The frontal soft tissue changes in the lower facial portion after orthodontic treatment combined with anterior segmental osteotomy

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Aim: To evaluate changes of the lower facial portion on the frontal view before and after orthodontic treatment combined with anterior segmental osteotomy (ASO) in patients with bimaxillary protrusion. Methods: The sample consisted of 16 women in the experimental group who had received ASO and 24 women in the untreated control group. Twelve linear measurements, 5 angular measurements, and the lip perimeter and area were measured and analyzed using unpaired and paired t tests. Results: The upper lip height and lower lip to chin length were significantly greater after treatment. The upper and lower vermilion heights and all vermilion areas decreased significantly, while lip width did not change. Upper lip height was significantly greater in the posttreatment group than in the control group, but there was no difference in upper and total lip areas. Conclusion: Treatment combined with ASO significantly improved the frontal soft tissue proportions. Anticipated frontal soft tissue changes of the lower face should be considered by clinicians for accurate diagnosis and treatment planning. ORTHODONTICS (CHIC) 2011;12:232–241.

Key words: anterior segmental osteotomy, bimaxillary protrusion, frontal soft tissue change, lips, vermilion

The primary objectives of orthodontic treatment include function, esthetics, and stability. It has been reported that an increasing number of adults are seeking orthodontic treatment, primarily because of esthetic concerns.¹,²

Due to the increased awareness of facial esthetics, the demand for orthodontic treatment to correct lip protrusion has increased, especially with the bimaxillary protrusion common in African American and Asian populations.³,⁴ Currently, anterior segmental osteotomy (ASO) combined with orthodontic treatment with extraction may be preferred since conventional nonsurgical correction of bimaxillary protrusion may be complicated by a variety of factors, such as unstable periodontal status, limited physiologic tooth movement, active social involvement, and longer treatment time.⁵-⁹
Previous studies on the relationship between hard and soft tissue have demonstrated that an attractive lip proportion is one of the key esthetic features of the lower face.\textsuperscript{8–10} To evaluate the lip position and proportions, the lateral view was most frequently used,\textsuperscript{8–17} even though the chief esthetic concern was often based on the frontal view.\textsuperscript{18–21} In 2004, Bisson and Grobbelaar\textsuperscript{21} performed a frontal evaluation of models and nonmodels in Caucasians. Recently, Kang et al\textsuperscript{18} evaluated and compared ethnic differences in esthetic preferences between Caucasians and Koreans. These previous studies mainly focused on esthetic standards and ethnic preferences, but did not report any substantial soft tissue changes resulting from specific treatment procedures. In the literature, there is still a lack of information in the area of frontal soft tissue changes following surgical orthodontic treatment.

Therefore, the aim of this study was to evaluate the changes in the lower facial portion on the frontal view before and after orthodontic treatment combined with ASO in women with bimaxillary protrusion and to compare them with an untreated control group.

METHODS

The sample for the experimental group consisted of 16 women who had been diagnosed with bimaxillary dentoalveolar protrusion and treated with maxillary and mandibular ASO. The patients’ ages at the time of surgery ranged from 18.8 to 32.2 years, with a mean of 25.3 ± 4.7 years. The mean treatment duration was 17 ± 11 months.

The inclusion criteria for the experimental group were an Angle Class I molar relationship and a minimum arch length discrepancy (less than 2 mm of crowding or spacing).

The exclusion criteria applied to the experimental group were deviations in the dental midline greater than 1.5 mm; history of previous orthodontic treatment, genioplasty, cosmetic surgery, or trauma at the perioral area; cleft lip and palate; and presence of muscle strain and edema around the lips in closed position on frontal facial photos.

ASO was performed by the same surgeon following procedures previously reported by Park and Hwang.\textsuperscript{10} The four first premolars were extracted during ASO; the remaining space was closed orthodontically.
The untreated control group consisted of 24 women from the nursing school at the Catholic University of Korea who gave consent to participate in this study. The control group represented Korean women with good facial appearance from frontal and lateral views selected by a consensus of three experienced orthodontists. Their mean age was 20.8 ± 2.6 years at the time of facial evaluation. To be included in the control group, the subjects had a Class I occlusion, straight profile, and frontal symmetry with an interlabial gap less than 1 mm. Exclusion criteria consisted of a history of trauma or previous orthodontic treatment and presence of mentalis hyperactivity at the time of initial evaluation. This study was approved by the university’s internal review board.

