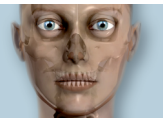
Orthodontics & Craniofacial Research



ORIGINAL ARTICLE

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Three-dimensional analysis of lip and perioral soft tissue changes after debonding of labial brackets

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Structured Abstract

Objectives – To evaluate the possible soft tissue changes after debonding of labial brackets using three-dimensional (3D) images acquired by a laser scanner.

Methods – On the same day, 3D facial scans were taken immediately before debonding (T1) and immediately after debonding (T2) from 53 patients, and follow-up scans were taken 3 months after debonding (T3) from 31 patients. To compare the scans, superimpositions were performed and shell-to-shell deviations were used for quantitative analysis.

Results – Shell-to-shell deviation map showing warm colors in lip and perioral tissue represented the retrusion of soft tissue after bracket removal. Soft tissue retrusion was significant for all landmarks immediately after debonding (T1–T2) and 3 months after debonding (T1–T3). Gender, bracket type, and the lip thickness variables did not show a clinically significant influence on the amount of soft tissue retrusion at the T1–T3 period. Lip corners and vermilion borders were significantly retruded at the T1–T3 period more than other perioral areas. A negative linear relationship was found in the amount of soft tissue retrusion immediately after debonding (T1–T2) and from debonding to 3 months after debonding (T2–T3).

Conclusion – Three-dimensional imaging showed significant changes in lip and perioral soft tissue after debonding of labial brackets. Clinically significant changes, approximately 2 mm of retrusion, occurred in the mouth corners bilaterally. Vermilion border landmarks also demonstrated significant changes in more than 1 mm. However, it was not possible to predict the soft tissue changes. A wide range of individual variability in the response to treatment and soft tissue adaptation was noted.

Key words: dental debonding; imaging; lip; orthodontics; soft tissue change; three-dimensional analysis

Introduction

Esthetic facial appearance at the completion of treatment is of paramount importance to contemporary orthodontists and patients. Accordingly, the detailed assessment of facial appearance is an integral part of routine diagnosis and treatment planning. The lips and perioral soft tissues manifest the most significant changes among facial appearance subsequent to orthodontic treatment (1). The influence of lip thickness and strain on lip response to treatment modalities has been reported (2). Patients have some expectations or worries about the changes in lip posture after debonding of labial brackets. However, to the best of our knowledge, little consideration has been given to the possible effect of lip posture change caused by labial brackets. Sometimes, a clinician may need to make a mid-treatment decision and the re-evaluation could be affected by a perceived soft tissue appearance that is actually not representative of the true resulting soft tissue drape. A simple example is the decision to extract teeth in the middle of treatment because of a bimaxillary appearance that is exaggerated by the thickness of the labial brackets. Therefore, detailed and reliable information is needed to quantify the soft tissue changes after debonding and to give more definite answers to the patients.

Previous studies about soft tissue analysis were designed to measure and predict changes on lateral cephalograms and photographs. Projecting three-dimensional (3D) morphology on a two-dimensional plane implies some degree of information loss (3). Recent advances in technology, however, have generated a variety of 3D techniques to capture facial topography and overcome the deficiencies of conventional methods (4). Laser surface scanning is a valuable tool as a non-invasive alternative for generating a 3D computerized image (5). Advantages in ease of use, self-calibration, and automatic image distortion correction make it possible to establish databases for normative populations (6), cross-sectional growth changes (7), and also to assess clinical outcomes in surgical (8–10) and non-surgical treatments (11, 12) in the head and neck region.

Aim of the present study was to evaluate soft tissue changes after debonding of labial brackets using 3D images acquired by a laser scanner and to improve the clinician's ability to predict the 3D soft tissue changes after debonding.

Materials and methods

The subjects included in the study completed orthodontic treatment in a Class I normal occlusion and the labial brackets were removed from September 2008 to March 2009 at the Department of Orthodontics, Seoul National University. The subjects were East Asian and of Korean ethnicity. The institutional review board for the protection of human subjects reviewed and approved the research protocol.

