Can commonly used profile planes be used to evaluate changes in lower lip position?

Peter H. Buschang; Kimberly Fretty; Phillip M. Campbell

ABSTRACT

Objectives: To determine the validity of five profile planes commonly used to describe the horizontal changes of the lower lip during orthodontic treatment.

Materials and Methods: Pretreatment and posttreatment cephalograms of 79 patients (12.4 ± 2.8 years of age) were evaluated. Lower lip (labrale inferiorus) changes over time were measured relative to the Rickett’s E-line, Steiner’s S1-line, Burstone’s B-line, Sushner’s S2-line, and Holdaway’s H-line. As an independent measure of actual horizontal lip changes, the labrale inferiorus was measured relative to a stable reference plane registered on the sella and oriented on the SN-7u.

Results: The lower lip actually moved anteriorly 2.35 ± 3.35 mm during orthodontic treatment; the five profile planes indicated that the lower lip moved to a more retrusive, posterior position. The five profile planes also showed no statistically significant sex differences in terms of the treatment changes that occurred, while the actual lip changes showed that males exhibited significantly greater changes than females. Actual treatment changes showed that the lower lip moved to a more protrusive position with nonextraction than with extraction treatments, changes that were not evident based on the five profile lines. While lip changes based on the five profile planes demonstrated moderately high to high intercorrelations ranging from 0.81 to 0.97, they showed only weak correlations (r < .35) with the actual horizontal changes of the labrale inferiorus.

Conclusions: While all five planes measured similar aspects of positional change, none of them closely reflected the actual lower lip changes that occurred. These planes should not be used to measure changes in lip position that occur during treatment. (Angle Orthod. 2011;81:557–563.)

KEY WORDS: Profile; Cephalometrics; Human; Soft tissues

INTRODUCTION

The soft tissue (ST) profile has always played a significant role in orthodontics because appearance has a major psychosocial effect on acceptance and perceived success in society. Harmonious facial esthetics have long been recognized as a major goal of orthodontic treatment. Because occlusion and facial beauty are interdependent, they have become simultaneous and equal treatment goals. For clinical orthodontists, the ST profile has always been one of the most important aspects of diagnosis and treatment planning. As a result of its influence with regard to malocclusions, tooth stability, and facial esthetics, lip position has become one of the most important ST measures relied upon by orthodontists.

Multiple methods have been used to describe anteroposterior lip profile changes. Ricketts recommended relating lip position to the E-Line, which uses the ST pogonion and pronasale as reference points. Steiner evaluated the ST profile by drawing a line from the ST pogonion to the columella of the nose (S1-line). Burstone used the ST subnasale as the superior point and the ST pogonion as the inferior point of the B-Line. Sushner developed a line from the ST pogonion to the ST nasion to measure the position of the lower lip. Holdaway related the position of the lower lip to the H-Line, which extends from the ST pogonion to the vermilion border of the upper lip.
While these measures were originally designed to measure lip profile, they have been increasingly used to measure the changes in lip position that occur during orthodontic treatment and growth. For example, Bishara et al. used the E-line to determine the incremental changes in lower lip position that occurred during extraction and nonextraction treatments. The H-line and B-line have been used to determine the amount of protrusion or retrusion of the lips that occurs during treatment. More recently Stalpers et al. used the E-line to measure the changes that occur in lower lip position with the extraction of maxillary first permanent molars in Class II division I patients, and Zablocki et al. relied upon the E-line to evaluate lower lip changes produced with a transpalatal arch during the treatment of extraction cases. Pecora et al. used the E-line to measure the changes in the lip position that occur between late adolescence, mid-adulthood, and late adulthood.

Anteroposterior positional changes of the lips measured by these reference planes could be confounded by growth changes and sexual dimorphism. Subtelny found that the ST pogonion becomes more prominent between the ages of 7 and 18 years, with males demonstrating greater changes than females. The ST-thickness overlying pogonion also increases over time, as do the STs overlying the nasion. Reference lines relying on the nose could be confounded by nasal growth, which occurs in a forward and downward direction until early adulthood.

