

Effects of Twin Block Appliance Therapy on Elasticity of Maxillofacial Soft Tissue

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The purpose of this study was to clarify the effects of twin block appliance (TBA) therapy on the elasticity of maxillofacial soft tissue in patients with Class II malocclusion.

Materials and Methods : We treated 13 patients (6 boys, 7 girls, 9.8 ± 1.4 years old) with Class II malocclusion (Class II group) and 14 (7 boys, 7 girls, 9.2 ± 1.7 years old) with Class I malocclusion (control group). The Class II patients were treated with TBA therapy, while the controls were followed and their natural growth was noted. The elasticity of the soft tissue was measured at 7 facial points with the mouth closed using a skin elasticity measuring device (Cutometer®, MPA 580, Courage + Khazaka Co., Ltd.). Elasticity measurements and lateral cephalograms were obtained twice for both groups : at the first examination (T1) and 1 year later (T2).

Results : At T1, elasticity values at the midpoint between the left nosewing and the angular nodal, the one between the right nosewing and the angular nodal, and the soft tissue pogonion were significantly lower in the Class II group ($p < 0.05$). As a result of TBA therapy, the Class II group showed forward growth of the mandible and labial inclination of the anterior teeth of the mandible. Furthermore, the elasticity of the soft tissue became closer to that of the control group at T2.

Conclusion : Our findings indicate that TBA therapy for patients with Class II malocclusion is useful for the improvement of intermaxillary relationship and the lateral profile of soft tissue, as well as the functional improvement in the maxillofacial region. Thus, it was suggested that TBA therapy was useful to measure the elasticity of maxillofacial soft tissue in malocclusion patients.

Key words : skin elasticity, Cutometer, Twin block appliance, Class II malocclusion

INTRODUCTION

Class II division 1 malocclusion is frequently caused by mandibular retrusion^{1,2)}, which is characterized by large overjet and overbite

of the anterior teeth, and aggravated by compensatory functions of the perioral muscles to accommodate the hard tissue. In particular, excessive horizontal overjet prevents normal labial activity, resulting in upper lip curling and

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Table 1 Summary of subjects.

Total		Groups				Period		
Age(years)	N	N	Sex	N	Age (years)	Significance	T1-T2 (years)	
9.6±1.5	27	Class II	13	Male	6	9.8±1.4	NS	1.2±0.4
				Female	7			
		Control	14	Male	7	9.2±1.7		
				Female	7			

NS ; not significant.

labial asthenia, as well as further increases in mentalis and orbicular muscle activities.

For treatment of this condition in growing children, a twin block appliance (TBA) is frequently used as a functional orthognathic device. ATBA enables bite raising and mandibular forward growth³⁾, as well as improvements in profile-related soft tissue⁴⁾ and provides an attractive profile silhouette⁵⁾. Since use of a TBA also enables good lip closure^{6,7)}, hard and soft tissues are morphologically modified to change soft tissue functions.

The soft tissue includes the skin, fat, and muscular tissue. Recently, it has been reported that elasticity of the buccal soft tissue and functions of the mimic muscle are related⁸⁾. In other studies, skin elasticity has been widely used to determine age-related changes of skin⁹⁾ and elasticity in patients with skin diseases¹⁰⁾, as well as to evaluate skin sagging and turgor in an anti-aging investigation¹¹⁾. However, changes in the elasticity of maxillofacial soft tissue in patients with mandibular retrusion following orthodontic treatment have not been clarified. In the present study, we investigated the effects of TBA therapy on elasticity of maxillofacial soft tissue in patients with Class II division 1 malocclusion induced by mandibular retrusion.

SUBJECTS and METHODS

1. Subjects

We studied 13 patients (6 males, 7 females; mean age at first examination 9.8±1.4 years) with Class II division 1 malocclusion with

perioral tension when closing the lips, who were diagnosed and treated at the Department of Orthodontics, Ohu University Hospital (Class II group). In addition, 14 patients (7 males, 7 females, mean age at first examination 9.2±1.7 years) with Class I malocclusion and no perioral tension when closing the lips were used as the control group. The subject characteristics are shown in Table 1. The criteria for selecting all subjects were as follow.

- 1) Bilaterally symmetric dental arch, with a midline shift of the upper and lower jaws within 2 mm.
- 2) No missing teeth, excluding third molar.
- 3) No excessive restoration.
- 4) No previous orthodontic treatment.
- 5) No history of temporomandibular symptoms.
- 6) No history of skin disease.
- 7) Prior to reaching pubertal growth peak.
- 8) Mild tooth crowding.
- 9) Rohrer index within the standard range of 130±15.

The following conditions were seen in the two groups.

【Class II group】

- 1) Bilateral molar teeth rated as angle Class II.
- 2) Overbite and overjet of +4 mm or greater.
- 3) Incomplete lip closure.

【Control group】

- 1) Bilateral molar teeth rated as angle Class I.
- 2) Overbite and overjet of +1-3 mm.
- 3) No incomplete lip closure.