On the same day, three-dimensional facial scans were taken immediately before debonding (T1) and immediately after debonding (T2). Follow-up scans were taken 3 months after debonding (T3) in consideration of soft tissue adaptation subsequent to bracket removal (11, 13). On the day of debonding, 71 patients agreed to participate in the study. The acquired scans were carefully checked and, consequently, scans with lip strain, mentalis action, or blurred by a subject's motion were excluded from the study. Hence, the final study sample comprised 53 patients [19 men with a mean age of 25.3 years, standard deviation (SD): 6.6; 34 women with a mean age of 25.1 years, SD: 8.1] with T1 and T2 facial scans. For the T3 scans, 31 patients (13 men with a mean age of 27.3 years, SD: 6.7; 18 women with a mean age of 27.1 years, SD: 8.4) were included. Exclusion from the initial sample was mainly due to a lack of 3-month follow-up or poor image quality (Table 1).

After debonding and on the same day, the upper lip thickness was measured on the lateral cephalograms. The post-treatment lateral cephalograms, as well as dental casts and photos, were taken as part of the post-treatments records.

Three types of brackets were used in this study: SmartClip (3M Unitek, Monrovia, CA, USA), Clarity (3M Unitek), and Clippy-C (Tomy, Tokyo, Japan). With a microscope's eyepiece containing a micrometer, the heights of the brackets were

Table 1. **Excluded subjects with reasons for exclusion**

Category	Reason for exclusion	Excluded subjects	No. of subjects
Subjects immediately before debonding, T1	Motion artifacts (blurring)	10	71
	Mentalis action	5	
	Lip strain	3	
Subjects immediately after debonding, T2	Lost at 3-month follow-up	12	53
	Motion artifacts (blurring)	5	
	Mentalis action	3	
	Lip strain	2	
Subjects at 3-month follow-up, T3			31

measured. The height of the upper central incisor bracket for SmartClip was 2.15 mm, and those for Clarity and Clippy-C were 2.08 and 2.05 mm, respectively.

The facial scans were produced using a high-resolution Vivid 910 3D laser scanner (Minolta, Tokyo, Japan) with a reported manufacturing accuracy of 0.1 mm. The scanner emits a Class I laser (rated eye-safe by FDA, $\lambda = 690$ nm at 30 mW), with a fast mode scan time of 0.3 s. A medium range lens (focal distance f = 14 mm) with an object-to-scanner distance of 600 to 2500 mm was used. For the scanning procedures, the subjects sat on a revolving chair with the teeth in occlusion and lips relaxed, in a room illuminated by two fluorescent lights. The subjects were scanned from three different views (−45°, 0°, and 45°) with the subject-to-scanner distance of 1 m and each scan took approximately 2.5 s to complete.

The data were recorded on a desktop computer and transferred to a software package (Rapidform 2006; Inus Technology Inc., Seoul, Korea) for analysis. The facial scans were carefully checked, and unwanted areas, such as hair, ears, clothing, were manually cropped to more precisely focus on the tissue being evaluated before proceeding to the next stage.

To properly evaluate soft tissue changes, two scans were precisely superimposed and measurements taken between them. The areas to be compared were first registered by matching the area that has not been altered (11). In our experiment, this process called registration was performed by manually aligning five points on the facial scans (right medial and lateral canthus, left medial and lateral canthus, and pronasale) (Fig. 1) (7, 11, 14–16). The software then determined the best fit of the two scans in a process called fine registration. This iterative-closest-point algorithm or the best-fit method has been used in previous studies and been shown to be a reliable tool (17, 18). The acquired scan is called 'shell'. Shell-to-shell deviation was utilized for a quantitative analysis of the magnitude of change between the two surfaces. This tool compiled all surface changes and produced a mean absolute value. Once the superimposition and subsequent shell-to-shell deviation procedures had been applied to each pair of scans, the amount and direction of movement that occurred after debonding, represented by a color millimetric scale, was displayed on the colored face map. Increasing differences between the two scans are represented as the color scale moves from cold colors (blue-green) to warm colors (yellow-orange-red) (11, 15, 19). In areas where there had been no change, the original color of the scan remained (20). As indicated by the warm colors around the lips and perioral soft tissue, shell-to-shell deviation maps, shown in Fig. 2, demonstrated the varying degrees of soft tissue retrusion after debonding of labial brackets. The accuracy of the superimposition of the forehead and eyes, together with the expected lack of tissue change in these areas, further demonstrates the validity of this objective assessment tool.

