forward movement of the maxilla is limited because vertical movement of the maxilla–mandible complex causes redundancy of soft tissue and facial muscle and pulling from the retaining ligaments. This midfacial soft tissue change with maxillary posterior impaction could be advantageous to patients who have paranasal depression and protrusion of the upper lip due to proclined upper incisors, which are prevalent among Asian Class III patients.

Key words: Skeletal Class III; Cone-beam computed tomography; 2-Jaw surgery; Midface; Soft tissue

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I. Introduction

Facial appearance (esthetics) is one of the most important reasons for undergoing orthognathic surgery, which is a reliable treatment modality with a positive impact on the patient's facial appearance, oral function, and quality of life.(Choi et al., 2015b; Murphy et al., 2011; Rustemeyer and Gregersen, 2012) With the "Soft tissue paradigm", it is very important to predict soft tissue appearance after orthognathic surgery, as ideal repositioning of the jaws does not necessarily imply ideal change of soft tissue.(Lee et al., 2014)

The midfacial contour is important in our concept of youth and beauty; moreover, a flat midfacial contour makes the face appear uninteresting. (Nkenke et al., 2008) Approximately 40% of Korean Class III patients scheduled for surgery had a maxilla within one standard deviation of the normal position (retrognathic maxilla) and prognathic mandible.(Baik et al., 2000) Therefore, their midfacial soft tissues need to be advanced for a more esthetic facial appearance. However, maxillary advancement should be used with caution, because it widens the already broad Asian nose and advances the already protruded Asian upper lip. (Lee et al., 2013)

Technologies such as photogrammetry and laser scanning have major limitations, which include the inability to show soft tissue and hard tissue simultaneously. This requires merging of hard tissue analysis from 2-dimensional data and soft tissue analysis from 3-dimensional data, which requires additional data processing and has innate inaccuracies. Cone-beam computed tomography (CBCT) imaging is suitable for 3-dimensional analysis and prediction for orthognathic surgery because it provides images of the soft tissues and underlying hard tissues simultaneously and additionally has the benefits of low costs, reduced radiation dose, and shorter acquisition time than conventional CT, and can be recorded in the upright position with a natural head position. (Fourie et al., 2010; Lee et al., 2014)

There have been studies to analyze the soft tissue changes after 2-jaw surgery using CBCT.(Kim et al., 2010; Lee et al., 2013; Lee et al., 2014) Most of studies have used landmark method or grid method to analyze soft tissue changes and both methods have limitations. Landmark method is an easy and familiar way because it has been used for cephalometric analysis but it also has limitations that most of replicable landmarks are placed in midsagittal area so cannot be a useful method to analyze parasagittal area. Grid method shows soft tissue changes including parasagittal area using color variation but it is difficult to apply in clinical use because of complexity. Moreover, a brief review of previous studies has shown that most of the analytical sites are distributed in the midsagittal region, and the analysis of the parasagittal region has limited the clinical applications because of the lack of definite analysis of the amount of movement between the hard tissue and the soft tissue and their ratio. (Almukhtar et al., 2016; Lee et al., 2013; Lee et al., 2014)

To date, few studies have reported an analysis of the changes of midfacial soft tissues, including the parasagittal area, after orthognathic surgery, with maxillary posterior impaction and bilateral intraoral vertical ramus osteotomy (B-IVRO), by using CBCT, and most of these studies were based on short-term follow-up. Because the face is usually observed from a slightly lateral angle in daily life and people are best presented in angled photographs, the parasagittal area of facial tissue should be included in soft tissue analysis. (Honn and Goz, 2007)

The purpose of this study was to find the correlation between the 3-dimensional changes in midfacial soft tissues, including the parasagittal area and maxilla–mandible complex after maxillary posterior impaction and B-IVRO using CBCT. The hypothesis was that the vertical movement of the maxilla–mandible complex due to maxillary posterior impaction would affect the midfacial soft tissues.

II. Materials and Methods

1. STUDY DESIGN AND SAMPLE

This retrospective study included 22 adult skeletal Class III patients (6 males and 16 females; mean age: 21.6 years) who underwent Le Fort-I osteotomy with maxillary posterior impaction and bilateral intraoral vertical ramus osteotomy (B-IVRO) with mandibular setback (12 patients received genioplasty additionally) from 2012 through 2014 at the Department of Oral and Maxillofacial surgery, Yonsei Dental Hospital (Seoul, Korea).

The patients included in this study were individuals aged older than 18 years with skeletal Class III and an ANB angle smaller than 0°, who underwent orthognathic surgery (maxillary posterior impaction with Le Fort I osteotomy and mandibular setback with B-IVRO), with pre- and postsurgical orthodontic treatment, and for whom a series of CBCT records before and 1- year after surgery, in an upright position and with maximum intercuspation, were available. Patients who required maxillary premolar extraction for crowding relief or de-compensation were included (5 patients underwent both maxillary 1st premolar extraction; 1 patient underwent right maxillary 1st premolar extraction; 16 patients were non-extraction cases).

The exclusion criteria were the presence of craniofacial disorders, such as cleft lip and palate; a history of fracture in the facial area; presence of medical, physical, or mental conditions that could affect the healing potential; additional reduction or augmentation surgery on the piriform region; additional plastic surgery on the nasal and paranasal area, and requirement for single-jaw surgery.

This study conformed to the tenets of the Declaration of Helsinki on medical protocols and ethics and was approved by the institutional review board of Yonsei Dental Hospital (IRB number 2-2013-0028)

2. SURGICAL AND ORTHOGNATIC TREATMENT

All patients underwent conventional bimaxillary surgery, maxillary Le Fort-I osteotomy with posterior impaction and bilateral IVRO for setback of the mandible. Twelve patients underwent additional advance and reduction genioplasty. All surgeries were performed by a single surgeon.

Osteofixation using biodegradable system (hydroxyapatite/poly-L-lactide; Osteotrans MX®, Takiron, Osaka, Japan) was used to stabilize the maxilla after the Le Fort-I osteotomy. Four L-shaped plate and monocortical 2.0 mm-diameter screws were placed on bilateral pyriform aperture and zygomatic buttress.(Park et al., 2016)

Intermaxillary fixation was maintained for 2 weeks postoperatively. Then, patients were given instructions regarding active physiotherapy, using elastics to prevent the development of an open bite immediately after surgery, and to ensure sound postoperative rehabilitation.(Choi et al., 2015a) A surgical wafer was used as guidance for mandibular tooth positioning during the physiotherapy period. The wafer was removed after 1–2 weeks of physiotherapy, and physiotherapy was continued until the adequate range, more than 40 mm, of mouth opening as well as stable occlusion were achieved.

3. CBCT SCANNING

All patients underwent CBCT examinations (Alphard3030, Asahi Roentgen Inc., Kyoto, Japan) 1 month before surgery (T1) and 1 year after surgery (T2). CBCT scanning of the maxillofacial regions were performed for 17 s, with a field of view of 20 × 17.9 cm, 80 kVp, and 5 mA. During CBCT, patients were asked to be seated in an upright position, and to occlude with maximum intercuspation.

