

Changes in soft tissue structures around the lips associated with sagittal split ramus osteotomy in skeletal Class III female patients ——Differences in mandibular plane angle——

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We analyzed the craniofacial morphology in 25 skeletal Class III female patients with sagittal split ramus osteotomy (1) before the initial orthodontic treatment, (2) after the initial orthodontic treatment and before the operation, and (3) after completion of all treatment. We examined the relationship of hard and soft tissue changes with differences in mandibular plane angle. In particular, we focused on lip soft tissue changes. We classified the patients based on FMA of 30 degrees or less (L group) and of 34 degrees or more (H group). Arnett analysis showed a significant change in upper lip thickness, lower lip thickness, and upper lip height between the two groups. The mandibular plane affected the contact relationship between the upper and lower lips, and the muscles around the lips, resulting in changes in the lip soft tissues. In planning surgical orthodontic treatment, we should take into consideration how the soft tissues will change depending on the mandibular plane angle. (*J Osaka Dent Univ* 2018 ; **52 : 107-122)**

Key words : Lip soft tissue changes ; Surgical orthodontic treatment ; Sagittal split ramus osteotomy ; Mandibular plane angle

INTRODUCTION

Surgical orthodontic treatment emphasizes not only the improvement of morphological and functional problems resulting from problems with mastication and articulation, but also the achievement of an aesthetic facial appearance. Predicting pre-treatment to post-treatment changes in the soft tissue profile as accurately as possible based on an understanding of the association between changes in the hard and soft tissues provides information that is essential for devising a suitable therapeutic strategy and selecting a surgical method. This information is also useful in explanations to patients, informed consent, and patient satisfaction.

There have been many studies on the association between changes in hard and soft tissues following surgical orthodontic treatment for skeletal Class III cases.¹⁻⁶ There has also been a comparison of soft tissue changes in two-jaw surgery ver-

sus sagittal split ramus osteotomy (SSRO) alone,¹ as well as a comparison of soft tissue changes in orthodontic treatment alone versus surgical orthodontic treatment.² However, these studies calculated distances from coordinate axes and reference lines based on fixed points on the soft tissue. There have been no studies on changes in the soft tissue thickness of the upper and lower lips. Also, while there are studies that have used materials from before the initial orthodontic treatment and after completion of all treatment,^{2, 7-9} as well as studies using materials from before and after the operation,^{1, 3-5} no study has compared values before the initial orthodontic treatment, after the initial orthodontic treatment and before the operation, and after completion of all treatment. In addition, there have been no comparisons of soft tissue changes based on differences in mandibular plane angle.

Therefore, in the present study, we analyzed maxillofacial morphology before the initial orthodon-

tic treatment, after the initial orthodontic treatment and before the operation, and after completion of all treatment in female skeletal Class III patients who had undergone SSRO as surgical orthodontic treatment. In addition, we examined soft tissue changes, particularly changes in lip thickness, based on differences in mandibular plane angle. We adopted the Steiner¹⁰ and Tweed¹¹ analyses for the hard tissues, while using the Ricketts^{12,13} and Arnett¹⁴ analyses for the soft tissues.

MATERIALS AND METHODS

Subjects

The subjects were 25 women who were diagnosed with skeletal Class III and underwent SSRO alone as surgical orthodontic treatment at Osaka Dental University Hospital. These 25 women consisted of 15 with a mandibular plane angle (Frankfort mandibular plane angle; hereafter FMA) less than or equal to 30° (hereafter the L group) and 10 women with an FMA greater than or equal to 34° (hereafter the H group). Based on analysis of frontal cephalograms, patients with prominent facial asymmetry (defined as a chin deviation greater than or equal to 10 mm relative to the facial midline according to Ricketts analysis) were excluded, as were patients who also underwent genioplasty. The patients had been diagnosed with skeletal Class III based on Angle Class III malocclusion and, before treatment, had an overjet less than or equal to 0 mm, demonstrated maxillary and mandibular crowding of at least -7 mm, and had their maxillary premolars extracted. Before initial orthodontic treatment, the mean ages of the L and the H groups were 24 years 8 months (between 16 years 4 months and 36 years 1 month) and 20 years 9 months (between 18 years 3 months and 30 years 1 month), respectively. The mean durations of treatment in the L and the H groups were 3 years 6 months, and 4 years 4 months, respectively.

Cephalometric analysis

The materials consisted of lateral cephalograms taken before the initial orthodontic treatment, after the initial orthodontic treatment and before the op-

eration, and after completion of all treatment (hereafter T1, T2 and T3, respectively). All lateral cephalograms were traced by a single orthodontist who does cephalometric analysis daily. Hard tissue was analyzed with Steiner¹⁰ and Tweed¹¹ analyses, while soft tissue was analyzed with Ricketts analysis E-line^{12,13} and Arnett's soft tissue cephalometric analysis (STCA).¹⁴ The following items were calculated.

Steiner¹⁰ and Tweed¹¹ analyses (Fig. 1)

SNA angle: Angle formed by the SN line and the NA line

SNB angle: Angle formed by the SN line and the NB line

ANB angle: Angle formed by the NA line and the NB line

U1 to NA (mm): Shortest distance from the edge of the maxillary central incisor to the NA line

∠U1 to NA (°): Angle formed by the NA line and the axis of the maxillary central incisor

L1 to NB (mm): Shortest distance from the edge of the mandibular central incisor to the NB line

∠L1 to NB (°): Angle formed by the NB line and the axis of the mandibular central incisor

Interincisal angle: Angle formed by the axis of the maxillary and mandibular central incisors

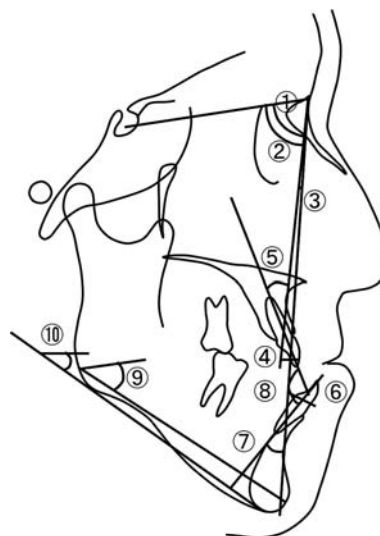


Fig. 1 Steiner and Tweed analyses.

① ∠SNA (°), ② ∠SNB (°), ③ ∠ANB (°), ④ ∠U1 to NA (mm), ⑤ U1 to NA (°), ⑥ L1 to NB (mm), ⑦ ∠L1 to NB (°), ⑧ ∠Interincisal (°), ⑨ ∠GoGn to SN (°), ⑩ FMA (°).

\angle GoGn to SN ($^{\circ}$): Angle formed by the GoGn line and the SN line

FMA: Frankfort mandibular plane angle

Ricketts analysis^{12, 13} (Fig. 2)

E-line: Esthetic plane drawn between Nt (tip of the nose) and Pg' (soft-tissue pogonion).