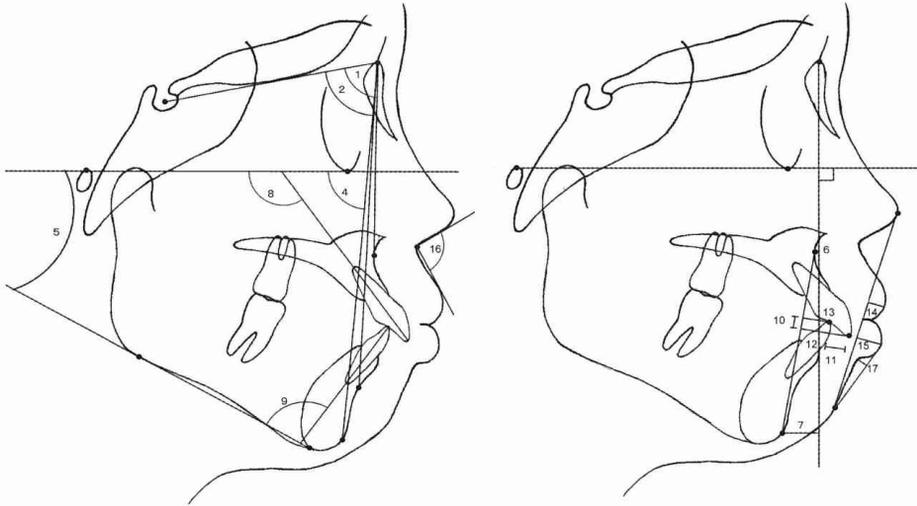


Figure 1. Cephalometric measurements.

left ; angular measurements, right ; linear measurements : 1 ; \angle SNA ($^{\circ}$), 2 ; \angle SNB ($^{\circ}$), 3 ; \angle ANB ($^{\circ}$), 4 ; facial angle ($^{\circ}$), 5 ; \angle FH plane to mandibular plane ($^{\circ}$), 6 ; A to McNamara's line (mm), 7 ; pogonion to McNamara's line (mm), 8 ; \angle U1 to FH plane ($^{\circ}$), 9 ; \angle L1 to mandibular plane ($^{\circ}$), 10 ; overbite (mm), 11 ; overjet (mm), 12 ; U1-APo line (mm), 13 ; L1-APo line (mm), 14 ; upper lip position (Rickett's E-line) (mm), 15 ; lower lip position (Rickett's E-line) (mm), 16 ; nasolabial angle ($^{\circ}$), 17 ; mentolabial sulcus (mm).

Those who fulfilled all of the above conditions were selected as subjects for the present study. In addition, all were school children with standard proportions according to the Rohrer index.

2. Methods

1) Preparation of TBA

The Class II group underwent TBA therapy, while the control group patients were followed during their natural growth. For preparing the TBA, a construction bite was taken vertically with the distance between the central incisors at 2 mm, that between the molar occlusal planes at 5-6 mm, and a horizontal distance of 0 mm. A cast model of the upper and lower jaws was attached to an FKO-split-post fixator (Dentaurum) with a Projet bite gauge (Great Lakes). Each TBA was prepared using orthodontic resin (Ortho Crystal, Rocky Mountain Morita). The design and use of the appliance were compliant with

the method of Clark¹²⁾.

2) Analysis of lateral cephalogram (roentgenograph) images

Lateral cephalogram images were used to evaluate the skeletal and dental systems, and soft tissue related to profile morphology before and after therapy in both groups. Each cephalogram was obtained in the intercuspation position at the first examination (T1) and 1 year later (T2) to determine each of the studied items (Fig. 1). The measurements were repeated 3 times and mean values were used for analysis.

3) Measurement of elasticity of maxillofacial soft tissue

For determining soft tissue elasticity, a skin measuring device (Cutometer[®], MPA580, Courage+Khazaka) skin elasticity measuring device was utilized (Fig. 2). The system consisted of an elastic probe, metal case with a built-in

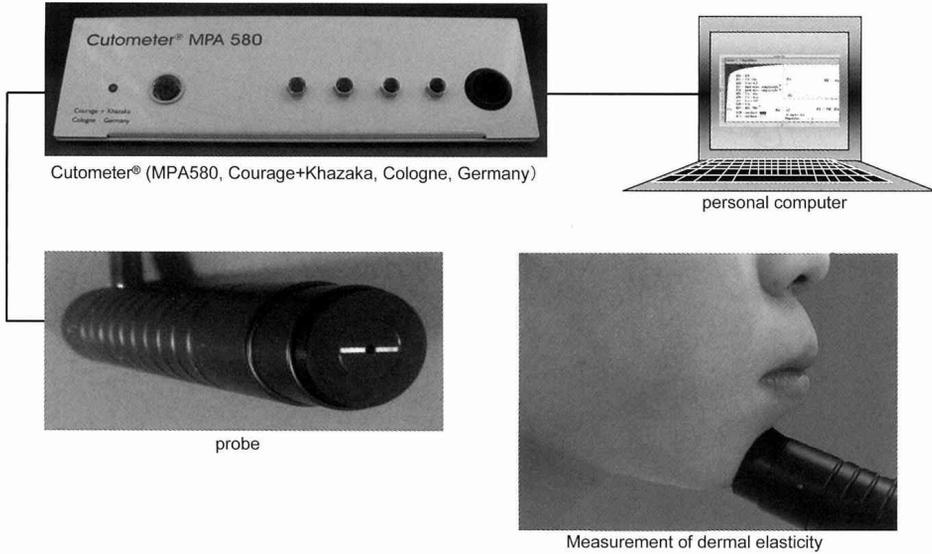


Figure 2. System configuration diagram.

