

Analysis of 3D Soft Tissue Changes After 1- and 2-Jaw Orthognathic Surgery in Mandibular Prognathism Patients

Bo-Ram Kim, DDS, Kyung-Min Oh, DDS, MSD,†*
Lucia H. S. Cevidanes, DDS, MSD, PhD,‡
Jeong-Eon Park, DDS, MSD,§ Hyoung-Seob Sim, DDS, MSD,||
Sung-Kyung Seo, DDS, MSD,¶ Mauricio Reyes, PhD,#
*Yoon-Ji Kim, DDS, MSD, PhD,** and*
Yang-Ho Park, DDS, MSD, PhD††

Purpose: Orthognathic surgery has the objective of altering facial balance to achieve esthetic results in patients who have severe disharmony of the jaws. The purpose was to quantify the soft tissue changes after orthognathic surgery, as well as to assess the differences in 3D soft tissue changes in the middle and lower third of the face between the 1- and 2-jaw surgery groups, in mandibular prognathism patients.

Materials and Methods: We assessed soft tissue changes of patients who have been diagnosed with mandibular prognathism and received either isolated mandibular surgery or bimaxillary surgery. The quantitative surface displacement was assessed by superimposing preoperative and postoperative volumetric images. An observer measured a surface-distance value that is shown as a contour line. Differences between the groups were determined by the Mann-Whitney *U* test. The Spearman correlation coefficient was used to evaluate a potential correlation between patients' surgical and cephalometric variables and soft tissue changes after orthognathic surgery in each group.

Results: There were significant differences in the middle third of the face between the 1- and 2-jaw surgery groups. Soft tissues in the lower third of the face changed in both surgery groups, but not significantly. The correlation patterns were more evident in the lower third of the face.

Conclusion: The overall soft tissue changes of the midfacial area were more evident in the 2-jaw surgery group. In 2-jaw surgery, significant changes would be expected in the midfacial area, but caution should be exercised in patients who have a wide alar base.

© 2013 American Association of Oral and Maxillofacial Surgeons
J Oral Maxillofac Surg 71:151-161, 2013

Facial appearance is an important factor in interrelationships between humans, and it affects social and psychological development¹; therefore orthognathic

surgery has the objective of correcting skeletal discrepancies, as well as altering facial balance, to achieve esthetic results in patients who have severe

*Resident, Department of Orthodontics, Kangdong Sacred Heart Hospital, Hallym University Medical Center, Chuncheon, South Korea.

†Resident, Department of Orthodontics, Kangdong Sacred Heart Hospital, Hallym University Medical Center, Chuncheon, South Korea.

‡Assistant Professor, Department of Orthodontics and Pediatric Dentistry, University of Michigan School of Dentistry, Ann Arbor, MI.

§Graduate Student, Graduate School, Hallym University, Chuncheon, South Korea.

||Graduate Student, Graduate School, Hallym University, Chuncheon, South Korea.

¶Graduate Student, Graduate School, Hallym University, Chuncheon, South Korea.

#Group Head, Institute for Surgical Technology and Biomechanics, University of Bern, Bern, Switzerland.

**Clinical Instructor, Department of Orthodontics, Kangdong Sacred Heart Hospital, Hallym University Medical Center, Chuncheon, South Korea.

††Professor, Department of Orthodontics, Kangdong Sacred Heart Hospital, Hallym University Medical Center, Chuncheon, South Korea.

Address correspondence and reprint requests to Dr Park: Department of Orthodontics, Kangdong Sacred Heart Hospital, Hallym University Medical Center, Gil-dong 445, Gangdong-gu, Seoul 134-701, South Korea; e-mail: dentpark64@hanmail.net

© 2013 American Association of Oral and Maxillofacial Surgeons

0278-2391/13/7101-0\$36.00/0

doi:10.1016/j.joms.2012.02.005

disharmony of the jaws.^{1,2} Thus the treatment goals of orthodontics and orthognathic surgery have changed. This paradigm shift in practice has placed more emphasis on normal soft tissue as a primary treatment goal, whereas functional occlusion and normal skeletal relationships have become secondary.^{3,4} The ideal positioning of the jaws through orthognathic surgery does not always result in an ideal soft tissue appearance because the response of a patient's facial soft tissue does not reflect the exact movements of the underlying jaws in a 1:1 ratio.^{5,6} Therefore treatment objectives should focus on the final soft tissue changes, and the ideal soft tissue proportions should be considered when planning orthognathic surgery.⁷

The rate of bimaxillary (2-jaw) surgery in the treatment of mandibular prognathism has increased because it leads to more favorable corrections of the facial proportions and a better esthetic result with increased stability.⁸ In addition, bimaxillary surgeries cause minimal narrowing of the pharyngeal airway, which can prevent the development of breathing disorders.^{9,10} It has been reported that the volume of the upper part of the pharyngeal space is greater in mandibular prognathism patients¹¹; therefore, bimaxillary surgeries are preferable for maintaining the patient's airway.

The development of computer imaging technology has allowed surgeons and orthodontists to analyze facial structures in patients, visualize final treatment goals, and assess the actual treatment results.¹² Several imaging-based methods for evaluating facial soft tissue changes after orthognathic surgery have been reported, including lateral cephalometric radiography, 3D computed tomography, and 3D laser scanning.^{1,2,13,14} Although lateral cephalometric radiography has been widely used to evaluate the facial profile, this method is limited because much of the 3D structural information of the face is lost during the 2D data acquisition.^{1,12} Consequently, it is difficult to identify some of the landmarks that are located on both sides of the face and are often observed as double images.¹⁵ Three-dimensional laser scanners are preferable because patients are not exposed to ionizing radiation, they reproduce the color and texture of soft tissue more accurately, and 3D images can be reconstructed immediately with the appropriate software.² However, a major drawback of facial scanners is that they only produce images of the soft tissue, not the underlying hard tissues.¹⁴

Numerous 2D studies have evaluated soft tissue changes in mandibular setback (1-jaw) surgery alone or compared the differences in soft tissue and hard tissue changes in bimaxillary surgery.^{16,17} In contrast, there are only a few studies concerning 3D evaluation of soft tissue changes after orthognathic surgery in mandibular prognathism patients, especially with re-

spect to the various effects of isolated mandibular setback surgery and bimaxillary surgery.

The establishment of cone-beam computed tomography (CBCT) has made it possible to produce an accurate representation of both the hard and soft tissues of the face, using significantly less radiation than conventional spiral computed tomography.^{12,18} In addition, CBCT scans have been reported to have greater dimensional accuracy, without any clinically significant differences between the measurements made on the CBCT images and the corresponding physical measurements.¹⁸ In addition, the volumetric assessment of the pharyngeal airway has been performed with CBCT scans.^{19,20}

The goals of this study were as follows: 1) to quantify the soft tissue landmark changes of the middle and lower third of the face after orthognathic surgery in anteroposterior, transverse, and vertical directions by measuring the distance between the coordinates; and 2) to assess the patterns of 3D soft tissue changes between 1- and 2-jaw surgeries. Our null hypothesis was that soft tissue changes of the middle and lower third of the face do not differ between patients who have undergone either 1- or 2-jaw orthognathic surgery.

