Original Article

The Influence of Extraction Treatment on Holdaway Soft-Tissue Measurements

Faruk Ayhan Basciftci, DDS, MS[a]; Tancan Uysal, DDS[b]; Ahmet Buyukerkmen, DDS[b]; Abdullah Demir, DDS, MS[b]

Abstract: The aims of this study were (1) to determine the changes in the soft-tissue measurements of orthodontic patients treated with four first premolars extractions as determined by the Holdaway Analysis, (2) to investigate the sexual differences between pre- and posttreatment values, and (3) to compare the Holdaway soft-tissue norms with findings in Anatolian Turkish adults. Pretreatment and posttreatment lateral cephalograms of 58 patients (26 boys and 32 girls) were evaluated. During treatment, the H angle, soft tissue subnasale to H line, and upper-lip strain decreased, and the upper-lip thickness, inferior sulcus to H line, and nose prominence increased. No statistically significant sex differences were found between the pre- and posttreatment values of the four premolar extraction cases. When the pretreatment values were compared with the Holdaway soft-tissue norms of Anatolian Turkish adults, seven variables showed statistically significant differences. When the posttreatment values were compared, six measurements showed statistically significant differences. It was determined that some measurements (H angle, inferior sulcus to H line, upper-lip thickness) moved closer to the Anatolian Turkish norms with extraction of four first premolars. However, upper-lip strain measurement changed in an undesirable direction during the treatment. In this study, the sample began treatment with greater facial imbalance, and the facial esthetics improved during treatment. It is necessary to investigate this difference in future studies using larger sample sizes. (*Angle Orthod* 2004;74:167–173.)

Key Words: Soft-tissue analysis; Holdaway soft-tissue analysis; Extraction treatment

INTRODUCTION

Broadbent's introduction of the cephalometer in 1931[1] began a new period in orthodontics. More stable relationships among teeth, jaws, face, and head structures and more successful treatment were deemed possible.[2] Since then, cephalometric analyses have been used to determine relationships in the dentofacial complex. Cephalograms also can help the orthodontist determine the changes that are associated with growth or orthodontic treatment (or both).[3]

The study of beauty and harmony of the facial profile has been central to the practice of orthodontics from its earliest days.[4] Because treatment mechanics are becoming more effective, there has been an increased emphasis on the soft tissues, both in diagnostic and treatment results. Holdaway,[5] Spradley et al,[6] Bell et al,[7] Owen,[8,9] and Park and Burstone[10] are among the many who stress the importance of soft tissues in their diagnoses.

The changes that occur in the soft-tissue profile during orthodontic treatment have played a significant role in the diagnosis and treatment planning process.[11] Although, orthodontists have long recognized that the extraction of premolars often is accompanied by changes in the soft-tissue profile,[12] investigations[13–17] indicate that the soft tissue does not always respond favorably to hard-tissue retraction.

Lip structure seems to have an influence on lip response to incisor retraction. Oliver[18] found that patients with thin lips or a high lip strain displayed a significant correlation between incisor retraction and lip retraction, whereas patients with thick lips or low lip strain displayed no such correlation. In addition, Wisth[19] found that lip response, as a proportion of incisor retraction, decreased as the amount of incisor retraction increased. This seems to indicate that the lips have some inherent support.

Several line analyses have been suggested for evaluating lip posture and the esthetic quality of the profile.[20] Rickett's ''E'' line,[21] is influenced a great deal by the growth of the nose, Steiner's ''S'' line[22] eliminates half the change in integumental profile due to the growth of the nose, whereas

[a] Assistant Professor, Department of Orthodontics, School of Dentistry, Selcuk University, Konya, Turkey.

[b] Research Assistant, Department of Orthodontics, School of Dentistry, Selcuk University, Konya, Turkey.

Corresponding author: Faruk Ayhan Basciftci, DDS, MS, Selçuk Üniversitesi, Diş Hekimliği Fakültesi, Ortodonti Anabilim Dali, Kampüs, 42079 Konya, Turkey
(e-mail: fbasciftci@hotmail.com).

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Holdaway's ''H'' line[5] has the advantage of removing the influence of nasal growth in the evaluation of lip posture.

Although many studies have evaluated the relationship between incisor movement and soft-tissue profile changes,[15,18,23–26] there is surprisingly little information directly concerning the magnitude of soft-tissue changes in premolar extraction treatment and the desirability of these changes.