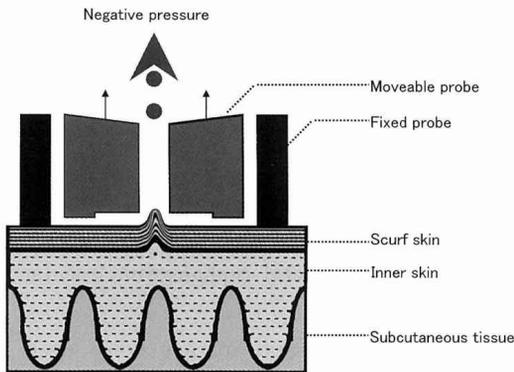


Figure 3. Chart that absorbed the skin surface with probe.

negative-pressure aspirator, and pressure sensor, and a computer for operation, data processing, and display (LaVie G, NEC). An elastic probe 2 mm in diameter was used. Soft tissue elasticity was measured at 0.10 mm intervals without friction or mechanical effect, as follows. The skin surface was drawn into the opening of the movable part of the probe by negative pressure and the height of the skin sucked into the device was determined by a prism installed there (Fig. 3). In the present study, the measurement time was set at 4 seconds ; 2 seconds for suction at

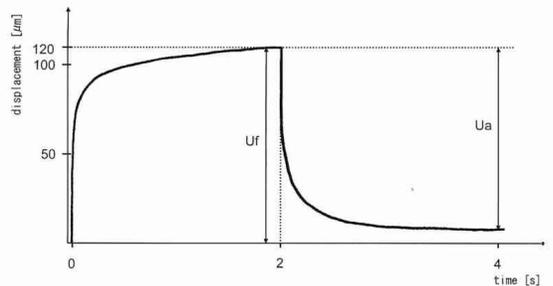


Figure 4. Curve illustrating the viscoelastic properties of the skin using vertical negative pressure. Uf, final distension ; Ua, final retraction ; Ua/Uf, skin elasticity.

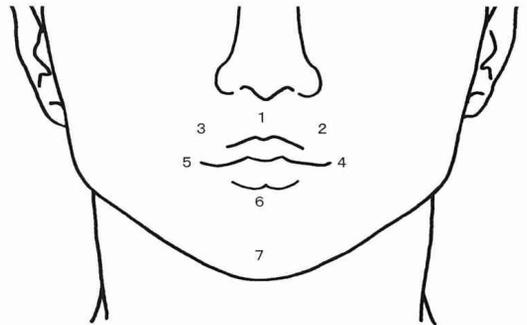


Figure 5. Facial landmarks.

1 ; upper lip point, 2 ; midpoint between left nose wing and angular nodal, 3 ; midpoint between right nose wing and angular nodal, 4 ; left angular nodal point, 5 ; right angular nodal point, 6 ; lower lip point, 7 ; soft tissue pogonion.

Table 2 Comparison of cephalometric measurements

Measurements	Class II n=13				Control n=14				Class II T1 -Control T1	Class II T2 -Control T2	Class II T1-T2	Control T1-T2
	T1		T2		T1		T2					
	Mean	SD	Mean	SD	Mean	SD	Mean	SD				
1; ∠SNA (°)	81.56	4.65	81.88	4.15	81.12	3.31	81.19	3.26	NS	NS	NS	NS
2; ∠SNB (°)	75.88	3.95	78.25	4.16	78.31	2.72	78.27	3.13	NS	NS	†	NS
3; ∠ANB (°)	5.69	2.20	3.63	1.62	2.81	1.13	2.92	1.10	**	NS	†	NS
4; Facial angle (°)	83.06	1.94	85.56	2.06	86.27	2.18	86.62	3.08	**	NS	†	NS
5; ∠FH plane to mandibular plane (°)	26.13	4.23	25.69	4.19	27.04	5.55	27.08	6.14	NS	NS	NS	NS
6; A to McNamara's line (mm)	-1.38	2.43	-0.25	2.73	-0.85	2.82	-0.50	2.80	NS	NS	NS	NS
7; Pogonion to McNamara's line (mm)	-14.50	3.58	-9.25	4.28	-8.00	3.39	-8.08	4.76	**	NS	†	NS
8; ∠U1 to FH plane (°)	118.13	2.76	116.44	4.08	117.62	4.50	116.35	5.44	NS	NS	NS	NS
9; ∠L1 to mandibular plane (°)	98.13	6.56	104.88	7.57	94.96	5.74	93.77	6.64	NS	**	†	NS
10; Overbite (mm)	4.88	0.83	2.75	1.04	1.73	1.09	2.27	0.93	**	NS	†	NS
11; Overjet (mm)	5.75	1.13	2.81	1.81	2.73	0.88	2.62	0.74	**	NS	†	NS
12; U1-Apo line (mm)	9.63	2.34	8.56	1.92	7.24	2.47	7.31	2.42	*	NS	†	NS
13; L1-Apo line (mm)	3.44	1.90	5.19	2.91	3.92	2.16	4.31	2.85	NS	NS	†	NS
14; Upper lip position (Rickett's E-line)(mm)	4.13	1.43	2.94	1.32	1.52	1.79	0.92	2.08	**	*	†	NS
15; Lower lip position (Rickett's E-line)(mm)	5.13	1.98	4.63	1.41	2.27	1.82	2.22	1.97	**	**	NS	NS
16; Nasolabial angle (°)	97.81	10.08	96.75	10.83	93.62	4.95	96.69	6.57	NS	NS	NS	NS
17; Mentolabial sulcus(mm)	5.52	1.54	5.14	2.56	4.04	1.38	4.54	1.65	*	NS	NS	NS

