Original Article

Three-dimensional evaluation of soft tissue change gradients after mandibular setback surgery in skeletal Class III malocclusion

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ABSTRACT

Objective: To evaluate whether mandibular setback surgery (MSS) for Class III patients would produce gradients of three-dimensional (3D) soft tissue changes in the vertical and transverse aspects.

Materials and Methods: The samples consisted of 26 Class III patients treated with MSS using bilateral sagittal split ramus osteotomy. Lateral cephalograms and 3D facial scan images were taken before and 6 months after MSS, and changes in landmarks and variables were measured using a Rapidform 2006. Paired and independent *t*-tests were performed for statistical analysis.

Results: Landmarks in the upper lip and mouth corner (cheilion, Ch) moved backward and downward (respectively, cupid bow point, 1.0 mm and 0.3 mm, $P < .001$ and $P < .01$; alar curvature-Ch midpoint, 0.6 mm and 0.3 mm, both $P < .001$; Ch, 3.4 mm and 0.8 mm, both $P < .001$). However, landmarks in stomion (Stm), lower lip, and chin moved backward (Stm, 1.6 mm; labrale inferius [Li], 6.9 mm; LLBP, 6.9 mm; B′, 6.7 mm; Pog′, 6.7 mm; Me′, 6.6 mm; $P < .001$, respectively). Width and height of upper and lower lip were not altered significantly except for a decrease of lower vermilion height (Stm-Li, 1.7 mm, $P < .001$). Chin height (B′-Me′) was decreased because of backward and upward movement of Me′ (3.1 mm, $P < .001$). Although upper lip projection angle and Stm-transverse projection angle became acute (Ch_{Rt}-Ls-Ch_{Lt}, 5.7°; Ch_{Rt}-Stm-Ch_{Lt}, 6.4°, both $P < .001$) because of the greater backward movement of Ch than Stm, lower lip projection angle and Stm-vertical projection angle became obtuse (Ch_{Rt}-Li-Ch_{Lt}, 10.8°; Ls-Stm-Li, 23.5°, both $P < .001$) because of the larger backward movement of Li than labrale superius (Ls).

Conclusions: Three-dimensional soft tissue changes in Class III patients after MSS exhibited increased gradients from upper lip and lower lip to chin as well as from Stm to Ch. (*Angle Orthod.* 2010;80:896–903.)

KEY WORDS: Three-dimensional evaluation; Facial scanning images; Class III malocclusion; Soft tissue change gradients; Mandibular setback surgery

INTRODUCTION

One important goal of orthodontic treatment and orthognathic surgery is the improvement of facial esthetics.[1,2] Conventional lateral cephalometric analysis can estimate soft tissue changes at the midsagittal area. However, patients usually evaluate their own soft tissue esthetics on the basis of how they look in a frontal view. Therefore, three-dimensional (3D) imaging methods, such as 3D computed tomography[3–6] and 3D facial scan images (3D-FSIs),[7–12] are used to analyze and evaluate the soft tissues of the entire face.

To predict soft tissue changes of the face more precisely after two-jaw surgery, alterations in the lower third of the face that are affected by mandibular surgery should be estimated first. Moreover, in skeletal Class III malocclusion patients, soft tissue changes

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Table 1. Comparison of the Cephalometric Measurements Before (T1) and Six Months After Mandibular Setback Surgery (T2)[a]

	T1		T2		
Cephalometric Measurements	Mean	SD	Mean	SD	*P*-value
SNA (°)	81.37	3.45	81.37	3.44	.6826
A-N Perpendicular (mm)	−0.28	3.48	−0.27	3.48	.5962
SNB (°)	83.26	3.72	79.05	3.23	.0000***
Pog-N Perpendicular (mm)	4.56	7.43	−3.48	5.38	.0000***
ANB (°)	−1.71	2.74	2.32	1.98	.0000***
Wits appraisal (mm)	−9.21	3.77	−2.29	2.64	.0000***
SN-GoGn (°)	34.57	6.24	36.87	6.45	.0223*
FMA (°)	26.17	5.99	28.48	5.75	.0220*
U1-SN (°)	102.63	6.21	103.23	5.54	.4090
IMPA (°)	89.60	7.29	85.25	5.93	.0101*
Interincisal angle (°)	133.20	9.53	134.65	7.80	.1699
Cant of the maxillary occlusal plane to FH plane (°)	10.33	4.57	6.39	5.58	.0428*

[a] Paired *t*-test was done. *$P < .05$; ***$P < .001$; U indicates the upper central incisor.

after mandibular setback surgery (MSS) have been reported not only in the lower lip and chin areas but also in the upper lip and paranasal areas.[6,12] However, changes in the lip and mouth corner are more difficult to predict than change in the chin. Also, few studies have investigated the 3D gradient changes in the lips and chin after MSS. In addition, although Soncul and Bamber[9] reported backward and downward movement of the lower lip and backward movement of B′ and Pog′ after MSS in a 3D-FSI study, they did not include the angulation change in the lips.