Ls to E-line: Distance (mm) from labrale superior to the E-line

Li to E-line: Distance (mm) from labrale inferior to the E-line

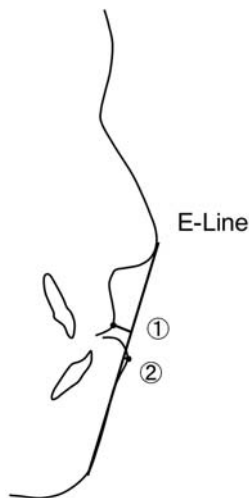


Fig. 2 Ricketts analysis.
① Ls to E-line, ② Li to E-line.

Arnett analysis¹⁴ (Figs. 3-5)

A true vertical line (TVL) was drawn through the subnasale (Sn) parallel to the vertical line and perpendicular to the natural head position.

Soft tissue structures

Upper lip thickness: Upper vermillion thickness

Lower lip thickness: Lower vermillion thickness

Nasolabial angle: Angle formed by the nasal base and the upper lip

Upper lip angle: Angle formed by the line connecting Sn, the upper lip anterior (ULA) and TVL

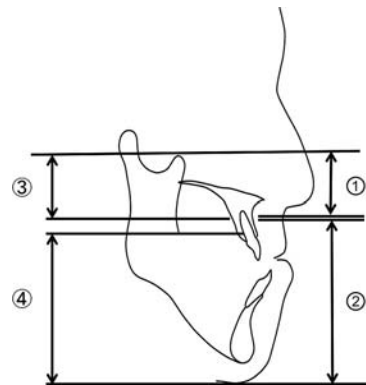


Fig. 4 Arnett analysis (facial lengths).
① Upper lip length, ② Lower lip length,
③ Mx height, ④ Md height.

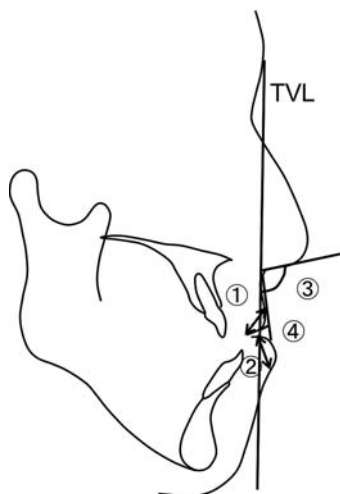


Fig. 3 Arnett analysis (soft tissue structures).
① Upper lip thickness, ② Lower lip thickness,
③ Nasolabial angle, ④ Upper lip angle.

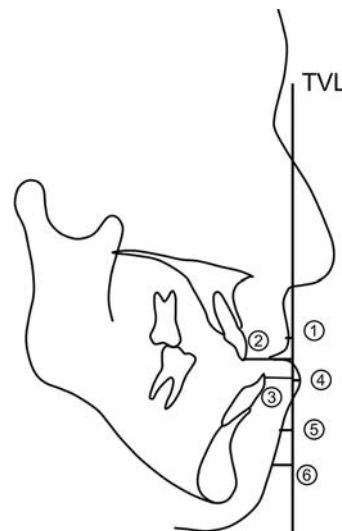


Fig. 5 Arnett analysis (TVL projections).
① Upper lip anterior, ② Mx1, ③ Md1, ④ Lower lip anterior,
⑤ Soft tissue B point, ⑥ Soft tissue pogonion.

Facial lengths

Upper lip length : Vertical distance from the Sn to the inferior border of the upper lip

Lower lip length : Vertical distance from the superior border of the lower lip to Me' (soft-tissue menton)

Mx height : Distance from Sn to the incisal edge of the maxillary central incisor

Md height : Distance from the incisal edge of the maxillary central incisor to Me'

TVL projections

TVL projections were anteroposterior measurements to the TVL. The horizontal distances measured from these landmarks to the TVL were given negative values when located posterior to the TVL, and positive values when located anterior.

Upper lip anterior : ULA to TVL

Mx1 : Maxillary incisor tip to TVL

Md1 : Mandibular incisor tip to TVL

Lower lip anterior : Most prominent point of the lower lip contour (LLA) to TVL

Soft tissue B point : B' to TVL

Soft tissue Pogonion : Pog' to TVL

Using calculations for the items above, we determined the means and standard deviations of all measurements in the L and the H groups at T1, T2 and T3. After testing for significant differences at T1, T2 and T3 using one-way ANOVA (StatPlus ; AnalystSoft, Washington, DC, USA), the Bonferroni multiple comparisons test was applied, with $p < 0.05$ considered significant. We also compared the L and the H groups at T1, T2 and T3 to test for significant differences. Also, the mean and standard deviation were calculated for changes in all items from T1 to T2, T2 to T3, and T1 to T3. All calculated values were compared between the L and H groups to test for significant differences. Spearman's rank correlation coefficient was done to abstract vertical and horizontal items in the maxillary and mandibular incisor hard tissue changes and lip soft tissue changes, and to determine the correlations between them. The correlation coefficients in the L and H groups were ≥ 0.52 and ≥ 0.7 , respectively, indicating strong correlation.¹⁵ Normality was

also investigated for the significant difference tests above. For items which demonstrated normality, a *t*-test was performed. For items which did not demonstrate normality, a Wilcoxon rank sum test was performed.

RESULTS

Hard and soft tissue changes in the L and H groups (Tables 1-3)

Hard tissue changes were as follows. In skeletal relationships, there were no significant differences in SNA angle in either group at any point in time (T1, T2 or T3). Significant differences were observed in the SNB and ANB angles in both groups at all points in time. Significant differences were observed in the SNB and ANB angles between T2 and T3, and between T1 and T3 (SNB : $T2 > T3$, $T1 > T3$; ANB : $T2 < T3$, $T1 < T3$). No significant differences were observed in FMA or GoGn to SN in either group at any point in time. In dental relationships, there were no significant differences in U1 to NA (mm), $\angle U1$ to NA, or in the interincisal angle in either group at any point in time. Significant differences were observed in L1 to NB (mm) and $\angle L1$ to NB ($^{\circ}$) in both groups at all points in time. For L1 to NB (mm), a significant difference was observed between T2 and T3 ($T2 > T3$). For $\angle L1$ to NB ($^{\circ}$) in the L group, significant differences were observed between T1 and T2 and between T2 and T3 ($T1 < T2$, $T2 > T3$). In the H group, a significant difference was observed only between T2 and T3 ($T2 > T3$) (Table 1).

