

Unpredictability of soft tissue changes after camouflage treatment of Class II division 1 malocclusion with maximum anterior retraction using miniscrews

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ABSTRACT

Objective: To compare soft and hard tissue responses based on the degree of maxillary incisor retraction using maximum anchorage in patients with Class II division 1 malocclusion.

Materials and Methods: This retrospective study sample was divided into moderate retraction (<8.0 mm; n = 28) and maximum retraction (≥8.0 mm; n = 29) groups based on the amount of maxillary incisor retraction after extraction of the maxillary and mandibular first premolars for camouflage treatment. Pre- and posttreatment lateral cephalograms were analyzed.

Results: There were 2.3 mm and 3.0 mm of upper and lower lip retraction, respectively, in the moderate group; and 4.0 mm and 5.3 mm, respectively, in the maximum group. In the moderate group, the upper lip was most influenced by posterior movement of the cervical point of the maxillary incisor ($\beta = 0.94$). The lower lip was most influenced by posterior movement of B-point ($\beta = 0.84$) and the cervical point of the mandibular incisor ($\beta = 0.83$). Prediction was difficult in the maximum group; no variable showed a significant influence on upper lip changes. The lower lip was highly influenced by posterior movement of the cervical point of the maxillary incisor ($\beta = 0.50$), but this correlation was weak in the maximum group.

Conclusions: Posterior movement of the cervical point of the anterior teeth is necessary for increased lip retraction. However, periodic evaluation of the lip profile is needed during maximum retraction of the anterior teeth because of limitations in predicting soft tissue responses. (*Angle Orthod.* 2017;87:230–238)

KEY WORDS: Soft tissue; Tooth extraction; Skeletal Class II; Skeletal anchorage

INTRODUCTION

The goals of orthodontic treatment are providing ideal masticatory function and esthetic improvement to facial and dental features. To achieve these goals, it is necessary to create a balance between the soft and hard tissues, including the nose, lips, and jaw, and it is

important to consider variability among individuals.¹ Among the facial soft tissue changes resulting from orthodontic treatment, there is particular interest in changes in the position and contour of the lips, and various methods of predicting posttreatment soft tissue changes have been reported to establish a

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diagnosis and treatment plan.²⁻⁵ Choi et al.² reported that in adult female patients with Class II Division 1 malocclusion, the ratios of movement between labrale superioris (Ls) and labrale inferioris (Li) to the extent of anterior teeth retraction are 1:0.45 and 1:2.08, respectively, and that the amount of posterior movement of Ls is correlated with posterior movement of the maxillary incisal edge.

With recent advances in maximum anchorage devices such as miniscrews, a significant amount of posterior movement of the anterior teeth has become possible, which has expanded the boundaries of camouflage treatment for skeletal malocclusion. When Class II malocclusion patients are treated with miniscrew anchorage, the maxillary incisors show posterior retraction of 8.2 to 9.3 mm.^{6,7} However, to our knowledge, few studies have investigated soft and hard tissue responses depending on the amount of maxillary incisor retraction with and without maximum anchorage. To help clinicians predict treatment outcome, soft tissue responses need to be evaluated when using maximum anchorage to retract the anterior teeth maximally.

The aim of this study was to compare soft and hard tissue responses based on the degree of maxillary incisor retraction with and without maximum anchorage following extraction of the maxillary and mandibular first premolars for camouflage treatment in Korean patients with Class II Division 1 malocclusion. We hypothesized that soft tissue responses would differ when using maximum anchorage for retracting anterior teeth maximally in patients with Class II Division 1 malocclusion.

MATERIALS AND METHODS

Subjects

This retrospective study group included 3300 patients who visited the Department of Orthodontics, Yonsei Dental Hospital (Seoul, Korea) between November 2005 and July 2012 for Class II Division 1 malocclusion.

Inclusion criteria for the study were as follows: Korean ethnicity, age >18 years, presence of skeletal Class II Division 1 malocclusion with the angle formed by point A, nasion, and point B (ANB angle) >4°, a Class II canine and molar relationship, no missing teeth except for the third molars, and extraction of the four first premolars. Exclusion criteria were loss of one or more permanent teeth, severe craniofacial deformities such as a cleft lip or palate, history of orthodontic treatment or orthognathic surgery, and the presence of an anterior open bite.

Among the 3300 patients, 57 (23 men and 34 women) fulfilled the inclusion criteria. The sample was

divided into two groups according to the amount of retraction observed at the maxillary incisal edge after extraction of the maxillary and mandibular first premolars for camouflage treatment to improve the protrusive profile and to obtain a Class I occlusion with ideal overjet and overbite: moderate retraction (<8.0 mm; n = 28) group and maximum retraction (≥8.0 mm; n = 29) group. The mean pretreatment age of the subjects was 21.99 years (moderate group: 22.35 years; maximum group: 21.64 years), and the average treatment duration was 2.94 years (moderate group: 2.91 years; maximum group: 2.97 years).