Therefore, the purpose of this study was to evaluate the 3D linear and angular changes of the lips and chin after MSS in skeletal Class III patients using 3D-FSI. The null hypothesis was that 3D soft tissue changes in Class III patients after MSS would not exhibit increased gradients from the upper lip and the lower lip to the chin and from the midline (Stm) to the lateral area (cheilion).

MATERIALS AND METHODS

The samples consisted of 26 Class III patients (eight males and 18 females, mean age = 25.0 ± 6.0 years, range = 18.5 to 33.2 years) without severe facial asymmetry (less than 3 mm of chin deviation from the facial midline at Pog′). They had undergone MSS with bilateral sagittal split ramus osteotomy (mean amount of setback at point B = 8.0 ± 4.1 mm) by a single surgeon (Table 1). Approval for this study was granted by the Institutional Review Board of the Seoul University Medical Center (IRB No. GR0791).

Lateral cephalograms were taken immediately both before (T1) and 6 months after MSS (T2) with centric occlusion, reposed lip, and natural head position.[13] Cephalometric tracing and measurements were performed by a single operator using the V-Ceph program (Osstem, Seoul, Korea).

The 3D-FSIs were taken at T1 and T2 from three different horizontal angles (the front side and the right and left sides at an angle of 45°) and from two different vertical angles (the upper and lower sides at an angle of 30° in the midline) to scan the entire face without shadows. Patients sat wearing a hair band, with centric occlusion, reposed lips, and natural head position.[13] OptoTOP-SE (Breuckmann, Meersburg, Germany; white-light scanner; 30–40 μm accuracy according to the manufacturer, scanning time <3 seconds) was used by a single operator. The 3D-FSIs were reconstructed using Rapidform 2006 and Rapidform XO scanning software (Inus Technology Inc, Seoul, Korea).

A period lasting 6 months after MSS was chosen as the T2 stage because adequate stabilization of the facial soft tissue is expected to occur during this period, and any subsequent changes should be small enough to be neglibile.[14]

Landmarks for the superimposition of T1 and T2 images and the reference axes[6,9,11,15,16] are defined in Figures 1 and 2, respectively. The extent and direction of changes in the landmarks and variables during T1–T2 stages (Figures 3 and 4) were measured by a single operator using Rapidform 2006 software (Inus Co, Seoul, Korea).

Four weeks after the first digitization of the landmarks, 30 3D-FSIs were selected randomly and the landmarks were redigitized by a single operator. Because paired *t*-tests showed that there were no significant differences in the values between the first and second sets of the x, y, and z coordinates (Table 2), the first set of measurements was used in this study. Because there was no statistical significant

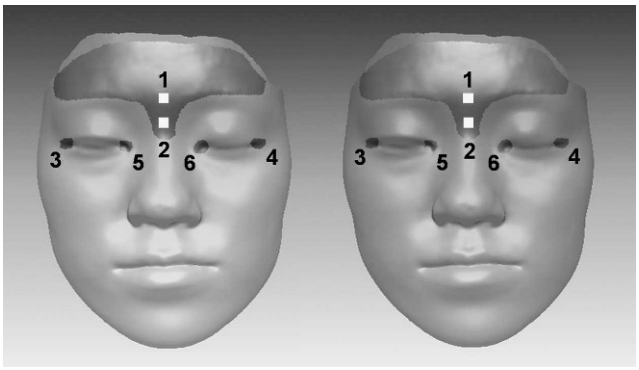

Figure 1. References used to superimpose T1 (yellow) and T2 (green): Forehead area (1, glabella, the most prominent midline point between the eyebrows), nasion area (2, soft tissue nasion, the corresponding soft tissue point of the frontonasal suture), exocanthion (3/4, The point at the outer commissure of the eye fissure), and endocanthion (5/6, the point at the inner commissure of the eye fissure).

difference in the soft tissue changes between males and females, the samples were mixed for statistical analyses. Paired *t*-tests and independent *t*-tests were performed for statistical analysis.