Keeping these points in mind and using the soft-tissue analysis of Holdaway, in this study we have three objectives:

- determine changes in the soft tissue of orthodontic patients treated with extraction of four first premolars as determined by the Holdaway analysis;
- identify possible sexual differences between pre- and posttreatment values;
- compare all values with the Holdaway soft-tissue norms of Anatolian Turkish adults.[27]

MATERIALS AND METHODS

This retrospective study was designed to evaluate the differences in soft-tissue characteristics as determined by the Holdaway soft-tissue analysis of orthodontic patients treated with extraction of four first premolars. A total of 58 patients (26 boys and 32 girls), treated in the Department of Orthodontics at the Selcuk University Faculty of Dentistry, were included in this study. Lateral cephalometric films were obtained before treatment (T1) and after treatment (T2). The age range of the patients at the beginning of treatment was 11 years 10 months to 14 years one month for girls and 10 years three months to 13 years 10 months for boys. All the patients were classified as skeletal Class I. The mean initial value for ANB was 2.25° ± 1.05 and that for SN-GoGn was 31.35° ± 2.68.

Data were obtained from pre- and posttreatment lateral cephalometric radiographs of 38 patients all of whom met the following additional criteria:[28]

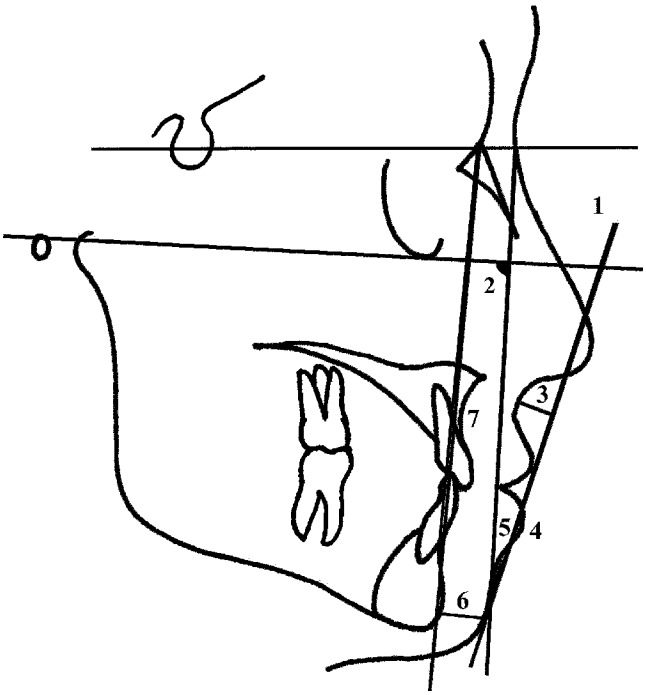

FIGURE 1. Cephalometric measurements: 1, H line; 2, Soft tissue facial angle; 3, Measurement of soft tissue subnasale to H line; 4, Lower lip to H line; 5, H angle; 6, Soft-tissue chin thickness; 7, Skeletal profile convexity.

- four first premolars extracted during treatment;
- no congenitally missing teeth (excluding third molars);
- treatment completed in ≥30 months;
- the duration between pre- and posttreatment cephalometric radiographs ≥12 months of nontreatment time. This restriction was used to minimize the confounding effects

TABLE 1. Pre- and Posttreatment Mean Values and Standard Deviations of Holdaway Soft-Tissue Measurements and Results of Statistical Comparisons

	Pretreatment (T1)		Posttreatment (T2)		Difference (T2 − T1)		*P* value[a] Paired samples
n = 58	Mean	SD	Mean	SD	Mean	SD	*t*-test
Soft-tissue facial angle	87.34	3.43	87.74	3.87	0.40	2.80	NS
H angle	16.79	4.66	15.42	4.07	−1.37	2.60	.003**
Nose prominence	17.71	2.39	19.45	2.34	1.74	1.78	.000***
Soft-tissue subnasale to H line	5.84	2.07	5.26	1.66	−0.58	1.37	.013*
Inferior sulcus to H line	4.97	2.03	5.42	1.91	0.45	1.20	.027*
Lower lip to H line	1.36	2.00	1.17	1.63	−0.18	1.16	NS
Soft-tissue chin thickness	11.79	1.83	11.89	1.72	0.11	1.23	NS
Upper-lip thickness	12.16	2.26	13.05	2.13	0.89	1.50	.001**
Basic upper-lip thickness	14.55	2.25	14.63	2.39	0.08	1.78	NS
Upper lip sulcus depth	2.86	1.20	2.58	1.03	−0.28	0.98	NS
Skeletal profile convexity	3.13	2.42	2.71	2.47	−0.42	1.39	NS
Upper-lip strain	2.39	1.90	1.58	1.93	−0.82	2.06	.020*

[a] * $P < .05$; ** $P < .01$; *** $P < .001$; NS, not significant.

of growth on changes in profile from those resulting from treatment;
- no functional appliance or surgical procedure was used between the two radiographs noted above.