All orthodontic treatment was performed by an orthodontist. After extraction of the four first premolars, the brackets having 0.018-inch slots in the Roth prescription were applied. Leveling and alignment were started using 0.016-inch nickel-titanium archwires followed by 0.016-inch round stainless steel archwires. Subsequently, the maxillary and mandibular anterior teeth were retracted using a 0.017 × 0.025-inch stainless rectangular archwire. In a maximum retraction case, two miniscrews (1507C, Biomaterials Korea, Seoul, Korea) were placed between the maxillary second premolars and first molars to reinforce anchorage during space closure. Elastic chains (Ormco, Glendora, Calif) were stretched from each miniscrew head to corresponding crimpable hooks (TP Orthodontics, La Porte, Ind) with a force magnitude of approximately 150 g on each side. This study conformed to the tenets of the Declaration of Helsinki on medical protocols and ethics and was approved by the Institutional Review Board of Yonsei Dental Hospital (IRB 2-2015-0016).

Methods

Before and after treatment, lateral cephalograms (Cranex 3+ Ceph, Soredex, Helsinki, Finland) were obtained in the natural head position with the teeth in centric occlusion and lips relaxed and in contact, then digitized using V-Ceph software (version 3.5; Cybermed, Seoul, Korea) by a trained and calibrated observer who was blinded to the clinical status of the patients. The horizontal reference plane (HRP) was established on sella and oriented 7° inferior to the sellanasion line, while the vertical reference plane (VRP) passed through sella, perpendicular to the HRP. Perpendicular distances of the landmarks from the HRP and VRP and lip thicknesses before and after treatment were measured and compared. The cephalometric landmarks, reference planes, skeletal and dental measurements, soft tissue measurements, and abbreviations used in the present study are organized in Figure 1.