RESULTS

Changes of the X, Y, and Z Coordinates of Landmarks After MSS (Table 3)

Landmarks of the nose, mouth, and lips did not show any significant changes in position in the X-axis (transverse direction). However, in the Y- axis (vertical direction) and Z-axis (anteroposterior direction), there were significant changes in the positions of the landmarks with different patterns. For example, alar curvature point (Ac) in the nose moved forward (0.7 mm, $P < .05$) and labrale superius (Ls) in the upper lip moved backward (1.4 mm, $P < .001$). Most of the landmarks of the upper lip and mouth corner moved backward and downward (alar curvature-cheilion midpoint [ACMP], 0.6 mm and 0.3 mm, both $P < .001$; cupid bow point [CBP], 1.0 mm and 0.3 mm,

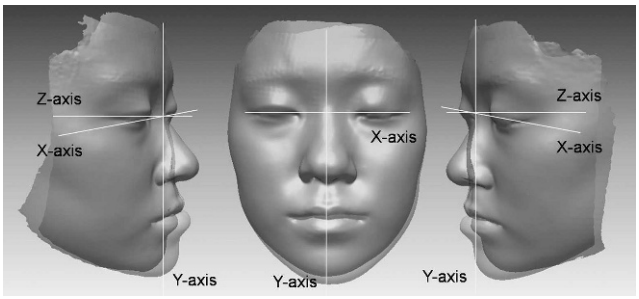

Figure 2. Reference axes established on the original point (nasion): A midsagittal line (Y coordinate: vertical axis), a parallel line to the floor (Z coordinate: anteroposterior axis), and a parallel line to a line connecting both exocanthions (X coordinate: transverse axis).

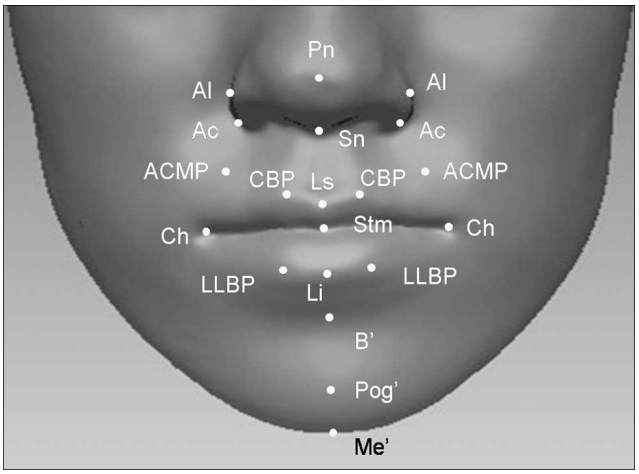

Figure 3. Soft tissue landmarks. Nose-related: pronasale (Pn, the most protruded point of the soft tissue nose); subnasale (Sn, the midpoint of the angle at the columella base where the lower border of the nasal septum and the surface of the upper lip meet); nasal ala (Al, the most lateral point on each alar contour); alar curvature point (Ac, the most lateral point in the curved base line of each ala, indicating the facial insertion of the nasal wingbase). Upper lip-related: labrale superius (Ls, the midpoint of the upper vermilion line); cupid bow point (CBP, the most elevated point of the philtrum on the upper vermilion border line); alar curvature-cheillion midpoint (ACMP, the midpoint between ala curvature and cheilion). Lower lip-related: Labrale inferius (Li, the midpoint of the lower vermilion line); lower lip bow point (LLBP, the breakpoint on the lower vermilion border line). Stomion-related: stomion (Stm, the point at the midline of labial fissure between gently closed lips); cheilion (Ch, the point located at each labial commissure). Chin-related: soft tissue B point (B′, the deepest point on the facial midline, between the lower lip and chin); soft tissue pogonion (Pog′, the most anterior midpoint of the chin); soft tissue menton (Me′, the lowest median landmark on the lower border of the mandible).

$P < .001$ and $P < .01$; cheilion [Ch], 3.4 mm and 0.8 mm, both $P < .001$). However, landmarks of the lower lips and Stm moved backward only (labrale inferius [Li], 6.9 mm; Stm, 1.6 mm; respectively, $P < .001$). In the chin, B′, Pog′, and Me′ moved backward (6.6 mm, 6.7 mm, 6.6 mm, respectively, $P < .001$) and upward (Me′, 3.1 mm, $P < .001$).

Changes in the Width of the Nose and Lips After MSS

Although the nasal width decreased, there was no significant difference observed. In addition, the widths of the mouth and lips did not exhibit any significant change (Table 4).