Materials and Methods

STUDY DESIGN/SAMPLE

CBCT scans were analyzed to assess facial soft tissue changes in patients who had undergone bimaxillary surgeries and those who had only undergone mandibular setback surgeries. This study protocol was approved by the Ethics Review Committee at Kangdong Sacred Heart Hospital, Hallym University Medical Center, Seoul, South Korea (Institutional Review Board 10-123), and informed consent was obtained from all patients in this study. The study included CBCT scans of mandibular prognathism patients who visited the Department of Orthodontics at Kangdong Sacred Heart Hospital for orthognathic surgery from December 2008 to August 2011. All of the subjects in this study had undergone preoperative and postoperative orthodontic treatments. Patients with a cleft lip or cleft palate and patients with skeletal disharmonies due to trauma or degenerative conditions, such as rheumatoid arthritis of the temporomandibular joint, were excluded. The surgery type was determined based on the lateral cephalometric analyses and the clinical impression of each patient. Patients who had maxillary retrusion and severe midfacial concavity were treated with 2-jaw surgery.

STUDY VARIABLES

The primary predictor variable was surgery type, and the patients were assigned to either the isolated

mandibular setback surgery group or the bimaxillary surgery group. The outcome variables were 6-month postoperative changes of facial landmarks. Other variables included age, gender, surgical variables, and lateral cephalometric analysis.

SURGICAL PROCEDURES

The 1-jaw patients underwent isolated mandibular setback surgery with a sagittal split ramus osteotomy (SSRO). The 2-jaw patients underwent SSRO of the mandible and posterior impaction of the maxilla with a Le Fort I osteotomy. SSRO of the mandible was achieved with a short lingual osteotomy method for enhanced stability.²¹ The posterior maxilla was impacted and was consequently rotated in a clockwise direction, with the center of rotation located between the anterior nasal spine of the maxilla and the upper incisal tip. Some of the 1- and 2-jaw patients underwent advanced genioplasty as an adjunctive procedure. Rigid internal fixation of the maxilla and mandible was performed with miniplates and miniscrews, and intermaxillary fixation was applied for 1 week after surgery. Elastics were placed to stabilize the occlusion after intermaxillary fixation.

IMAGE ACQUISITION

CBCT scans were performed before surgery (T0) and 6 months after surgery (T1). Patients were asked to bite with maximum intercuspation, and they were not allowed to swallow, breathe, or move their heads or tongues during image acquisition. All CBCT images were obtained with the Master 3D dental imaging system (Vatech, Seoul, South Korea) with the following parameters: 90 kV, 3.6 mA, 15-second scan time, and 20 × 19-cm field of view. The slice thickness was set at 0.3 mm, and the voxels were isotropic. Three-dimensional rendering was performed with ITK-SNAP (open-source software).²²

LATERAL CEPHALOMETRIC ANALYSIS

Lateral cephalometric images were acquired from CBCT scans by importing the scans to the InVivoDental software program, version 6.0 (Anatomage, San Jose, CA), and creating an orthogonal projection with parallel rays (Fig 1). The lateral cephalometric images were imported into the V-Ceph software program, version 5.5 (Osstem, Seoul, South Korea), for lateral cephalometric analysis. Landmark identifications and lateral cephalometric measurements were performed by the same investigator (B.-R.K.).

FACIAL SOFT TISSUE CHANGES

The cranial base is a stable structure; therefore, it was used as a reference point when the T0 and T1 images were registered.²³ Registration was performed

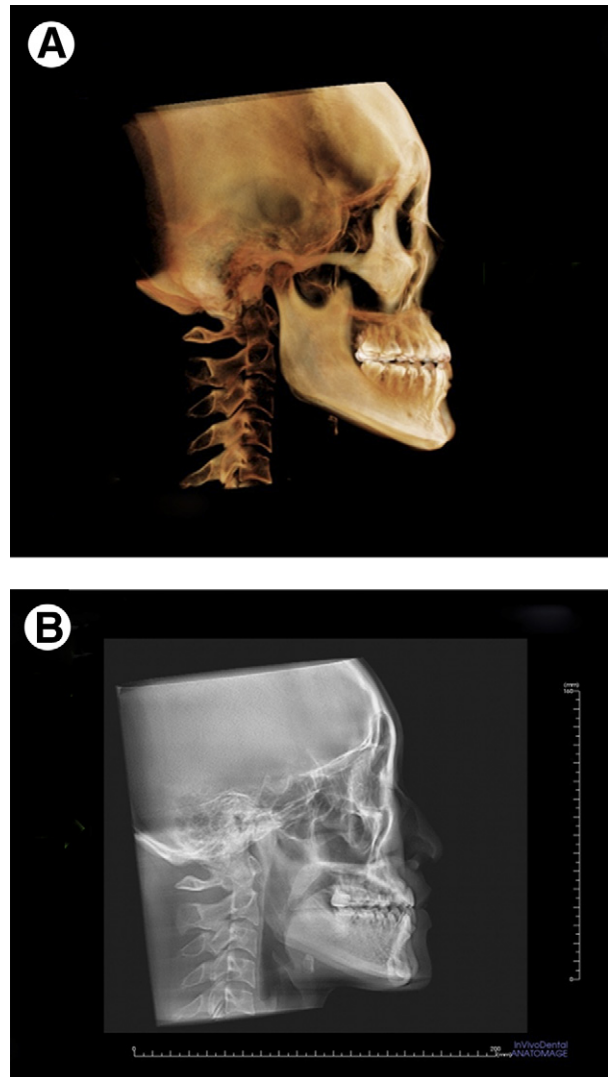


FIGURE 1. Images imported from CBCT scans by use of InVivoDental software. A, Volume rendering image. B, Lateral cephalometric image acquired from A.

Kim et al. Soft Tissue Changes in Mandibular Prognathism. J Oral Maxillofac Surg 2013.

with IMAGINE software (open-source software), and the T1 image was reoriented in accordance with the cranial base of the T0 image. After the registration step, skin segmentation was performed on the reoriented image, which was then converted into the open inventor format (.iv) by use of Vol2Surf (publicly available software). Subsequently, by use of CMF application software (developed at the M. E. Müller Institute for Surgical Technology and Biomechanics, University of Bern, Bern, Switzerland, under the funding of the Co-Me network), the quantitative surface displacement between the T0 and T1 images was performed by superimposing the 2 volumetric images.²⁴ This allows the observer to measure a surface-distance value that is shown as a contour line (isoline)