The lateral cephalometric radiograph of each subject was taken using a Planmeca Cephalometer (PM 2002 EC Proline; Helsinki, Finland). All subjects were positioned in the cephalostat with the sagittal plane at a right angle to the path of the X-rays, the Frankfort plane parallel to the horizontal, the teeth in centric occlusion, and the lips slightly closed.[29]

The radiographs were traced and measured by the same investigator (Dr Basciftci). Ten linear and two angular measurements were analyzed on each radiograph. The landmarks were located according to the definition provided by Holdaway.[5] The following measurements were used (Figures 1 and 2):

- H line: tangent drawn from the tip of the chin to the upper lip;
- Soft tissue facial angle: the downward and inner angle formed at a point where the sella-nasion line crosses the soft tissue and a line combining the suprapogonion with the Frankfort horizontal plane;
- Measurement of soft tissue subnasale to H line: measurement from subnasale to the H line;
- Lower lip to H line: the measurement of the lower lip to the H line;
- H angle: the angle formed between the soft-tissue facial plane line and the H line;
- Soft-tissue chin thickness: the distance between the hard and soft-tissue facial planes at the level of supra-pogonion;
- Skeletal profile convexity: the dimension between point A and facial line;
- Nose prominence: the dimension between the tip of the nose and a perpendicular line drawn to the Frankfort plane from the vermillion;
- Upper lip sulcus depth: the measurement between the upper lip sulcus and a perpendicular line drawn from the vermillion to the Frankfort plane;
- Inferior sulcus to the H line (lower lip sulcus depth): the measurement at the point of greatest convexity between the vermillion border of the lower lip and the H line;
- Basic upper-lip thickness: the dimension measured approximately three mm below point A and the drape of the upper lip;
- Upper-lip thickness: the dimension between the vermillion point and the labial surface of the upper incisor; and
- Upper-lip strain measurement: the difference between the basic upper-lip thickness and the upper-lip thickness.

All statistical analyses were performed using the SPSS software package (SPSS for Windows 98, version 10.0, SPSS Inc., Chicago, Ill, USA). For each variable, arithmetic mean and standard deviation were calculated for each measurement.

To determine the errors associated with radiographic measurements, 30 radiographs were selected at random from the observation group. Their tracings and measurements were repeated three weeks after the first measurement. A paired samples *t*-test was applied to the first and second measurements. It was found that the difference between the first and second measurements of the 30 radiographs was insignificant. Correlation analysis applied to the same measurements showed the highest *r* value of 0.973 for the upper lip sulcus depth and the lowest *r* value of 0.912 for inferior sulcus to the H line.[30] For statistical evaluation, paired samples *t*-test and independent-samples *t*-test were performed.

RESULTS

The difference between the means of the pre- and posttreatment measurements of H angle ($P < .01$), soft tissue subnasale to H line ($P < .05$), and upper-lip strain ($P < .05$) decreased. The differences between the means of the pre- and posttreatment measurements of upper-lip thickness ($P < .01$) and inferior sulcus to H line ($P < .05$) increased, and nose prominence also increased ($P < .001$) (Table 1).

Sexual differences between pre- and posttreatment measurements are shown in Table 2. In boys, statistically significant differences ($P < .05$) were found for H angle, nose prominence, soft tissue subnasale to H line, and upper-lip thickness values, whereas in girls, H angle, upper-lip thickness, upper-lip strain ($P < .05$), and nose prominence ($P < .001$) values were found to be statistically significant. However, no statistically significant sexual differences were found between pre- and posttreatment values of four premolars extraction cases.