* p< 0.05, ** p< 0.01 (Mann-Whitney U-test), † p< 0.05 (Wilcoxon t-test)

400 mbar into the probe opening and 2 seconds for releasing the negative pressure. Elasticity^{8,13)} was quantified by calculating Ua/Uf, where Uf represented extension ability or the maximum amplitude of the displacement waveform of the skin height and Ua represented retraction ability of the skin height at 2 seconds after negative pressure was released (Fig. 4). These data were simultaneously transferred to the computer at the time of measurement. Determination of elasticity was performed in a dental unit of the orthodontic clinic with the room temperature set at 25±1°C and humidity at 35±5%. The subjects were placed in a sitting position with natural head posture.

4) Maxillofacial points for measuring soft tissue elasticity

The maxillofacial measuring points were determined with reference to the body measuring points reported by Martin¹⁴⁾, as follows (Fig. 5).

- (1) Upper lip point.
- (2) Mid-point between left nosewing and angular nodal point.
- (3) Mid-point between right nosewing and

angular nodal point.

- (4) Left angular nodal point.
- (5) Right angular nodal point.
- (6) Lower lip point.
- (7) Soft tissue pogonion.

Soft tissue elasticity was measured after instructing the subjects to close their lips in the intercuspation position at the first examination (T1) and 1 year later (T2).

5) Statistical analysis

- (1) Comparison of age at the time of measurement

The age difference at the time of measurement between the groups was examined using a Mann-Whitney U-test.

- (2) Lateral cephalogram analysis

Cephalogram images obtained at T1 and T2 in both groups were compared using a Mann-Whitney test. Those were also examined within each group before and after therapy using a Wilcoxon t-test.

- (3) Comparisons of soft tissue elasticity
 - a. Elasticity (Ua/UF) values at T1 and T2 were compared between the groups using

Table 3 Ua/Uf, skin elasticity

Measurements	Class II (n=13)				Control (n=14)				Class II T1 -Control T1	Class II T2 -Control T2	Class II T1-T2	Control T1-T2
	T1		T2		T1		T2					
	Mean	SD	Mean	SD	Mean	SD	Mean	SD				
① Upper lip point	0.141	0.024	0.199	0.047	0.225	0.066	0.222	0.014	*	NS	†	NS
② Midpoint between left nosewing and angular nodal	0.229	0.060	0.216	0.066	0.289	0.019	0.265	0.037	NS	NS	NS	NS
③ Midpoint between right nosewing and angular nodal	0.234	0.072	0.235	0.098	0.292	0.037	0.293	0.022	NS	NS	NS	NS
④ Left angular nodal point	0.262	0.056	0.210	0.087	0.291	0.043	0.285	0.020	NS	NS	NS	NS
⑤ Right angular nodal point	0.285	0.078	0.240	0.102	0.293	0.018	0.285	0.020	NS	NS	NS	NS
⑥ Lower lip point	0.241	0.032	0.245	0.072	0.286	0.045	0.293	0.036	NS	NS	NS	NS
⑦ Soft tissue pogonion	0.164	0.028	0.132	0.059	0.166	0.034	0.189	0.025	NS	NS	NS	NS

*p<0.05 (Mann-Whitney U-test) ; † p<0.05 (Wilcoxon t-test)

Table 4 Uf, final distension. (mm)

Measurements	Class II (n=13)				Control (n=14)				Class II T1 -Control T1	Class II T2 -Control T2	Class II T1-T2	Control T1-T2
	T1		T2		T1		T2					
	Mean	SD	Mean	SD	Mean	SD	Mean	SD				
① Upper lip point	0.130	0.022	0.183	0.049	0.208	0.066	0.209	0.013	*	NS	†	NS
② Midpoint between left nosewing and angular nodal	0.215	0.064	0.206	0.064	0.276	0.018	0.251	0.038	*	NS	NS	NS
③ Midpoint between right nosewing and angular nodal	0.218	0.069	0.224	0.094	0.279	0.036	0.280	0.023	*	NS	NS	NS
④ Left angular nodal point	0.248	0.055	0.193	0.081	0.271	0.048	0.265	0.023	NS	*	NS	NS
⑤ Right angular nodal point	0.265	0.069	0.225	0.093	0.272	0.020	0.260	0.021	NS	NS	NS	NS
⑥ Lower lip point	0.229	0.031	0.238	0.073	0.275	0.048	0.285	0.037	NS	NS	NS	NS
⑦ Soft tissue pogonion	0.116	0.017	0.123	0.056	0.151	0.032	0.176	0.021	*	NS	NS	NS