Changes in the Height of the Lips and Chin After MSS

Although lower vermilion height was decreased (Stm-Li, 1.7 mm, $P < .001$), upper lip height, upper vermilion height, and total vermilion height (Sn-Ls, Ls-Stms, and Ls-Li) did not change significantly (Table 5).

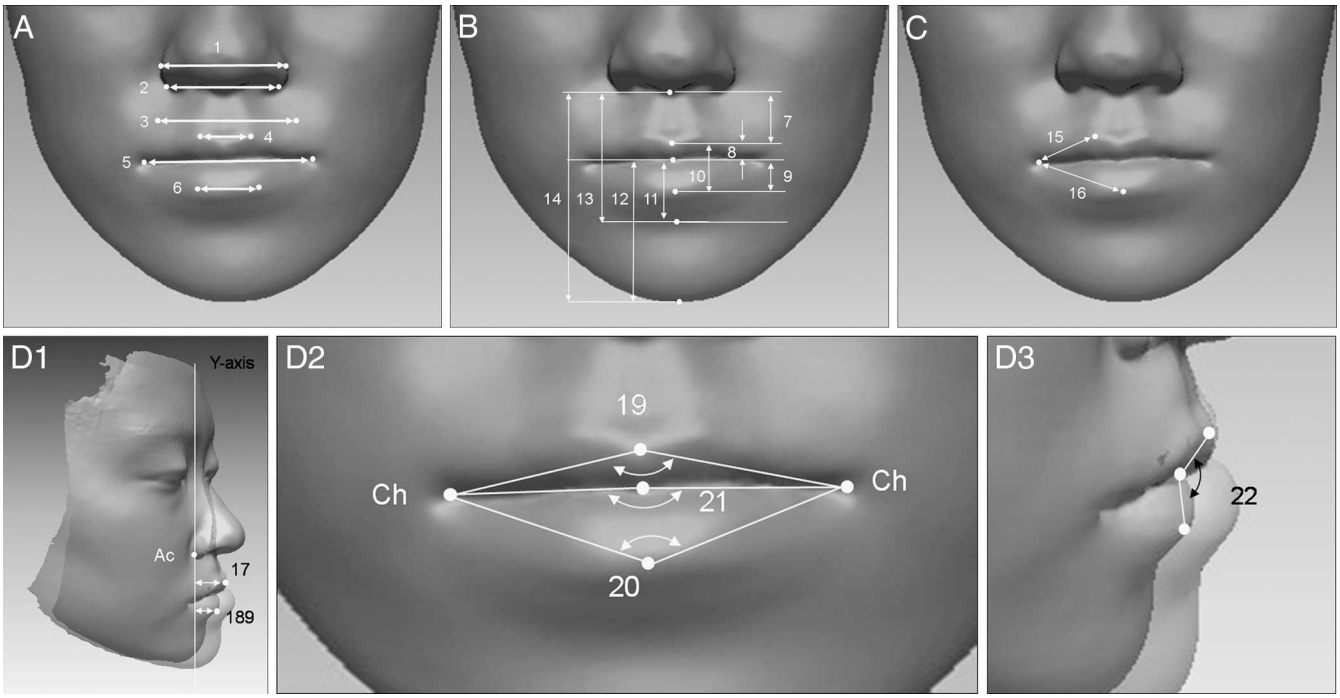

Figure 4. Variables. (A) Width of the nose and lips: 1. Al_{Rt}-Al_{Lt} (mm), 2. Ac_{Rt}-Ac_{Lt} (mm), 3. $ACMP_{Rt}$-$ACMP_{Lt}$ (mm), 4. CBP_{Rt}-CBP_{Lt} (mm), 5. Ch_{Rt}-Ch_{Lt} (mm), 6. $LLBP_{Rt}$-$LLBP_{Lt}$ (mm). (B) Height of the lips and chin: 7. Sn-Ls (mm), 8. Ls-Stm (mm), 9. Stm-Li (mm), 10. Ls-Li (mm), 11. Stm-B′ (mm), 12. Stm-Me′ (mm), 13. Sn-B′ (mm), 14. Sn-Me′ (mm). (C) Vermilion border length: 15. Ch-CBP (mm), 16. Ch-Li (mm). (D) Lip projection: 17. Ls-Ac perp (mm), 18. Li-Ac perp (mm), 19. Ch_{Rt}–Ls-Ch_{Lt} (°); 20. Ch_{Rt}–Li-Ch_{Lt} (°), 21. Ch_{Rt}–Stm-Ch_{Lt} (°), 22. Ls–Stm–Li (°).