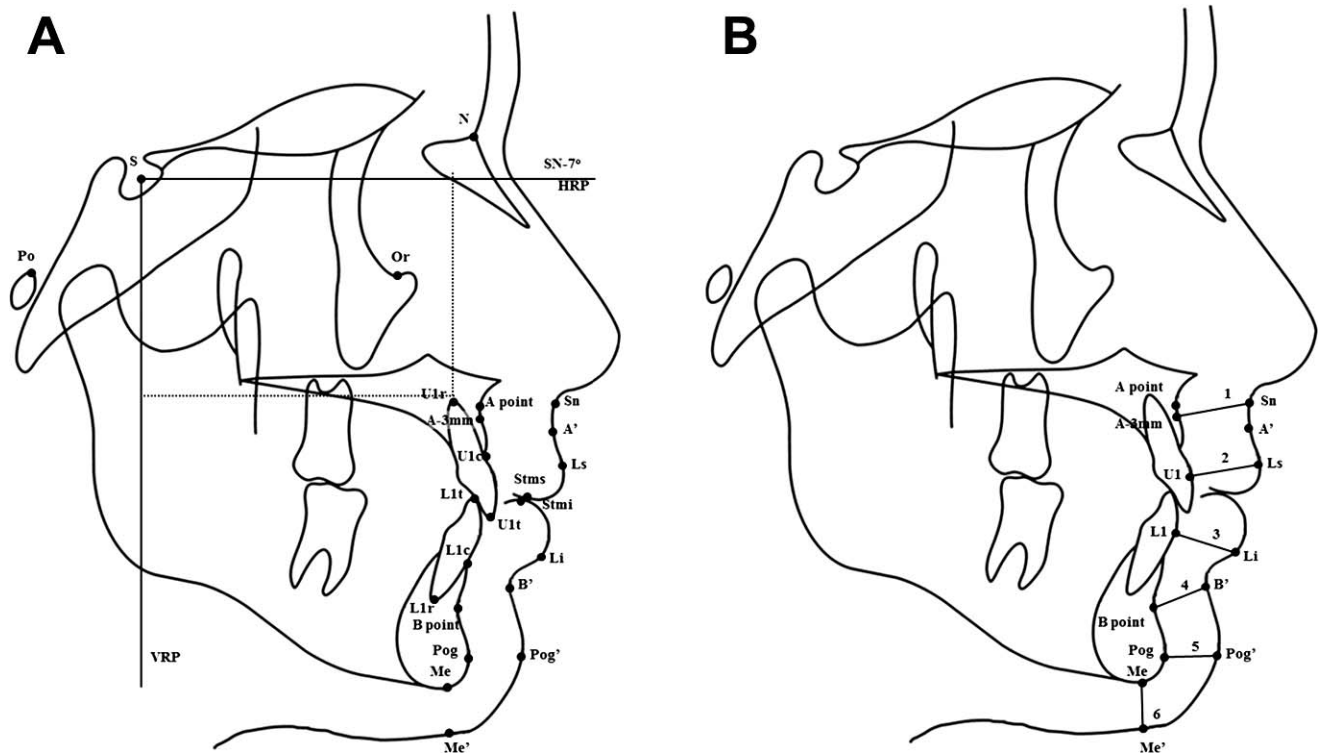


Figure 1. Landmarks, reference lines, and definitions of measurement for cephalometric analysis. **(A)** Skeletal, dental, and soft tissue landmarks. Horizontal reference planes (HRPs) and vertical reference planes (VRPs) used to measure movements of individual landmarks: sella (S), nasion (N), point A (A), 3 mm below point A (A-3), point B (B), pogonion (Pog), menton (Me), maxillary central incisor (U1), mandibular central incisor (L1), root apex of the maxillary central incisor (U1r), cervical point (cemento-enamel junction) of the maxillary central incisor (U1c), tip (most anterior and inferior point) of the maxillary central incisor (U1t), tip (most anterior and superior point) of the mandibular central incisor (L1t), cervical point of the mandibular central incisor (L1c), root apex of the mandibular central incisor (L1r), subnasale (Sn), soft tissue point A (A'), labrale superioris (Ls), stomion superioris (Stms), stomion inferioris (Stmi), labrale inferioris (Li), soft tissue point B (B'), soft tissue pogonion (Pog'), soft tissue menton (Me'). **(B)** Lip thickness. (1) Basic upper lip thickness; (2) upper lip thickness (shortest distance between Ls and U1 surface); (3) lower lip thickness (shortest distance between Li and L1 surface); (4) basic lower lip thickness; (5) horizontal chin thickness; (6) vertical chin thickness; upper lip strain (difference between basic upper lip thickness and upper lip thickness).

Reliability

All cephalometric radiographs were traced and digitized by the same observer. Sixteen samples were randomly selected and retraced and redigitized after a 1-week interval. Errors in measuring values were calculated using intraclass correlation coefficients to determine reliability. These coefficients were all ≥ 0.91 , except for the overbite (0.84) and occlusal plane to GoMe angle (0.76), indicating a lack of significant error in the measurements.

Statistical Analysis

All statistical analyses were performed using SAS version 9.2 for Windows (SAS Inc, Cary, NC). Based on a preliminary study, a minimum sample size of 34 was determined (G*Power 3, Dusseldorf, Germany) using a significance level of $P < .05$, a power of 80%, and an effect size of 1.00 to detect differences in the amount of Ls retraction between the moderate and maximum retraction groups by using an independent t -

test. In order to verify the normality of the data distribution, the Kolmogorov-Smirnov test was applied. Descriptive statistics, such as mean and standard deviation (SD), were used to describe the distribution of each variable in the study. Independent t -tests were used to evaluate differences in treatment-related soft and hard tissue changes between the two groups. Pearson's correlation coefficients were calculated to assess the association between soft and hard tissue changes. A simple linear regression analysis was used to determine variables that predicted soft tissue changes of the lips at a significance level of $P < .05$.

RESULTS

There was no significant difference in pretreatment skeletal measurements between the two groups, but there was significant difference in pretreatment dental measurements, including the angle of the sella-nasion plane to the upper incisor axis (U1 to SN) or in the angle or distance of the nasion-point A plane to the maxillary incisor (U1 to NA) between groups (Table 1).

Table 1. Comparison of Pretreatment Cephalometric Characteristics Between Moderate and Maximum Retraction Groups

Variable	Moderate Retraction Group		Maximum Retraction Group		P Value
	Mean	SD ^a	Mean	SD	
SNA (°)	81.67	3.53	81.45	3.66	.819
SNB (°)	75.69	3.43	75.72	3.75	.973
ANB difference (°)	5.98	1.66	5.73	1.59	.563
Wits (mm)	1.45	2.31	2.69	2.43	.052
SN-GoMe (°)	39.55	5.91	39.74	5.88	.902
Occlusal plane to GoMe (°)	19.03	4.33	20.53	4.77	.221
FMA (°)	30.86	5.61	30.61	5.65	.868
U1 to SN (°)	106.53	6.32	112.28	6.39	.001**
U1 to NA (°)	24.86	5.82	30.83	6.98	.001**
U1 to NA (mm)	6.18	2.28	8.67	2.37	.000***
L1 to NB (°)	35.71	7.07	38.90	5.41	.062
L1 to NB (mm)	11.68	3.41	12.16	2.61	.547
IMPA (°)	100.50	8.28	103.48	7.97	.172
Interincisal angle (°)	113.45	10.18	104.54	9.24	.001**

^a SD indicates standard deviation; U1, maxillary central incisor; L1, mandibular central incisor.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

In terms of posttreatment skeletal changes, there was almost no horizontal change in B-point in the moderate group, but in the maximum group it moved about 1.2 mm posteriorly ($P < .01$) (Table 2).

The maxillary incisal tip (U1t) and cervical point (U1c) showed retractions of 5.28 ± 1.71 mm and 4.19 ± 1.18 mm, respectively, in the moderate group, and 9.91 ± 1.33 mm and 6.23 ± 1.31 mm, respectively, in the maximum group; differences between the two groups were significant ($P < .001$). The mandibular incisal tip (L1t) and cervical point (L1c) showed retractions of 4.39 ± 2.51 mm and 3.28 ± 2.08 mm, respectively, in the moderate group, and 6.87 ± 2.18 mm and 5.70 ± 1.58 mm, respectively, in the maximum group. The amount of posterior movement of the mandibular incisors also differed significantly between the two groups ($P < .001$) (Table 2). In both groups, clinically meaningful root resorption was not observed after treatment.