Soft tissue analysis was as follows. In Ricketts analysis, although the L group did not demonstrate significant differences in Ls to E-line at any point in time, there were significant differences in Li to E-line. Significant differences were observed between T2 and T3, and between T1 and T3 ($T2 > T3$, $T1 > T3$). The H group did not demonstrate significant differences in Ls to E-line or Li to E-line at any point in time (Table 2). In the Arnett analysis for soft tissue structures, the L group demonstrated significant differences in upper lip thickness, lower lip thickness, and upper lip angle at all points in time. Upper lip thickness significantly differed be-

Table 1 Comparison between T1, T2 and T3 in hard tissue changes by Steiner and Tweed analyses for a) the L group, and b) the H group

Variable	T1	T2	T3	ANOVA	Bonferroni correction		
				p-value	T1 vs T2	T2 vs T3	T1 vs T3
SNA (°)	82.13±3.89	82.17±3.96	82.17±3.83	ns	—	—	—
SNB (°)	83.3±3.99	83.7±4.25	79.7±4.20	*	ns	*	*
ANB (°)	-1.17±2.08	-1.53±2.09	2.47±2.00	**	ns	**	**
FMA (°)	26.93±2.79	27.13±3.58	28.9±3.57	ns	—	—	—
GoGn to SN (°)	36.5±3.62	36.1±3.70	38.43±4.34	ns	—	—	—
U1 to NA (mm)	7.6±2.84	5.43±2.19	6±2.49	ns	—	—	—
∠U1 to NA (°)	29.1±6.92	24.93±7.04	27.33±5.87	ns	—	—	—
L1 to NB (mm)	8.17±2.58	9.2±2.10	6.77±2.63	*	ns	*	ns
∠L1 to NB (°)	26.43±5.75	31.83±3.33	25.2±5.37	**	*	**	ns
Interincisal angle (°)	125.73±10.52	124.76±8.11	125.17±6.75	ns	—	—	—

Mean±standard deviation, ns : Not significant, —Not recorded,
*p<0.05, **p<0.01.

A

Variable	T1	T2	T3	ANOVA	Bonferroni correction		
				p-value	T1 vs T2	T2 vs T3	T1 vs T3
SNA (°)	79±1.35	79±1.35	78.83±1.27	ns	—	—	—
SNB (°)	78.67±1.79	78.83±1.85	76.28±2.09	*	ns	*	*
ANB (°)	0.33±1.20	0.17±1.56	2.56±1.42	**	ns	**	**
FMA (°)	36.44±1.88	34.89±2.26	35.11±2.89	ns	—	—	—
GoGn to SN (°)	43.39±3.27	42.72±3.59	43.78±4.41	ns	—	—	—
U1 to NA (mm)	8.06±3.38	6.11±3.38	6.67±2.5	ns	—	—	—
∠U1 to NA (°)	28.72±6.45	24.56±8.19	27.83±6.27	ns	—	—	—
L1 to NB (mm)	8.56±3.02	10.11±2.36	7.56±2.36	*	ns	*	ns
∠L1 to NB (°)	27±4.35	32.22±4.21	24.5±4.52	**	ns	**	ns
Interincisal angle (°)	124.22±9.31	123±10.15	125.06±6.42	ns	—	—	—

B

Table 2 Comparison between T1, T2 and T3 in soft tissue changes by Ricketts analysis for a) the L group, and b) the H group

Variable	T1	T2	T3	ANOVA	Bonferroni correction		
				p-value	T1 vs T2	T2 vs T3	T1 vs T3
Ls to E-line	-1.83±2.15	-2.77±2.06	-1.17±1.52	ns	—	—	—
Li to E-line	3.57±2.37	3.57±2.04	1.23±2.18	**	ns	*	*

(mm)

A

Variable	T1	T2	T3	ANOVA	Bonferroni correction		
				p-value	T1 vs T2	T2 vs T3	T1 vs T3
Ls to E-line	-2.94±2.07	-3.61±2.53	-1.67±2.47	ns	—	—	—
Li to E-line	1.67±1.92	3.89±1.75	1.44±2.72	ns	—	—	—

(mm)

B

tween T2 and T3 ($T2 < T3$), lower lip thickness significantly differed between T2 and T3, and between T1 and T3 ($T2 > T3$, $T1 > T3$), and upper lip angle significantly differed between T1 and T3 ($T1 > T3$). The H group did not demonstrate any significant differences in soft tissue structures at any point in time.

As for facial lengths, the L group demonstrated significant differences in upper lip length and lower lip length at all points in time. Upper lip length significantly differed between T1 and T2, and between T2 and T3 ($T1 > T2$, $T2 < T3$). Lower lip length significantly differed between T2 and T3 ($T2 > T3$). Significant differences in the Mx and Md heights

Table 3 Comparison between T1, T2 and T3 in soft tissue changes by Arnett analysis for a) the L group, and b) the H group

Variable	T1	T2	T3	ANOVA	Bonferroni correction		
				p-value	T1 vs T2	T2 vs T3	T1 vs T3
Soft tissue structures							
Upper lip thickness (mm)	13.8±2.54	12.1±1.74	14.07±1.61	*	ns	*	ns
Lower lip thickness (mm)	14.67±1.36	14.93±1.13	13.13±1.36	**	ns	**	*
Nasolabial angle (°)	86.6±6.01	88.1±11.08	92.13±6.64	ns	—	—	—
Upper lip angle (°)	24.8±7.05	23.4±7.00	18.03±6.12	*	ns	ns	*
Facial lengths (mm)							
Upper lip length	25.07±1.88	22.83±1.74	25.17±1.96	*	*	*	ns
Lower lip length	54.87±2.93	56.67±3.84	53.1±3.95	*	ns	*	ns
Mx height	26.87±2.06	26±2.01	25.77±3.14	ns	—	—	—
Md height	53.47±3.56	53.5±3.42	54.23±3.06	ns	—	—	—
TVL projections (mm)							
Upper lip anterior	7.03±2.12	6.53±2.26	5.3±2.13	ns	—	—	—
Mx1	-5.9±3.55	-8.03±2.67	-7.4±2.49	ns	—	—	—
Md1	-3.77±2.95	-1.9±2.97	-10.5±2.58	**	ns	**	**
Lower lip anterior	10.17±3.12	11±3.18	3.67±2.98	**	ns	**	**
Soft tissue B point	2.97±3.04	2.7±3.22	-4.5±3.21	**	ns	**	**
Soft tissue pogonion	3.03±3.38	3.17±3.91	-3.67±4.35	**	ns	**	**