*p<0.05 (Mann-Whitney U-test) ; † p<0.05 (Wilcoxon t-test)

Table 5 Ua, final retraction. (mm)

Measurements	Class II (n=13)				Control (n=14)				Class II T1 -Control T1	Class II T2 -Control T2	Class II T1-T2	Control T1-T2
	T1		T2		T1		T2					
	Mean	SD	Mean	SD	Mean	SD	Mean	SD				
① Upper lip point	0.917	0.030	0.917	0.032	0.929	0.019	0.943	0.009	NS	NS	NS	NS
② Midpoint between left nosewing and angular nodal	0.936	0.027	0.951	0.009	0.954	0.010	0.946	0.023	*	NS	NS	NS
③ Midpoint between right nosewing and angular nodal	0.931	0.013	0.951	0.017	0.955	0.015	0.956	0.015	*	NS	NS	NS
④ Left angular nodal point	0.943	0.017	0.936	0.018	0.934	0.021	0.929	0.028	NS	NS	NS	NS
⑤ Right angular nodal point	0.930	0.015	0.934	0.020	0.927	0.011	0.911	0.019	NS	NS	NS	NS
⑥ Lower lip point	0.950	0.012	0.971	0.015	0.961	0.018	0.974	0.013	NS	NS	†	NS
⑦ Soft tissue pogonion	0.708	0.027	0.928	0.007	0.923	0.015	0.934	0.016	*	NS	†	NS

*p<0.05 (Mann-Whitney U-test) ; † p<0.05 (Wilcoxon t-test)

a Mann-Whitney U-test, while those were also examined within each group before and after therapy using a Wilcoxon t-test.

b. Uf values at T1 and T2 were compared between the groups using a Mann-Whitney U-test, while those were also compared within each group before and after therapy using a Wilcoxon t-test.

c. Ua values at T1 and T2 were compared

between the groups using a Mann-Whitney U-test, while those were also examined within each group before and after therapy using Wilcoxon t-test.

For all statistical analyses, SPSS 17.0J software (SPSS) was used. The present study was conducted after receiving approval from the ethics committee of Ohu University and informed consent from each subject.

RESULTS

1. Lateral cephalogram

1) Comparisons of T1 between groups

In a comparison of T1 between the groups, the Class II group had a significantly greater ($p < 0.01$) \angle ANB value of $+5.69^\circ$ for the skeletal pattern, whereas it had a significantly smaller ($p < 0.01$) facial angle of 83.06° and pogonion to McNamara's line of -14.50 mm. For the dental pattern, the U1-APo line in the Class II group was significantly longer ($p < 0.05$) at $+9.63$ mm. In addition, overbite was $+4.88$ mm and overjet $+5.75$ mm, which were significantly larger values. Soft tissue in the Class II group had significantly larger parameters ($p < 0.01$) of $+4.13$ mm for the upper lip position, $+5.13$ mm for the lower lip position, and $+5.52$ mm for the mentolabial sulcus.

2) Comparisons within Class II group

Measurements were performed before and after TBA therapy, and then compared within the Class II group. Values for the skeletal pattern showed significant increases ($p < 0.05$) after TBA therapy, as \angle SNB increased from 75.88° to 78.25° , facial angle from 83.06° to 85.56° , and pogonion to McNamara's line from -14.50 to -9.25 mm. For the dental pattern, the values showed significant decreases ($p < 0.05$) after TBA therapy, as \angle ANB decreased from $+5.69^\circ$ to $+3.63^\circ$, overbite from $+4.88$ to $+2.75$ mm, overjet from $+5.75$ to $+2.81$ mm, and the U1-APo line from $+9.63$ to $+8.56$ mm. Meanwhile, a significant increase ($p < 0.05$) was demonstrated after therapy, as \angle L1 to the mandibular plane increased from 98.13° to 104.88° and the L1-APo line from $+3.44$ to $+5.19$ mm. The soft tissue demonstrated a significant decrease ($p < 0.05$), as the upper lip position decreased from $+4.13$ to $+2.94$ mm.

3) Comparisons of T2 between the groups

In a comparison of T2 between the groups

after TBA therapy, the Class II group showed a significantly larger ($p < 0.01$) value for \angle L1 to the mandibular plane at 104.88° for the dental pattern. For the soft tissue, the values were significantly larger at $+2.94$ mm ($p < 0.05$) for the upper and $+4.63$ mm ($p < 0.01$) for the lower lip positions.

4) Comparisons within the control group

In a comparison of T1 and T2, no statistically significant differences were observed for all measured items for the skeletal and dental pattern, and soft tissue.

2. Soft tissue elasticity

1) Comparisons of T1 between the groups

In a comparison of T1 between the groups, the Class II group demonstrated statistically lower elasticity ($p < 0.05$) at 0.936 for the mid-point between the left nosewing and angular nodal, and 0.931 for the mid-point between the right nosewing and angular nodal. Elasticity for the soft tissue pogonion was also significantly lower ($p < 0.05$) at 0.708.

2) Comparisons within the Class II group

In a comparison of elasticity before and after TBA therapy within the Class II group, the T1 value was significantly lower at 0.950 for the lower lip and 0.708 for the soft tissue pogonion. The values after TBA therapy were similar to those of the control group.