The CBCT scan data were converted into digital imaging and communication in medicine (DICOM) format. The DICOM images were created at 0.39-cm slice thicknesses after scanning and were reconstructed into 3-dimensional images using OnDemand software (CyberMed Inc., Seoul, Korea) (Fig. 1).

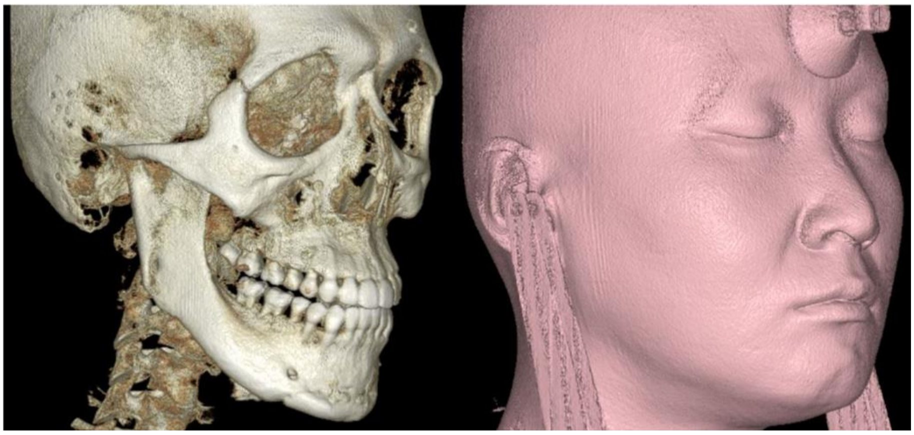

Figure 1. Reconstruction of 3D images of the soft and hard tissues using OnDemand software (CyberMed Inc., Seoul, Korea).

4. ANALYSIS OF 3-DIMENSIONAL CBCT DATA

Cranial base structures are stable and cannot be altered by orthognathic surgery.(Almeida et al., 2011) Therefore, the preoperative and postoperative 3-dimensional images were registered based on the cranial base. The automated registration was computed using the OnDemand software (Figs. 2, 3).

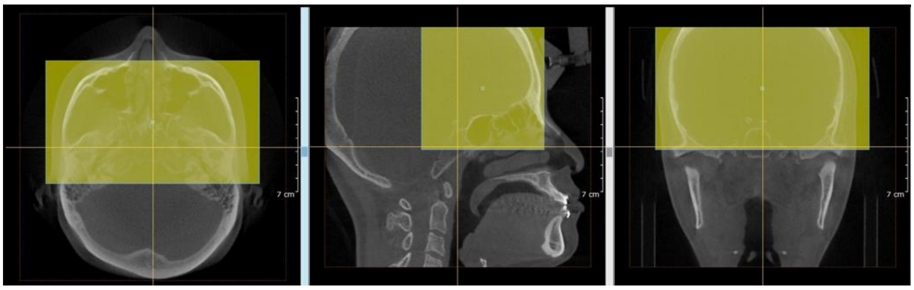

Figure 2. Superimposition of pre and postoperative 3-dimensional cone-beam computed tomography images using cranial base structures in OnDemand software. The yellow box indicates the superimposition area.

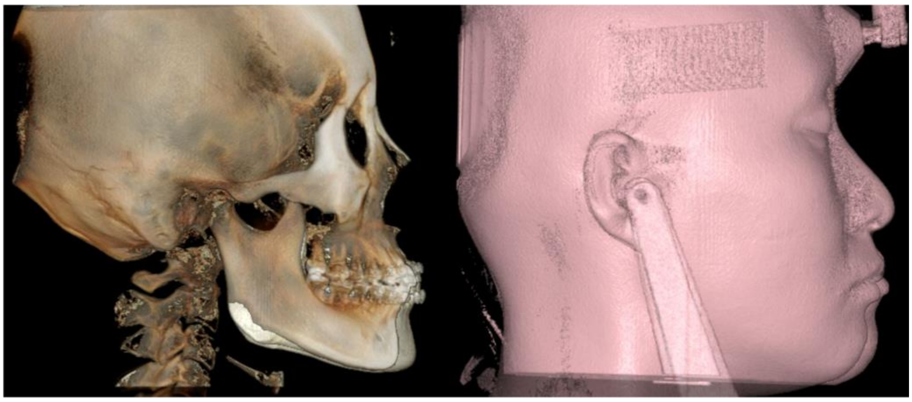

Figure 3. Superimposition of 3-dimensional cone-beam computed tomography images of the hard and soft tissues using OnDemand software.

The Frankfort horizontal (FH) plane was established using both orbitale points and the right side porion, and the horizontal reference plane was established parallel to the FH plane. The midsagittal plane was drawn perpendicular to the FH plane and passed through the nasion and midpoint of both orbitale points. The coronal plane was constructed at right angles to the horizontal and midsagittal planes, while passing through the nasion. The nasion was set to the zero point (0, 0, 0) and coordinates of other landmarks were acquired using this system. Positive coordinate values indicated values to the left, posterior, and superior to the 0 point, while negative values indicated values to the right, anterior, and inferior to the 0 point (Fig. 4).

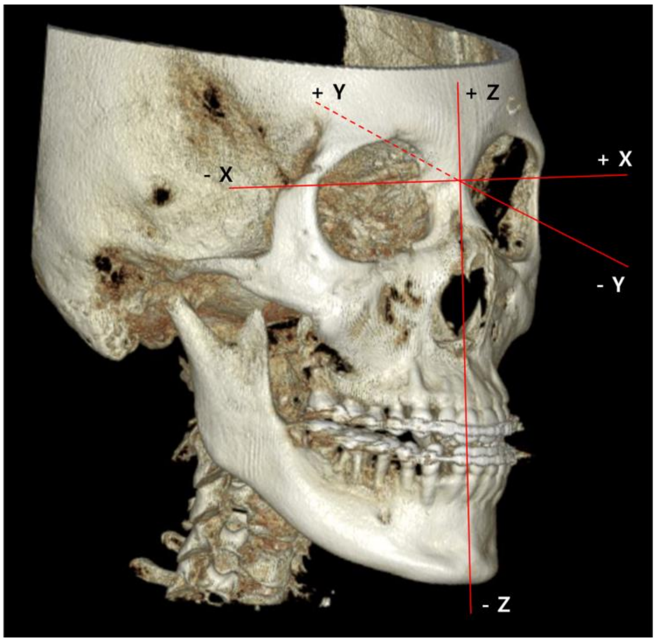

Figure 4. Coordinate system and 0 point (Nasion); X axis: (+) Left, (-) Right; Y axis: (+) Posterior, (-) Anterior; Z axis: (+) Superior, (-) Inferior

In the OnDemand program, 13 hard tissue landmarks and 21 soft tissue landmarks were designated (Table 1; Figs. 5, 6). Then, changes in the 6 linear and 2 angular measurements were calculated (Table 2). Categories with –v of 3D linear measurements were distances of projection on the Z axis. The landmark points and linear and angular measurements were selected based on a previous study. (Lee et al., 2014)