A

Variable	T1	T2	T3	ANOVA	Bonferroni correction			
				p-value	T1 vs T2	T2 vs T3	T1 vs T3	
Soft tissue structures								
Upper lip thickness (mm)	14.94±0.95	13.17±2.45	13.5±1.75	ns	—	—	—	
Lower lip thickness (mm)	14.11±2.27	14.22±1.56	12.17±1.92	ns	—	—	—	
Nasolabial angle (°)	88.11±10.98	88.06±11.09	89.44±7.23	ns	—	—	—	
Upper lip angle (°)	16.06±8.04	16.17±8.53	14.44±6.63	ns	—	—	—	
Facial lengths (mm)								
Upper lip length	25.07±1.88	22.83±1.74	25.17±1.96	ns	—	—	—	
Lower lip length	56.67±3.43	56.33±3.74	55.61±3.44	ns	—	—	—	
Mx height	28.17±2.68	27.83±2.84	27.5±2.71	ns	—	—	—	
Md height	53.28±2.71	52.56±3.34	54.89±4.23	ns	—	—	—	
TVL projections (mm)								
Upper lip anterior	4.78±2.33	5.11±2.84	4.67±2.32	ns	—	—	—	
Mx1	-6.83±3.78	-8.17±4.80	-7.56±3.96	ns	—	—	—	
Md1	-6.83±3.08	-4.28±3.63	-10.22±4.12	**	ns	**	ns	
Lower lip anterior	5.67±1.89	8.11±2.22	3.17±3.21	**	ns	**	ns	
Soft tissue B point	-1.39±2.34	-0.22±3.01	-4.94±5.23	*	ns	*	ns	
Soft tissue pogonion	-2.5±2.46	-1.39±3.25	-5.44±5.17	*	ns	*	ns	

B

were not observed at any point in time. The H group did not demonstrate significant differences in any facial length at any point in time. As for TVL projections, both groups demonstrated significant differences in Md1, lower lip anterior, soft tissue B point, and soft tissue pogonion at all points in time. The L group demonstrated significant differences between T2 and T3 and between T1 and T3 ($T2 > T3$, $T1 > T3$), while the H group demonstrated significant differences between T2 and T3 ($T2 > T3$) (Table 3).

Comparisons of the L and H groups at all points in time (Tables 4-6)

Comparisons at T1

Hard tissue analysis was as follows. In skeletal relationships, the SNA and SNB angles were both significantly larger in the L group. No significant difference was observed between groups in ANB angle. FMA was significantly larger in the H group. As for dental relationships, no significant differences were observed between the groups in any item (Table 4 A). Soft tissue analysis was as follows. In Ricketts analysis, there was no significant difference between groups in the distance from the labrale superior or the labrale inferior to the E-line (Table 4 B). In Arnett soft tissue analysis, among soft tissue structures, no significant differences were observed in upper lip thickness, lower lip thickness, or nasolabial angle, while upper lip angle was significantly larger in the L group. As for facial lengths, no significant differences were observed between groups in any item. As for TVL projections, significant differences were observed between groups in all items except Mx1, with all items being significantly larger in the L group.

Comparisons at T2

Hard tissue analysis was as follows. In skeletal relationships, SNA angle and SNB angle were both significantly larger in the L group. There was no significant difference in ANB angle between the groups. FMA was significantly larger in the H group. As for dental relationships, no significant differences were observed between the groups in any

Table 4 Comparison between the L and H groups at T1 for a) hard tissue items by Steiner and Tweed analyses, for b) soft tissue items by Ricketts analysis, and for c) soft tissue items by Arnett analysis

Variable	L	H	t-test
SNA (°)	82.13±3.89	79±1.35	*
SNB (°)	83.3±3.99	78.67±1.79	**
ANB (°)	-1.17±2.08	0.33±1.20	ns
FMA (°)	26.93±2.79	36.44±1.88	**
GoGn to SN (°)	36.5±3.62	43.39±3.27	**
U1 to NA (mm)	7.6±2.84	8.06±3.38	ns
∠U1 to NA (°)	29.1±6.92	28.72±6.45	ns
L1 to NB (mm)	8.17±2.58	8.56±3.02	ns
∠L1 to NB (°)	26.43±5.75	27±4.35	ns
Interincisal angle (°)	125.73±10.52	124.22±9.31	ns

A

Variable	L	H	t-test
LS to E-line	-1.83±2.15	-2.94±2.07	ns
LI to E-line	3.57±2.37	1.67±1.92	ns

(mm)

B

Variable	L	H	t-test
Soft tissue structures			
Upper lip thickness (mm)	13.8±2.54	14.94±0.95	ns
Lower lip thickness (mm)	14.67±1.36	14.11±2.27	ns
Nasolabial angle (°)	86.6±6.01	88.11±10.98	ns
Upper lip angle (°)	24.8±7.05	16.06±8.04	*
Facial lengths (mm)			
Upper lip length	25.07±1.88	26.11±2.20	ns
Lower lip length	54.87±2.93	56.67±3.43	ns
Mx height	26.87±2.06	28.17±2.68	ns
Md height	53.47±3.56	53.28±2.71	ns
TVL projections (mm)			
Upper lip anterior	7.03±2.12	4.78±2.33	*
Mx1	-5.9±3.55	-6.83±3.78	ns
Md1	-3.77±2.95	-6.83±3.08	*
Lower lip anterior	10.17±3.12	5.67±1.89	**
Soft tissue B point	2.97±3.04	-1.39±2.34	**
Soft tissue pogonion	3.03±3.38	-2.5±2.46	**

C

item (Table 5 A). Soft tissue analysis was as follows. In Ricketts analysis, there was no significant difference between groups in the distance from the labrale superior or the labrale inferior to the E-line (Table 5 B). In Arnett soft tissue analysis, among soft tissue structures, no significant differences

Table 5 Comparison between the L and H groups at T2 for a) hard tissue items by Steiner and Tweed analyses, for b) soft tissue items by Ricketts analysis, and for c) soft tissue items by Arnett analysis

Variable	L	H	t-test
SNA (°)	82.17±3.96	79±1.35	*
SNB (°)	83.7±4.25	78.83±1.85	**
ANB (°)	-1.53±2.09	0.17±1.56	ns
FMA (°)	27.13±3.58	34.89±2.26	**
GoGn to SN (°)	36.1±3.70	42.72±3.59	**
U1 to NA (mm)	5.43±2.19	6.11±3.38	ns
∠U1 to NA (°)	24.93±7.04	24.56±8.19	ns
L1 to NB (mm)	9.2±2.10	10.11±2.36	ns
∠L1 to NB (°)	31.83±3.33	32.22±4.21	ns
Interincisal angle (°)	124.76±8.11	123±10.15	ns

A

Variable	L	H	t-test
Ls to E-line	-2.77±2.06	-3.61±2.53	ns
Li to E-line	3.57±2.04	3.89±1.75	ns

(mm)

B

Variable	L	H	t-test
Soft tissue structures			
Upper lip thickness (mm)	12.1±1.74	13.17±2.45	ns
Lower lip thickness (mm)	14.93±1.13	14.22±1.56	ns
Nasolabial angle (°)	88.1±11.08	88.06±11.09	ns
Upper lip angle (°)	23.4±7.00	16.17±8.53	*
Facial lengths (mm)			
Upper lip length	22.83±1.74	24.78±1.80	*
Lower lip length	56.67±3.84	56.33±3.74	ns
Mx height	26±2.01	27.83±2.84	ns
Md height	53.5±3.42	52.56±3.34	ns
TVL projections (mm)			
Upper lip anterior	6.53±2.26	5.11±2.84	ns
Mx1	-8.03±2.67	-8.17±4.80	ns
Md1	-1.9±2.97	-4.28±3.63	ns
Lower lip anterior	11±3.18	8.11±2.22	*
Soft tissue B point	2.7±3.22	-0.22±3.01	*
Soft tissue pogonion	3.17±3.91	-1.39±3.25	**