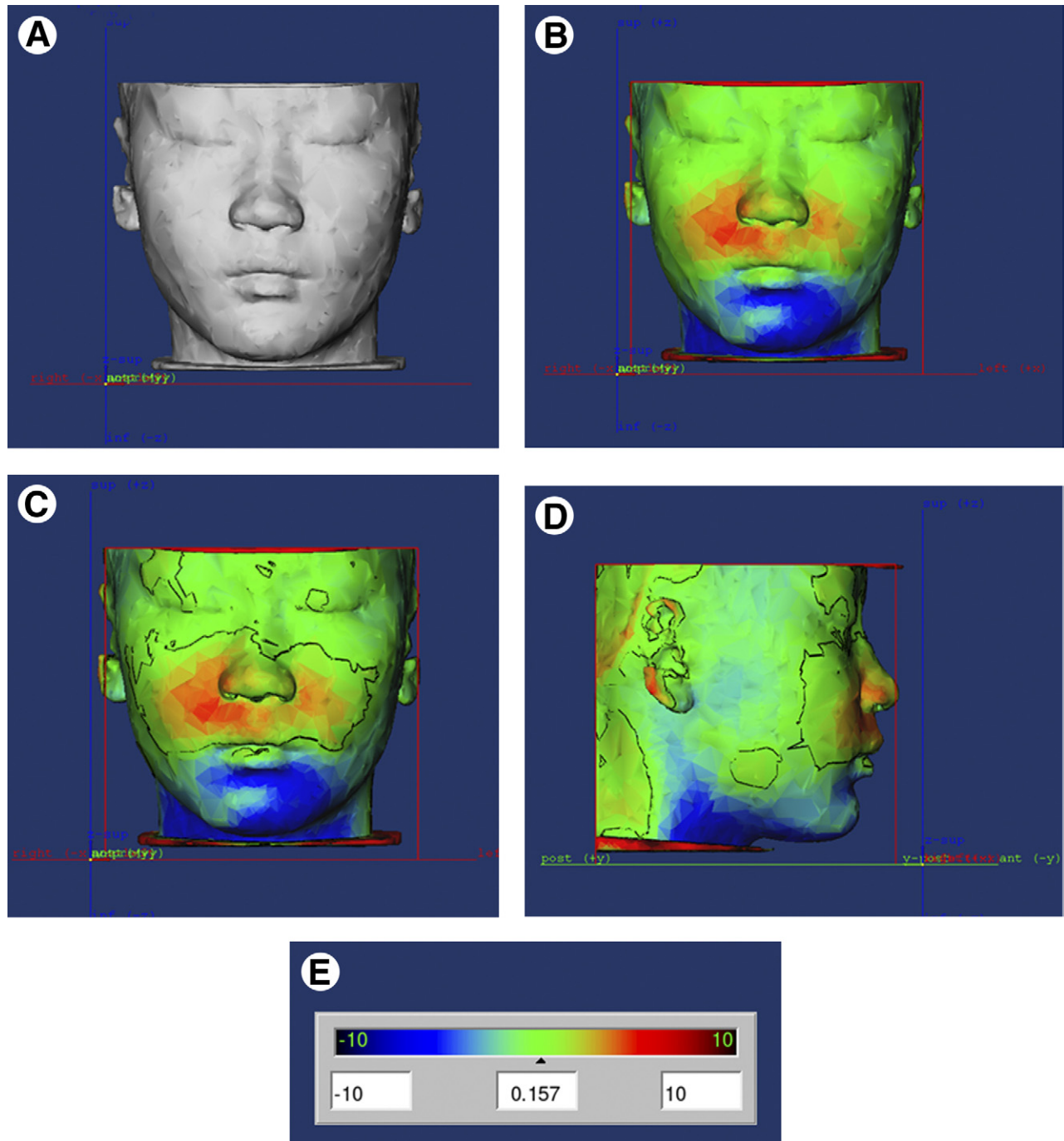


FIGURE 2. By use of CMF application software, the quantitative surface displacement between T0 and T1 was performed by superimposing 2 volumetric images. A, Image before color mapping application was performed. B, Color mapping image. C, D, Measurement of surface-distance value with contour line (isoline). E, Color map bar. By adjusting the arrow and matching the isoline, measuring the surface-distance value is possible.

Kim et al. Soft Tissue Changes in Mandibular Prognathism. J Oral Maxillofac Surg 2013.

on a color-mapped image (Fig 2). Positive measurements indicate that the postoperative surface has moved in an anterior, lateral, and superior direction, and negative measurements indicate posterior, medial, and inferior movement of the 3D surface model. Soft tissue landmarks used in this study are defined in

Figure 3 and Table 1. All distances were measured to the nearest 0.01 mm.

STATISTICAL ANALYSIS

SPSS software for Windows, version 12.0 (SPSS, Chicago, IL), was used for all statistical analyses. To