Based on these potentially confounding effects, the null hypothesis is that there are no differences between actual measured lower lip changes and the lip changes based on commonly used reference planes. Can reference planes be relied upon to reflect the actual lip changes in lip position that occur during treatment?

MATERIALS AND METHODS

This retrospective study included a sample of 79 treated patients: 22 female nonextraction patients, 22 nonextraction male patients, 16 female extraction patients, and 19 male extraction patients. The sample included five Hispanic patients, one African-American patient, and 73 White patients. There were 61 Class I, 17 Class II, and one Class III occlusions. The extraction patterns included four premolars in both arches as well as bilateral and unilateral premolar extractions in the maxilla. Extractions were used to correct bialveolar protrusion as well as anterior crowding. Each patient was treated by the same orthodontist. They were prescreened to ensure that treatment started when the patient was between 10 and 16 years of age and that the pre- and posttreatment records had been taken fewer than 36 months apart (Table 1). All patients were treated using 0.018-inch Alexander Ormco brackets. Class II elastics were used as needed.

The cephalograms were all taken by a single orthodontist using the same cephalostat, positioned 60 inches from the patient’s midsagittal plane, with the file cassette positioned to lightly touch the patient’s head. The small differences in magnification expected between subjects should have no effect on the within-subject comparisons being performed. For each patient, five different reference lines were evaluated, including the following: Rickett’s E-line, Steiner’s S1-line, Burstone’s B-line, Sushner’s S2-line, and Holdaway’s H-line (Figure 1). The cephalometric landmarks of the sella, nasion, ST pogonion, labrale inferioris, labrale superioris, subnasale, columella, pronasale, and ST nasion (Table 2) were digitized twice by one of the coinvestigators on both the pre- and posttreatment cephalograms using the Viewbox.

Table 1. Average Pretreatment and Posttreatment Ages*  

<table>
<thead>
<tr>
<th></th>
<th>Nonextraction</th>
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<th>Extraction</th>
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<tr>
<td></td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Pretreatment</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Posttreatment</td>
<td>12.5</td>
<td>1.2</td>
<td>12.9</td>
<td>1.2</td>
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<tr>
<td></td>
<td>14.8</td>
<td>1.2</td>
<td>15.1</td>
<td>1.2</td>
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* SD indicates standard deviation.
To measure lip changes that occurred during treatment, the shortest distance from each of the five reference planes to the labrale inferiorus was measured on both the pretreatment and posttreatment cephalometric tracings. This measurement was considered positive when the lip was located anterior to the reference planes and negative when it was located posterior to the reference planes. The actual horizontal change of the labrale inferiorus that occurred during treatment was measured from the sella to the labrale inferiorus parallel to SN-7°. The changes in this distance between pre- and posttreatment periods were calculated; it was positive if the labrale inferiorus moved anteriorly and negative if it moved posteriorly.

Reliability analyses were performed on 79 replicates. Paired t-tests showed no significant systematic error. The method error statistic ranged from 0.30 mm to 0.44 mm, with the horizontal changes of the labrale inferiorus showing the greatest errors. Actual errors were substantially smaller because the statistical evaluations of the five profile planes were based on the average of replicate measures taken at each time point.

The skewness and kurtosis statistics indicated that the variables were normally distributed. Treatment changes over time were evaluated using paired t-tests. The actual changes in lip position and changes estimated from the profile planes were compared using paired t-tests. Pearson product-moment corre-

Table 2. Definitions of Landmarks

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<thead>
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<th>Landmark</th>
<th>Definition</th>
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<tr>
<td>Sella</td>
<td>The midpoint of the cavity of sella turcica</td>
</tr>
<tr>
<td>Nasion</td>
<td>The anterior point of the intersection between the nasal and frontal bones</td>
</tr>
<tr>
<td>Soft tissue pogonion</td>
<td>The most prominent point on the soft tissue contour of the chin</td>
</tr>
<tr>
<td>Labrale inferiorus</td>
<td>The most anterior portion on the margin of the lower lip</td>
</tr>
<tr>
<td>Labrale superioris</td>
<td>The most anterior portion on the margin of the upper lip</td>
</tr>
<tr>
<td>Subnasale</td>
<td>The point where the lower border of the nose meets the outer contour of the upper lip</td>
</tr>
<tr>
<td>Columella</td>
<td>The fleshy lower margin (termination) of the nasal septum</td>
</tr>
<tr>
<td>Pronasale</td>
<td>The most anterior point of the nose</td>
</tr>
<tr>
<td>Soft tissue nasion</td>
<td>The point of deepest concavity of the soft tissue contour of the root of the nose</td>
</tr>
</tbody>
</table>