3) Comparisons of T2 between the groups

In a comparison between the groups after TBA therapy, no statistically significant differences were observed for all measuring points. The values after TBA therapy were similar to those of the control group.

3. Uf

1) Comparisons of T1 between the groups

In a comparison of T1 between the groups, the Class II group demonstrated a significantly lower ($p < 0.05$) Uf value at 0.141 for the upper lip point.

2) Comparisons within the Class II group

In a comparison between the values obtained before and after TBA therapy, Uf for the upper lip point at the first examination was significantly lower ($p < 0.05$) at 0.141, while that after TBA therapy was similar to value for the control group.

4. Ua

1) Comparisons of T1 between the groups

In a comparison of T1 between the groups, the Class II group demonstrated significantly lower ($p < 0.05$) Ua values of 0.130 for the upper lip, 0.215 for the mid-point between the left nosewing and angular nodal, 0.218 for the mid-point between the right nosewing and angular nodal, and 0.116 for the soft tissue pogonion.

2) Comparisons within the Class II group

In a comparison between values obtained before and after TBA therapy, Ua for the upper lip point at the first examination was significantly lower ($p < 0.05$) at 0.130 and then became similar to that of the control group after TBA therapy.

3) Comparisons of T2 between the groups

In a comparison of T2 between the groups after TBA therapy, the Class II group showed a significantly lower ($p < 0.05$) Ua value of 0.193 for the left angular nodal point, which became similar to that of the control group after TBA therapy.

DISCUSSION

1. Subjects

In the present study, Class II malocclusion patients who demonstrated mandibular retrusion were used as the Class II study group, while patients with Class I malocclusion comprised the control group. The control group did not show any abnormalities in regard to maxillomandibular relation and axial inclination of the anterior teeth in the upper and lower jaws, thus natural growth was encouraged by extracting deciduous teeth for oral care for the

permanent teeth. We considered that the control group had generally normal occlusion.

2. Evaluation of soft tissue elasticity

A variety of methods for measuring soft tissue elasticity *in vivo* have been reported. Those include a technique that utilizes a suction device to aspirate the skin surface and determine its elasticity on the basis of changes in the height of the skin, such as that employed here. Another uses a device that twists the skin and measures the amount of rotation. Other methods measure dents on the skin made by placing a force on the surface, or use devices that determine the amount of rebound of the skin after an outer force is applied or measures the height of the skin after being pinched up. The present subjects were school-age children, thus we employed a Cutometer[®], which determines soft tissue elasticity with a less-invasive suction device and quantifies the obtained values in a short period of time on the basis of the height of skin sucked into an elastic probe.

Cutometer[®] elastic probes are available in diameters of 2, 4, 6, and 8 mm. Enomoto *et al*¹⁵⁾ measured 74 points all over the body of normal subjects using 2- and 8-mm diameter probes. They reported that the 8-mm probe had less dispersion in multiple determinations performed by the same individual, demonstrating a high level of reproducibility. It is important to closely attach the elastic probe to the skin surface to obtain high reproducibility and consistent results. In the present study, for determining the curved surface, we used a 2-mm elastic probe, which has a smaller skin suction area. Skin is composed of 3 layers, namely, the epidermis, which protects from extraneous stimuli and retains moisture, the dermis, which occupies 95% of the epithelium and consists of fibers and elastic tissues, and subcutaneous tissue, which is mostly comprised of subcutaneous adipose. It has been shown that suction of skin by a 2-mm

elastic probe can accurately reflect the elasticity of the epidermis and dermis¹³. For elasticity measurements with a Cutometer[®], age, body fat, skin disease, burn injury, and scarring are factors that can affect the results¹⁶⁻¹⁹. Accordingly, a history of skin diseases and Rohrer index were confirmed before performing the measurements in the present study.

3. Elasticity of maxillofacial soft tissue

1) Effects of obesity and gender difference on elasticity

It has been proposed that elasticity in the buccal region of the face and body fat percentage are correlated¹¹. However, Ishikawa *et al*²⁰. reported that elasticity of the dorsal surface of the middle section of the forefinger, center of the dorsal surface of the hand, center of the extensor side of the forearm, and lower part of the clavicle were not affected by gender difference and degree of obesity shown by Broca index. Thus, consensus has not been reached. The present subjects were school-aged children and those in the standard range within 130 ± 15 according to the Rohrer index for calculating obesity were selected.

2) Measuring points

Thin and small mimic muscles can be found in abundance under the skin of the face. These mimic muscles originate in and end in the skin, or in a combination of bone and skin. It is considered that the muscles move the skin itself, or the corresponding eye, ear, nose, and lip areas. Eisler noted that a small minority of striated muscle had a close relation with the outer skin²¹. This muscle tissue is differentiated from skeletal muscle and termed cutaneous muscle. In the present study, the measuring points of the mimic muscles fell within cutaneous muscle. Accordingly, it was considered that the elasticity reflected the mimic muscle activities.

4. Lateral cephalogram

In our comparisons of T1 between the Class

II and control groups, horizontal and vertical disagreement of the upper and lower jaws, and retrusion of the pogonion were observed, demonstrating horizontal and vertical abnormalities of the anterior teeth. Meanwhile, in soft tissue, protrusion of the upper and lower lips, and deep mentolabial sulcus were observed, demonstrating maxillary prognathism due to retrusion of the mandible.