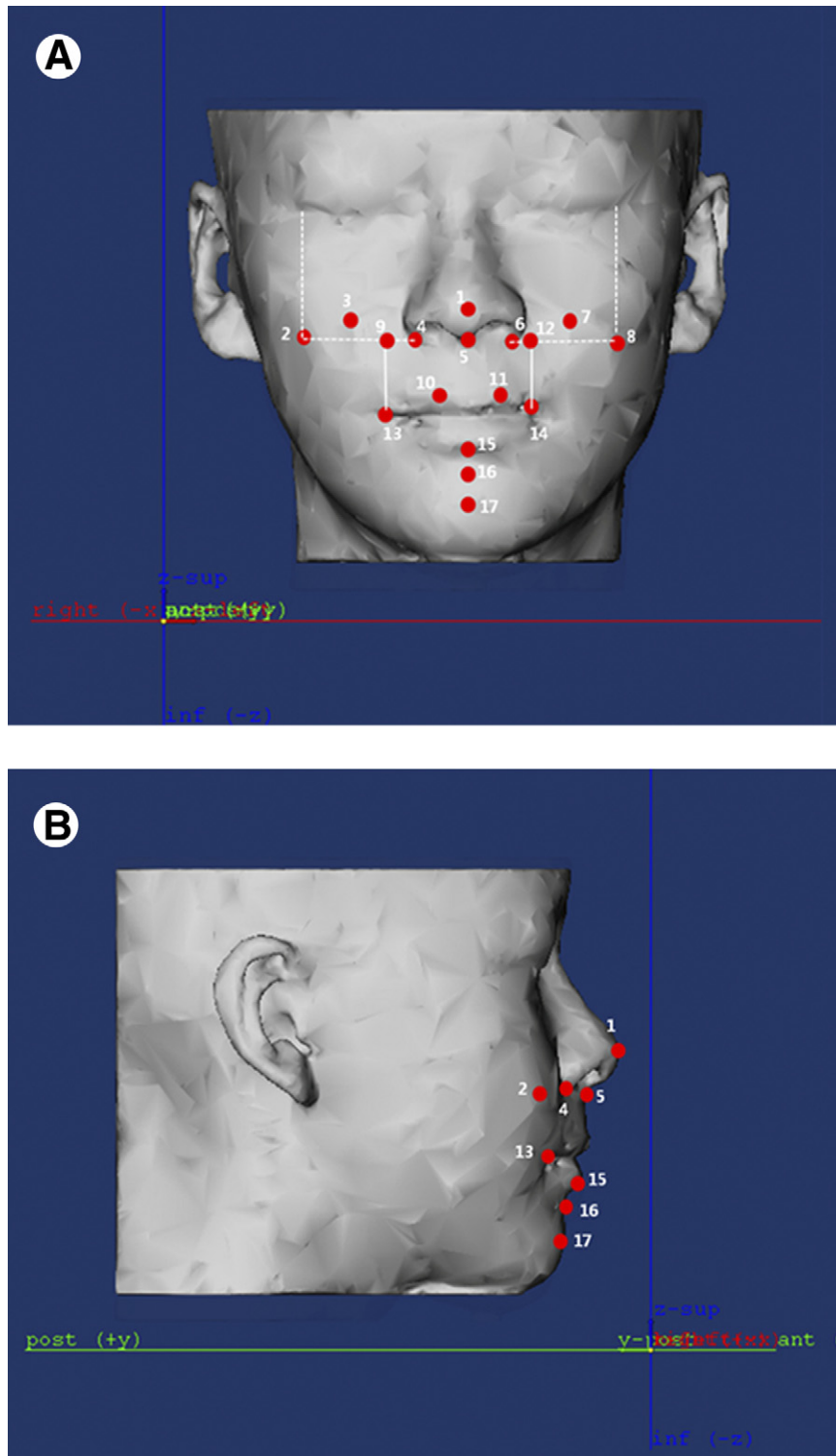


FIGURE 3. Soft tissue landmarks used in study: 1, pronasale (Pn); 2, right exocanthus–alar base (Rt.Exo-Al); 3, right cheek (Rt.Ck); 4, right alar base (Rt.Al); 5, subnasale (Sn); 6, left alar base (Lt.Al); 7, left cheek (Lt.Ck); 8, left exocanthus–alar base (Lt.Exo-Al); 9, right cheilion–alar base (Rt.Ch-Al); 10, right Cupid’s bow (Rt.Cu); 11, left Cupid’s bow (Lt.Cu); 12, left cheilion–alar base (Lt.Ch-Al); 13, right cheilion (Rt.Ch); 14, left cheilion (Lt.Ch); 15, lower lip (LL); 16, soft tissue B point (B’); and 17, soft tissue pogonion (Pog’). A, Frontal view; B, lateral view.

Kim et al. Soft Tissue Changes in Mandibular Prognathism. J Oral Maxillofac Surg 2013.

Table 1. DEFINITIONS OF SOFT TISSUE LANDMARKS USED IN STUDY

Soft Tissue Landmarks	Definition
Lip measurements	
Rt.Cu (right Cupid's bow)	Most prominent point of vermilion border of right Cupid's bow of upper lip
Lt.Cu (left Cupid's bow)	Most prominent point of vermilion border of left Cupid's bow of upper lip
Rt.Ch (right cheilion)	Most lateral extent of outline of lip on right side
Lt.Ch (left cheilion)	Most lateral extent of outline of lip on left side
LL (lower lip)	Most prominent point of vermilion border of Cupid's bow of lower lip
Cheek measurements	
Rt.Ck (right cheek)	Most prominent point of cheek on right side
Lt.Ck (left cheek)	Most prominent point of cheek on left side
Rt.Exo-Al (right exocanthus-alar base)	Intersection point of right exocanthus and right alar base
Lt.Exo-Al (left exocanthus-alar base)	Intersection point of left exocanthus and left alar base
Rt.Ch-Al (right cheilion-alar base)	Intersection point formed by line parallel to midsagittal plane passing through right cheilion and line perpendicular to midsagittal plane passing through right alar base
Lt.Ch-Al (left cheilion-alar base)	Point of intersection formed by line parallel to midsagittal plane passing through left cheilion and line perpendicular to midsagittal plane passing through left alar base
Chin measurements	
Pog' (soft tissue pogonion)	Most anterior point in chin
B' (soft tissue B point)	Most concave point on curve between LL and Pog'
Nasal measurements	
Pn (pronasale)	Most anterior point in nose
Rt.Al (right alar base)	Most lateral point in curved base line of alar on right side, indicating facial insertion of nasal wing base
Lt.Al (left alar base)	Most lateral point in curved base line of alar on left side, indicating facial insertion of nasal wing base
Sn (subnasale)	Point at which columella merges with upper lip in sagittal plane

Kim et al. *Soft Tissue Changes in Mandibular Prognathism. J Oral Maxillofac Surg* 2013.

evaluate the systemic error of the method used, 10 CBCT scans were randomly selected and all distances were measured twice on each scan by the same investigator. A paired *t* test was used. Random errors for the linear measurements were calculated with the Dahlberg formula ($Standard\ error = \frac{\sum d^2}{2n}$), where *d* is the difference between repeated measurements and *n* is the number of double recordings.²⁵

Descriptive statistics, including the means and standard deviations for each group, were calculated. The Mann-Whitney *U* test was used to determine whether there were significant differences in soft tissue changes between the 1- and 2-jaw groups. In addition, the Spearman correlation coefficient was used to evaluate a potential correlation between patients' surgical and cephalometric variables and soft tissue changes after orthognathic surgery in each group. $P \leq .05$ was considered statistically significant for all analyses.

Results

PATIENT DEMOGRAPHICS

A total of 25 consecutive mandibular prognathism patients were included in this retrospective study (Table 2). All the measurements were

free of any systemic error, and the random error varied from 0.39 to 2.14 mm, which was considered insignificant.

Of the patients, 8 underwent SSRO only (6 men and 2 women), and the mean setbacks were 7.00 mm and 8.40 mm on the right and left sides, respectively. A total of 17 patients underwent bimaxillary surgery (10 men and 7 women), with mean setbacks of 7.82 mm and 8.00 mm on the right and left sides, respectively. The posterior maxilla was impacted by a mean of 3.59 mm as measured at the upper first molar. Advanced genioplasty was performed in 3 patients (3 men) in

Table 2. DISTRIBUTION OF SUBJECTS (N = 25)

Classification	No. of Patients	Age (yr)		P Value
		Mean	SD	
Male				
1-Jaw	6	22.9	2.4	.88
2-Jaw	10	23.5	1.9	
Female				
1-Jaw	2	22	3.1	.67
2-Jaw	7	23.4	5.4	

Kim et al. *Soft Tissue Changes in Mandibular Prognathism. J Oral Maxillofac Surg* 2013.

Table 3. SAMPLE CHARACTERISTICS

	Mean		<i>P</i> Value	95% Confidence Interval	
	1-Jaw (n = 8)	2-Jaw (n = 17)		Minimum	Maximum
Cephalometric variables					
ANB (°)	-2.30	-3.04	.46	-2.66	4.97
Wits appraisal (mm)	-8.71	-13.88	.08	-2.44	12.29
Facial convexity (°)	-6.61	-7.87	.69	-7.06	10.71
Overjet (mm)	-2.20	-2.75	.46	-4.38	3.75
FMA (°)	26.64	29.54	.13	-12.81	3.27
Lower facial height (°)	50.35	51.79	.78	-8.10	5.16
Upper occlusal plane-FH (°)	7.86	9.72	>.99	-5.38	3.18
Changes of SNA (°)	0.00	1.23	.15	-2.86	0.39
Changes of palatal plane (°)	0.00	-0.33	.15	-3.72	0.49
Changes of A to N-perpendicular (mm)	0.00	2.95	.15	-5.33	0.58
Changes of gonial angle (°)	5.15	1.56	.23	-4.47	11.66
Changes of SNB (°)	-4.26	-3.87	.61	-1.69	0.90
Changes of mandibular plane angle (°)	3.22	0.23	.62	-1.08	7.07
Surgical variables					
Genioplasty (mm)	2.20	1.59	.33	-2.88	4.10
Posterior impaction (mm)	0.00	3.59	<.01*	-4.48	-2.70
Mandibular setback on right side (mm)	7.00	7.82	.45	-3.54	1.91
Mandibular setback on left side (mm)	8.40	8.00	.57	-2.55	3.35

NOTE. The Mann-Whitney *U* test was performed.