Upper lip thickness increased and upper lip strain decreased in both groups, but the changes in the maximum group were significantly greater than those observed in the moderate group ($P < .01$). There was no significant difference between the two groups with respect to changes in the lower lip (Table 3).

Horizontal changes in soft tissue, such as subnasale (Sn), soft tissue point A (A'), Ls, stomion superioris (Stms), stomion inferioris (Stmi), and Li were significantly greater in the maximum group than in the moderate group ($P < .05$). Especially, the amounts of Ls and Li retraction were 2.28 ± 1.73 mm and 3.04 ± 2.20 mm, respectively, in the moderate group, and 4.00

± 1.68 mm and 5.34 ± 1.62 mm, respectively, in the maximum group, and significantly different between the two groups ($P < .001$). In contrast, vertical changes in the soft tissue were minimal, and we observed no significant difference between the two groups (Table 3).

In the moderate group, posterior movement of Ls was most strongly correlated with posterior movement of U1c ($r = .64$; $P < .001$; Table 4). Posterior movement of Li was most highly correlated with posterior movements of L1c ($r = .79$; $P < .001$). In the maximum group, posterior movement of Li was highly correlated with posterior movements of L1t ($r = .51$; $P < .01$).

A simple regression analysis revealed that in the moderate group, posterior movement of Ls was also mostly influenced by posterior movement of U1c ($\beta = 0.94$; $P < .001$; Table 5). Posterior movement of B-point had the largest influence on posterior movement of Li ($\beta = 0.84$; $P < .001$). In the maximum group, no variable significantly influenced posterior movements of Ls or Stms. Posterior movement of U1c had the greatest influence on horizontal movement of Li ($\beta = 0.50$; $P < .05$).

DISCUSSION

Although previous studies have examined the responses of Ls and Li from posterior movements of the maxillary and mandibular incisors in orthodontic treatment involving premolar extraction, they have used traditional anchorage to estimate various soft tissue responses during maxillary incisal retraction based on the skeletal and dental characteristics of the subjects.^{2-4,8-11} In this study, we used maximum anchorage for treating Class II Division 1 malocclusion to examine how soft and hard tissues respond in cases with very large retractions of the anterior teeth. Soft and hard tissue responses were compared between the moderate and maximum retraction groups, with the hypothesis that soft and hard tissue responses differ when using maximum anchorage for retracting the anterior teeth maximally.

For the camouflage treatment of patients with Class II malocclusion, the amount of retraction of the maxillary teeth in the maximum group was similar to that observed in a previous study by Kuroda et al.,⁶ in which 9.3 mm of retraction was detected in a group with skeletal anchorage. As expected, the amount of retraction in the maxillary incisal region in this study increased noticeably when using maximum anchorage.

In both groups, the upper and lower lips were retracted along with tooth movement, but the movement was significantly greater in the maximum group than in the moderate group. A previous study that used traditional anchorage after extraction of the premolars

Table 2. Comparison of Hard Tissue Pre- and Posttreatment Measurements and Treatment Changes Between Moderate and Maximum Retraction Groups

Skeletal Variable	T1 ^a				T2				T1-T2				P Value
	Moderate Retraction Group		Maximum Retraction Group		Moderate Retraction Group		Maximum Retraction Group		Moderate Retraction Group		Maximum Retraction Group		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
SNA (°)	81.67	3.53	81.45	3.66	81.00	3.13	80.44	3.60	0.66	1.24	1.01	1.09	.262
SNB (°)	75.69	3.43	75.72	3.75	75.64	3.30	75.13	3.79	0.05	0.90	0.59	0.86	.024*
ANB difference (°)	5.98	1.66	5.73	1.59	5.37	1.90	5.31	1.46	0.61	1.22	0.42	1.22	.558
Wits (mm)	1.45	2.31	2.69	2.43	-0.03	2.44	-0.20	2.92	1.47	2.41	2.90	3.30	.070
SN-GoMe (°)	39.55	5.91	39.74	5.88	39.53	6.12	39.77	5.81	0.02	1.33	-0.03	1.49	.903
Occlusal plane to GoMe (°)	19.03	4.33	20.53	4.77	17.88	4.50	17.09	4.23	1.16	1.85	3.44	3.46	.003**
FMA (°)	30.86	5.61	30.61	5.65	30.41	6.62	30.50	5.53	0.45	2.42	0.11	2.04	.562
VRP to A (mm)	69.15	5.14	70.20	5.18	68.44	4.92	68.93	4.96	0.71	1.20	1.27	1.19	.085
VRP to B (mm)	55.96	7.63	57.39	7.29	56.01	7.45	56.18	7.80	-0.05	1.72	1.21	1.54	.005**
VRP to Pog (mm)	55.06	8.24	55.84	8.26	55.40	8.31	55.48	8.75	-0.34	2.01	0.36	1.79	.171
HRP to A (mm)	57.79	5.08	58.61	4.28	58.22	4.88	59.08	4.41	-0.43	1.38	-0.47	1.75	.918
HRP to B (mm)	106.79	9.23	105.30	7.78	106.07	10.15	105.13	8.04	0.72	2.74	0.17	1.84	.376
HRP to Pog (mm)	118.00	8.54	118.78	8.43	118.19	8.31	119.28	8.50	-0.19	1.26	-0.50	1.48	.399