C

Table 6 Comparison between L and H groups at T3 for a) hard tissue items by Steiner and Tweed analyses, for b) soft tissue items by Ricketts analysis, and for c) soft tissue items by Arnett analysis

Variable	L	H	t-test
SNA (°)	82.17±3.83	78.83±1.27	*
SNB (°)	79.7±4.20	76.28±2.09	*
ANB (°)	2.47±2.00	2.56±1.42	ns
FMA (°)	28.9±3.57	35.11±2.89	**
GoGn to SN (°)	38.43±4.34	43.78±4.41	**
U1 to NA (mm)	6±2.49	6.67±2.5	ns
∠U1 to NA (°)	27.33±5.87	27.83±6.27	ns
L1 to NB (mm)	6.77±2.63	7.56±2.36	ns
∠L1 to NB (°)	25.2±5.37	24.5±4.52	ns
Interincisal angle (°)	125.17±6.75	125.06±6.42	ns

A

Variable	L	H	t-test
Ls to E-line	-1.17±1.52	-1.67±2.47	ns
Li to E-line	1.23±2.18	1.44±2.72	ns

(mm)

B

Variable	L	H	t-test
Soft tissue structures			
Upper lip thickness (mm)	14.07±1.61	13.5±1.75	ns
Lower lip thickness (mm)	13.13±1.36	12.17±1.92	ns
Nasolabial angle (°)	92.13±6.64	89.44±7.23	ns
Upper lip angle (°)	18.03±6.12	14.44±6.63	ns
Facial lengths (mm)			
Upper lip length	25.17±1.96	25.61±2.41	ns
Lower lip length	53.1±3.95	55.61±3.44	ns
Mx height	25.77±3.14	27.5±2.71	ns
Md height	54.23±3.06	54.89±4.23	ns
TVL projections (mm)			
Upper lip anterior	5.3±2.13	4.67±2.32	ns
Mx1	-7.4±2.49	-7.56±3.96	ns
Md1	-10.5±2.58	-10.22±4.12	ns
Lower lip anterior	3.67±2.98	3.17±3.21	ns
Soft tissue B point	-4.5±3.21	-4.94±5.23	ns
Soft tissue pogonion	-3.67±4.35	-5.44±5.17	ns

C

were observed in the upper lip thickness, lower lip thickness, or nasolabial angle, while the upper lip angle was significantly larger in the L group. As for facial lengths, a significant difference was observed between groups only in upper lip length, which was significantly shorter in the L group. As for TVL pro-

jections, significant differences were observed between groups in the anterior of the lower lip, the soft tissue B point, and the soft tissue pogonion, all of which were significantly larger in the L group (Table 5 C).

Comparisons at T3

Hard tissue analysis was as follows. In skeletal relationships, the SNA and SNB angles were both significantly larger in the L group. There was no significant difference in ANB angle between the groups. FMA was significantly larger in the H group. As for dental relationships, no significant differences were observed between groups in any item (Table 6 A). Soft tissue analysis was as follows. In Ricketts analysis, there was no significant difference between groups in the distance from the labrale superior or the labrale inferior to the E-line (Table 6 B). In Arnett soft tissue analysis, no significant differences were observed between the groups in any item (Table 6 C).

Comparisons of changes between all pairs of time points between the L and the H groups (Tables 7-9)

Steiner analysis and Tweed analysis of hard tissue changes

There were no significant differences between the groups in the skeletal relationships between T1 and T2 with respect to changes in the SNA, SNB or ANB angles. Although FMA increased in the L group, it decreased in the H group, thus showing a significant difference. There were no significant differences in changes in the dental relationships (Table 7 A). Although there was no significant difference between groups between T2 and T3 with respect to changes in SNA angle, the L group demonstrated a significant decrease in SNB angle. Consequently, the ANB angle significantly increased in the L group. As for FMA, no significant differences were observed between the groups. As for changes in dental relationships, there were no significant differences between groups (Table 7 B). Although there was no significant difference between groups between T1 and T3 with respect to changes in SNA angle, the L group demonstrated a significant decrease in SNB angle. The L group also demonstrated a significant increase in ANB angle. Although FMA increased in the L group, it decreased in the H group, thus showing a significant

Table 7 Comparison between the L and H groups of hard tissue changes by Steiner and Tweed analyses from a) T1 to T2, b) T2 to T3, and c) T1 to T3

Variable	L	H	t-test
SNA (°)	0.03±0.12	0	ns
SNB (°)	0.4±0.66	0.17±0.71	ns
ANB (°)	-0.37±0.62	-0.17±0.71	ns
FMA (°)	0.2±1.68	-1.56±1.01	*
GoGn to SN (°)	-0.4±0.95	-0.67±1.11	ns
U1 to NA (mm)	-2.17±1.68	-1.94±2.65	ns
∠U1 to NA (°)	-4.17±5.32	-4.17±9.10	ns
L1 to NB (mm)	1.03±1.68	1.56±1.44	ns
∠L1 to NB (°)	5.4±5.50	5.22±4.44	ns
Interincisal angle (°)	-0.97±8.40	-1.22±11.41	ns

A

Variable	L	H	t-test
SNA (°)	0±0.26	-0.17±0.33	ns
SNB (°)	-4±1.26	-2.56±1.32	*
ANB (°)	4±1.11	2.39±1.26	**
FMA (°)	1.77±1.80	0.22±2.51	ns
GoGn to SN (°)	2.33±2.08	1.06±2.18	ns
U1 to NA (mm)	0.57±1.45	0.56±1.36	ns
∠U1 to NA (°)	2.4±5.63	3.28±3.90	ns
L1 to NB (mm)	-2.43±1.67	-2.56±1.48	ns
∠L1 to NB (°)	-6.63±3.73	-7.72±4.20	ns
Interincisal angle (°)	0.4±5.97	2.06±6.44	ns

B

Variable	L	H	t-test
SNA (°)	0.03±0.29	-0.17±0.33	ns
SNB (°)	-3.6±1.34	-2.39±1.05	*
ANB (°)	3.63±1.19	2.22±1.06	*
FMA (°)	1.97±2.58	-1.33±1.97	**
GoGn to SN (°)	1.93±1.97	0.39±1.91	ns
U1 to NA (mm)	-1.6±1.64	-1.39±2.62	ns
∠U1 to NA (°)	-1.77±3.61	-0.89±7.67	ns
L1 to NB (mm)	-1.4±2.08	-1±1.90	ns
∠L1 to NB (°)	-1.23±5.70	-2.5±5.25	ns
Interincisal angle (°)	1.97±2.58	-1.33±1.97	**

C

cant difference. As for changes in dental relationships, there were no significant differences between the groups (Table 7 C).