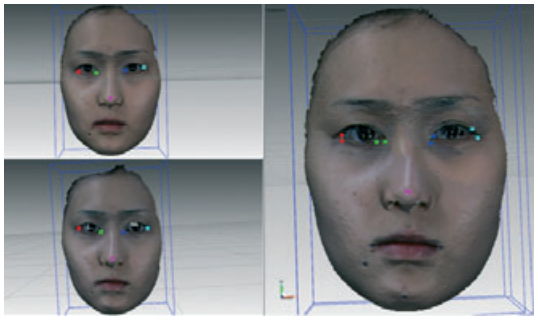

Fig. 1. Registration procedure: this was performed by manually aligning five points on the facial scans (right medial and lateral canthus, left medial and lateral canthus, and pronasale).

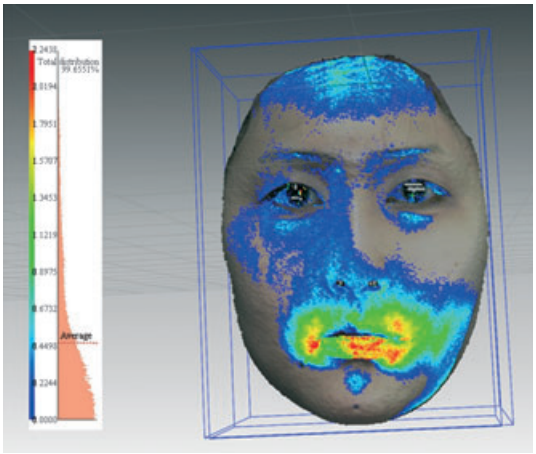

Fig. 2. The color changes in shell-to-shell deviation maps: the colored face map was beneficial for showing the regions and the directions of changes. These changes were analyzed in millimeters and as percentages. Warm colors around the lip and perioral areas represent the soft tissue retrusion after debonding of labial brackets.

For each subject, a set of landmarks was identified by careful inspection. The position of each landmark was confirmed from various angles. The localization of the soft tissue landmark was determined on the colored face map (shell-to-shell deviation map) by positioning the mouse pointer on the landmark and generating automatic co-ordinate readings. In some cases, specific landmarks (i.e. the subnasale and soft tissue pogonion) were pre-marked with an erasable, biocompatible pen before scanning for better localization (21). Soft tissue landmarks used in this study were based on the classic points defined by Farkas and represented those used most commonly in previous studies of 3D facial imaging (Table 2, Fig. 3) (6, 22).

In studies with 3D shell-to-shell deviation, errors of measurement are considered to arise from both landmark identification and the linear measurements derived from those landmarks either directly or through the use of a scanner and *x-y-z* coordinates. This study has, as an additional source of error, the error of superimposition as well. To evaluate the intra-examiner reliability associated with the method, 10 subjects from the final sample were randomly selected, superimposed, and measured twice, 4 weeks apart. The results demonstrated no statistically significant differences between the two sets of measurements at the 95% confidence level ($p > 0.05$). The intraclass correlation coefficient (ICC) was used to assess the intra-examiner reliability. When a paired data set shows a perfect match, the ICC value would be 1. The intra-examiner reliability measure, in terms of ICC, was 0.79–1.00. Random error refers to inherently unpredictable error in repeated measurements. In the terms of root mean squares, the random error between the two repeated measurements ranged from 0.01 to 0.23 mm.