This study followed the method of Bisson and Grobbelaar in terms of the measurements recorded and sampling of subject photo images. Frontal photographs were taken by the same clinician using a camera (EOS 450D, Canon) set at a shutter speed of 1/125 second at a uniform distance between the subject and camera (1 m). The subjects were asked to remove all facial makeup and sit in a relaxed, upright position. To correct for the variation of image size among the photos, all lengths and perimeters were expressed as a ratio of the intercanthal distance in each image, which was given a nominal value of 10 units. Measurement lengths were divided by intercanthal distances and multiplied by 10.

Twelve lengths, five angles, and upper and lower lip area as well as the perimeter of each image were measured using AutoCAD 2005 software (Autodesk).

The following linear measurements were taken (Fig 1):

1. Full face width: The distance between the two most distal points along a horizontal line passing through the right and left corners of the mouth.
2. Full lip width: The distance between the right and left corners of the mouth.
3. Lower facial height: The distance from the subnasale to the soft tissue menton.
4. Upper lip height: The distance from the subnasale to the upper lip commissure line.
5. Upper vermilion height: The distance between the bottom of Cupid's bow to the most inferior portion of the vermilion of the upper lip.
7. Lower lip to chin: The distance between middle of lip commissure line to the soft tissue menton.
8. Upper vermilion left height: The distance of line connecting left Cupid's bow tip to inferior portion of vermilion of upper lip.
9. Upper vermilion right height: The distance of line connecting right Cupid's bow tip to inferior portion of vermilion of upper lip.
10. Bow tip to tip: The distance between left and right cupid's bow tips of the upper lip.
11. Right angle to bow tip: The distance between the right corner of the mouth and the right Cupid's bow tip of the upper lip.
12. Left angle to bow tip: The distance between the left corner of the mouth and the left Cupid's bow tip of the upper lip.

The following angles, perimeter, and vermilion areas were measured (Fig 2):

1. Upper vermilion angle: The angle formed between the lip commissure line and the line connecting Cupid's bow tip and mouth corner.
2. Lower vermilion angle: The angle formed between the lip commissure line and the lower vermilion borderline from the corner of the lower lip.
3. Right bow angle: The angle between the vermilion border line connecting right Cupid’s bow tip to right mouth corner and right Cupid’s bow inner slope.
4. Left bow angle: The angle between the vermilion border line connecting left Cupid’s bow tip to left mouth corner and left Cupid’s bow inner slope.
5. Central bow angle: The angle between right and left Cupid’s bow slope.
6. Total vermilion perimeter.
7. Upper vermilion area.
8. Lower vermilion area.
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Table 1  Mean ± SD of pre- and posttreatment cephalometric measurements