Ricketts analysis of soft tissue

There was no significant difference between groups in changes in Ls to E-line or Li to E-line between

Table 8 Comparison between the L and H groups in soft tissue changes by Ricketts analysis from a) T1 to T2, b) T2 to T3, and c) T1 to T3

Variable	L	H	t-test
Ls to E-line	-0.93±1.39	-0.67±1.65	ns
Li to E-line	0±2.05	1.72±1.31	ns
(mm)			
A			
Variable	L	H	t-test
Ls to E-line	1.6±1.36	1.94±1.55	ns
Li to E-line	-2.33±1.98	-1.94±1.94	ns
(mm)			
B			
Variable	L	H	t-test
Ls to E-line	0.67±1.62	1.28±1.83	ns
Li to E-line	-2.33±1.64	-0.22±1.93	*
(mm)			
C			

Table 9 Comparison between the L and H groups of soft tissue changes by Arnett analysis from a) T1 to T2, b) T2 to T3, and c) T1 to T3

Variable	L	H	t-test
Soft tissue structures			
Upper lip thickness (mm)	-1.7±2.59	-1.78±2.27	ns
Lower lip thickness (mm)	0.27±1.41	0.11±1.29	ns
Nasolabial angle (°)	1.5±10.93	-0.06±5.25	ns
Upper lip angle (°)	-1.4±6.95	0.11±5.07	ns
Facial lengths (mm)			
Upper lip length	-2.23±1.57	-1.33±1.18	ns
Lower lip length	1.8±2.6	-0.33±3.23	ns
Mx height	-0.87±1.38	-0.33±1.89	ns
Md height	0.03±4.01	-0.72±2.19	ns
TVL projections (mm)			
Upper lip anterior	-0.5±1.88	0.33±1.60	ns
Mx1	-2.1±2.27	-1.33±3.02	ns
Md1	1.87±1.04	2.56±3.03	ns
Lower lip anterior	0.83±2.34	2.44±2.41	ns
Soft tissue B point	-0.27±2.21	1.17±2.05	ns
Soft tissue pogonion	0.13±1.92	1.11±2.05	ns
A			

T1 and T2 or between T2 and T3 (Table 8 A-B). Between T1 and T3, although there was no significant difference between groups in change in Ls to

Variable	L	H	t-test
Soft tissue structures			
Upper lip thickness (mm)	1.97±1.60	0.33±1.81	*
Lower lip thickness (mm)	-1.8±1.49	-2.06±1.67	ns
Nasolabial angle (°)	4.03±8.56	1.39±8.06	ns
Upper lip angle (°)	-5.37±5.24	-1.72±4.87	*
Facial lengths (mm)			
Upper lip length	2.33±1.11	0.83±1.37	*
Lower lip length	-3.57±3.43	-0.72±3.30	ns
Mx height	-0.23±1.80	-0.33±0.91	ns
Md height	0.73±3.37	2.33±2.49	ns
TVL projections (mm)			
Upper lip anterior	-1.23±1.59	-0.44±1.71	ns
Mx1	0.63±1.67	0.61±1.95	ns
Md1	-8.6±1.8	-5.94±2.70	*
Lower lip anterior	-7.33±2.47	-4.94±3.02	ns
Soft tissue B point	-7.2±2.09	-4.72±3.04	*
Soft tissue pogonion	-6.83±2.02	-4.06±2.94	*
B			
Variable	L	H	t-test
Soft tissue structures			
Upper lip thickness (mm)	0.27±2.24	-1.14±1.62	ns
Lower lip thickness (mm)	-1.53±1.43	-1.94±1.88	ns
Nasolabial angle (°)	5.53±6.54	1.33±8.60	ns
Upper lip angle (°)	-6.77±6.36	-1.61±6.15	*
Facial lengths (mm)			
Upper lip length	0.1±1.92	-0.5±1.45	ns
Lower lip length	-1.77±3.41	-1.06±1.46	ns
Mx height	-1.1±1.96	-0.67±1.86	ns
Md height	0.77±3.28	1.61±2.61	ns
TVL projections (mm)			
Upper lip anterior	-1.73±1.70	-0.11±1.68	*
Mx1	-1.47±2.47	-0.72±1.40	ns
Md1	-6.73±1.96	-3.39±3.45	**
Lower lip anterior	-6.5±1.79	-2.5±2.85	**
Soft tissue B point	-7.47±2.15	-3.56±3.55	**
Soft tissue pogonion	-6.7±2.74	-2.94±3.47	*
C			

E-line, the L group demonstrated a significant reduction in Li to E-line (Table 8 C).

Arnett soft tissue analysis

Between T1 and T2, there were no significant differences between groups in any item (Table 9 A). Between T2 and T3, among soft tissue structures, the L group demonstrated a significant increase in upper lip thickness and a significant decrease in upper lip angle. As for facial lengths, the L group

demonstrated a significant increase in upper lip length. Among TVL projections, the L group demonstrated significant reductions in soft tissue B point and soft tissue pogonion (Table 9 B). Between T1 and T3, among soft tissue structures, the L group demonstrated a significant reduction in upper lip angle. As for facial lengths, no significant differences were observed between groups at any time. Among TVL projections, the L group demonstrated significant reductions in all items except for Mx1 (Table 9 C).

Table 10 Correlation coefficients for comparison of vertical changes in the hard and soft tissues in a) the L group, b) the H group, and horizontal changes in the hard and soft tissues in c) the L group, in d) the H group, and in the upper lip thickness and the lower lip thickness in e) the L group, and f) the H group

T1-T2	Upper lip length	Lower lip length
Mx height	0.33	-0.35
Md height	0.04	0.58*

T2-T3		
Mx height	0.07	0.29
Md height	0.46	0.41

T1-T3		
Mx height	0.4	0.05
Md height	-0.28	0.74*

r : Spearman's rank correlation, $*r > 0.52$.