Abbreviations: SNA, sella-nasion-A point; SNB, sella-nasion-B point; ANB, the difference between SNA and SNB; FMA, the angle between FH plane and mandibular plane; FH, Frankfort horizontal plane.

**P* < .01.

Kim et al. *Soft Tissue Changes in Mandibular Prognathism. J Oral Maxillofac Surg* 2013.

the 1-jaw surgery group, with a mean amount of 2.20 mm, and 6 patients (4 men and 2 women) in the 2-jaw surgery group, with a mean amount of 1.59 mm (Table 3).

The results for the bivariate analysis of the clinical and demographic subject characteristics are listed in Table 3. No statistically significant differences with regard to lateral cephalometric variables were noted.

SOFT TISSUE ANALYSIS

To compare the soft tissue changes after surgery between the 1- and 2-jaw surgery groups, the Mann-Whitney *U* test was used. There were statistically significant differences between the 2 groups for the following parameters: left Cupid's bow, right cheek, left cheek, left exocanthus-alar base, right cheilion-alar base, left cheilion-alar base, right alar base, left alar base, and subnasale. According to these data, the measurements showed higher values in the 2-jaw surgery group than in the 1-jaw surgery group (Table 4).

As a result of surgery, the upper and lower lips moved backward in the 1-jaw surgery group. However, in the 2-jaw surgery group, the upper lip moved approximately 1.5 mm forward and both cheilions moved backward by 1.2 mm. The subnasale in the 1-jaw surgery group moved 0.3 mm posteriorly, whereas the alar base moved in a lateral and anterior

direction and the pronasale moved superiorly and anteriorly in the 2-jaw surgery group. Cheeks in the 2-jaw surgery patients moved more anteriorly by approximately 3 mm (Tables 4, 5).

We used the Spearman correlation coefficient to evaluate the correlation between surgical and cephalometric variables as well as soft tissue changes in each group. In the 2-jaw surgery group, the amount of mandibular setback on the right side was positively correlated to the right cheilion-alar base (*P* < .01) and the left side was negatively correlated to the right alar base (*P* < .05). Changes of the sella-nasion-A point were negatively correlated to lower lip, soft tissue B point (*P* < .01), and soft tissue pogonion (*P* < .05). Changes of gonial angles were positively correlated to right alar base (*P* < .05). The correlation between changes of the sella-nasion-B point and soft tissue pogonion was statistically significant (*P* < .05). In the 1-jaw surgery group, the amount of mandibular setback on the right side was positively correlated to both cheeks (*P* < .05), and on the left side, it was negatively correlated to the right Cupid's bow (*P* < .01). The amount of advancement genioplasty was positively correlated to the right cheilion-alar base (*P* < .05). Changes of gonial angle were negatively correlated to the left exocanthus-alar base (*P* < .05). The right cheilion was negatively correlated to

Table 4. COMPARISON OF SOFT TISSUE DISPLACEMENT BETWEEN 1-JAW AND 2-JAW SURGERY GROUPS IN MIDDLE THIRD OF FACE

	Mean (mm)		P Value	95% Confidence Interval (mm)	
	1-Jaw (n = 8)	2-Jaw (n = 17)		Minimum	Maximum
Rt.Cu	-0.40	1.55	.07	-3.90	0.01
Lt.Cu	-0.78	1.34	.02*	-3.94	-0.01
Rt.Ch	-1.47	-1.21	.86	-1.82	1.30
Lt.Ch	-2.11	-1.23	.15	-2.49	0.73
Rt.Ck	0.50	2.79	<.01 [†]	-3.40	-1.19
Lt.Ck	0.61	3.29	<.01 [†]	-3.67	-1.70
Rt.Exo-Al	0.99	1.71	.13	-1.75	0.30
Lt.Exo-Al	0.23	1.76	.03*	-2.75	-0.33
Rt.Ch-Al	0.63	2.41	<.01 [†]	-2.82	-0.74
Lt.Ch-Al	0.16	2.54	<.01 [†]	-3.55	-1.22
Pn	0.66	1.46	.06	-1.59	0.01
Rt.Al	-0.13	1.69	<.01 [†]	-2.32	-1.31
Lt.Al	-0.17	1.75	<.01 [†]	-2.50	-1.34
Sn	-0.30	0.70	<.01 [†]	-1.74	-0.27

NOTE. The Mann-Whitney *U* test was performed.

Abbreviations: Lt.Al, left alar base; Lt.Ch, left cheilion; Lt.Ch-Al, left cheilion-alar base; Lt.Ck, left cheek; Lt.Cu, left Cupid's bow; Lt.Exo-Al, left exocanthus-alar base; Pn, pronasale; Rt.Al, right alar base; Rt.Ch, right cheilion; Rt.Ch-Al, right cheilion-alar base; Rt.Ck, right cheek; Rt.Cu, right Cupid's bow; Rt.Exo-Al, right exocanthus-alar base; Sn, subnasale.

**P* < .05.

†*P* < .01.

Kim et al. *Soft Tissue Changes in Mandibular Prognathism. J Oral Maxillofac Surg* 2013.

changes of the sella-nasion-B point and changes of the mandibular plane angle (*P* < .05) (Tables 6, 7).

Discussion

Analysis of soft tissue changes in the 1- and 2-jaw surgery groups showed variable results depending on the specific parts of the face. The soft tissue changes in the lower third of the face were similar in both surgery groups, but the middle third of the face showed significant differences between the 2 groups (Tables 4, 5). The upper lip moved forward after 2-jaw surgery, whereas 1-jaw surgery resulted in a backward movement. The paranasal area (cheek, exocanthus-alar base, cheilion-alar base) moved anteriorly in the 2-jaw surgery group and was almost unchanged in patients who had undergone 1-jaw surgery. The mid-facial changes were concentrated in the center of the face around the nose, and the soft tissue changes decreased in the infraorbital area. There were no significant differences in chin-area changes between the 2 types of surgery.

The soft tissue measurements related to the lower jaws were not significantly different in the 1- and

2-jaw surgery groups (Table 5). Horizontally, mandibular setback surgery in both groups resulted in similar changes of the soft tissue B point and soft tissue pogonion, and the retraction of the lower lip also showed no significant difference between the 2 groups.