3° (dHal Software, Kifissia, Greece). To measure lip changes that occurred during treatment, the shortest distance from each of the five reference planes to the labrale inferiorus was measured on both the pretreatment and posttreatment cephalometric tracings. This measurement was considered positive when the lip was located anterior to the reference planes and negative when it was located posterior to the reference planes. The actual horizontal change of the labrale inferiorus that occurred during treatment was measured from the sella to the labrale inferiorus parallel to SN-7°. The changes in this distance between pre- and posttreatment periods were calculated; it was positive if the labrale inferiorus moved anteriorly and negative if it moved posteriorly.

Figure 1. Profile planes and actual lip changes.
lations were used to measure the intercorrelations. A significance level of .05 was used for all of the statistical tests.

RESULTS

The actual change in lower lip position, as measured by the change in labrale inferiorus along SN-7, was 2.35 mm (standard deviation [SD] = 3.36) anteriorly. Nonextraction lips moved 2.97 mm (SD = 2.67) anteriorly, while extraction lips moved a total of 1.58 mm (SD = 3.98) anteriorly during treatment, with the difference approaching statistical significance ($P = .083$). Males showed significantly more anterior movements of the lower lip than did females (3.68 and .92 mm, respectively).

In contrast to the actual changes, the E-line, S1-line, B-line, and S2-line showed that the lips became more retrusive during treatment, except the H-line, which did not indicate significant movement (Table 3). The E-line demonstrated the greatest change ($-1.43 \pm 1.67$ mm). Extraction cases showed greater lip changes during orthodontic treatment than did nonextraction cases, but significant differences were only seen when lip changes were measured with the H-line. The E-line and S1-line showed that the lips became more retrusive in nonextraction cases, while the B-line, S2-line, and H-line did not indicate statistically significant changes. The E-line showed the largest SD among the lines, whereas the H-line showed the smallest SD. In females, the B-line, E-line, and S1-line showed that the lower lip moved to a more posterior position, whereas the H-line and S2-line did not indicate a statistically significant movement (Figure 3). Each of the profile lines demonstrated more posterior movement of the lips in males than in females, except the H-line, which again did not show statistically significant movement. While males showed greater changes in lip position than did females based on the five profile planes, the sex differences in the changes were not statistically significant (Table 3).

The horizontal lip changes measured relative to the five reference planes showed moderately high to high intercorrelations (Figure 4). Correlations between the actual horizontal movements of the lower lip and the lip changes measured relative to the reference planes were weak to very weak (Figure 2). All of the correlations were statistically significant ($P < .05$).

DISCUSSION

The reference planes typically used to evaluate treatment changes of the lower lip should not be used to describe changes in lower lip position. They do not
reflect the amount or the type of change that takes place. The actual changes, as measured by the labrale inferiorus, were not only significantly greater than the changes determined by each of the profile lines, but they were also often in different directions. Moreover, the correlations showed that the profile planes explained only 6% (E-line) to 12% (B-line) of the variation in the actual lip changes that occurred. The lack of correlation between lower lip changes, as measured by the profile planes, and actual lower lip changes is probably due to ST growth. This indicates that the growth that occurs at pronasale, labrale superiorus, and pogonion masks the actual lower lip changes that occur during orthodontic treatment.

Although not closely related to the actual lip changes, the lip changes measured by the five reference planes showed moderately high to high intercorrelations. The highest correlations were found between the profile lines involving the ST pogonion and a part of the nose (E-line, S1-line, and B-line) and were probably due either to the relatively large amount of nasal growth that occurs or to the close proximity of the landmarks (subnasale and columella). The lowest correlation was between Sushner’s S2-line and Holdaway’s H-line, which involve landmarks that are widely separated and have little in common.