Table 2. **Soft tissue landmarks and definition (6, 22)**

Soft tissue landmark	Definition
Sn (subnasale)	Point at junction of columella and upper lip
Ls (labrale superius)	Midpoint of the vermilion line of the upper lip
Cph rt (crista philtri right)	Point at crossing of the vermilion line and the elevated margin of the right philtrum
Cph lt (crista philtri left)	Point at crossing of the vermilion line and the elevated margin of the left philtrum
Ls rt (labrale superius right)	Midpoint between crista philtri right and cheilion right on the upper vermilion line
Ch rt (cheilion right)	Point located at right labial commissure
Ls lt (labrale superius left)	Midpoint between crista philtri left and cheilion left on upper vermilion line
Ch lt (cheilion left)	Point located at left labial commissure
Sto (stomion)	Midpoint of the horizontal labial fissure
Li (labrale inferius)	Midpoint of the vermilion line of the lower lip
Li rt (labrale inferius right)	Midpoint between labrale inferius and cheilion right on the lower vermilion line
Li lt (labrale inferius left)	Midpoint between labrale inferius and cheilion left on the lower vermilion line
B′ (soft tissue B point)	Most concave point on the curve of the lower lip
Pog′ (soft tissue pogonion)	Most anterior point on the soft tissue chin

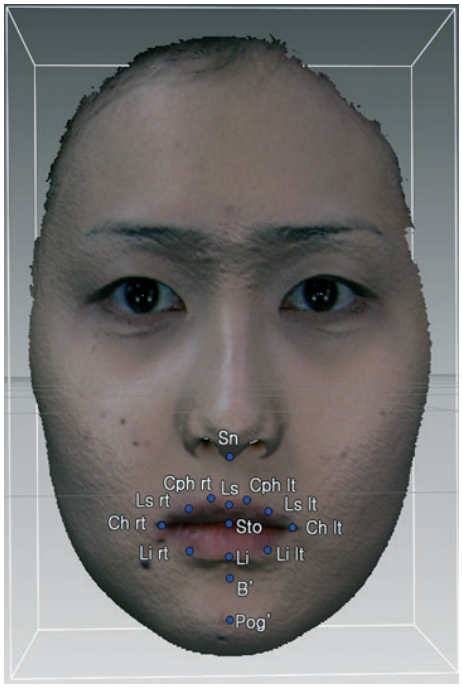

Fig. 3. Soft tissue landmarks.

The R programming language (R Foundation for Statistical Computing, Vienna, Austria) was utilized to perform the data analysis. To compare the soft tissue changes between immediately before and after debonding (T1–T2), and between after debonding and 3 months after debonding (T2–T3), Wilcoxon tests were performed. A multiple regression analysis was implemented to deduce the existence of significant influential factors upon the outcome variable, soft tissue changes, among the three variables: sex, bracket type, and pre-existing lip thickness.

Results

The color changes in shell-to-shell deviation maps are shown in Fig. 2. Warm colors around the lip and perioral areas represent soft tissue retrusion after debonding of labial brackets. The difference is illustrated in the color millimetric scale that shows the regions and the degree of change. In areas where there had been no change, the original color of the scan remained.

Soft tissue changes immediately before and after debonding (T1–T2), from immediately after debonding to 3 months after debonding (T2–T3), and between before debonding and 3 months after debonding (T1–T3) are summarized in Table 3. Superimpositions demonstrated that soft tissue changes in all landmarks were statistically significant between T1–T2 and T1–T3. The median changes measured at fourteen soft tissue landmarks were in direction of soft tissue retrusion in all time periods. Positive values in this study would mean that the soft tissue changes occurred toward lip retrusion.