Table 3 shows the comparisons of pre- and posttreatment Holdaway soft-tissue values of four premolars extraction patients with norms of Anatolian Turkish adults. In the comparison of pretreatment values and Holdaway soft-tissue norms of Anatolian Turkish adults, seven variables showed statistically significant differences. Statistically significant differences between the pretreatment values of extraction cases and Anatolian Turkish adults' norms were found in the H angle ($P < .001$), inferior sulcus to H line ($P < .01$), lower lip to H line ($P < .01$), soft-tissue chin thickness ($P < .01$), upper-lip thickness ($P < .01$), basic upper-lip thickness ($P < .001$), and skeletal profile convexity ($P < .001$).[27] However, statistically significant differences between the posttreatment values and Anatolian Turkish adults' norms were found in the H angle ($P < .05$), lower lip to H line ($P < .01$), soft-tissue chin thickness ($P < .01$), basic upper-lip thickness ($P < .001$), skeletal profile convexity ($P < .001$), and upper-lip strain ($P < .05$).[27]

TABLE 2. Comparison of Mean and Standard Deviation Differences of Cephalometric Measurements Changes Between Boys and Girls

	Boys (n = 26)						
	Pretreatment (T1)		Posttreatment (T2)		Difference (T2 − T1)		*P* value[a] Paired samples *t*-test
	Mean	SD	Mean	SD	Mean	SD	
Soft-tissue facial angle	87.58	3.99	87.83	4.80	0.25	2.90	NS
H angle	18.25	4.45	16.50	4.54	−1.75	2.70	.046*
Nose prominence	17.92	2.47	19.92	2.43	2.00	2.41	.015*
Soft-tissue subnasale to H line	6.75	2.05	6.08	1.93	−0.67	0.78	.013*
Inferior sulcus to H line	5.75	2.67	6.33	2.50	0.58	1.08	NS
Lower lip to H line	1.33	2.50	1.08	2.23	−0.25	1.06	NS
Soft-tissue chin thickness	12.00	1.71	12.17	1.59	0.17	1.03	NS
Upper-lip thickness	13.75	2.49	15.17	1.85	1.42	1.88	.024*
Basic upper-lip thickness	16.17	2.21	16.92	1.62	0.75	1.54	NS
Upper-lip sulcus depth	3.33	1.15	3.17	1.19	−0.17	0.58	NS
Skeletal profile convexity	2.42	2.19	2.17	1.80	−0.25	1.54	NS
Upper-lip strain	2.42	2.15	1.75	2.18	−0.67	1.87	NS

[a] * $P < .05$; *** $P < .001$; NS, not significant.

DISCUSSION

In the literature, there are few studies with which the pre- and posttreatment Holdaway soft-tissue measurements can be directly compared. Most studies of profile change during orthodontic tooth movement have been concerned with the predictive relationship between incisor retraction and lip position.[15,18,23–26] Several other studies that provide specific data on soft-tissue profile changes combine extraction and nonextraction cases.[31]

Statistical test results of this study suggest that before orthodontic treatment no significant difference existed in soft-tissue position between the two sexes. After orthodontic treatment, no significant difference existed for the soft-tissue position between boys and girls. These results do not agree with previous studies by Baum[32] indicating that soft-tissue growth tendencies are different between the two sexes. Baum's studies[32] of children between 11 and 14 years of age indicate that girls develop at an earlier age than boys and tend to achieve a mature adult face earlier. Therefore, all soft-tissue changes in this study were statistically examined selectively for each sex. To limit growth effects on lip thickness and lip strain, an effort was made to select subjects who started treatment at a similar age.

Although Holdaway[5] ideally preferred a soft-tissue facial angle of 90° to 92°, he also recognized a wide range of acceptable variation, possibly as high as ±seven degrees, for at least some cases. In this study, both pre- and posttreatment values of soft-tissue facial angle were lower than Holdaway's norms.[5] However, during the treatment, this angle changed favorably because of growth and treatment effect. These pre- and posttreatment measurements were in accordance with the Anatolian Turkish adult's norm values.[27]

The H angle measures the prominence of the upper lip in relation to the overall soft-tissue profile.[5] This measurement shows a significant decrease during the orthodontic treatment ($P < .01$) and becomes closer to the Anatolian Turkish norms.

Lo and Hunter[26] proposed that extraction treatment did not show significant differences in the changes of the nasolabial angle. Waldman[33] found a significant correlation between the horizontal retraction of the maxillary incisors and the increase in the nasolabial angle. Holdaway[5] noted that he disapproved of the term ''nasolabial angle'' and stated that it did not adequately describe the contour of the subnasal profile. In this study, the nose prominence changed significantly during the treatment period in accordance with Holdaway.[5] In the subjects with the extraction treatment, the noses became more prominent either because of the effects of growth or treatment.