A

T1-T2	Upper lip length	Lower lip length
Mx height	-0.4	-0.47
Md height	-0.16	0.77*

T2-T3		
Mx height	0.28	0.26
Md height	0.79*	0.57

T1-T3		
Mx height	0.34	-0.62
Md height	0.35	0.29

$*r > 0.7$

B

Correlations between hard tissue and lip soft tissue

Table 10 A shows correlations between maxillary and mandibular incisor vertical positions (Mx height, Md height) and upper and lower lip vertical positions (U lip length, L lip length). Between T1 and T2, a strong positive correlation between Md height and L lip length was observed in both groups. Between T2 and T3, Md height was positively corre-

T1-T2	Upper lip anterior	Lower lip anterior	Upper lip thickness	Lower lip thickness
Mx1	0.36	0.02	0.04	-0.22
Md1	-0.07	-0.07	-0.34	0.07
SNB	0.07	0.19	-0.27	-0.32

T2-T3				
Mx1	0.39	0.25	-0.05	0.07
Md1	0.06	0.58*	0.17	-0.05
SNB	0.11	0.41	0.32	-0.13

T1-T3				
Mx1	-0.34	0.16	0.02	-0.09
Md1	-0.14	-0.05	-0.28	-0.37
SNB	0.47	0.48	0.15	-0.27

(mm)

$*r > 0.52$

C

T1-T2	Upper lip anterior	Lower lip anterior	Upper lip thickness	Lower lip thickness
Mx1	0.56	0.23	0.02	0.19
Md1	0.49	0.56	0.13	0.23
SNB	0.19	0.69	0.19	0.2

T2-T3				
Mx1	0.1	-0.45	0.06	-0.52
Md1	-0.07	0.51	0.08	0.45
SNB	0.51	0.77*	0.3	0.75*

T1-T3				
Mx1	0.32	0.63	-0.42	0.14
Md1	0.15	0.79*	-0.22	0.45
SNB	0.28	0.77*	-0.36	0.71*

(mm)

$*r > 0.7$

D

T1-T2	Lower lip thickness
Upper lip thickness	0.51
T2-T3	
Upper lip thickness	0.53*
T1-T3	
Upper lip thickness	0.02

(mm)

* $r > 0.52$

E

T1-T2	Lower lip thickness
Upper lip thickness	-0.06
T2-T3	
Upper lip thickness	0.44
T1-T3	
Upper lip thickness	-0.22

(mm)

* $r > 0.7$

F

lated with U lip length and L lip length in both groups. A particularly strong positive correlation was observed between Md height and U lip length in the H group. Between T1 and T3, the L group demonstrated a strong positive correlation between Md height and L lip length. Table 10 B shows the correlations of maxillary and mandibular incisor horizontal position (Mx1, Md1) and mandibular anteroposterior position (SNB) with the upper and lower lip horizontal position (U lip anterior, L lip anterior) and upper and lower lip thickness (U lip thickness, L lip thickness).

The L group demonstrated a strong positive correlation between Md1 and L lip anterior between T2 and T3. In the H group, SNB was strongly positively correlated with L lip anterior and L lip thickness between T2 and T3. Between T1 and T3, the H group also demonstrated strong positive correlations between Md1 and L lip anterior, between SNB

and L lip anterior, and between SNB and L lip thickness. Table 10 C shows correlations between upper lip thickness (U lip thickness) and lower lip thickness (L lip thickness). The L group demonstrated strong positive correlations between T1 and T2, and between T2 and T3.

DISCUSSION

Materials and methods

For skeletal class III patients who require surgical orthodontic treatment, it is important to predict post-treatment changes in the soft tissue profile before the initial orthodontic treatment. Previous studies have shown that postoperative soft tissue changes are affected by differences in surgical method^{3, 5, 9} and in pre-treatment maxillofacial morphology.^{8, 16} To learn whether differences in FMA lead to differences in soft tissue changes in surgical orthodontic treatment with SSRO, we assembled patients who were as similar in maxillofacial morphology as possible aside from FMA, divided these patients into two groups based on the size of their FMA, and examined their hard and soft tissue changes. According to Tweed,¹¹ the mean FMA in adult women is $28.81^\circ \pm 5.23^\circ$. Therefore, the present study classified patients with an average FMA (defined as less than 30° to establish a distinction) as the L group and patients with an FMA greater than or equal to 34° as the H group. The range of FMA in our study in the L and H groups was 23.5° - 30° and 34° - 39° , respectively. Also, because many skeletal class III patients have labial inclination of the maxillary incisors as dental compensation, we selected patients whose maxillary premolars had been extracted.

To eliminate differences in soft tissue profile changes associated with differences in surgical method, we selected patients who had undergone SSRO alone. We also excluded patients with prominent lateral mandibular deviation and those with cleft lip and palate because it is difficult to accurately grasp their soft tissue changes associated with hard tissue changes. For example, in patients with lateral mandibular deviation, hard tissue changes associated with surgery cannot be determined from lateral morphology alone; while cleft lip

and palate patients often present with scarring and deformation of the ala of the nose, the lips, and other soft tissue, which limit soft tissue changes.

In analysis, lateral cephalograms from before the initial orthodontic treatment, after the initial orthodontic treatment and before the operation, and after completion of all treatment were traced by a single orthodontist who does cephalometric analysis daily. Regarding error in the time of designation of anatomical landmarks in cephalograms, when cephalogram landmark designation was conducted 10 times, the standard error of measurements at all landmarks was within 0.5 mm (minimum 0 mm, maximum 1.0 mm). Hard tissues were analyzed using Steiner¹⁰ and Tweed¹¹ analyses, while soft tissues were analyzed using Ricketts analysis,^{12, 13} E-line and STCA.¹⁴ Steiner analysis, which uses the cranial base SN plane as a reference, focuses on ANB angle, U1 to NA angle and distance, and L1 to NB angle and distance, as a specialized analysis for determining hard tissue characteristics.

We used nine items that illustrate skeletal and lip changes. From Tweed analysis, we used the mandibular plane angle, with which the characteristics of the jaw can be grasped. In Ricketts soft tissue analysis, profile balance can be grasped easily based on two items that assess the distances of the labrale superior and labrale inferior from a reference line called the E-line. Arnett's STCA has a total of 45 items for assessing soft tissue, which is more than other soft tissue analyses. Of the items listed by John C. Bennett and Richard P. McLaughlin,¹⁷ we abstracted 14 dedicated soft tissue analysis items that affect facial appearance and are necessary when drafting a profile treatment plan. These items included lip thickness, horizontal and vertical positions of the lips, nasal angle, and lower facial length.

Using these 14 items, which are thought to change as a result of surgical orthodontic treatment with SSRO alone, the present study combined the above four analyses to analyze hard and soft tissue in detail. Values in STCA are taken from adult radiographs in a natural head position with the upper and lower lips in a resting position. Although meas-

urements were taken with the head in a fixed position, the conditions for radiography before and after treatment were identical. Therefore, we used STCA values for comparisons.