Between T1 and T2, the corners of the mouth (right cheilion, median: 1.35 mm; left cheilion, median: 1.25 mm) showed the largest changes. Stomion (Sto, median 1.20 mm) and labrale inferius (Li, median 1.18 mm) also demonstrated more retrusion than other perioral areas. Likewise, between T1 and T3, the corners of the mouth (right cheilion, median: 1.97 mm; left cheilion, median: 1.92 mm) showed the greatest changes. Furthermore, the landmarks on the vermilion borders changed more than 1 mm. On the other hand, 3 months after debonding, between T2 and T3, statistically significant changes were limited to the corners of the mouth and lower lip.

The soft tissue changes at different time periods were investigated for three variables: 1) sex, 2) bracket type, and 3) lip thickness (Table 4). First, the bracket type did not demonstrate any significant result in the soft tissue change. Second, immediately after debonding (T1–T2), several landmarks on the upper lip retruded more in males than in female patients. On the contrary, 3 months after debonding (T2–T3), female patients showed more retrusion than males in several landmarks mainly on the lower lip. However, between before debonding and 3 months after debonding (T1–T3), female patients showed more retrusion in the lower lip region than males did. Third, immediately after debonding, the patients who have relatively thicker lips showed less retrusion than those with thinner lips. However, 3 months after debonding, the thicker lip patients showed the more retrusive change on Ls, Ls lt, and Li lt. Collectively, between before debonding and 3 months after debonding, there existed no difference in the soft tissue changes, according to the lip thickness (Table 4).

Comparisons between the changes during T1–T2 and T2–T3 demonstrated that statistically

Table 3. **Soft tissue changes immediately before and after debonding (T1–T2), immediately before debonding and 3 months after debonding (T2–T3), and between immediately before debonding and 3 months after debonding (T1–T3). Positive values indicate retrusive change**

	T1–T2			T2–T3			T1–T3		
	Median	IQR	*p* value	Median	IQR	*p* value	Median	IQR	*p* value
Sn	0.35	0.33	< 0.001**	0.10	0.39	0.356 NS	0.53	0.36	< 0.001**
Ls	0.71	0.90	< 0.001**	0.06	1.01	0.210 NS	1.19	0.90	< 0.001**
Cph rt	0.54	0.65	< 0.001**	0.22	1.44	0.176 NS	1.01	0.88	< 0.001**
Cph lt	0.57	0.65	< 0.001**	0.27	1.10	0.063 NS	1.13	0.87	< 0.001**
Ls rt	1.03	0.58	< 0.001**	0.34	1.20	0.031 NS	1.52	0.88	< 0.001**
Ch rt	1.35	0.84	< 0.001**	0.35	1.66	0.104 NS	1.97	1.09	< 0.001**
Ls lt	1.05	0.68	< 0.001**	0.19	1.07	0.122 NS	1.23	0.77	< 0.001**
Ch lt	1.25	0.97	< 0.001**	0.75	1.45	0.014*	1.92	1.16	< 0.001**
Sto	1.20	0.98	< 0.001**	0.01	1.29	0.445 NS	1.49	1.18	< 0.001**
Li	1.18	1.18	< 0.001**	0.18	0.96	0.015*	1.58	1.60	< 0.001**
Li rt	1.01	0.66	< 0.001**	0.24	1.21	0.024 NS	1.40	1.14	< 0.001**
Li lt	1.04	0.66	< 0.001	0.19	1.04	0.098 NS	1.41	1.27	< 0.001**
B′	0.52	0.75	< 0.001**	0.12	0.49	0.130 NS	0.70	0.55	< 0.001**
Pog′	0.40	0.53	< 0.001**	0.08	0.45	0.439 NS	0.42	0.55	< 0.001**

IQR, interquartile range.
Probability value shows the result of Wilcoxon test with Bonferroni correction of the alpha error. *$p < 0.017$; **$p < 0.0003$; NS, statistically not-significant.

significant differences were found in most landmarks (Table 5). On the other hand, comparisons between the changes during T1–T2 (before debonding to immediately after debonding) and T1–T3 (before debonding to 3 months after debonding) suggested that statistically significant changes were limited to several landmarks on the vermilion borders, such as Ls rt, Ch lt, Li, and Li rt. This result has demonstrated that the vermilion borders are significantly more retruded during the post-debonding period than other perioral areas. This can be explained by soft tissue adaptation or remodeling that occurs along the vermilion borders during the post-debonding period.