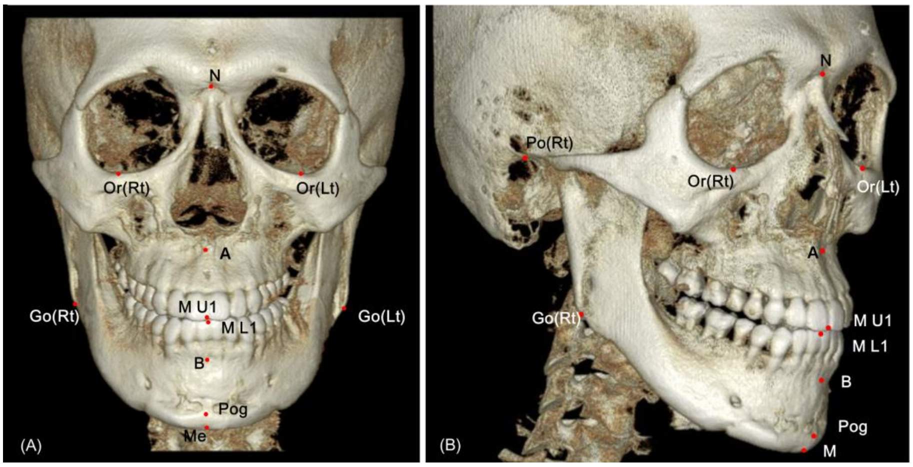

Figure 5. Hard tissue landmarks (A) frontal view, (B) lateral view

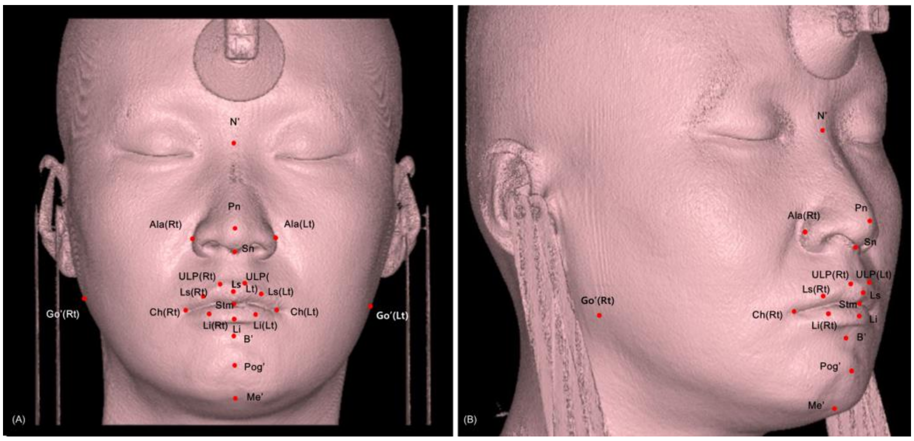

Figure 6. Soft tissue landmarks (A) frontal view, (B) lateral view

Table 1. Description of landmarks

	Landmark	Description
Hard tissue	N (nasion)	The most posterior point on the curvature between the frontal and nasal bones on the midsagittal plane
	Or (orbital)	The lowest point on the infraorbital margin of each orbit (bilateral)
	Po (porion, anatomical)	The highest midpoint on the roof of external auditory meatus (bilateral)
	A (subspinale)	The most posterior point on the curvature of the maxillary bone between anterior nasal spine and the dental alveolus
	M U1	The midpoint of the incisal tips of the anterior maxillary central incisors
	M L1	The midpoint of the incisal tips of the anterior mandibular central incisors
	B (supramentale)	The most posterior point of the bony curvature of the mandible below infradentale and above pogonion
	Pog (pogonion)	The most anterior midpoint of the symphysis of the mandible
	Me (menton)	The most inferior midpoint on the symphysis of the mandible
	Go (gonion)	The point on the curvature of the mandibular angle located by bisecting the angle formed by lines tangent to the posterior ramus and inferior border of the mandible (bilateral)
Soft tissue	N′ (soft tissue nasion)	The deepest point of the concavity of the soft tissue contour of the root of the nose
	Pn (pronasale)	The most protruded point of the nasal soft tissue
	Alar(nasal alar)	The most lateral point on each alar contour (bilateral)
	Sn (subnasale)	The midpoint of the angle at the columella base where the lower border of the nasal septum and the surface of the upper lip meet
	Ls (labrale superius)	The protruded point of the upper vermilion line
	ULP (upper lip point)	The most elevated point of the philtrum on the upper vermilion border line (bilateral)
	Ls(right, left) (right and left labrale superius)	The midpoint between ULP and Ch
	Ch (cheilion)	The most lateral extent of the outline of the lip (bilateral)
	Stm (stomion)	The point at the midline of the labial fissure between gently closed lips
	Li (labrale inferius)	The protruded point of the lower vermilion line
	Li (right, left) (right and left labrale inferius)	The midpoint between Li and Ch
	B′ (soft tissue B point)	The deepest point between the lower lip and chin
	Pog′ (soft tissue pogonion)	The most protruded point of the chin
	Me′ (soft tissue menton)	The lowest median point on the lower border of the mandible
	Go′ (soft tissue gonion)	The outermost point the mandible angle region (bilateral)

Table 2. Description of 3-dimensional linear and angular measurements.

Measurements		Description
Linear measurement	Go(Rt)-Go(Lt)	Mandibular width
	Go′(Rt)-Go′(Lt)	Lower face width
	N-Me	Hard tissue anterior face height
	N-Me-v	Hard tissue anterior face height(vertical)
	N′-Me′	Soft tissue anterior face height
	N′-Me′-v	Soft tissue anterior face height(vertical)
Angular measurements	Sn-N′-Pog′	Angle of convexity excluding the nose
	Pn-Sn-Ls	Nasolabial angle

-v: linear distance through true vertical

In order to visualize the changes in midfacial soft tissues, including the parasagittal area, reconstructed pre- and postoperative CBCT images were transferred using OnDemand and superimposed using Geomagic Control 2014.0 (Geomagics, Morrisville, NY, USA). Superimposition was performed at both the supra-auricular and supraorbital area, both the exocanthion and endocanthion area, and the soft tissue nasion area (Fig. 7).(Baik and Kim, 2010; Soncul and Bamber, 2004) A color map showed the magnitudes of the soft tissue changes and a region of interest could be distinguished more precisely by resetting the color code (Fig. 8). The color map allowed visualization of the tendency of soft tissue changes and indicated the amount of changes in 3-dimensions, by marking a point (Fig. 9). It was divided by area on a scale of 15×20 mm^2 to evaluate the variation in the parasagittal area; paranasal area, anterior cheek area, and lateral cheek area (Fig. 10). The width (15 mm) was determined that the half of the average length from the endocanthion to the exocanthion of Asian which is 30 mm. The height (20 mm) was determined, according to the previous study that the vertical length of midfacial soft tissue which showed clinically significant soft tissue changes after surgery.(Kim et al., 2010) More than 10 points were marked randomly in each area to determine changes in parasagittal soft tissues.

1) Paranasal area: The area around intersections between the alar–tragus line and the line perpendicular to the endocanthal line at the endocanthion, the midpoint of the endocanthion–exocanthion.

2) Anterior cheek area: The area around intersections between the alar–tragus line and the line perpendicular to the exocanthal line at the exocanthion.