However, significant differences between the 1- and 2-jaw surgery groups were observed in the upper lip and landmarks related to the nose and cheek areas (Table 4). The upper lip moved backward in the 1-jaw surgery group by 0.40 mm (right Cupid's bow) to 2.11 mm (left cheilion). This result is consistent with previous reports that showed that the upper lip had retracted after isolated mandibular setback surgery.^{6,16,26,27} In mandibular prognathism patients, the upper and lower lips are influenced by the protruded mandibular incisors, and because the mandible was moved back by surgery, the maxillary incisors provided the main support for the upper lip, resulting in the retruded position for the upper lip.⁶

In contrast, the upper lip moved forward after 2-jaw surgery (Table 4). This finding is similar to that of Jensen et al,²⁸ who reported that the occlusal plane rotates when rotational surgery is performed in the maxilla, and additional support is obtained for the upper lip area. However, Altug-Atac et al²⁹ reported that maxillary advancement had no effect on the anteroposterior position of the upper lip in patients who received bimaxillary surgery.

After 1- and 2-jaw orthognathic surgeries, both cheilions moved backward, and there was no significant difference in changes observed between the 2 types of surgery (Table 4). Interestingly, the cheilions moved backward after 2-jaw surgery, despite the forward movement of the upper lip. A recent study reported backward movement of the cheilions after mandibular setback surgery only,⁶ but there have been no studies regarding cheilion changes after maxillary rotational surgery in Class III malocclusion pa-

Table 5. COMPARISON OF SOFT TISSUE DISPLACEMENT BETWEEN 1-JAW AND 2-JAW SURGERY GROUPS IN LOWER THIRD OF FACE

	Mean (mm)		P Value	95% Confidence Interval (mm)	
	1-Jaw (n = 8)	2-Jaw (n = 17)		Minimum	Maximum
LL	-3.55	-3.53	.86	-1.85	1.83
B'	-6.25	-7.26	.24	-1.11	3.13
Pog'	-4.97	-4.95	.98	-2.67	2.62

NOTE. The Mann-Whitney *U* test was performed.

Abbreviations: B', soft tissue B point; LL, lower lip; Pog', soft tissue pogonion.

Kim et al. *Soft Tissue Changes in Mandibular Prognathism. J Oral Maxillofac Surg* 2013.

Table 6. CORRELATION BETWEEN SURGICAL AND CEPHALOMETRIC VARIABLES AND SOFT TISSUE CHANGES IN 1-JAW SURGERY GROUP

	Mandibular Setback on Right Side		Mandibular Setback on Left Side		Genioplasty		Changes of Gonial Angle		Changes of SNB		Changes of Mandibular Plane Angle	
	Spearman Correlation	P Value	Spearman Correlation	P Value	Spearman Correlation	P Value	Spearman Correlation	P Value	Spearman Correlation	P Value	Spearman Correlation	P Value
Rt.Cu	-0.21	.74	-0.98 [†]	<.01	0.16	.80	0.50	.39	-0.20	.75	0.20	.75
Lt.Cu	-0.67	.22	-0.56	.32	0.32	.60	-0.10	.87	0.40	.50	-0.40	.50
Rt.Ch	-0.15	.80	-0.21	.74	0.63	.25	-0.10	.87	0.90*	.04	-0.90*	.04
Lt.Ch	-0.31	.61	-0.56	.32	0.63	.25	0.00	>.99	0.70	.19	-0.70	.19
LL	-0.67	.22	-0.56	.32	0.32	.60	-0.10	.87	0.40	.50	-0.40	.50
Rt.Ck	0.95*	.01	0.08	.90	0.08	.90	0.46	.43	-0.21	.74	0.21	.74
Lt.Ck	0.95*	.01	0.08	.90	0.08	.90	0.46	.43	-0.21	.74	0.21	.74
Rt.Exo-Al	-0.66	.23	0.26	.67	-0.16	.79	-0.31	.61	0.41	.49	-0.41	.49
Lt.Exo-Al	-0.56	.32	0.67	.22	0.00	>.99	-0.90*	.04	0.40	.50	-0.40	.50
Rt.Ch-Al	0.00	>.99	-0.29	.64	0.89*	.04	-0.46	.43	0.62	.27	-0.62	.27
Lt.Ch-Al	-0.16	.80	0.55	.33	0.41	.50	-0.67	.22	0.82	.09	-0.82	.09
Pog'	-0.21	.74	-0.67	.22	0.79	.11	-0.10	.87	0.60	.28	-0.60	.28
B'	-0.31	.61	-0.56	.32	0.63	.25	0.00	>.99	0.70	.19	-0.70	.19
Pn	0.54	.34	0.54	.34	0.56	.33	-0.35	.56	0.71	.18	-0.71	.18
Rt.Al	-0.54	.34	0.00	>.99	0.56	.33	-0.71	.18	0.71	.18	-0.71	.18
Lt.Al	-0.52	.37	0.46	.44	0.18	.78	-0.67	.22	0.67	.22	-0.67	.22
Sn	-0.52	.37	0.46	.44	0.18	.78	-0.67	.22	0.67	.22	-0.67	.22

Abbreviations: B', soft tissue B point; LL, lower lip; Lt.Al, left alar base; Lt.Ch, left cheilion; Lt.Ch-Al, left cheilion-alar base; Lt.Ck, left cheek; Lt.Cu, left Cupid's bow; Lt.Exo-Al, left exocanthus-alar base; Pn, pronasale; Pog', soft tissue pogonion; Rt.Al, right alar base; Rt.Ch, right cheilion; Rt.Ch-Al, right cheilion-alar base; Rt.Ck, right cheek; Rt.Cu, right Cupid's bow; Rt.Exo-Al, right exocanthus-alar base; Sn, subnasale; SNB, sella-nasion-B point.

* $P < .05$.

[†] $P < .01$.

Kim et al. *Soft Tissue Changes in Mandibular Prognathism. J Oral Maxillofac Surg* 2013.

tients. On the basis of our results, it can be assumed that the cheilions are mainly affected by the antero-posterior position of the mandible, whereas the central portion of the upper lip (Cupid's bow) is primarily influenced by the maxillary movement.

There was no significant difference in changes to the nasal tips between the 2 surgery groups (Table 4). Forward and upward movement occurred in both groups. Park et al³⁰ observed similar nasal tip changes after 2-jaw surgery resulting in superior and anterior movement of the maxilla and mandibular setback. Lim et al⁶ also reported forward movement of the nose tip after isolated mandibular setback by SSRO. Jung et al¹⁴ suggested that mandibular setback affects the nose and upper lip as the perioral musculature undergoes remodeling.

The cheek area moved forward in both the 1- and 2-jaw surgery groups, but the amount of change observed in the 2-jaw surgery group was significantly greater than that observed in the 1-jaw surgery group (Table 4). In their 3D soft-tissue studies, which used laser scanning, Baik and Kim² found that in patients who had maxillary advancement and posterior impaction, a forward movement of the paranasal area occurred. McCance et al³¹ also reported that performance

of maxillary advancement resulted in movement of the paranasal area in a forward direction at a 1.25:1 ratio. These results suggest that 2-jaw surgery with maxillary advancement or posterior impaction could be effective in augmenting the midfacial area.