In the Class II group, the therapeutic effects of forward growth of the mandible, which exceeded natural growth, and improvement of the overbite relationship of the anterior teeth were observed. Concerning the therapeutic effects of TBA therapy for Class II division 1 malocclusion, Trenouth²². and Illing *et al*²³. reported effective improvements of $\angle ANB$, while Patel *et al*²⁴, Baccetti²⁵ reported advancement of the pogonion. In the present study, advancements of the mandible and pogonion were evident after TBA therapy. Also, we observed that the anteroposterior position of the upper anterior teeth was retruded from the U1-APo line, which was considered to reflect a reduction of the U1-APo line due to advancement of the chin, as no labial inclination of the tooth axis was observed. The lower anterior teeth showed an increase in $\angle L1$ to the mandibular plane and the L1-APo line, demonstrating labial inclination. Siara *et al*²⁶. reported that the lower anterior teeth inclined to the labial side by 2.59° as a result of mandibular advancement by TBA therapy, while Jamilian *et al*²⁷. reported that the lower anterior teeth inclined to the labial side by $0.5 \pm 5.1^\circ$. Patel *et al*²⁴. classified their subjects into 2 groups on the basis of $\angle ANB$ changes improved by TBA therapy and reported that the lower anterior teeth showed a labial inclination of about 5° in both groups. On the basis of these findings, it is considered that the labial inclination of the lower anterior teeth can be affected by TBA therapy.

Varlik *et al*²⁸⁾. compared therapeutic effects between a TBA and an activator. They reported forward advancement of the mandibular soft tissue reference point and suggested that the effects of the devices might be similar. Meanwhile, Quintao *et al*⁴⁾. investigated TBA-treated and untreated groups, and found that the upper lip was retruded and the soft tissue pogonion advanced forward in the treated group, demonstrating improvement of the lateral profile of soft tissue. In the present study, for soft tissue changes, we considered that upper lip protrusion might be improved relatively by the decrease in upper lip position. Labial inclination of $\angle L1$ to the mandibular plane and an increase in the L1-APo line were observed as dental changes. However, since they were not associated with changes in the lower lip position and mentolabial sulcus, it was considered lower lip morphology might not be affected by axial inclination and anteroposterior positional changes of the lower anterior teeth.

In our comparison between the Class II and control groups after therapy, only $\angle L1$ to the mandibular plane, and the upper and lower lip positions demonstrated significant differences. Accordingly, it was considered that the skeletal morphology of the Class II group became similar to that of the control as a result of TBA therapy.

5. Relationship between soft tissue elasticity and maxillofacial morphology

1) Upper lip

Analysis of roentgenographic cephalograms indicated that the upper anterior teeth had forward positioning in association with upper lip protrusion in the Class II group at the time of the first examination, whereas there was no difference in axial inclination between the groups. Saxby *et al*²⁹⁾. studied the effects of the upper anterior teeth on the upper lip, and reported that the positions of the upper and

lower anterior teeth from the APo line were closely correlated with the positions of the upper and lower lips. Iwahashi *et al*³⁰⁾. showed that incomplete lip closure was induced by an increase in overbite due to labial inclination of the upper central incisor in subjects who could close their lips. In the present study, the Class II group demonstrated forward positioning of the upper anterior teeth at the time of the first examination. It was considered that lip closure might be difficult, as this condition affected the position of the upper lip. However, Kasai³¹⁾ pointed that the lower anterior teeth were closely related with the upper lip and point B of the soft tissue. Also, Kusnoto *et al*³²⁾. reported a correlation between backward movement of the lower anterior teeth and anteroposterior positioning of the lower lip. In our subjects, the position of the lower central incisor in the Class II group showed labial inclination due to dental compensation in comparison to that in the control group at the first examination. However, there was no significant difference in regard to the L1 to APo line. Accordingly, we concluded that the lower anterior teeth axis might not exert effects on the upper lip.

In the present study, elasticity at the upper lip point was not significantly different within the Class II group or between the groups. However, Uf and Ua values for the upper lip point were smaller at the first examination in the Class II group, and were increased after TBA therapy. Moreover, in a comparison between the groups at the first examination, elasticity at the mid-point between the left nosewing and angular nodal point, and mid-point between the right nosewing and angular nodal point showed reductions due to a low Ua value. In the Class II group, Ua was also observed to be low at the upper lip point, mid-point between the left nosewing and angular nodal point, and mid-point between the right nosewing and angular

nodal point at the first examination. Those points coincided with the sites where the upper orbicular muscle travels. Mashita³³⁾ investigated upper lip function and found that the upper lip moved less during closure in patients with Class II division 1 malocclusion. They suggested that lip pressure at the median of the upper lip might be low due to lower tension in the upper lip. On the basis of these findings, it was speculated that the reductions in lip pressure and Ua in the Class II group might be related.