3) Lateral cheek area: The area around intersections between the alar–tragus line and the

line perpendicular to the exocanthion–tragus line at the midpoint between the exocanthion and tragus.

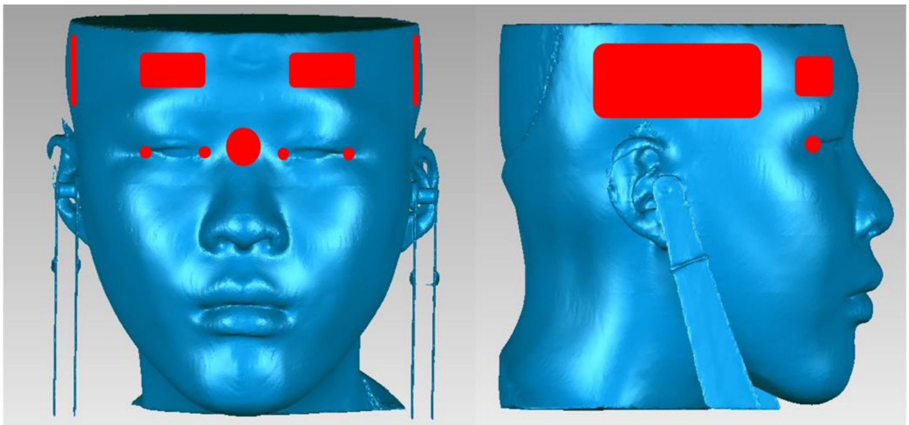

Figure 7. Reference areas for superimposition of pre- and postoperative 3-dimensional images in Geomagic Control 2014.0. Red boxes and circles indicate superimposition area.

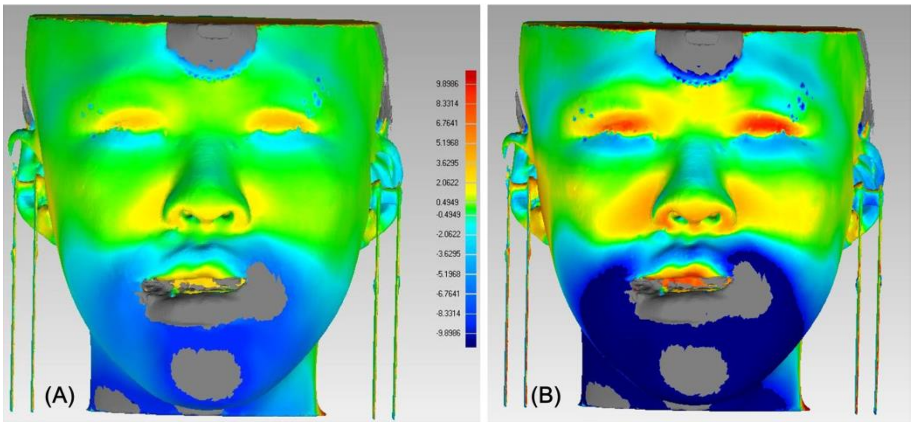

Figure 8. Superimposed 3-dimensional images of the soft tissues using Geomagic Control 2014.0. The colors diverge from green to visualize the soft tissue changes. (A) Broad color map scale for visualization of the whole parasagittal area. (B) Subdivided color map scale for more detailed visualization of region of interest.

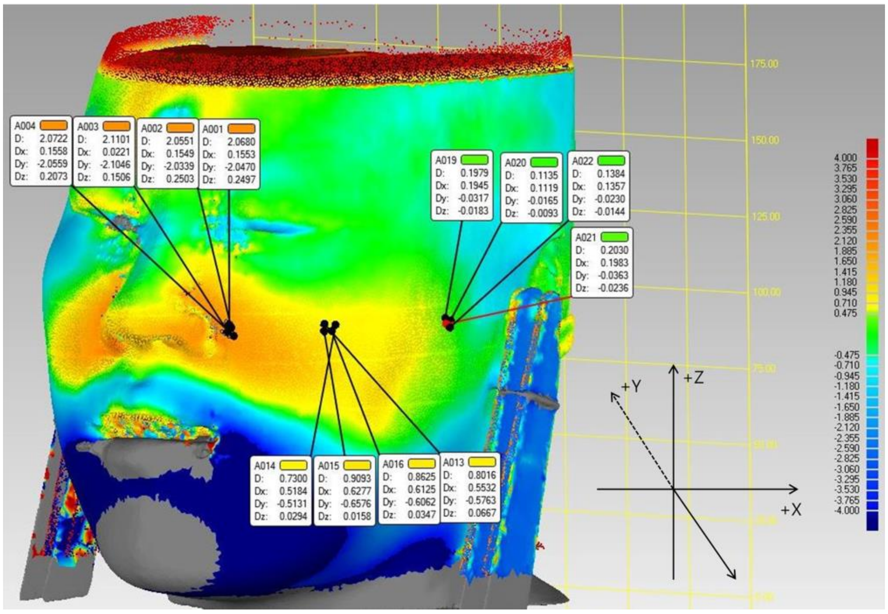

Figure 9. Annotation of soft tissue change in marked point by 3-dimensional coordinates; X axis: (+) Left, (-) Right; Y axis: (+) Posterior, (-) Anterior; Z axis: (+) Superior, (-) Inferior

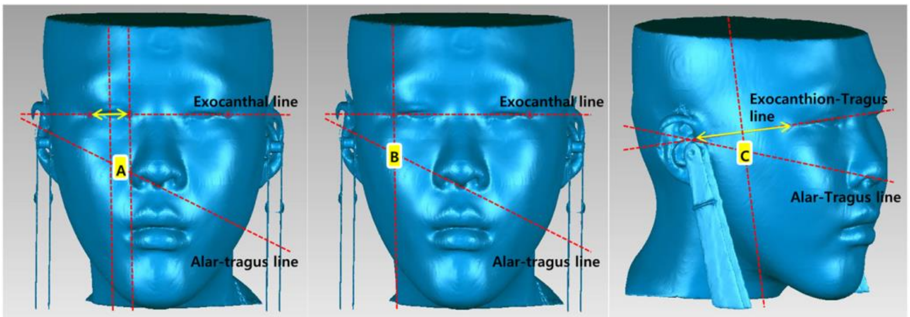

Figure 10. Facial regions in upper parasagittal area were divided on a scale of 15 × 20 mm², A: Paranasal area; B: Anterior cheek area; C: Lateral cheek area

5. RELIABILITY

The landmarks of all subjects were re-digitized at 2 weeks after the first digitization by a single researcher. The reproducibility test was performed by comparing measurements from original and repeated digitization using SPSS software for Windows, version 20.0 (SPSS, Chicago, IL, USA). Based on the intraclass correlation coefficient (ICC) of 0.999 ($P < 0.001$), all measured variables had a high reliability.

6. STATISTICAL ANALYSIS

All statistical analyses were processed using SPSS software for Windows, version 20.0 (SPSS, Chicago, IL, USA). The Shapiro–Wilk test was used to confirm that the data had a normal distribution. Therefore, parametric statistics were used in this study. Descriptive statistics, including means and standard deviations, were used to describe each variable analyzed in this study.

A paired *t*-test was used to compare the hard and soft tissue changes (landmarks, linear and angular measurements) between pre and post-surgery.