<table>
<thead>
<tr>
<th></th>
<th>Pretreatment</th>
<th>Posttreatment</th>
<th>Mean changes</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNA (degrees)</td>
<td>81.19 ± 2.54</td>
<td>79.25 ± 3.41</td>
<td>1.94 ± 1.32</td>
<td>*</td>
</tr>
<tr>
<td>SNB (degrees)</td>
<td>78.11 ± 2.64</td>
<td>75.87 ± 3.21</td>
<td>2.24 ± 0.84</td>
<td>***</td>
</tr>
<tr>
<td>ANB (degrees)</td>
<td>3.08 ± 1.12</td>
<td>3.38 ± 1.40</td>
<td>–0.30 ± 0.89</td>
<td>–</td>
</tr>
<tr>
<td>FMA (degrees)</td>
<td>29.42 ± 2.84</td>
<td>30.35 ± 4.13</td>
<td>–0.93 ± 2.76</td>
<td>–</td>
</tr>
<tr>
<td>U1–NA (degrees)</td>
<td>31.77 ± 5.12</td>
<td>18.19 ± 4.87</td>
<td>13.58 ± 4.11</td>
<td>***</td>
</tr>
<tr>
<td>U1–NA (mm)</td>
<td>10.30 ± 2.82</td>
<td>5.21 ± 2.40</td>
<td>5.09 ± 1.50</td>
<td>***</td>
</tr>
<tr>
<td>L1–NB (degrees)</td>
<td>38.85 ± 4.71</td>
<td>28.11 ± 5.76</td>
<td>10.73 ± 3.72</td>
<td>***</td>
</tr>
<tr>
<td>L1–NB (mm)</td>
<td>11.42 ± 1.39</td>
<td>7.08 ± 1.96</td>
<td>4.34 ± 1.64</td>
<td>***</td>
</tr>
<tr>
<td>E-line to UL (mm)</td>
<td>2.17 ± 1.16</td>
<td>–0.47 ± 0.65</td>
<td>2.64 ± 1.22</td>
<td>***</td>
</tr>
<tr>
<td>E-line to LL (mm)</td>
<td>5.32 ± 0.9</td>
<td>–0.02 ± 1.56</td>
<td>5.34 ± 1.37</td>
<td>***</td>
</tr>
</tbody>
</table>

SD, standard deviation; –not significant; *P < .01; ***P < .001.

Linear and angular measurements were also made and compared between pre- and posttreatment values on the cephalometric radiographs (Table 1). SAS for Windows 8.01 (SAS Institute) was used to conduct paired t tests to compare the mean cephalometric values for the subjects before and after treatment. For comparison between the experimental and untreated control groups, unpaired t tests were performed.

The measurement error was assessed by analyzing the difference between the duplicate means of eight randomly selected patients and 10 controls using the Dahlberg formula: \( \sqrt{\frac{\sum d^2}{2n}} \), where d is the difference between duplicated measurements and n is the number of replications. Errors were fewer than 0.25 units for linear measurements, fewer than 3.74 degrees for angular measurements, and fewer than 28.28 units for the area. Analysis of the measurement error showed that the reported values were highly reliable for replication.

RESULTS

Cephalometric measurements in Table 1 show that ANB was maintained after orthodontic treatment combined with ASO. However, both the maxillary and mandibular anterior teeth were significantly retracted as well as the upper and lower lips (\( P < .001 \)) (Fig 3).

Table 2 presents changes of the facial and lip proportions in the experimental group following ASO. The upper lip height and lower lip to chin lengths increased significantly (\( P < .001 \)). All vermilion parameters were significantly decreased except for total vermilion perimeter and lower vermilion angle, but the decrease in full face and lip width was not statistically significant.

A comparison of the pretreatment measurements with the control group in Table 2 shows that the lower vermilion angle was significantly greater than in the control group. Meanwhile, the lower lip to chin length was significantly shorter in the experimental group. Differences in the right, left, and central bow angles were all found to be statistically insignificant when compared between groups.
Table 2 also shows a comparison of posttreatment measurements with the control group. It demonstrates that full face width was narrower and upper lip height was longer in the posttreatment group compared to the control. Lower vermilion angle remained greater than in the control group ($P < .001$).

**DISCUSSION**

Recent advances in surgical techniques have resulted in increased demand among adult orthodontic patients for more rapid correction than previously possible by conventional treatment. ASO has been performed mainly to reduce treatment time in patients with bimaxillary protrusion.\textsuperscript{6–9}

Clinicians have traditionally evaluated the lateral view and hard tissue changes.\textsuperscript{8–17} However, little information is available from frontal evaluations of treatment results following ASO.\textsuperscript{18–20} It is therefore important to be more attentive to the frontal facial features when predicting soft tissue changes after surgery.

Thus, the present study measured the frontal soft tissue changes following anterior segmental osteotomy and then compared these results with a control group of young women. To avoid the effects of edema from recent surgical procedures on the accuracy of soft tissue measurements, sample selection was limited to those with at least 6 months of postsurgical healing. In addition, a rigorous patient-screening process was used throughout the study to focus on the female skeletal Class I condition in contrast to previous investigations where dental diagnosis was used only as an inclusion criterion.\textsuperscript{8,10,16} These procedures made the inclusion of cases in the study difficult; no more than 16 cases have matched the criteria. Although it would have been better to increase the sample size, it was considered statistically powerful enough to show the differences among the groups.