For the height of the chin and lower anterior face, there were significant decreases in Stm-Me′ (3.8 mm, $P < .001$) and Sn-Me′ (3.4 mm, $P < .001$). Therefore, the lower part of the chin decreased (symphysis height, B′-Me′) and not the lower lip height (Sn-B′ and Stm-B′, $P > .05$).

Changes in the Vermilion Border Length After MSS (Table 6)

Changes in the vermilion border length after MSS are shown in Table 6. Upper vermilion border length increased (Ch-CBP, 1.1 mm, $P < .05$) because of the backward and downward movement of Ch (3.4 mm,

Table 2. Results of Reliability Test for Landmark Digitization[a]

		ΔX (mm)			ΔY (mm)			ΔZ (mm)		
Difference between T1 and T2		Mean	SD	*P*-value	Mean	SD	*P*-value	Mean	SD	*P*-value
Nose-related	Pn	0.10	0.19	.0048	0.00	0.21	.8988	0.03	0.12	.2620
	Sn	0.03	0.24	.4717	−0.02	0.17	.5119	−0.01	0.27	.8720
	Al	0.01	0.09	.1867	0.00	0.20	.8508	0.04	0.18	.0804
	Ac	0.01	0.10	.4154	**0.07**	0.21	.0084**	0.04	0.27	.2292
Upper lip-related	Ls	0.05	0.18	.1228	0.02	0.16	.5570	−0.00	0.04	.8495
	CBP	0.04	0.20	.1761	0.01	0.21	.6253	−0.01	0.13	.6559
	ACMP	**0.10**	0.36	.0357*	−0.01	0.26	.7976	0.05	0.20	.0502
Lower lip-related	Li	0.04	0.19	.2810	**0.07**	0.18	.0433*	**0.10**	0.23	.0321*
	LLBP	0.01	0.20	.6995	0.00	0.22	.9406	0.04	0.18	.0733
Stomion-related	Stm	0.02	0.18	.5924	0.06	0.28	.2249	0.13	0.73	.3280
	Ch	0.01	0.26	.7696	**0.11**	0.28	.0037**	**0.12**	0.44	.0311*
Chin-related	B′	0.06	0.18	.0689	**0.12**	0.28	.0316*	0.04	0.11	.0788
	Pog′	0.03	0.27	.4952	0.05	0.24	.2538	0.02	0.08	.2644
	Me′	0.02	0.34	.7407	−**0.09**	0.25	.0436*	0.05	0.19	.1918

[a] Paired *t*-test was done. *$P < .05$; **$P < .01$; X axis: (+) lateral, (−) medial; Y axis: (+) superior, (−) inferior; Z axis: (+) anterior, (−) posterior; Pn indicates pronasale; Sn, subnasale; Al, nasal ala; Ac, alar curvature point; Ls, labrale superius; CBP, cupid bow point; ACMP, alar curvature-cheillion midpoint; Li, labrale inferius; LLBP, lower lip bow point; Stm, stomion; Ch, cheilion; B′, soft tissue B point; Pog′, soft tissue pogonion; Me′, soft tissue menton.

Table 3. Change of the X, Y, and Z Coordinates of Landmark (mm) After Mandibular Setback Surgery[a]

Landmarks		ΔX (T2-T1)			ΔY (T2-T1)			ΔZ (T2-T1)		
		Mean	SD	*P*-value	Mean	SD	*P*-value	Mean	SD	*P*-value
Nose-related	Pn	−0.10	0.41	.206	−0.16	1.09	.459	−0.27	0.52	.015*
	Sn	−0.08	0.39	.317	−0.28	0.86	.107	0.22	0.95	.238
	Al	−1.51	7.5	.151	−0.1	0.72	.321	−0.28	1.82	.272
	Ac	1.5	10.39	.308	0.06	0.68	.514	0.69	1.9	.014*
Upper lip-related	Ls	−0.07	0.54	.540	−0.39	0.66	.006**	−1.35	0.91	.000***
	CBP	−0.01	0.69	.949	−0.31	0.54	.000***	−1.05	0.83	.000***
	ACMP	−0.09	0.65	.313	−0.28	−0.66	.003**	−0.6	0.93	.000***
Lower lip-related	Li	0.01	0.38	.859	0.05	1.69	.877	−6.85	3.85	.000***
	LLBP	−0.14	0.49	.169	−0.37	1.54	.229	−6.94	3.81	.000***
Stomion-related	Stm	−0.05	0.51	.603	−0.67	1.55	.038*	−1.56	1.86	.000***
	Ch	0.05	9.16	.969	−0.81	1.33	.000***	−3.39	2.59	.000***
Chin-related	B′	−0.17	0.43	.059	1.13	1.92	.006**	−6.69	4.01	.000***
	Pog′	−0.12	0.51	.245	1.33	2.89	.027*	−6.67	4.91	.000***
	Me′	0.02	0.57	.888	3.11	3.54	.000***	−6.64	6.15	.000***

[a] Independent *t*-test was done. *$P < .05$; **$P < .01$; ***$P < .001$. SD indicates standard deviation.