Pearson’s correlation analysis was used to obtain the correlation between hard and soft tissue changes including landmarks and the upper parasagittal area. In terms of the strength of correlations, an r value greater than 0.40 was considered to indicate a strong correlation, while that less than 0.40 was considered to indicate a weak correlation.

III. Results

Twenty–two patients (6 men and 16 women) fulfilled the inclusion criteria (Table 3, 4). For the 3-dimensional CBCT variable for menton (Me) deviation, which was evaluated only on the X-coordinate, all data were converted to absolute values.

Table 3. Demography of subjects

Variable	**Subjects**
Gender, n (%)	
Male	6 (27.3)
Female	16 (72.7)
Age (yr), mean±SD	21.6 ± 3.35
Additional surgery, n	
Geniplasty	12
No	10
Premolar ext., n	
Both M U4	5
M U4 (Rt)	1
No	16

Abbreviation: yr, year; ext, extraction; M U4, maxillary 1st premolar; Rt, right

Table 4. Characteristics of subjects

	Norm.	Mean	S.D.
Lateral Cephalometric variables			
SNA (°)	81.62	80.70	3.06
SNB (°)	79.17	82.78	3.56
ANB (°)	2.46	-2.09	2.08
Wits (mm)	-2.74	-12.21	3.39
Facial convexity (°)	3.65	-4.89	5.01
A to N perpendicular (mm)	0.85	-0.84	2.48
U1 to SN (°)	106.90	108.98	5.12
IMPA (°)	95.91	85.75	7.87
3-dimensional CBCT variable			
Me deviation on x-axis		3.55	2.42

SNA, sella-nasion-A point; SNB, sella-nasion-B point; ANB, the difference between SNA and SNB; U1 to SN, the angle between the axis of the upper incisor and sella-nasion plane; IMPA, incisor mandibular plane angle; Me, Menton point; Norm., Normal mean value of cephalometric measeuements

After surgery, the maxilla showed a small amount of upward and backward movement, while the mandible showed significant upward and backward movement. The upper and lower lip also showed significant backward movement but in contrast to lower lip, upper lip showed a slight downward movement. Mandibular soft tissues, such as B′, Pog′, and Me′ showed significant backward and upward movement and bilateral landmarks, such as Alar, Ch, Go, Ls, and Go′ moved in the opposite direction to each other (Table 5).

Table 5. Comparison of changes of the landmarks between pre- and post- surgery on the coordinate system (mm)

	ΔX			ΔY			ΔZ		
Variables	**Mean**	**S.D.**	**Sig**	**Mean**	**S.D.**	**Sig**	**Mean**	**S.D.**	**Sig**
A	-0.14	0.96	NS	0.75	1.14	**	1.37	1.72	**
ANS	0.18	1.14	NS	1.30	1.33	***	0.91	1.20	**
B	-0.98	2.50	NS	9.82	3.39	***	4.00	3.08	***
Pog	-0.84	2.63	NS	9.12	3.81	***	4.38	2.85	***
Me	-0.77	3.09	NS	9.29	4.11	***	4.62	2.69	***
Alar(Rt)	-0.35	0.71	*	-1.64	1.73	***	0.21	1.14	NS
Alar(Lt)	0.52	0.67	**	-1.38	1.91	**	0.39	1.36	NS
Pn	-0.09	0.42	NS	-0.96	1.00	***	-0.01	1.00	NS
Sn	-0.05	0.50	NS	-0.72	1.12	**	0.09	0.92	NS
Ls	0.04	0.94	NS	2.26	2.33	***	-0.80	1.98	NS
Li	-0.56	2.76	NS	8.59	2.67	***	2.95	4.30	**
ULP(Rt)	0.28	1.41	NS	1.51	1.94	**	-1.79	1.50	***
Stm	-0.71	1.64	NS	4.73	2.04	**	0.34	2.32	NS
B′	-0.88	2.14	NS	9.17	3.30	***	2.24	3.66	**
Pog′	-0.94	2.77	NS	9.48	3.66	***	2.43	4.81	*
Me′	-1.31	2.82	*	9.76	4.70	***	3.60	3.14	***
Ch(Rt)	2.33	3.25	**	3.33	2.83	***	0.37	2.50	NS
Ch(Lt)	-2.25	3.25	**	2.86	4.14	**	0.27	2.86	NS
Go(Rt)	-1.58	2.85	*	-0.38	3.02	NS	7.83	4.38	***
Go(Lt)	1.94	2.42	**	-0.78	3.07	NS	5.91	3.80	***
M U1	-0.08	0.96	NS	2.84	1.36	***	-0.13	1.51	NS
M L1	-0.26	2.25	NS	7.68	2.75	***	3.50	2.80	***
ULP(Lt)	-0.03	1.28	NS	1.51	1.83	**	-1.89	1.46	***
Ls(Rt)	1.25	2.23	*	2.05	2.30	***	-0.73	1.42	*
Ls(Lt)	-1.07	1.88	*	2.50	2.43	***	-0.80	1.58	*
Li(Rt)	1.08	2.57	NS	6.93	3.71	***	1.67	3.28	*
Li(Lt)	-1.22	2.40	*	6.58	4.02	***	1.60	3.33	*
Go′ (Rt)	-2.07	3.28	**	0.80	5.14	NS	5.35	4.71	***
Go′ (Lt)	2.78	2.87	***	0.42	6.10	NS	6.59	5.24	***

NS, not significant; *, between pre and postop ($P<0.05$); **, between pre and postop ($P<0.01$); ***, between pre and postop ($P<0.001$); X axis: (+) Left, (-) Right; Y axis: (+) Posterior, (-) Anterior; Z axis: (+) Superior, (-) Inferior

In the midfacial soft tissues, both paranasal areas showed significant forward movement (about 2.0 mm) and the largest upward movement (about 0.15 mm) among the 3 areas. The anterior and lateral cheek areas also showed forward movement, but the amount of movement was markedly smaller than that of the paranasal areas. The anterior cheek area showed the largest movement on the X-axis among the 3 areas. The anterior cheek (Rt) moved in the right direction for about 0.21 mm and the anterior cheek (Lt) moved in the left direction for about 0.16 mm (Table 6). For statistical analysis of parasagittal area of midfacial soft tissue, median value was used. More than 10 points were designated in each parasagittal area to evaluate the changes after surgery and the amount of variation was so large (despite the actual amount of soft tissue movement was almost decimal units) that simple mean value could not represent the soft tissue changes. For this reason, median value was used for statistical analysis of midfacial soft tissues.