In the Class II group, Ua and Uf values at the upper lip point were increased after therapy. Although elasticity at the mid-point between the left nosewing and angular nodal point and the mid-point between the right nosewing and angular nodal point was elevated, Uf and Ua values did not show any changes after therapy. Quintao *et al.*⁴⁾ reported that the lateral profile of soft tissue improved and that the upper lip receded, while the soft tissue pogonion moved forward as a result of TBA therapy. On the basis of these findings, it is speculated that upper lip function might be restored by improvement of the soft tissue profile, though elasticity showed a variable improving tendency that was dependent on the site.

In the Class II group, elasticity at the mid-point between the left nosewing and left angular nodal point, and mid-point between the right nosewing and angular nodal point was increased after therapy as compared that measured at the first examination, and became close to that of the control group 1 year later. This was considered to demonstrate that mouth closure can be restored due to improvements in the anteroposterior position of the mandible and overjet, irrespective of the effect of axial inclination on the upper anterior teeth.

2) Lower lip

Elasticity at the lower lip point at the first examination was not significantly different

between the groups, while it was increased after therapy in the Class II group. It was considered that elasticity might be increased in association with an increase in Ua due to morphological changes caused by TBA therapy, though elasticity, and Uf and Ua at the lower lip point were not problematic in the Class II group.

Tamari *et al.*³⁴⁾ analyzed lateral cephalograms of 50 adult women with individual normal occlusion, and reported that an anteroposterior position of the upper and lower lips might reflect the position of the upper and lower incisal edges, and upper and lower jaws. Moreover, Tomiyama *et al.*³⁵⁾ suggested that patients with incomplete lip closure had increased activity of the lower lip and lower orbicular muscle at the time of lip closure as compared to those who could close their lips. In addition, they speculated that the position of the lower anterior teeth and angle of inclination might exert effects on the lips. In the present study, elasticity at the lower lip point was increased after therapy in the Class II group and lateral cephalogram analysis revealed labial inclination of the axis of the lower anterior teeth. However in a comparison between the groups at T2, elasticity at the lower lip point did not show a significant difference, even though the axis of the lower anterior teeth demonstrated labial inclination in the Class II group. We considered the increase in elasticity at the lower lip point in the Class II group might have resulted from improvement of lip closing function due to forward growth of the mandible and reduction of overjet, but was not related to axial inclination or the degree of protrusion of the lower anterior teeth.

3) Chin

Lateral cephalogram analysis at the first examination revealed skeletal Class II malocclusion due to retrusion of the mandible in a comparison between the Class II and control groups. Elasticity of the soft tissue pogonion was

significantly low. Generally, Class II division 1 malocclusion patients with a large overjet have incomplete lip closure, for which the lower lip must be raised more when closing the lips due to anteroposterior abnormality. The lower lip is lifted more by the activity of the mentalis muscle, by which the skin surface of the chin becomes wrinkled. Tosello *et al*³⁶⁾ reported that the activities of the lower orbicular and mentalis muscles increased when closing the lips in Class II division 1 malocclusion patients with incomplete lip closure. The mentalis muscle originates from the alveolar border of the lower incisor and ends in the skin of the chin. The soft tissue pogonion, which was used as a measuring point in the present study, is located in the median of the chin and does not fall on the path of the mentalis muscle. However, as the subjects were instructed to close the lips during the measurements, our findings implicated that the activity of the mentalis muscle might affect the soft tissue pogonion.

In a comparison between measurements before and after the therapy in the Class II group, forward advancement of the chin and mandible was observed as a therapeutic effect of the TBA. Quintao *et al*⁴⁾ used Class II division 1 patients as subjects, and compared findings between those treated with and without TBA therapy. They reported that the TBA group showed retrusion of the upper lip and forward movement of the soft tissue pogonion, which resulted in improvement of the soft tissue profile. Singh^{6,7)} treated Class II division 1 subjects with TBA therapy and reported that the depth of the mentolabial sulcus improved, while the distance between the upper and lower lips decreased, resulting in favorable lip closure. In the present study, the depth of the mentolabial sulcus, which is located in the upper part of the chin, did not improve after therapy in the Class II group. However, it is considered that tension

in the chin might have been alleviated to the level of the control group.

In our study, elasticity of the soft tissue pogonion was increased after therapy due to the decrease in Uf and increase in Ua. Nishimura, Tsuji¹⁵⁾ found that Uf was increased, while Ua and elasticity were decreased in the left portion with aging. Ryu *et al*⁹⁾ measured the left portion, and reported that age and elasticity as well as Ua in the left were negatively correlated. Ezure *et al*⁸⁾ measured the lower part and reported that elasticity decreased with aging. In the present study, the soft tissue pogonion in the Class II group showed a significant increase in elasticity due to a decrease in Uf and increase in Ua after therapy, which demonstrated changes in contrast to the observations regarding aging reported previously. We consider that TBA therapy causes changes to the elasticity mechanism of the soft tissue pogonion in Class II patients.

CONCLUSION

In the Class II group, the elasticity of maxillofacial soft tissue was variably different from that of the control group before TBA therapy and then became close to that of the controls due to forward growth of the mandible as a result of TBA therapy. Since therapy not only improved the intermaxillary relationship and lateral profile of soft tissue, but also made the maxillofacial function close to that of the control, it is suggested that measurement of maxillofacial soft tissue elasticity is useful in patients with malocclusion.

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