Spearman correlation coefficients between the changes in different time intervals demonstrated the negative linear relationship between T1–T2 and T2–T3 (Table 6, Fig. 4).

Discussion

As is inherent in any new advance in technology, the accuracy of a newly developed 3D imaging system in recording facial morphology must be assessed. Previous research has shown that laser scanners are capable of imaging the face with an accuracy of 0.5 mm (11, 14). Kau et al. (18) showed that the Minolta 900 is accurate to 0.56 ± 0.25 mm, and the error in computerized registration of left and right scans is 0.13 ± 0.18 mm. With this proven validity of the system, 3D imaging with laser scanners has great potential in assessing changes in facial morphology as a result of bracket removal and would eventually help clinicians to communicate the expected changes with their patients.

Most soft tissue landmarks showed statistically significant change immediately before and after debonding (T1–T2) and between immediately before debonding and 3 months after debonding (T1–T3). However, when there is statistical significance, it does not always mean clinical relevance. Considering that the accuracy of the equipment is 0.5 mm, small changes (<1 mm) may not have actual clinical significance. However, likely clinically significant changes of approximately 2 mm of retrusion were shown in

Table 4. **The *p* values after multiple regression analyses of sex, lip thickness, and bracket type on the soft tissue changes. Variables at different time periods: immediately before and after debonding (T1–T2), immediately before debonding and 3 months after debonding (T2–T3), and between immediately before debonding and 3 months after debonding (T1–T3)**

	T1–T2						T2–T3						T1–T3					
	Sex		Lip thickness		Bracket type		Sex		Lip thickness		Bracket type		Sex		Lip thickness		Bracket type	
Sn	NS	0.097	NS	0.094	NS	0.797	NS	0.506	NS	0.466	NS	0.092	NS	0.214	NS	0.725	NS	0.260
Ls	M > F**	0.009	Negative**	0.007	NS	0.216	M < F*	0.020	Positive*	0.020	NS	0.372	NS	0.398	NS	0.622	NS	0.067
Cph rt	M > F*	0.010	NS	0.058	NS	0.375	NS	0.091	NS	0.247	NS	0.543	NS	0.901	NS	0.974	NS	0.190
Cph lt	M > F*	0.019	Negative*	0.034	NS	0.194	NS	0.053	NS	0.154	NS	0.490	NS	0.538	NS	0.934	NS	0.090
Ls rt	NS	0.116	Negative*	0.034	NS	0.637	NS	0.270	NS	0.503	NS	0.651	NS	0.986	NS	0.629	NS	0.918
Ch rt	M > F*	0.047	NS	0.072	NS	0.868	NS	0.158	NS	0.374	NS	0.433	NS	0.766	NS	0.531	NS	0.196
Ls lt	NS	0.067	Negative*	0.013	NS	0.919	M < F*	0.024	Positive*	0.047	NS	0.832	NS	0.137	NS	0.268	NS	0.494
Ch lt	NS	0.073	Negative*	0.041	NS	0.329	NS	0.081	NS	0.256	NS	0.658	NS	0.285	NS	0.823	NS	0.108
Sto	NS	0.259	NS	0.452	NS	0.261	M < F*	0.020	NS	0.452	NS	0.893	NS	0.055\	NS	0.920	NS	0.377
Li	NS	0.918	NS	0.553	NS	0.205	M < F*	0.025	NS	0.340	NS	0.213	NS	0.055	NS	0.938	NS	0.836
Li rt	NS	0.762	NS	0.804	NS	0.091	M < F*	0.017	NS	0.083	NS	0.279	M < F*	0.036	NS	0.423	NS	0.926
Li lt	NS	0.222	NS	0.480	NS	0.241	M < F*	0.017	Positive*	0.034	NS	0.156	NS	0.091	NS	0.405	NS	0.729
B′	NS	0.957	NS	0.899	NS	0.992	NS	0.067	NS	0.214	NS	0.943	M < F*	0.047	NS	0.394	NS	0.813
Pog′	NS	0.636	NS	0.690	NS	0.459	NS	0.430	NS	0.469	NS	0.550	NS	0.284	NS	0.990	NS	0.238

NS, statistically not-significant; M, male subject; F, female subject.