Based on the profile planes, males tended to have a greater change in lip position than did females, but none of the differences were statistically significant. Previous studies have also shown small and statistically insignificant sex differences in the changes of the lower lip position during orthodontic treatment. While sex differences (favoring males) in the thickness and growth of STs have been demonstrated, profiles measures tend to show no significant differences between males and females between 7 and 18 years of age. This indicates that the sex differences in ST profiles are proportionate.

With the exception of the Holdaway H-Line, the profile measurements showed no significant differences between extraction and nonextraction cases. Although not statistically significant, greater changes in the position of the labrale inferiorus were observed in extraction cases than in nonextraction cases. It has been previously shown that the extraction cases become significantly more retrusive than nonextraction cases based on measurements determined by the E-line and B-Line. In contrast, Janson et al. showed no significant differences between nonextraction and maxillary first premolar extraction cases using the Steiner’s S1-line and the Rickett’s E-line; they did find significant differences based on the Burstone’s B-line. Differences between the present and previous studies could be due to the fact that the present study was not limited to four premolar extractions or bilateral premolar extractions.

The Holdaway’s H-line was the only method that detected differences between the nonextraction and extraction cases. The average lip profile changes in the extraction and nonextraction groups with the H-line were $-0.34 \pm 1.33$ mm and $0.19 \pm 0.90$ mm, respectively. The labrale inferiorus has been previously shown to become more retrusive in patients treated with premolar extraction. The reason that the other profile planes do not show differences between extraction and nonextraction cases is probably due to the large amount of nasal growth that occurs during orthodontic treatment.

Table 3. Treatment Changes by Sex and Type of Treatment

<table>
<thead>
<tr>
<th></th>
<th>Nonextraction</th>
<th>Extraction</th>
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<tbody>
<tr>
<td></td>
<td>Female Mean</td>
<td>Female SD</td>
</tr>
<tr>
<td>Horizontal movements, mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labrale inferiorus</td>
<td>1.57</td>
<td>2.24</td>
</tr>
<tr>
<td>Profile planes, mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-line</td>
<td>$-0.92$</td>
<td>1.67</td>
</tr>
<tr>
<td>S1-line</td>
<td>$-0.39$</td>
<td>1.45</td>
</tr>
<tr>
<td>S2-line</td>
<td>$-0.29$</td>
<td>1.47</td>
</tr>
<tr>
<td>B-line</td>
<td>$-0.35$</td>
<td>1.19</td>
</tr>
<tr>
<td>H-line</td>
<td>$-0.20$</td>
<td>0.80</td>
</tr>
</tbody>
</table>

* Bold type indicates statistically significant ($P < .05$) change; SD, standard deviation.
traction patients is probably related to the relatively larger growth changes that occur at the nose and chin. These profile planes should not be used to determine the changes that occur in lower lip position during orthodontic treatment. Each of the above reference planes has been proven to be affected by the ST growth that occurs during the adolescent time period, especially in the reference planes associated with the nasal complex. Growth, therefore, produces inaccurate estimates of both the magnitude and direction of lower lip changes that occur during treatment, which are judged relative to the profile lines. The profile lines may be more effective at evaluating the relative position of the lower lip at a single point in time in order to determine whether an individual’s profile is esthetically pleasing, which is what these planes were originally created to do.

**CONCLUSIONS**

- The above reference planes do not reflect the magnitude of the change and, in most instances, the direction in which the lower lip changes during orthodontic treatment.
- While the five profile plane measures showed moderately high to high intercorrelations, none of them were related to the actual amount of anteroposterior lip change that occurred. Something else must be contributing to the position of the lips, and we believe this contributor is the ST growth that occurs during the adolescent period.
- From the data above, we were able to conclude that there are no differences between males and females in the lip changes that occur during orthodontic treatment.
- The H-line was the only measure to show statistically significant differences between extraction and non-extraction treatments.
- These five reference planes should not be used to measure the changes in lower lip position that occur during orthodontic treatment.

**ACKNOWLEDGMENT**

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**REFERENCES**