Table 4. Changes in Width of the Nose and Lips After Mandibular Setback Surgery[a]

Variables		T1		T2			ΔT2-T1	
		Mean	SD	Mean	SD	Sig	Mean	SD
Nose-related	Al_{Rt}-Al_{Lt} (mm)	38.38	3.38	35.98	8.75	0.122	−2.40	7.64
	Ac_{Rt}-Ac_{Lt} (mm)	39.16	2.94	37.07	9.09	0.231	−2.10	8.72
Upper lip-related	$ACMP_{Rt}$-$ACMP_{Lt}$ (mm)	44.06	3.10	44.07	3.27	0.941	0.02	1.11
	CBP_{Rt}-CBP_{Lt} (mm)	13.77	1.88	13.68	1.86	0.223	−0.09	0.35
Mouth corner-related	Ch_{Rt}-Ch_{Lt} (mm)	50.49	4.59	50.84	4.89	0.124	0.34	1.10
Lower lip-related	$LLBP_{Rt}$-$LLBP_{Lt}$ (mm)	21.40	2.27	21.54	2.12	0.656	0.14	1.55

[a] Independent *t*-test was done. SD indicates standard deviation; Al, nasal ala; Ac, alar curvature point; ACMP, alar curvature-cheilion midpoint; CBP, cupid bow point; Ch, cheilion; LLBP, lower lip bow point; Rt, right; Lt, left.

Table 5. Changes in Height of the Lips and Shin after Mandibular Setback Surgery[a]

Variables		T1		T2			ΔT2-T1	
		Mean	SD	Mean	SD	*P*-value	Mean	SD
Lip height	Sn-Ls (mm)	16.66	1.92	16.54	1.91	.4120	−0.12	0.73
	Ls-Stm (mm)	7.79	1.46	8.15	1.55	.295	0.36	1.73
	Stm-Li (mm)	12.73	2.29	11.08	1.52	.001**	−1.65	2.16
	Ls-Li (mm)	18.80	2.64	18.68	2.33	.707	−0.12	1.59
Chin height	Stm-B′ (mm)	21.83	2.61	20.03	2.36	.123	−1.80	2.33
	Stm-Me′ (mm)	49.40	4.51	45.62	3.86	.000***	−3.78	4.28
Lower anterior facial height	Sn-B′ (mm)	44.92	7.25	43.50	3.67	.103	−1.41	1.76
	Sn-Me′ (mm)	72.49	5.56	69.09	4.82	.000***	−3.39	3.63

[a] Independent *t*-test was done. **$P < .01$; ***$P < .001$. Linear measurements of chin height and lower facial height were done in relation to the Y axis (vertical direction). SD indicates standard deviation; Sn, subnasale; Ls, labrale superius; Stm, stomion; Li, labrale inferius; B′, soft tissue B point; Me′, soft tissue menton.

Table 6. Changes in the Vermilion Border Length After Mandibular Setback Surgery[a]

Variables		T1		T2			ΔT2-T1	
		Mean	SD	Mean	SD	*P*-value	Mean	SD
Upper vermilion-related	Ch-CBP (mm)	24.74	2.95	25.86	2.76	.036*	1.12	2.58
Lower vermilion-related	Ch-Li (mm)	31.26	3.02	29.59	2.77	.000***	−1.67	2.23

[a] Independent *t*-test was done. *$P < .05$; ***$P < .001$. SD indicates standard deviation; Ch, cheilion; CBP, cupid bow point; Li, labrale inferius.