*$p < 0.05$; **$p < 0.01$.

'Positive' indicates that the patients who had relatively thicker lips showed more retrusion than those with thinner lips.

'Negative' indicates that the patients who had relatively thicker lips showed less retrusion than those with thinner lips.

both mouth corners. This could not have been revealed in a two-dimensional evaluation. Vermilion border landmarks also demonstrated significant changes of more than 1 mm.

The technology of scanning the face with a laser relies on projecting a known pattern of light to infer an object's shape. The straight-line access of the beam can be hindered by areas under the eyebrow, nose, and chin, resulting in voids and artifacts. To compensate for this, we took three different images from three different angles for one subject. Because the geometry of the setup of the laser light and the camera is in a triangular formation (triangulation based), calculation of the depth in which the light stripe falls is possible. Coordinates of the facial surface can be derived, and computer software can be used to create a 3D model of the object. As noted, previous articles proved this method to be accurate and reliable (17, 23, 24). Before proceeding to the merging process, visual inspection was further implemented to exclude voids, blurring, and image roughness in the final sample.

The influence of sex, lip thickness, and bracket types on the soft tissue change after debonding requires a complex interpretation (Table 4). Immediately after debonding, male and the thinner lip patients showed the most retrusive change. However, during the post-debonding period, the relationship was reversed. Collectively, no difference was found for lip thickness before debonding and 3 months later. However, it is possible that the overall difference in lip thickness among the population was not great enough to result in a significant difference.

Although females showed more lower lip retrusion than males at Li rt and B' at T1–T3, the amount is likely clinically insignificant. However, this statistical difference is not consistent with a previous 2D cephalometric study (13), which reported that during the post-debonding period, the lower lip of males was retruded more than that of females, but that there was no statistical gender difference 1.5 months after debonding. Therefore, it is not prudent to make a hasty generalization about the gender difference in soft

Table 5. **Comparisons of soft tissue changes between time intervals. Immediately before and after debonding (T1–T2); immediately after debonding and 3 months after debonding (T2–T3); immediately before debonding and 3 months after debonding (T1–T3)**

	T1–T2 vs. T2–T3			T1–T2 vs. T1–T3		
	Median	IQR	*p* value	Median	IQR	*p* value
Sn	0.22	0.74	0.001**	-0.10	0.39	0.356 NS
Ls	0.38	1.75	0.028*	−0.06	1.01	0.210 NS
Cph rt	0.25	1.97	0.092 NS	−0.22	1.43	0.182 NS
Cph lt	0.11	1.42	0.116 NS	−0.27	1.10	0.063 NS
Ls rt	0.51	1.20	0.001**	−0.34	1.20	0.031*
Ch rt	1.14	2.34	0.001**	−0.35	1.66	0.104 NS
Ls lt	0.85	1.82	0.001**	−0.19	1.07	0.122 NS
Ch lt	0.78	2.83	0.009**	−0.75	1.45	0.012*
Sto	0.89	1.74	0.001**	−0.01	1.29	0.445 NS
Li	0.74	1.36	0.006**	−0.18	0.96	0.015*
Li rt	0.68	1.50	0.004**	−0.24	1.21	0.023*
Li lt	0.66	1.45	0.003**	−0.19	1.04	0.100 NS
B′	0.18	1.28	0.022*	−0.12	0.49	0.130 NS
Pog′	0.10	0.82	0.028**	−0.08	0.45	0.452 NS

IQR, interquartile range.
Probability value shows the result of Wilcoxon test *$p < 0.05$; **$p < 0.01$; NS, statistically not-significant.