Dental Variable	T1 ^a				T2				T1-T2				P Value
	Moderate Retraction Group		Maximum Retraction Group		Moderate Retraction Group		Maximum Retraction Group		Moderate Retraction Group		Maximum Retraction Group		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
U1 to SN (°)	106.53	6.32	112.28	6.39	100.31	6.95	96.83	5.46	6.22	7.38	15.45	5.46	.000***
U1 to NA (°)	24.86	5.82	30.83	6.98	19.30	6.76	16.40	4.80	5.56	8.08	14.44	5.62	.000***
U1 to NA (mm)	6.18	2.28	8.67	2.37	2.31	1.81	1.43	1.25	3.87	2.45	7.24	2.55	.000***
L1 to NB (°)	35.71	7.07	38.90	5.41	28.47	5.66	30.63	5.42	7.24	7.38	8.27	6.94	.589
L1 to NB (mm)	11.68	3.41	12.16	2.61	7.10	2.82	6.23	1.92	4.58	2.62	5.93	2.41	.048*
IMPA (°)	100.50	8.28	103.48	7.97	93.33	7.09	95.76	6.94	7.17	7.16	7.71	7.10	.775
Interincisal angle (°)	113.45	10.18	104.54	9.24	126.86	8.57	127.66	6.69	-13.41	11.62	-23.13	9.15	.001***
VRP to U1t (mm)	74.74	5.81	78.18	6.12	69.45	5.78	68.27	6.17	5.28	1.71	9.91	1.33	.000***
VRP to U1c (mm)	73.31	5.36	75.05	5.43	69.12	5.48	68.82	5.59	4.19	1.18	6.23	1.31	.000***
VRP to U1r (mm)	63.64	4.96	64.55	4.77	61.70	5.02	61.96	4.87	1.94	2.55	2.59	2.21	.307
VRP to L1t (mm)	70.75	6.63	72.46	5.94	66.36	5.49	65.59	5.75	4.39	2.51	6.87	2.18	.000***
VRP to L1c (mm)	66.64	7.16	67.89	6.61	63.36	6.23	62.19	6.65	3.28	2.08	5.70	1.58	.000***
VRP to L1r (mm)	55.69	7.32	56.34	6.65	53.69	6.69	52.23	7.33	2.00	1.99	4.11	1.96	.000***
HRP to U1t (mm)	85.07	6.20	85.89	5.62	84.48	6.07	85.81	5.53	0.59	1.14	0.08	1.46	.148
HRP to U1c (mm)	72.10	6.08	72.93	5.30	71.59	6.08	72.83	5.47	0.51	1.05	0.10	1.45	.230
HRP to U1r (mm)	59.80	5.38	61.64	5.06	59.84	5.23	60.44	5.47	-0.04	1.47	1.20	2.08	.013*
HRP to L1t (mm)	82.68	6.34	83.22	5.56	81.21	6.03	82.81	5.53	1.47	1.89	0.41	2.14	.053
HRP to L1c (mm)	91.91	6.48	92.21	6.11	90.78	6.20	92.12	5.79	1.13	1.54	0.09	1.51	.013*
HRP to L1r (mm)	98.91	7.00	98.81	6.63	98.77	6.76	99.65	6.46	0.14	1.48	-0.84	1.58	.019*
Overjet (mm)	4.40	1.92	6.11	2.78	3.80	0.55	3.37	0.83	0.61	2.13	2.74	2.65	.001**
Overbite (mm)	1.54	1.49	1.56	1.84	2.40	0.81	2.19	0.81	-0.86	1.48	-0.63	1.92	.629

^a T1 indicates at pretreatment; T2, at posttreatment; SD, standard deviation; VRP, vertical reference plane; HRP, horizontal reference plane; U1t, tip of the maxillary central incisor; U1c, cervical point of the maxillary central incisor; U1r, apex of the maxillary central incisor; L1t, tip of the mandibular central incisor; L1c, cervical point of the mandibular central incisor; L1r, apex of the mandibular central incisor.

* $P < .05$; ** $P < .01$; *** $P < .001$.

reported upper and lower lip retractions of 2.5 to 3.2 mm and 3.4 to 3.5 mm, respectively, which were similar to the retractions of 2.3 and 3.0 mm observed in this study in the moderate group, but smaller than those seen in the maximum group (4.0 and 5.3 mm; Table 3). Because the amount of tooth movement in the maximum group was greater than that observed in

previous studies, the amount of soft tissue movement was also greater.