Table 7. Changes in the Lip Projection After Mandibular Setback Surgery[a]

Projection of the Lips		T1		T2			ΔT2-T1	
		Mean	SD	Mean	SD	Sig	Mean	SD
Upper lip-related	Ls-Ac (mm)	15.50	2.97	13.49	3.59	0.000***	−2.01	1.78
	Ch_{Rt}–Ls-Ch_{Lt} (°)	115.41	5.04	109.74	4.56	0.000***	−5.68	5.88
Lower lip-related	Li-Ac (mm)	17.40	5.15	9.80	4.07	0.000***	−7.60	4.16
	Ch_{Rt}–Li-Ch_{Lt} (°)	110.54	6.28	121.36	5.67	0.000***	10.82	6.38
Stomion-related	Ch_{Rt}–Stm-Ch_{Lt} (°)	136.04	5.99	129.61	6.06	0.000***	−6.43	5.22
	Ls–Stm–Li (°)	131.77	8.5	155.30	14.13	0.000***	23.53	14.86

[a] Independent *t*-test was done. ***$P < .001$. Linear measurements of the lip projection were done in relation with the Z axis (anteroposterior direction). SD indicates standard deviation; Ls, labrale superius; Ac, alar curvature point; Ch, cheilion; Stm, stomion; Li, labrale inferius; Rt, right; Lt, left.

0.8 mm, respectively, $P < .001$, Table 3). However, lower vermilion border length decreased (Ch-Li, 1.7 mm, $P < .001$) because of the greater backward movement of Li than Ch (6.9 mm vs 3.4 mm, Table 3).

Changes in the Lip Projection After MSS

Changes in lip projection after MSS are shown in Table 7. Upper lip projection length and angle both decreased (Ls-Ac, 2.0 mm, Ch_{Rt}-Ls-Ch_{Lt}, 5.7°, both $P < .001$) because of the greater backward movement of Ch than Ls (3.4 mm vs 1.4 mm, Table 3). Although lower lip projection length decreased (Li-Ac, 7.6 mm), lower lip projection angle became obtuse (Ch_{Rt}-Li-Ch_{Lt}, 10.8°, both $P < .001$) because of the greater backward movement of Li than Ch (6.9 mm vs 3.4 mm, Table 3).

Although upper lip projection angle and Stm-transverse projection angle became acute (Ch_{Rt}-Ls-Ch_{Lt}, 5.7°; Ch_{Rt}-Stm-Ch_{Lt}, 6.4°, both $P < .001$) because of the increased backward movement of Ch relative to Stm, lower lip projection angle and Stm-vertical projection angle (Ch_{Rt}-Li-Ch_{Lt}, 10.8°; Ls-Stm-Li, 23.5°, both $P < .001$) both became obtuse because of the increased backward movement of Li and Stm relative to Ls (6.9 mm and 1.6 mm vs 1.4 mm, Table 3).

DISCUSSION

Changes of the X, Y, and Z Coordinate of Landmarks After MSS

The finding that MSS did not produce significant changes in landmark positions in the transverse direction (Table 3) seems to be due to the selection criteria for the samples, which included less than 3 mm of chin deviation from the facial midline at Pog′.

Although the mean amount of setback at point B in the samples was 8.0 mm, the upper lip (Ls) and Stm moved backward by 17.5%–20% (1.4 mm and 1.6 mm), the mouth corner (Ch) by 42.5% (3.4 mm), the lower lip (Li) by 86.2% (6.9 mm), and the soft tissue chin (B′ and Pog′) by 82.5%–83.4% (6.6 mm and 6.7 mm) with an increasing gradient pattern (Table 3). Therefore, soft tissue changes after MSS were more greatly expressed in the lower lip and chin than in the upper lip and mouth corner. These results were in accordance with the results of two-dimensional cephalometric studies[17–19] and 3D computed tomography studies.[6,20,21] In addition, the lips and mouth corners moved backward after MSS with an increasing gradient from the midline to the lateral area (Table 3). McCance et al.[3] reported similar results with greater changes in the lateral areas than in the midline of the chin and mentalis regions after MSS. These findings suggest that the upper lip (Ls), Stm, and mouth corner are under the influence of muscle and soft tissue as well as positional change of the mandible in patients with MSS.

The movement patterns of landmarks differed for the upper lip/mouth corner and the lower lip/Stm. Because of the backward movement of the lower lip and Stm (Li, 6.9 mm; Stm, 1.6 mm; $P < .001$; Table 3), the upper lip and mouth corner moved backward and downward (ACMP, 0.6 mm and 0.3 mm, both $P < .001$; CBP, 1.0 mm and 0.3 mm, $P < .001$ and $P < .01$; Ch, 3.4 mm and 0.8 mm, both $P < .001$, Table 3). These results suggest that because the maxillary hard tissues were not changed in 3D coordinates by MSS, soft tissue change in the upper lip most likely occurred because of the postoperative orthodontic treatment, continuity of the orbicularis oris muscle and soft tissue tension.[6]

Changes in the Width of the Nose and Lips After MSS

Although nasal width slightly decreased (Al_{Rt}-Al_{Lt} and Ac_{Rt}-Ac_{Lt}, $P > .05$, Table 4), Ac in the nose moved forward (0.7 mm, $P < .05$, Table 3) in spite of no actual maxillary advancement, which is similar to results reported by Jung et al.[6] These findings suggest that MSS can alter the nose indirectly through the continuity of the orbicularis oris muscle and soft tissue tension.