Because midfacial convexity is increased by maxillary surgery, the alar base showed significant lateral movement in the 2-jaw surgery patients (Table 4). These results are consistent with those of Park et al,³⁰ who reported a widening of the alar base and the nostrils after bimaxillary surgery in mandibular prognathism patients with an alar cinch suture and a V-Y closure. Honrado et al³² stated that maxillary movement during treatment of skeletal Class II malocclusion, Class III malocclusion, open bite deformity significantly increased the inter-alar width regardless of the amount and direction of rotation of the maxilla. According to Altman and Oeltjen,³³ increases in the alar width are the result of the surgical approach to the maxilla rather than the relocation of the maxilla itself. Finally, 1-jaw surgery patients showed slight narrowing of the alar base area, but this amount was clinically insignificant.

Surgical outcome was more predictable in the lower third of the face. This was significantly corre-

Table 7. CORRELATION BETWEEN SURGICAL AND CEPHALOMETRIC VARIABLES AND SOFT TISSUE CHANGES IN 2-JAW SURGERY GROUP

	Mandibular Setback on Right Side		Mandibular Setback on Left Side		Changes of SNA		Changes of Gonial Angle		Changes of SNB	
	Spearman Correlation	P Value	Spearman Correlation	P Value	Spearman Correlation	P Value	Spearman Correlation	P Value	Spearman Correlation	P Value
Rt.Cu	0.45	.16	0.33	.32	-0.23	.50	-0.10	.77	0.23	.50
Lt.Cu	0.54	.09	0.38	.24	-0.18	.59	-0.12	.73	0.30	.37
Rt.Ch	0.44	.18	0.26	.49	-0.10	.77	-0.10	.77	0.05	.89
Lt.Ch	0.46	.16	0.49	.13	-0.02	.96	-0.33	.33	-0.02	.96
LL	0.03	.94	-0.10	.78	-0.85 [†]	<.01	0.06	.87	-0.06	.85
Rt.Ck	0.32	.33	0.21	.54	0.20	.56	0.10	.77	0.05	.89
Lt.Ck	0.44	.17	0.10	.98	0.01	.98	0.24	.48	0.20	.56
Rt.Exo-Al	0.36	.28	0.19	.58	0.18	.62	0.13	.70	0.17	.62
Lt.Exo-Al	0.01	.98	-0.24	.47	-0.23	.49	0.42	.21	0.08	.82
Rt.Ch-Al	0.08 [†]	<.01	0.39	.23	0.04	.92	-0.11	.74	0.31	.35
Lt.Ch-Al	0.38	.25	0.06	.99	-0.10	.78	0.30	.38	0.08	.82
Pog'	0.13	.70	-0.13	.70	-0.63*	.04	0.14	.69	0.65*	.03
B'	0.22	.53	-0.04	.92	-0.75 [†]	<.01	0.03	.94	0.34	.31
Pn	0.46	.15	0.45	.17	0.14	.68	-0.22	.51	0.01	.99
Rt.Al	-0.45	.16	-0.61*	<.05	0.22	.52	0.73*	.01	-0.25	.47
Lt.Al	-0.24	.47	-0.29	.39	0.34	.31	0.34	.31	0.09	.79
Sn	-0.33	.32	0.04	.90	-0.25	.47	0.06	.86	-0.31	.35

Abbreviations: B', soft tissue B point; LL, lower lip; Lt.Al, left alar base; Lt.Ch, left cheilion; Lt.Ch-Al, left cheilion-alar base; Lt.Ck, left cheek; Lt.Cu, left Cupid's bow; Lt.Exo-Al, left exocanthus-alar base; Pn, pronasale; Pog', soft tissue pogonion; Rt.Al, right alar base; Rt.Ch, right cheilion; Rt.Ch-Al, right cheilion-alar base; Rt.Ck, right cheek; Rt.Cu, right Cupid's bow; Rt.Exo-Al, right exocanthus-alar base; Sn, subnasale; SNA, sella-nasion-A point; SNB, sella-nasion-B point.

* $P < .05$.

[†] $P < .01$.

Kim et al. Soft Tissue Changes in Mandibular Prognathism. *J Oral Maxillofac Surg* 2013.

lated to the changes of the sella-nasion-A point, the gonial angle, and the amount of mandibular setback. Although significant differences between the 1- and 2-jaw surgery groups were observed in the midfacial area, it was difficult to find significant correlations in the soft tissue change patterns (Tables 6, 7). These results are consistent with those of Cho and Yang,³⁴ who reported that the ratio of the soft tissue displacement in the middle third of the face varied because the amount of soft tissue change is affected by soft tissue manipulation during maxillary surgery. Moreover, the soft tissues of the mandible and the underlying jaw were closely related to each other, but the soft tissue of the maxilla is strongly connected to the nasal cavity as well as the upper jaw.³⁴ In addition, Betts et al³⁵ stated that the soft tissue change is more affected by incisional location or suture type than the maxillary displacement from maxillary surgery. Mansour et al³⁶ reported that soft tissue was affected by postoperative swelling, formation of scar tissue, and position of the upper incisors resulting from a Le Fort I osteotomy. These results suggest that soft tissue changes related to the maxilla are more difficult to predict than those associated with the mandible. The aforementioned studies investigated the difficulties

of predicting the 2D soft tissue changes in the midfacial area. However, our study identified the correlation between surgical and cephalometric variables and soft tissue changes in each group 3-dimensionally (Tables 6, 7).

The overall soft tissue changes of the midfacial area were more evident in the 2-jaw surgery group than the 1-jaw surgery group, but the correlated patterns were more evident in the lower third of the face. The alar base showed significant lateral movement in the 2-jaw surgery patients. One-jaw surgery patients showed slight narrowing of the alar base area, but this amount was clinically insignificant.

The lower third of the face has changed in both surgery groups, but the changes were not significantly different. On the basis of the data from our study, we can conclude that there are significant differences in the changes observed in the middle third of the face between the 1- and 2-jaw surgery groups. In particular, the cheek area moved forward in both the 1- and 2-jaw surgery groups, but the amount of change observed in the 2-jaw surgery group was significantly greater.

A limitation of this study is the relatively small sample size because not all patients agreed to undergo postop-

erative CBCT. However, we evaluated the 3D changes of various soft tissue landmarks and compared the changes based on the type of orthognathic surgery. Long-term follow-up of these changes and increasing the sample size may be helpful in understanding the remodeling that occurs in the soft tissue.

Our null hypothesis (ie, soft tissue changes in the middle and lower third of the face do not differ between 1- and 2-jaw surgery patients) was rejected. In 2-jaw surgery, significant changes would be expected in the midfacial area, but because an increase in the inter-alar width is inevitable, caution should be exercised in patients who have a wide alar base. Collaboration between surgeons and orthodontists would be required at this point.