There was no major change in basic upper lip thickness in either group following treatment; however, posttreatment upper lip thickness and lip strain did show significant differences between the groups. Upper lip thickness increased by 1.7 mm in the moderate group and by 2.8 mm in the maximum

Table 3. Comparison of Soft Tissue Pre- and Posttreatment Measurements and Treatment Changes Between Moderate and Maximum Retraction Groups

Soft Tissue Variable	T1 ^a				T2				T1-T2				P Value
	Moderate Retraction Group		Maximum Retraction Group		Moderate Retraction Group		Maximum Retraction Group		Moderate Retraction Group		Maximum Retraction Group		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Basic upper lip thickness (mm)	14.97	1.86	14.64	1.69	14.41	1.93	13.99	1.64	0.56	0.58	0.65	0.62	.570
Upper lip thickness (mm)	13.24	2.17	12.63	1.64	14.97	2.49	15.44	1.86	-1.73	1.29	-2.81	1.61	.007**
Upper lip strain (mm)	1.73	2.02	2.01	2.13	-0.56	1.90	-1.45	1.99	2.29	1.16	3.46	1.58	.002**
Lower lip thickness (mm)	14.81	1.76	15.31	1.73	15.49	2.33	15.66	1.80	-0.68	1.68	-0.35	1.90	.498
Basic lower lip thickness (mm)	17.08	2.88	16.34	2.22	15.29	2.58	14.66	2.03	1.79	1.69	1.68	1.78	.811
Horizontal chin thickness (mm)	15.43	3.52	14.55	3.10	15.09	3.11	14.25	2.99	0.34	2.92	0.30	1.56	.954
Vertical chin thickness (mm)	7.27	1.96	7.51	1.60	8.03	2.51	8.31	1.94	-0.76	1.23	-0.80	0.96	.891
Nasolabial angle (°)	99.33	11.63	96.2	10.13	103.98	9.48	103.15	8.89	-4.65	6.18	-6.95	6.52	.177
Mentolabial sulcus angle (°)	142.43	11.59	141.67	14.23	139.50	9.00	138.48	15.98	2.92	12.66	3.19	13.13	.938
VRP to Sn (mm)	83.93	6.24	84.11	5.30	83.10	6.23	82.78	5.32	0.82	0.84	1.32	0.95	.040*
VRP to A' (mm)	83.62	6.09	83.93	5.16	82.38	6.39	82.09	5.28	1.23	0.86	1.84	0.80	.007**
VRP to Ls (mm)	87.81	6.31	89.42	6.01	85.53	6.86	85.42	5.60	2.28	1.73	4.00	1.68	.000***
VRP to Stms (mm)	79.94	6.24	83.01	6.65	76.35	6.97	76.13	5.97	3.59	2.24	6.88	2.32	.000***
VRP to Stmi (mm)	78.92	6.23	81.45	5.91	74.94	6.31	74.69	6.73	3.98	2.07	6.76	1.76	.000***
VRP to Li (mm)	82.08	7.89	83.97	6.79	79.04	7.67	78.62	7.07	3.04	2.20	5.34	1.62	.000***
VRP to B' (mm)	72.61	7.67	73.43	7.70	70.70	7.83	70.34	8.03	1.91	2.20	3.09	2.22	.050
VRP to Pog' (mm)	69.71	8.99	69.79	8.17	69.74	8.90	69.03	8.30	-0.03	2.79	0.76	2.20	.238
HRP to Sn (mm)	56.61	5.24	57.05	4.44	57.24	5.02	58.04	4.61	-0.64	1.03	-0.99	0.86	.160
HRP to A' (mm)	59.83	5.58	59.62	4.56	60.54	5.26	60.95	4.73	-0.71	1.17	-1.33	1.35	.067
HRP to Ls (mm)	71.76	7.60	72.47	5.25	72.73	6.69	74.13	5.72	-0.96	1.54	-1.66	1.50	.089
HRP to Stms (mm)	82.27	7.29	82.97	5.55	82.58	6.90	83.51	5.37	-0.31	1.22	-0.54	1.44	.534
HRP to Stmi (mm)	83.54	6.79	84.32	6.63	82.73	6.92	84.04	5.69	0.81	2.06	0.28	2.34	.370
HRP to Li (mm)	95.64	7.10	96.30	7.11	94.44	7.79	95.20	6.54	1.20	2.68	1.10	2.52	.883
HRP to B' (mm)	104.08	9.38	104.27	8.23	103.33	9.48	103.11	7.77	0.75	2.59	1.16	2.02	.512
HRP to Pog' (mm)	114.84	10.51	116.2	8.51	114.92	9.64	116.54	8.04	-0.08	3.58	-0.34	2.68	.753

^a T1 indicates at pretreatment; T2, at posttreatment; SD, standard deviation; VRP, vertical reference plane; HRP, horizontal reference plane.
 * $P < .05$; ** $P < .01$; *** $P < .001$.