Table 6. **Spearman correlation analysis between the changes immediately before and after debonding (T1–T2) and immediately before debonding and 3 months after debonding (T2–T3)**

	T1–T2 vs. T2–T3	
	Correlation coefficient	*p* value
Sn	−0.57	< 0.001***
Ls	−0.60	< 0.001***
Cph rt	−0.63	< 0.001***
Cph lt	−0.59	< 0.001***
Ls rt	−0.42	0.020*
Ch rt	−0.61	< 0.001***
Ls lt	−0.66	< 0.001***
Ch lt	−0.64	< 0.001***
Sto	−0.45	0.013**
Li	−0.21	0.258 NS
Li rt	−0.46	< 0.001***
Li lt	−0.37	0.043*
B′	−0.53	0.002**
Pog′	−0.49	0.005**

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; NS, statistically not-significant.

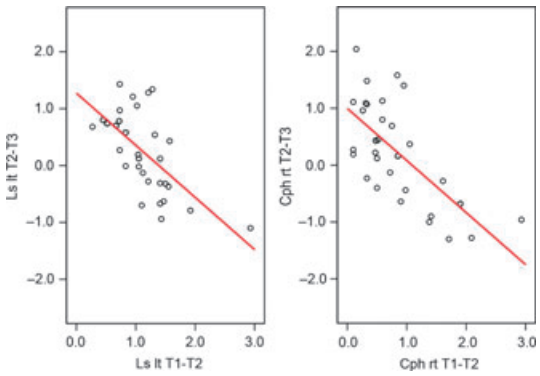

Fig. 4. Scatter plot for soft tissue variables Ls lt and Cph rt changes between T1–T2 vs. T2–T3. The fitted line in red shows the negative slope that indicates negative correlation between these two time intervals.

tissue changes after debonding of labial brackets. Furthermore, it is possible that the difference might have originated from the method used because the previous report was based on two-dimensional cephalometric analysis.

We found that the more soft tissue changes that occur immediately after debonding, the less soft tissue changes would follow during the post-debonding period. This explains the negative correlation coefficients between the changes of different time intervals. Conversely, the less soft tissue changes that occur immediately after debonding, the more soft tissue changes would be estimated during the post-debonding period. This negative correlation may be caused by the time lag in soft tissue adaptation or remodeling among individuals.

On the other hand, changes during T1–T2 were positively correlated with changes during T1–T3 in Li, B' and Pog' (data not shown). This means that more soft tissue changes are expected to occur during the post-debonding period in mid-sagittal points of the lower lip (Li and B') and chin (Pog'), when more soft tissue changes have occurred immediately after debonding. This would be consistent with a previous study (25) that reported the changes in the lower lip in response to orthodontic tooth movement were generally more predictable than those of the upper lip. The lack of such a correlation in upper lip changes was consistent

with the previous findings (26, 27). The low degree of predictability associated with the upper lip response may be caused by the complex anatomy and dynamics of the upper lip.

As discussed, this three-dimensional investigation demonstrated statistically significant soft tissue changes after bracket removal. It would be of great interest to compare these three-dimensional results with corresponding cephalograms. It would also be elucidating to further this research by also evaluating the effects of the type of treatment, duration of treatment, age changes, and various ethnic populations on soft tissue changes.

Conclusions

Three-dimensional imaging showed significant lip and perioral soft tissue changes after debonding of labial brackets. Clinically significant changes, approximately 2 mm of retrusion, occurred in the mouth corners bilaterally. Vermilion border landmarks also demonstrated significant changes of more than 1 mm. According to the comparisons between time intervals, the vermilion borders are significantly more retruded during the post-debonding period. However, based on the variables used such as lip thickness, bracket type, and gender, it was not possible to predict the soft tissue changes. A wide range of individual variability in the response to treatment and soft tissue adaptation was noted.

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