Table 6. Soft tissue changes of upper parasagittal area between pre and post-surgery (mm)

		ΔX			ΔY			ΔZ		
		Min	**Max**	**Median**	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**
Paranasal(Rt)	Mean	-0.04	-0.07	-0.05	-1.76	-2.18	-1.97	0.10	0.19	0.15
	SD	0.17	0.43	0.27	0.78	0.72	0.73	0.16	0.27	0.21
	Sig			NS			***			**
Paranasal(Lt)	Mean	0.11	0.17	0.14	-1.75	-2.17	-1.96	0.11	0.20	0.16
	SD	0.19	0.44	0.27	0.69	0.72	0.70	0.14	0.23	0.17
	Sig			*			***			***
Ant. Cheek(Rt)	Mean	-0.17	-0.24	-0.21	-0.22	-0.41	-0.32	0.03	0.03	0.03
	SD	0.49	0.70	0.59	0.71	0.98	0.84	0.05	0.12	0.08
	Sig			NS			NS			NS
Ant. Cheek(Lt)	Mean	0.12	0.20	0.16	-0.20	-0.42	-0.31	0.01	0.05	0.03
	SD	0.40	0.64	0.51	0.57	0.84	0.70	0.55	0.09	0.07
	Sig			NS			NS			*
Lat. Cheek(Rt)	Mean	-0.11	-0.23	-0.17	-0.04	-0.05	-0.04	-0.03	-0.08	-0.06
	SD	0.79	1.05	0.92	0.15	0.23	0.19	0.09	0.19	0.14
	Sig			NS			NS			NS
Lat. Cheek(Lt)	Mean	-0.01	0.13	0.06	-0.01	-0.03	-0.02	0.02	0.01	0.01
	SD	0.89	1.00	0.94	0.13	0.19	0.16	0.05	0.13	0.09
	Sig			NS			NS			NS

NS, not significant; *, between pre and postop (P<0.05); **, between pre and postop (P<0.01); ***, between pre and postop (P<0.001); Ant. Cheek: Anterior cheek area; Lat. Cheek: Lateral cheek area; X axis: (+) Left, (-) Right; Y axis: (+) Posterior, (-) Anterior; Z axis: (+) Superior, (-) Inferior

The paranasal area showed correlations with the ANS and M U1, with ratio of 1.5 and 0.7, respectively, on the Y coordinate (Table 7). Mandibular and midfacial soft tissue changes showed correlations on the Z coordinate, between the paranasal area and B, a ratio of 0.5 (Table 8).

Table 7. Correlations and proportions between upper hard tissue and upper parasagittal soft tissue area

			Δ ANS			**Δ A**			**Δ MU 1**		
			X	Y	Z	X	Y	Z	X	Y	Z
	X	Proportion									
Δ Paranasal(Rt)	Y	Proportion		-1.52**						-0.69**	
	Z	Proportion									
	X	Proportion									
Δ Paranasal(Lt)	Y	Proportion		-1.51**						-0.69*	
	Z	Proportion									
	X	Proportion		0.16**							
Δ Ant. cheek (Rt)	Y	Proportion		0.25**							
	Z	Proportion									
	X	Proportion									
Δ Ant. cheek (Lt)	Y	Proportion									
	Z	Proportion									
	X	Proportion									
Δ Lat. cheek (Rt)	Y	Proportion									
	Z	Proportion									
	X	Proportion									
Δ Lat. cheek (Lt)	Y	Proportion									
	Z	Proportion									

*, $P < 0.05$; **, $P < 0.01$; Ant. Cheek: Anterior cheek area; Lat. Cheek: Lateral cheek area

Table 8. Correlations and proportions between lower hard tissue and upper parasagittal soft tissue area

			Δ B			**Δ Pog**			**Δ Me**			**Δ M L1**		
			X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
	X	Proportion												
Δ Paranasal(Rt)	Y	Proportion		-0.69*	0.49								0.26*	
	Z	Proportion												
	X	Proportion												
Δ Paranasal(Lt)	Y	Proportion			0.49*									
	Z	Proportion												
	X	Proportion												
Δ Ant. cheek (Rt)	Y	Proportion												
	Z	Proportion												
	X	Proportion												
Δ Ant. cheek (Lt)	Y	Proportion												
	Z	Proportion												
	X	Proportion												
Δ Lat. cheek (Rt)	Y	Proportion												
	Z	Proportion												
	X	Proportion												
Δ Lat. cheek (Lt)	Y	Proportion												
	Z	Proportion												

*, $P < 0.05$; **, $P < 0.01$; Ant. Cheek: Anterior cheek area; Lat. Cheek: Lateral cheek area

The upper lip showed significant correlations with the maxilla mainly on the Y coordinate and the ratio between the upper lip and M U1 was 0.8 (Table 9). The lower lip and M L1 showed significant correlation on Y and Z coordinates with ratio of 1.1 and 0.8, respectively (Table 10). Midsagittal mandibular soft tissue showed significant correlations with the paired hard tissue landmarks on all coordinates (Table 11), but the parasagittal mandibular soft tissue landmark (Go′) showed no correlation with its paired hard tissue landmarks (Table 12).

Facial shape changed after surgery, with an increase in the mandibular width, a reduced vertical facial profile, and increased facial convexity (Table 13).

Table 9. Correlations between hard and soft tissue changes associated with the maxilla and upper midsagittal soft tissue

			ΔPn	**ΔAlar (Rt)**	**ΔAlar (Lt)**	**ΔSn**	**ΔLs**	**ΔULP (Rt)**	**ΔULP (Lt)**	**ΔLs (Rt)**	**ΔLs (Lt)**
	X	Proportion									
ΔANS	**Y**	Proportion									1.92**
	Z	Proportion									
	X	Proportion									
ΔA	**Y**	Proportion					3.01***	2.01***	2.01**		3.33***
	Z	Proportion									
	X	Proportion									
ΔM U1	**Y**	Proportion					0.80**				
	Z	Proportion									

**, P < 0.01; ***, P < 0.001

Table 10. Correlation and proportion between lower incisor and lower lip

			ΔCh(Rt)	ΔCh(Lt)	ΔStm	ΔLi	ΔLi(Rt)	ΔLi(Lt)
ΔM L1	X	Proportion						
	Y	Proportion				1.12**		
	Z	Proportion				0.84**	0.48**	0.46***

**, P < 0.01; ***, P < 0.001

Table 11. Correlations and proportions between hard and soft tissue changes associated with the mandible

			Total
ΔB′ to ΔB	X	Proportion	1.17***
	Y	Proportion	1.03***
	Z	Proportion	0.84*
ΔPog' to ΔPog	X	Proportion	0.95***
	Y	Proportion	1.04***
	Z	Proportion	0.59*
ΔMe′ to ΔMe	X	Proportion	1.10***
	Y	Proportion	0.87***
	Z	Proportion	0.86***

*, P < 0.05; **, P < 0.01; ***, P < 0.001

Table 12. Correlation and proportion between the hard and soft tissue changes associated with the gonial area

			Total	
			ΔGo′ (Rt)	**ΔGo′ (Lt)**
ΔGo(Rt)	**X**	Proportion	NS	NS
	Y	Proportion	NS	NS
	Z	Proportion	NS	NS
ΔGo(Lt)	**X**	Proportion	NS	NS
	Y	Proportion	NS	NS
	Z	Proportion	NS	NS

NS, not significant

Table 13. Three dimensional linear and angular measurements (mm)

	Variables	**ΔT(T2-T1)**		
		Mean	**S.D.**	**Sig**
Linear measurements	Go(Rt)-Go(Lt)	3.53	3.88	***
	Go'(Rt)-Go'(Lt)	4.96	5.22	***
	N-Me	-4.27	2.71	***
	N-Me-v	-4.62	2.69	***
	N'-Me'	-2.83	3.42	**
	N'-Me'-v	-3.68	3.17	***
Angular measurements	Sn-N'-Pog'	5.23	2.05	***
	Pn-Sn-Ls	10.25	6.61	***