According to Holdaway,[5] the contour in the inferior sulcus area should fall into harmonious lines with the superior sulcus form. He proposed that this measurement is an indicator of how well we manage axial inclinations of the lower anterior teeth. In this study, the inferior sulcus to H line measurement changed significantly with extraction treatment and became closer to the norm value of Turkish adults as did the H angle and upper-lip thickness.

The retraction of the maxillary incisors, however, may or may not be the most important factor influencing the retraction of the upper lip.[34] Factors other than the maxillary incisor retraction may have a greater influence on the upper-lip response. Such factors may include the complex anatomy of the upper lip and difficulty involved in assessing the tension in the lips when the cephalometric radiographs are taken.[34] In this study, no statistically significant change occurred between the pre- and posttreatment periods for basic upper-lip thickness, and no significant sex differences were found. However, statistically significant differences ($P < .001$) were found between pre- and posttreat-

TABLE 2. Extended

Girls (n = 32)							
Pretreatment (T1)		Posttreatment (T2)		Difference (T2 − T1)		*P* value[a]	
						Paired samples *t*-test	Independent samples *t*-test
Mean	SD	Mean	SD	Mean	SD		
87.23	3.23	87.69	3.46	0.46	2.80	NS	NS
16.12	4.68	14.92	3.83	−1.19	2.59	.027*	NS
17.62	2.40	19.23	2.32	1.62	1.44	.000***	NS
5.42	1.98	4.88	1.40	−0.54	1.58	NS	NS
4.62	1.60	5.00	1.44	0.38	1.27	NS	NS
1.40	1.79	1.24	1.33	−0.15	1.22	NS	NS
11.69	1.91	11.77	1.80	0.08	1.32	NS	NS
11.42	1.75	12.08	1.44	0.65	1.26	.014*	NS
13.81	1.88	13.58	1.90	−0.23	1.82	NS	NS
2.60	1.27	2.31	0.84	−0.33	1.12	NS	NS
3.46	2.49	2.96	2.72	−0.50	1.33	NS	NS
2.38	1.81	1.50	1.84	−0.88	2.18	.049*	NS

TABLE 3. Comparison of Pretreatment and Posttreatment Values with the Holdaway Soft-Tissue Norms of Anatolian Turkish Adults

	Turkish Norms (N)		Pretreatment (T1)		Posttreatment (T2)		*P* value[a]	
	Mean	SD	Mean	SD	Mean	SD	N–T1	N–T2
Soft-tissue facial angle	87.31	8.84	87.34	3.43	87.74	3.87	NS	NS
H angle	13.75	3.01	16.79	4.66	15.42	4.07	.000***	.030*
Nose prominence	18.74	3.59	17.71	2.39	19.45	2.34	NS	NS
Soft-tissue subnasale to H line	5.12	3.33	5.84	2.07	5.26	1.66	NS	NS
Inferior sulcus to H line	6.2	2.3	4.97	2.03	5.42	1.91	.007**	NS
Lower lip to H line	0.03	1.91	1.36	2.00	1.17	1.63	.001**	.002**
Soft-tissue chin thickness	12.96	2.05	11.79	1.83	11.89	1.72	.004**	.007**
Upper-lip thickness	13.96	2.7	12.16	2.26	13.05	2.13	.001**	NS
Basic upper-lip thickness	16.64	2.43	14.55	2.25	14.63	2.39	.000***	.000***
Upper lip sulcus depth	2.97	1.53	2.86	1.20	2.58	1.03	NS	NS
Skeletal profile convexity	−0.21	2.31	3.13	2.42	2.71	2.47	.000***	.000***
Upper-lip strain	2.68	2.39	2.39	1.90	1.58	1.93	NS	.016*

[a] * $P < .05$; ** $P < .01$; *** $P < .001$; NS, not significant.

ment values and Turkish norm value for basic upper-lip thickness. Oliver,[18] however, observed significant changes for basic upper-lip thickness during extraction treatment only in the males.