Hard tissue changes

In skeletal relationships, the SNB angle greatly decreased in the L group between T2 and T3. Consequently, the ANB angle in the L group significantly increased. In skeletal Class III patients who required surgery, ANB angles after completion of all treatment of $-0.5^\circ \pm 1.6^\circ$,¹⁸ $-0.5^\circ \pm 2.4^\circ$,¹⁹ and $-0.2^\circ \pm 1.5^\circ$ ² have been reported. However, in the present study, ANB angles after completion of all treatment in both groups were standard values¹⁰ that were larger than the above values. Before the initial orthodontic treatment, ANB angles in the L and H groups were $-1.17^\circ \pm 2.08^\circ$, and $0.33^\circ \pm 1.20^\circ$, respectively. Because these values were not small, it is conceivable that ANB angles after completion of all treatment improved due to retrusion of the mandible as a result of the operation. Also, the H group demonstrated a significant decrease in FMA from T1 to T2. In a comparison of T1 and T3, the L group demonstrated an increase in FMA, signifying clockwise rotation; while the H group demonstrated a decrease in FMA, signifying counterclockwise rotation. This may be why the L group demonstrated a greater decrease in SNB angle between T2 and T3, and between T1 and T3.

As for dental relationships, both groups demonstrated labial tilt of the maxillary incisors, protrusion of the maxillary incisors, and protrusion of the mandibular incisors at T1. Both groups demonstrated lingual tilt of the maxillary incisors between T1 and T2, and labial tilt between T2 and T3. However, there were no significant differences in changes or between groups at any point in time. As for the mandibular incisors, both groups demonstrated labial tilt between T1 and T2, and lingual tilt between T2 and T3. However, there were no significant differences in changes or between groups at any point in time. Therefore, in the present study, there were no significant differences between groups in changes in dental relationships.

Soft tissue changes

Comparisons of soft tissue changes between groups showed the L group had more items with significant differences. The L group showed significant differences in upper and lower lip thickness at all points in time, as well as a significant difference between T2 and T3. The H group did not demonstrate significant differences in upper or lower lip thickness at any point in time. Consequently, the L group showed greater change in lip thickness in relation to movement of the teeth and the mandible. The upper lip angle was larger in the L group at T1 and T2, thus indicating that the L group demonstrated greater eversion of the upper lip. Also, between T2 and T3, the L group showed a significant decrease in upper lip angle, thus demonstrating that upper lip eversion was lower in the L group from before to after the operation than in the H group.

As for facial lengths, the L group showed a significant reduction in lower lip length from T2 to T3. Upper lip length at T2 was lower in the L group, and a significant difference was observed between groups. The change in upper lip length from T2 to T3 was significantly larger in the L group. These results indicate that from T1 to T2, the upper lip moved in superiorly, and that as a result of mandibular retrusion associated with the subsequent operation, incisor overlap improved, and the upper lip descended. This is consistent with a report by Hida *et al.*⁷ in which the upper lip, which had been pushed up by the mandibular incisors before the operation, moved downward and covered the lower lip while being restored to its original length in association with improvement in incisor overlap.

Despite the absence of changes in the vertical and horizontal positions of the maxillary incisors, the vertical position and the thickness of the upper lip did change. Lip thickness is believed to be affected by the teeth beneath the lip, the muscles around the lip, and contact between the lips.^{20, 21} It is conceivable that in the L group of our study, the muscles around the lips and the contact between the upper and lower lips exerted a greater effect, which was responsible for the change in lip thick-

ness. As for the lower lip, Sakai *et al.*⁸ reported that a smaller FMA caused actual posteroinferior displacement of the lower lip landmark to be greater than predicted due to excessive eversion of the lower lip before the operation. Although we found that both groups demonstrated decreased lower lip thickness from T2 to T3, thus signifying posteroinferior movement, there were no significant differences between groups in thickness or vertical change.

In both Ricketts and Arnett analyses, horizontal lower lip change between T1 and T3 was significantly different between groups, with the L group showing significant reduction. All TVL projections among the patients in the present study at all points in time were more anterior than the reference values for Japanese women²² (Table 11). At T1 and T2, there were significant differences in most items between the groups, with the L group demonstrating more anterior positions. From T2 to T3, the L group showed significant decreases in lower lip anterior, soft tissue B point, and soft tissue pogonion. Consequently, there were no significant differences between groups in any items at T3. Although there was improvement in protrusion of the lower face, the values calculated for the anterior of the lower lip, soft tissue B point, and soft tissue po-

Table 11 Means values for facial features of female adult Japanese with normal occlusion from a previous study using the Arnett analysis

Variable	Mean
Soft tissue structures	
Upper lip thickness (mm)	13.0±1.8
Lower lip thickness (mm)	13.3±1.4
Nasolabial angle (°)	100.1±6.9
Upper lip angle (°)	11.5±5.3
Facial lengths (mm)	
Upper lip length	23.6±1.8
Lower lip length	47.3±3.6
Mx height	26.2±2.7
Md height	49.5±3.5
TVL projections (mm)	
Upper lip anterior	3.1±1.6
Mx1	-9.9±2.7
Md1	-12.7±2.8
Lower lip anterior	-0.2±2.4
Soft tissue B point	-8.8±3.2
Soft tissue pogonion	-9.1±3.9

gonion were more protruded than reference values for Japanese women,²² thus signifying a residual tendency towards mandibular prognathism.

Relationships between hard tissue and soft tissue changes

We found no significant vertical or horizontal correlations between the maxillary incisors and the upper lip in either group. A past study stated that the postoperative horizontal and vertical positions of the upper lip are correlated with the maxillary incisors.⁷ In our study, neither group demonstrated significant differences in maxillary incisor changes at any time, which may have been why no correlations were observed. Both groups demonstrated strong positive vertical and horizontal correlations between the mandibular incisors and the lower lip, thus demonstrating that the mandibular incisors and the lower lip are directly related to each other. Therefore, we examined the ratio of change in the lower lip (lower lip anterior) before and after treatment in relation to changes in the mandibular incisors (Md1) from before and after treatment.

The ratios of Md1 to the lower lip anterior in the L and H groups were 0.96 and 0.74, respectively. Thus, the H group showed smaller change in the lower lip relative to change in the mandibular incisors. High-angle cases have been reported to feature a great deal of activity in the mentalis, the orbicularis oris, and other muscles around the lips during lip closure.⁸ In the H group, contraction of muscles around the lips may have affected lower lip changes. The L group demonstrated a strong correlation between upper lip thickness and lower lip thickness. The H group demonstrated a strong positive correlation between lower lip thickness and SNB angle, which suggests that mandibular position changes directly affect lower lip thickness.

CONCLUSION

We found that although there were no significant differences between groups in hard tissue changes, there were some significant differences between the groups in labial soft tissue changes. This suggests that differences in FMA lead to differences in

soft tissue changes. These differences in soft tissue changes may originate from the effects of contact with the upper and lower lips, and differences in muscle activity surrounding the lips. Conceivable factors in upper lip changes include not only changes in the maxillary incisors beneath the lips, but also the state of contact with the mandibular incisors or the lower lip. This tendency is stronger when FMA is smaller. It was also learned that when FMA is large, lower lip changes relative to changes in the mandibular incisors are small. These findings suggest that when predicting soft tissue changes in surgical orthodontic treatment, it is important to account for the effects of FMA on lip soft tissue changes when drafting a treatment plan.

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