T1, within 2 weeks before surgery; T2, 12 months after surgery

NS : not significant; *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$; -v: linear distance through true vertical axis

IV. Discussion

This study set out to find the correlation between the 3-dimensional changes in midfacial soft tissues including the parasagittal area, and the maxilla–mandible complex after maxillary posterior impaction and B-IVRO, using CBCT. We hypothesized that the vertical movement of the maxilla–mandible complex, due to maxillary posterior impaction, would affect the midfacial soft tissues. To test this hypothesis and evaluate whether the soft tissue changes resulted from hard tissue movement, facial hard and soft tissue landmarks and midfacial soft tissues, including those in the parasagittal area, were assessed using 3–dimensional CBCT. We found that vertical movement of the maxilla–mandible complex, due to maxillary posterior impaction, has an effect on midfacial soft tissues such that the ratio of forward movement of the paranasal area to vertical movement of B was 0.5.

After orthognathic surgery, soft tissue changes are reduced due to subsidence of post-operative swelling, remodeling, and adaptation.(Oh et al., 2013) Some studies have suggested that considerable soft tissue changes are observed during the 6 months post-operation(Kau et al., 2006; Moss et al., 1994) and previous studies have recommended waiting for 6 months to 1 year after surgery before performing soft tissue analysis.(Chung et al., 2008; Rosen, 1988) In this study, 1-year-postoperative CBCT data were chosen to allow enough time for remodeling and adaptation.

When comparing pre- and post-surgery, Alar(Rt) moved to the right side and Alar(Lt) moved to the left side, resulting in widening of the nose. Usually, widening of nose is considered as un-esthetic change, particularly in females; the nose is one of the most important factors of perceived attractiveness.(Honn and Goz, 2007) At the same time, both Alar, Pn, and Sn showed forward movement, albeit minimal. Hellak et al (Hellak et al., 2015) have reported that an increase in the width of the nose corresponded to maxillary advancement, but in this study, A and ANS points moved in posterior–superior direction, although only slightly. It has been reported that maxillary impaction displaced the Pn in an anterior direction and even displaced soft tissue associated with the nose in an anterior direction.(Kim et al., 2010; Lee et al., 2014) Lee et al(Lee et al., 2013) reported similar results that paranasal and subalar regions moved forward even though maxillary setback movement was performed. Kim et al (Kim et al., 2013) reported that the cheek area (which corresponds to the paranasal area in this study) moved forward, even in the one-jaw (mandible) surgery group. Jeon et al(Jeon et al., 2014) reported that in Le Fort-I osteotomy, posterior impaction of the maxilla can negate the effect of maxilla setback in the region above the A point and the ANS. In this study, not only the nose, but also the midfacial soft tissues, including the parasagittal area, showed forward movement even though the maxilla moved backward.

It seems that two factors could affect the movement of the midfacial soft tissues: redundant soft tissue due to maxillary posterior impaction and facial retaining ligaments and muscle. Maxillary posterior impaction can affect the area above the ANS, causing it to move forward even though setback surgery was performed simultaneously (Fig. 11).

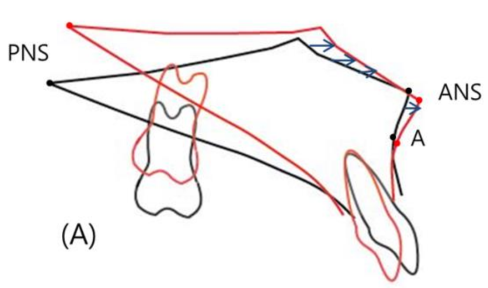

Figure 11. Schematic drawing of the maxillary Le Fort-I osteotomy with posterior impaction. (A) Posterior impaction exerts an advancing effect on the maxilla, (B) Posterior impaction exerts an advancing effect on the area above the ANS and negates the setback effect, resulting in forward movement of the midfacial soft tissues, Black line: pre-surgery; Red line: post-surgery; Blue arrow: movement of the area

Moreover, with posterior impaction, redundant soft tissue may be increased as compared to only mandibular setback surgery. In a previous study, maxillary posterior impaction was the main difference between one-jaw and two-jaw surgery, and the two-jaw surgery group showed more forward movement of the paranasal soft tissue.(Kim et al., 2013) In maxillary advancement surgery, paranasal soft tissue showed forward movement; yet, maxillary setback surgery also resulted in forward movement of the paranasal soft tissue when combined with posterior impaction.(Almukhtar et al., 2016; Lee et al., 2013; Nkenke et al., 2008) In this study, forward movement of the paranasal soft tissue correlated significantly with mandibular vertical reduction (Table 8). Redundant soft tissue might be pulled by the retaining ligaments of the face; this may also be affected by facial muscles. The zygomatic and masseteric ligaments are located in midface and are related to the zygomaticus major muscle.(Rossell-Perry and Paredes-Leandro, 2013) It seems that redundant soft tissue is pulled by zygomatic and masseteric ligaments, and is moved in an upward, forward, and lateral direction. Upward movement would be limited by the origin of the facial expression muscles, and lateral movement would be limited by the anterior superficial fibers of the masseter muscle.(Almukhtar et al., 2016) Because of these anatomical structures, the paranasal area moves mainly forward, the anterior cheek moves forward and outward by almost the same amount, and the lateral cheek moves mainly outward.

The midfacial soft tissues change caused by maxillary posterior impaction could be advantageous to patients who have paranasal depression and a protruded upper lip due to proclined upper incisors; these features are prevalent among Asian Class III patients. To date, it has been difficult to predict how much of the midfacial soft tissues would move forward, as previous studies, have indicated that midfacial soft tissues move forward after maxilla advancement, and yet midfacial soft tissues move forward after maxilla setback with posterior impaction. In other words, opposite sagittal movements of the maxilla therefore results in the same outcome in terms of midfacial soft tissue movement. In this study, sagittal movement of the maxilla was clinically insignificant, but midfacial soft tissues moved forward, indicating that vertical movement of the maxilla–mandible complex is the primary reason for the forward movement of midfacial soft tissues. When measured at B, the ratio between these two movements was 0.5.

Backward movement of the upper lip resulted in improvement of upper lip esthetics, including an increased nasolabial angle (Pn-Sn-Ls). Moreover, downward movement of the upper lip induces appropriate vertical height and an esthetic lip curl. Upper lip movement correlates with maxilla movement, particularly in the Y coordinate (Table 9). The upper lip has a curtain-like structure, in that the upper section is relatively fixed, but the lower part is relatively free to move, supported by the upper incisors. Therefore, if the upper incisors move posteriorly, the upper lip loses its support and moves in the same direction in an arc, and not simply in parallel. For this reason, the upper lip moved posteriorly, but also inferiorly, and there was no correlation between M U1 and the upper lip on the Z coordinate, in contrast with the Y coordinate, which showed a strong correlation. M U1 was significantly correlated with upper lip movement on the Y coordinate, with a ratio of 0.8 (Table 9). The ratio of upper lip to upper incisor movement on the Y coordinate was in agreement with previous studies. (Lee et al., 2013; Nadkarni, 1986) Although A and ANS showed significant correlation with the upper lip, the ratio was not calculated, because its movement on the Y coordinate was not clinically significant.