Rains and Nanda[25] and Talass et al[34] reported that the length of the lower lip increased with extraction orthodontic treatment. Holdaway proposed that the ideal position of the lower lip is zero to 0.5 mm anterior to the H line, but individual variations from one mm behind to two mm anterior to the H line are considered to be in a good range. In addition, Basciftci et al[27] found that the ideal position of the lower lip to the H line is 0.03 ± 1.91 for Anatolian Turkish adults. There were statistically significant differences between pre- and posttreatment values and Turkish norms for lower lip to H line measurement ($P < .01$).

Singh's[35] study showed that in a group of 31 male and 29 female patients, the soft-tissue chin thickness increases after orthodontic treatment. The females showed less increase at all levels than did the males. In this study, soft-tissue chin thickness value did not change significantly and was similar with the lower lip to H line, basic upper-lip thickness, and skeletal profile convexity. This value was found to be different from Turkish norms.

James[36] determined that the average posttreatment lip-profile position of the nonextraction group was slightly more retrusive than that of the extraction group. In this study, upper lip sulcus depth and basic upper-lip thickness did not change during treatment period. During the treatment, upper-lip thickness measurement changed favorably. Therefore, our findings on lip-profile position were not in accordance with James's[36] results.

Holdaway[5] stated that skeletal profile convexity is not really a soft-tissue measurement. However, facial convexity is directly interrelated to harmonious lip positions and, therefore, has a bearing on the dental relationships needed to produce harmony of the features of the human face. In this study, the changes of skeletal profile convexity during the treatment period found no significant sexual differenc-

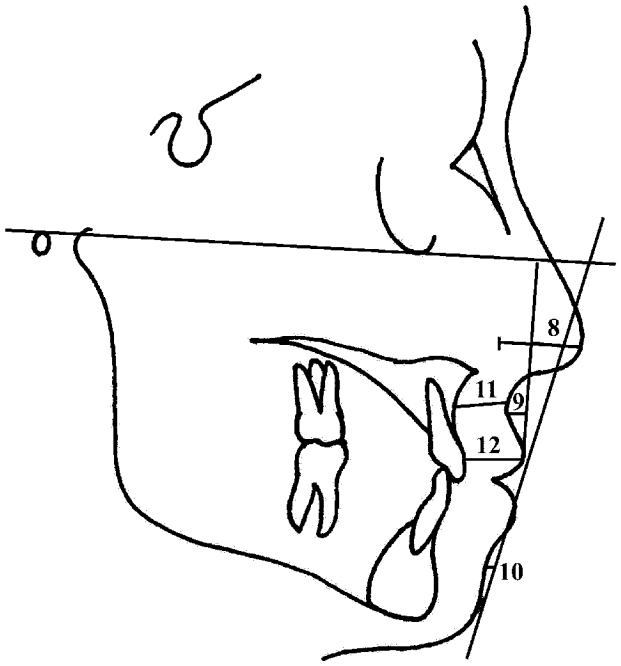

FIGURE 2. Cephalometric measurements: 8, Nose prominence; 9, Upper lip sulcus depth; 10, Inferior sulcus to the H line (lower lip sulcus depth); 11, Basic upper lip thickness; 12, Upper lip thickness.

es and changes during treatment. Statistically significant differences were found for skeletal profile convexity measurement between our subjects and Turkish norms ($P < .001$).

Oliver[18] stated that orthodontic treatment with extraction and growth in the 20 Class II, Division 1 females resulted in retraction of soft tissue and a significant decrease in lip strain in the midface. However, extraction treatment in the 20 Class II, division 1 males did not cause a significant alteration in lip strain. In this study, during the treatment, upper-lip strain decreased significantly ($P < .05$) only in girls. Lip strain in boys was not significantly altered. Only upper-lip strain measurement became worse during treatment when compared with the Turkish norms.[27]

CONCLUSIONS

In this study, the sample size was small and further investigations, using the parameters for soft-tissue analysis, need to be repeated with a larger sample. The results of this study indicated that generalizations concerning the negative effects of extraction of four first molars on the profile are not true. When the pre- and posttreatment measurements were compared, statistically significant differences were found in H angle ($P < .01$), nose prominence ($P < .001$), soft tissue subnasale to H line ($P < .05$), inferior sulcus to H line ($P < .05$), upper-lip thickness ($P < .001$), and upper-lip strain ($P < .05$) values. Except upper-lip strain all changes were desirable and appropriate for improvement of patients' soft-tissue profile.

The changes in Holdaway soft-tissue measurements in male and female samples during the extraction treatment showed similarities in all values, and no statistically significant differences were found between the two sexes.

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