The fact that the widths of the lips and mouth corners did not significantly change after MSS implies that muscle tonicity might not be changed within a short period of time.[6]

Changes in the Heights of the Lips and Chin

Heights of the upper lip, upper vermilion, and total vermilion did not change significantly (Sn-Ls, Ls-Stms, and Ls-Li, respectively; $P > .05$; Table 5). These results are in accordance with Jung et al.,[6] who reported that the lip heights were not significantly changed after MSS. The position of the lower lip in Class III patients before surgery was affected by the position of the lower incisors. However, after MSS, the position of the lower lip would be influenced by the position of the upper incisors. In addition, lower lip tension could be reduced after MSS and eventually resulted in decrease of the lower lip height and lower vermilion height (Stm-Li, 1.7 mm, $P < .001$, Table 5), which is consistent with Gjørup and Athanasiou.[18]

Significant decreases in Stm-Me′ (3.8 mm, $P < .001$, Table 5) and Sn-Me′ (3.4 mm, $P < .001$, Table 5), not lower lip height (Sn-B′ and Stm-B′, $P > .05$, Table 5), seems to be attributable to MSS along with the maxillary occlusal plane, resulting in backward and upward movement of the chin.[20,22] Therefore, MSS and/or vertical reduction genioplasty can potentially reduce the chin height rather than the lower lip height.

However, the vertical change of the soft tissue after surgery is still difficult to predict. Robinson et al.[17] and Jung et al.[6] reported that changes in the soft tissue did not closely follow those in the hard tissue in the vertical plane compared with the anteroposterior and transverse planes.

Changes in the Vermilion Border Length After MSS

Opposing changes of upper and lower vermilion border length (Ch-CBP, 1.1 mm increase, $P < .05$; Ch-Li, 1.7 mm decrease, $P < .001$, Table 6) seem to be attributable to different amounts of backward movement between CBP, Ch, and Li (1.1 mm, 3.4 mm, and 6.9 mm, respectively; Table 3). In addition, after MSS, there is a possibility of decrease in lower lip tension, which would allow for replacement of the upper lip over the lower lip and eventual opposing change in the vermilion border length.

Changes in the Lip Projection After MSS

Similar to changes in vermilion length, opposing changes of upper lip projection angle, Stm-transverse projection angle and lower lip projection angle (Ch_{Rt}-Ls-Ch_{Lt}, 5.7° decrease; Ch_{Rt}-Stm-Ch_{Lt}, 6.4° decrease vs Ch_{Rt}-Li-Ch_{Lt}, 10.8° increase, respectively; $P < .001$; Table 7) appeared to result from different amounts and movement patterns between Ls, Stm, Ch, and Li (1.3 mm backward movement, 1.6 mm backward movement, 3.4 mm backward and 0.8 mm downward movements, and 6.9 mm backward movement, respectively; Table 3). These results are in accordance with Jung et al.[6] Before MSS, soft tissue stretching of the chin in the prognathic mandible can pull the upper and lower lips downward. When normal lip posture is achieved after MSS, normal convexity of the upper and lower lips can be restored. In other words, after MSS, the upper lip becomes acute and the lower lip becomes obtuse in the horizontal plane, which normalizes the lip posture and establishes a better environment for appropriate lip sealing. Compared with the amounts of backward movement of Ls, Stm, and Li and Ch (1.3 mm, 1.6 mm, and 6.9 mm, vs 3.4 mm, Table 3), 3D soft tissue changes in Class III patients after MSS occurred more in the mouth corner (Ch) than in the midline of lips (Ls, Stm, and Li) with an increasing gradient.

Because there was more backward movement of Li than Ls (6.9 mm vs 1.4 mm, Table 3), Stm-vertical projection angle (Ls-Stm-Li, 23.5°, $P < .001$, Table 7) became obtuse. The positions of upper and lower lips were affected by the position of lower incisors in Class III patients before MSS. However, after MSS, the upper and lower lips were under influence of the upper incisors. Therefore, there was a significant increase in Stm-vertical PA.

CONCLUSION

- The null hypothesis was rejected.
- The 3D soft tissue changes in Class III patients after MSS did exhibit increased gradients from the upper lip and the lower lip to the chin and from the midline (Stm) to the lateral area (Ch).

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