Table 4. Pearson's Correlation Coefficients Between Soft Tissue Component of Upper and Lower Lips and Hard Tissue for Moderate and Maximum Retraction Groups^a

Soft Tissue Variables	Hard Tissue Variables						
	Moderate Retraction Group				Maximum Retraction Group		
VRP ^b to Sn	VRP to A 0.43*	VRP to L1c 0.41*	VRP to U1c 0.39*	VRP to B 0.38*			
VRP to A'	VRP to U1c 0.42*					VRP to L1c 0.48**	VRP to U1c 0.48**
VRP to Ls	VRP to U1c 0.64***	VRP to U1t 0.52**	HRP to U1c 0.38*	HRP to U1t 0.37*			
VRP to Stms	VRP to U1t 0.74***	VRP to U1c 0.57**	HRP to U1t 0.38*				
VRP to Stmi	VRP to U1t 0.73***	VRP to L1c 0.62***	VRP to L1t 0.58**	VRP to U1c 0.39*	VRP to B 0.38*	VRP to Pog 0.45*	VRP to U1t 0.44*
VRP to Li	VRP to L1c 0.79***	VRP to B 0.66***	VRP to L1t 0.64***	VRP to Pog 0.63***	VRP to U1t 0.56**	VRP to L1t 0.51**	VRP to L1c 0.46*
VRP to B'	VRP to Pog 0.73***	VRP to B 0.66***	VRP to L1c 0.52**			VRP to B 0.71***	VRP to Pog 0.63***
VRP to Pog'	VRP to Pog 0.53**	VRP to L1c 0.46*	VRP to B 0.46*	VRP to L1t 0.42*		VRP to Pog 0.86***	VRP to B 0.83***

^a This table presents only statistically significant results.

^b VRP indicates vertical reference plane; HRP, horizontal reference plane; U1t, tip of the maxillary central incisor; U1c, cervical point of the maxillary central incisor; L1t, tip of the mandibular central incisor; L1c, cervical point of the mandibular central incisor.

* $P < .05$; ** $P < .01$; *** $P < .001$.

group, while upper lip strain was reduced by 2.3 mm in the moderate group and by 3.5 mm in the maximum group, indicating greater changes in the maximum group (Table 3). The increased thickness of the upper lip was consistent with the results of previous studies,^{3,4,12} but the magnitude of change in the maximum group was relatively large. The reduction in lip strain may be a result of the recovery of upper lip thickness because of hard tissue retraction.

Posterior movement of the upper lip was not correlated with skeletal variables in the moderate group, but was correlated with dental variables. Unlike in the moderate group, no skeletal or dental variable was significantly correlated with horizontal movements of the upper lip in the maximum group. In the regression analysis, the prediction of soft tissue changes was also difficult. Ramos et al.¹³ reported that in cases with a large overjet from extreme maxillary incisor proclination prior to treatment, the amount of retraction of U1c was smaller than that of U1t, and resulted in less lip change. In this study, the incisal region protruded more in the maximum group before treatment, and the amount of U1c retraction was relatively smaller than that of U1t retraction compared with the moderate group, resulting in a reduced lip response.

Although posterior movements of the lower lip in the maximum group were correlated with posterior movements of dental and skeletal variables, most of these correlations were lower than those observed in the moderate group. Based on the regression analysis,

U1c and L1c had large influences on posterior movements of the lower lip, but these influences were smaller than those observed in the moderate group. These findings indicate that in the maximum group, the soft tissue response to the increase in the amount of mandibular incisal retraction was not proportional to the amount of mandibular incisal retraction.

There are a few limitations to the present study. First, the ratio of the amount of soft tissue movement to the amount of tooth retraction can be affected by many factors, including dentofacial morphology, age, sex, ethnicity, and study methodology.^{4,8,14} Moreover, owing to individual variability in soft tissues of the musculo-nervous system, it was difficult to determine the accuracy of lip posture during imaging. Although lip strain should be considered in both the soft tissue analysis and lip thickness evaluation, it does show not only differences between individuals, but also temporal differences within individuals; accordingly, these variables could not be controlled for or quantified. There is a lack of research methodology to categorize continuous variables such as the amount of retraction. Further studies using complementary research methods are needed.

CONCLUSIONS

- In the moderate retraction group, the upper lip was influenced by dental variables alone, whereas the lower lip was influenced by both dental and skeletal variables.
- The U1c had a greater influence than did the incisal tip on posterior movements of the upper and lower lips.
- In contrast, in the maximum retraction group, no dental or skeletal variable was significantly influenced by upper lip retraction; however, similar to the moderate retraction group, lower lip retraction was influenced by both dental and skeletal variables, although these effects were weak.
- These results suggest that as tooth retraction increases when using maximum anchorage, soft tissue changes do not match those of hard tissues. Periodic evaluation of the lip profile is needed during maximum retraction of the anterior teeth because of limitations in predicting soft tissue responses.