The lower lip moved backward and upward in the same direction as the M L1 and mandible. The ratio of ΔM L1 to the lower lip on the Y coordinate was 1.12, in agreement with a previous study.(Kaklamanos and Kolokitha, 2016) Because of the clockwise rotation of the maxilla–mandibular complex through maxillary posterior impaction, the mandible moved posteriorly, but also superiorly. Superior displacement of the mandible resulted in superior movement of the lower lip, with a ratio of 0.84 (ΔM L1 to ΔLi), which is in agreement with other study. (Chew, 2005) B′, Pog′, and Me′ moved backward and upward according to the mandibular movement. The ratios of ΔB′ to ΔB, ΔPog′ to ΔPog, and ΔMe′ to ΔMe were in the range of 0.8–1.1 for all coordinates (Table 11). Kaklamanos and Kolokitha (Kaklamanos and Kolokitha, 2016) have reported that sagittal changes in Pog, B, M L1 are strongly correlated with the respective soft tissue movements, with ratios ranging from 0.915 to 1.051. Chew et al (Chew, 2005) reported that M L1 and Li are highly correlated, with a ratio of 0.88 on the vertical plane. It seems that mandibular soft tissue, especially in midsagittal area (B′, Pog′, Me′), reflected the respective hard tissue changes nearly 1:1 ratio on the all coordinates. When comparing the maxilla and mandible, soft tissue responses in the mandible reflected hard tissue displacement, with a higher ratio.

In terms of both hard and soft tissue, the anterior facial height was decreased and the lower facial width was increased, improving the convexity of the face (Table 13). The increase in lower facial width is probably due to the overlap of the proximal and distal segments after surgery.(Baik and Kim, 2010) Jung et al(Jung et al., 2010) have reported that the transverse mandibular width of the soft tissues was increased after B-IVRO, and decreased as time progressed. Because the proximal and distal segments overlap and the gonial angle area undergoes remodeling after B-IVRO, accurate prediction of Go and Go′ movement is difficult. Taken together, the appearance of the face can be made relatively short and rounded, which is considered a “baby face”, from a relatively long and narrow face, which is considered an aged face. Such facial changes are more advantageous to females as a small chin and small jawbones, full lips, prominent cheekbones, and baby-like feature of face are considered characteristics of beauty in females. (Honn and Goz, 2007) Further considerations of how to maintain or enhance masculine facial features during such surgery are needed.

This study analyzed the changes in midfacial soft tissues, including the parasagittal area, to identify correlations between movement of the maxilla–mandible complex and midfacial soft tissues, by using CBCT. Furthermore, midsagittal areas of the face were also analyzed to determine whether soft tissues change according to hard tissue movement. However, this study also has limitations, such as the relatively small sample size. Additional studies with a large sample size, and longer follow-up could be helpful for predicting soft tissue changes after surgery. Moreover, it will be helpful if a patient’s annual weight changes are recorded and reflected in soft tissue changes.

V. Conclusion

This study investigated the correlation between the 3-dimensional changes in midfacial soft tissues including the parasagittal area, and the maxilla–mandible complex after maxillary posterior impaction and B-IVRO, using CBCT.

1. Orthognathic surgery, using Le Fort I maxillary posterior impaction with B-IVRO mandibular setback, results in forward movement of midfacial soft tissues, even though forward movement of the maxilla is limited. The paranasal area moved forward in a ratio of 0.5 to the vertical movement of B.
2. The upper lip and M U1 were correlated in the Y coordinate, in a ratio of 0.8. The lower lip and M L1 were correlated in the Y and Z coordinates, in a ratio of 1.12 and 0.84 respectively.
3. The soft tissue points of B′, Pog′, and Me′ moved in a ratio of 0.8–1.1 with their paired hard tissue landmarks, in all coordinates.

These results should be considered in the 3-dimensional prediction of orthognathic surgery outcomes in Class III patients.

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국문요약

골격성 제 III급 부정교합 환자의 양악 수술 후 경조직과 연조직 변화의 3차원 분석

서 승 원

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(지도교수 : 이 기 준)

이 연구의 목적은 Le Fort I 골절단술을 이용한 상악 후방부 상방이동 (posterior impaction) 과 하악 양측성 하악지 수직골절단술을 시행한 III급 부정교합 환자에서, CBCT 를 이용하여 3차원적으로 (1) 중안면 방시상 영역 (parasagittal area)을 포함한 연조직과 상하악 복합체 변화의 상관관계를 조사하고 (2) 상하순 및 하악 연조직과 경조직 변화의 상관관계에 대해 알아보는 것이다.

이 연구는 후향적 연구로서 2012년에서 2014년도까지 연세대학교 치과대

학병원에 내원하여 술전 교정 후 악교정 수술을 받았으며, 악교정 수술 1달 전과 수술 1년 후에 CBCT를 촬영한 III급 부정교합 성인 환자 22명 (남자 6명, 여자 16명, 평균 연령 21.6세) 을 대상으로 하였다. CBCT 상은 3차원 영상으로 재구성되었고, 두개저를 기준으로 중첩하여 3차원 계측점을 설정하였다. 중안모 방시상 영역과 정중시상 영역을 포함한 연조직과 상하순, 하안면 연조직과 경조직 변화에 대한 상관 분석 및 비율 계산이 이루어졌다.

악교정 수술 후 중안면 연조직 부비영역의 전방이동은 B point 의 수직적 이동과 유의성 있는 상관 관계를 보였으며 그 비율은 0.5 였다. 시상면에서 상순과 상악 전치는 0.8 의 비율을 가지는 유의성 있는 상관 관계를 보였다. 하순과 하악 전치는 시상면과 수직면에서 유의성 있는 상관 관계를 보였으며 그 비율은 각각 1.12, 0.84 였다. 연조직 B′, Pog′, Me′ point 는 대응되는 경조직 B, Pog, Me point 에 대하여 모든 평면에서 0.8-1.1 의 비율을 가지는 상관 관계를 보였다.

Le Fort I 골절단술을 이용한 상악 후방부 상방이동 (posterior impaction) 과 하악 양측성 하악지 수직골절단술을 이용한 하악 후방이동술을 통한 악교정 수술에서 상악골의 전방이동 없이도 중안면 연조직의 전방이동이 나타났다. 이는 상하악 복합체의 수직 이동이 잉여 연조직 발생을 야기하고, 안면 근육과 안면 유지 인대에 의한 당김 효과 때문인 것으로 보인다. 상악 후방부 상방이동 (posterior impaction) 에서 나타나는 이러한 중안면 연조직의 변화는, 특히 아시아인에서 많이 나타나는, 부비영역 함몰과 전방 경사된 상악 전치로

인한 입술 돌출을 가지는 III급 부정교합 환자의 치료에 유리하게 작용할 것으로 보인다.

핵심 되는 말 : 골격성 III 급, CBCT, 악교정 수술, 중안면, 연조직 변화