References

1. Soncul M, Bamber MA: Evaluation of facial soft tissue changes with optical surface scan after surgical correction of Class III deformities. *J Oral Maxillofac Surg* 62:1331, 2004
2. Baik HS, Kim SY: Facial soft-tissue changes in skeletal Class III orthognathic surgery patients analyzed with 3-dimensional laser scanning. *Am J Orthod Dentofacial Orthop* 138:167, 2010
3. Ackerman JL, Proffit WR, Sarver DM: The emerging soft tissue paradigm in orthodontic diagnosis and treatment planning. *Clin Orthod Res* 2:49, 1999
4. Proffit WR: The soft tissue paradigm in orthodontic diagnosis and treatment planning: A new view for a new century. *J Esthet Dent* 12:46, 2000
5. Ryckman MS, Harrison S, Oliver D, et al: Soft-tissue changes after maxillomandibular advancement surgery assessed with cone-beam computed tomography. *Am J Orthod Dentofacial Orthop* 137:S86, 2010
6. Lim YK, Chu EH, Lee DY, et al: Three-dimensional evaluation of soft tissue change gradients after mandibular setback surgery in skeletal Class III malocclusion. *Angle Orthod* 80:896, 2010
7. Sarver DM: *Esthetic Orthodontics and Orthognathic Surgery*. St Louis, MO, Mosby, 1998
8. Bailey LT, Proffit WR, White RP Jr: Trends in surgical treatment of Class III skeletal relationships. *Int J Adult Orthodon Orthognath Surg* 10:108, 1995
9. Hong JS, Park YH, Kim YJ, et al: Three-dimensional changes in pharyngeal airway in skeletal Class III patients undergoing orthognathic surgery. *J Oral Maxillofac Surg* 69:e401, 2011
10. Abdelrahman TE, Takahashi K, Tamura K, et al: Impact of different surgery modalities to correct Class III jaw deformities on the pharyngeal airway space. *J Craniofac Surg* 22:1598, 2011
11. Hong JS, Oh KM, Kim BR, et al: Three-dimensional analysis of pharyngeal airway volume in adults with anterior position of the mandible. *Am J Orthod Dentofacial Orthop* 140:e161, 2011
12. Bianchi A, Muyldermans L, Di Martino M, et al: Facial soft tissue esthetic predictions: Validation in craniomaxillofacial surgery with cone beam computed tomography data. *J Oral Maxillofac Surg* 68:1471, 2010
13. Kolokitha OE: Validity of a manual soft tissue profile prediction method following mandibular setback osteotomy. *Eur J Dent* 1:202, 2007
14. Jung YJ, Kim MJ, Baek SH: Hard and soft tissue changes after correction of mandibular prognathism and facial asymmetry by mandibular setback surgery: Three-dimensional analysis using computerized tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 107:763, 2009
15. Da Silveira HL, Silveira HE: Reproducibility of cephalometric measurements made by three radiology clinics. *Angle Orthod* 76:394, 2006
16. Sung SJ, Park HD, Kim JS, et al: Changes in soft tissue profile after surgical correction of prognathic mandible. *Korea J Orthod* 30:355, 2000
17. Marşan G, Cura N, Emekli U: Soft and hard tissue changes after bimaxillary surgery in Turkish female Class III patients. *J Craniomaxillofac Surg* 37:8, 2009
18. Fourie Z, Damstra J, Gerrits PO, et al: Accuracy and reliability of facial soft tissue depth measurements using cone beam computer tomography. *Forensic Sci Int* 199:9, 2010
19. Kim YJ, Hong JS, Hwang YI, et al: Three-dimensional analysis of pharyngeal airway in preadolescent children with different anteroposterior skeletal patterns. *Am J Orthod Dentofacial Orthop* 137:306.e1, 2010
20. Oh KM, Hong JS, Kim YJ, et al: Three-dimensional analysis of pharyngeal airway form in children with anteroposterior facial patterns. *Angle Orthod* 81:1075, 2011
21. Yang HJ, Lee WJ, Yi WJ, et al: Interferences between mandibular proximal and distal segments in orthognathic surgery for patients with asymmetric mandibular prognathism depending on different osteotomy techniques. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 110:18, 2010
22. Yushkevich PA, Piven J, Hazlett HC, et al: User-guided 3D active contour segmentation of anatomical structures: Significantly improved efficiency and reliability. *Neuroimage* 31:1116, 2006
23. Almeida RC, Cevidanes LH, Carvalho FA, et al: Soft tissue response to mandibular advancement using 3D CBCT scanning. *Int J Oral Maxillofac Surg* 40:353, 2011
24. Chapuis J, Schramm A, Pappas I, et al: A new system for computer-aided preoperative planning and intraoperative navigation during corrective jaw surgery. *IEEE Trans Inf Technol Biomed* 11:274, 2007
25. Dahlberg G: *Statistical Methods for Medical and Biological Students*. London, England, G. Allen & Unwin, 1940
26. Hershey HG, Smith LH: Soft-tissue profile change associated with surgical correction of the prognathic mandible. *Am J Orthod* 65:483, 1974
27. Suckiel JM, Kohn MW: Soft-tissue changes related to the surgical management of mandibular prognathism. *Am J Orthod* 73:676, 1978
28. Jensen AC, Sinclair PM, Wolford LM: Soft tissue changes associated with double jaw surgery. *Am J Orthod Dentofacial Orthop* 101:266, 1992
29. Altug-Atac AT, Bolatoglu H, Memikoglu UT: Facial soft tissue profile following bimaxillary orthognathic surgery. *Angle Orthod* 78:50, 2008
30. Park SB, Yoon JK, Kim YI, et al: The evaluation of the nasal morphologic changes after bimaxillary surgery in skeletal Class III malocclusion by using the superimposition of cone-beam computed tomography (CBCT) volumes. *J Craniomaxillofac Surg* in press, available online 2 July, 2011. doi:10.1016/j.jcms.2011.05.008
31. McCance AM, Moss JP, Fright WR, et al: A three dimensional analysis of soft and hard tissue changes following bimaxillary orthognathic surgery in skeletal III patients. *Br J Oral Maxillofac Surg* 30:305, 1992
32. Honrado CP, Lee S, Bloomquist DS, et al: Quantitative assessment of nasal changes after maxillomandibular surgery using a 3-dimensional digital imaging system. *Arch Facial Plast Surg* 8:26, 2006
33. Altman JI, Oeltjen JC: Nasal deformities associated with orthognathic surgery: Analysis, prevention, and correction. *J Craniofac Surg* 18:734, 2007
34. Cho EJ, Yang WS: Soft tissue changes after double jaw surgery in skeletal Class III malocclusion. *Korea J Orthod* 26:1, 1996
35. Betts NJ, Vig KW, Vig P, et al: Changes in the nasal and labial soft tissues after surgical repositioning of the maxilla. *Int J Adult Orthodon Orthognath Surg* 8:7, 1993
36. Mansour S, Burstone C, Legan H: An evaluation of soft-tissue changes resulting from Le Fort I maxillary surgery. *Am J Orthod* 84:37, 1983