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Table 4. Extended

Hard Tissue Variables		
Maximum Retraction Group		
VRP to B 0.42*	VRP to U1t 0.41*	VRP to Pog 0.39*
VRP to B 0.43*	VRP to U1c 0.39*	
VRP to B 0.43*	VRP to Pog 0.42*	VRP to U1c 0.41*
VRP to U1c 0.45*	VRP to L1c 0.41*	
VRP to L1c 0.48**		

Table 5. Simple Linear Regression Between Soft Tissue Component of Upper And Lower Lips and Hard Tissue for Moderate and Maximum Retraction Groups

Variables		Moderate Retraction Group					Maximum Retraction Group					P Value
Dependent	Independent	Beta	Intercept	SE	t	P Value	Beta	Intercept	SE	t	P Value	
VRP ^a to Ls	VRP to A	0.351	2.027	0.275	1.28	.213	0.29	3.637	0.266	1.09	.286	.873
	VRP to B	-0.018	2.277	0.197	-0.09	.928	0.017	3.983	0.209	0.08	.936	.903
	VRP to Pog	-0.031	2.267	0.169	-0.18	.858	-0.115	4.045	0.179	-0.64	.525	.732
	VRP to U1t	0.527	-0.505	0.17	3.1	.005**	0.443	-0.389	0.228	1.95	.062	.769
	VRP to U1c	0.942	-1.67	0.22	4.28	.000***	0.345	1.856	0.237	1.46	.157	.074
	VRP to L1t	0.166	1.55	0.131	1.26	.217	0.152	2.961	0.145	1.04	.306	.942
	VRP to L1c	0.187	1.662	0.159	1.18	.25	0.087	3.51	0.203	0.43	.673	.698
	HRP to U1t	0.57	1.939	0.277	2.06	.050*	-0.015	4.005	0.221	-0.07	.945	.107
HRP to U1c	0.627	1.956	0.298	2.1	.045*	-0.065	4.011	0.222	-0.29	.771	.07	
VRP to Stms	VRP to A	0.224	3.432	0.364	0.62	.543	0.598	6.12	0.359	1.67	.107	.467
	VRP to B	0.271	3.606	0.249	1.09	.287	0.003	6.874	0.29	0.01	.991	.486
	VRP to Pog	0.337	3.707	0.208	1.62	.117	-0.115	6.919	0.249	-0.46	.648	.168
	VRP to U1t	0.964	-1.499	0.174	5.55	<.0001***	0.501	1.91	0.323	1.55	.132	.197
	VRP to U1c	1.075	-0.911	0.305	3.52	.002**	0.2	5.631	0.338	0.59	.559	.065
	VRP to L1t	0.284	2.348	0.166	1.71	.099	0.137	5.938	0.204	0.67	.507	.577
	VRP to L1c	0.37	2.376	0.198	1.87	.073	0.151	6.015	0.281	0.54	.594	.523
	HRP to U1t	0.744	3.149	0.357	2.08	.047*	0.006	6.878	0.306	0.02	.984	.129
VRP to Stmi	VRP to A	0.356	3.723	0.331	1.07	.293	0.255	6.439	0.282	0.91	.373	.818
	VRP to B	0.454	4	0.218	2.08	.047*	0.495	6.165	0.198	2.5	.019*	.892
	VRP to Pog	0.348	4.096	0.189	1.84	.077	0.447	6.604	0.169	2.65	.013*	.701
	VRP to U1t	0.884	-0.696	0.162	5.47	<.0001***	0.582	1	0.23	2.53	.018*	.281
	VRP to U1c	0.688	1.093	0.315	2.18	.038*	0.517	3.54	0.238	2.17	.039*	.664
	VRP to L1t	0.474	1.897	0.132	3.6	.001**	0.202	5.374	0.151	1.34	.191	.18
	VRP to L1c	0.619	1.943	0.152	4.06	.000***	0.277	5.185	0.207	1.34	.193	.187
	HRP to U1t	0.655	2.571	0.336	1.95	.062	0.154	5.149	0.261	0.59	.56	.243
VRP to Li	VRP to A	0.655	2.571	0.336	1.95	.062	0.154	5.149	0.261	0.59	.56	.243
	VRP to B	0.837	3.082	0.189	4.43	.000***	0.45	4.801	0.182	2.47	.020*	.148
	VRP to Pog	0.691	3.275	0.166	4.17	.000***	0.38	5.209	0.158	2.41	.023*	.183
	VRP to U1t	0.714	-0.734	0.21	3.4	.002**	0.296	2.413	0.228	1.3	.205	.19
	VRP to U1c	0.544	0.758	0.349	1.56	.131	0.503	2.209	0.216	2.33	.028*	.919
	VRP to L1t	0.558	0.591	0.132	4.22	.000***	0.38	2.733	0.123	3.1	.005**	.333
	VRP to L1c	0.83	0.312	0.128	6.47	<.0001***	0.467	2.681	0.174	2.68	.013*	.098

^a VRP indicates vertical reference plane; HRP, horizontal reference plane; U1t, tip of the maxillary central incisor; U1c, cervical point of the maxillary central incisor; L1t, tip of the mandibular central incisor; L1c, cervical point of the mandibular central incisor.
* P < .05, ** P < .01, *** P < .001.

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