We found that after ASO, the upper lip height and lower lip to chin length increased, while the heights of the upper and lower vermilion decreased (Fig 4).
### Table 2  Comparison of soft tissue parameters of lower facial portion among pretreatment, posttreatment, and control groups

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Pretreatment (Pr) (n = 16)</th>
<th>Posttreatment (Po) (n = 16)</th>
<th>Control (Co) (n = 24)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Lengths (units)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full face width</td>
<td>32.76</td>
<td>2.42</td>
<td>32.5</td>
<td>2.63</td>
</tr>
<tr>
<td>Full lip width</td>
<td>13.07</td>
<td>1.12</td>
<td>12.89</td>
<td>1.55</td>
</tr>
<tr>
<td>Nose to chin</td>
<td>19.45</td>
<td>1.49</td>
<td>19.56</td>
<td>1.47</td>
</tr>
<tr>
<td>Upper lip height</td>
<td>4.37</td>
<td>0.57</td>
<td>4.83</td>
<td>0.48</td>
</tr>
<tr>
<td>Upper vermilion</td>
<td>2.71</td>
<td>0.54</td>
<td>2.24</td>
<td>0.38</td>
</tr>
<tr>
<td>Lower vermilion</td>
<td>3.64</td>
<td>0.57</td>
<td>3.21</td>
<td>0.48</td>
</tr>
<tr>
<td>Lower lip to chin</td>
<td>8.51</td>
<td>1.12</td>
<td>9.24</td>
<td>0.77</td>
</tr>
<tr>
<td>Upper vermilion left</td>
<td>3.14</td>
<td>0.50</td>
<td>2.65</td>
<td>0.36</td>
</tr>
<tr>
<td>Upper vermilion right</td>
<td>3.06</td>
<td>0.51</td>
<td>2.60</td>
<td>0.40</td>
</tr>
<tr>
<td>Bow tip to tip</td>
<td>3.28</td>
<td>0.52</td>
<td>3.36</td>
<td>0.63</td>
</tr>
<tr>
<td>Right angle to bow tip</td>
<td>6.07</td>
<td>0.78</td>
<td>5.73</td>
<td>0.56</td>
</tr>
<tr>
<td>Left angle to bow tip</td>
<td>5.84</td>
<td>0.55</td>
<td>5.41</td>
<td>0.47</td>
</tr>
<tr>
<td>Angles (degrees)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper vermilion angle</td>
<td>31.22</td>
<td>4.09</td>
<td>27.53</td>
<td>4.72</td>
</tr>
<tr>
<td>Lower vermilion angle</td>
<td>46.98</td>
<td>5.58</td>
<td>44.92</td>
<td>6.01</td>
</tr>
<tr>
<td>Right bow angle</td>
<td>130.97</td>
<td>8.23</td>
<td>132.62</td>
<td>8.92</td>
</tr>
<tr>
<td>Left bow angle</td>
<td>128.69</td>
<td>6.63</td>
<td>129.75</td>
<td>8.65</td>
</tr>
<tr>
<td>Central bow angle</td>
<td>150.17</td>
<td>10.13</td>
<td>143.63</td>
<td>11.69</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total vermilion perimeter</td>
<td>32.93</td>
<td>6.00</td>
<td>30.67</td>
<td>3.24</td>
</tr>
<tr>
<td>Total vermilion area</td>
<td>620.37</td>
<td>118.61</td>
<td>529.27</td>
<td>104.09</td>
</tr>
<tr>
<td>Upper vermilion area</td>
<td>279.52</td>
<td>65.92</td>
<td>223.87</td>
<td>47.99</td>
</tr>
<tr>
<td>Lower vermilion area</td>
<td>340.85</td>
<td>64.05</td>
<td>305.40</td>
<td>59.72</td>
</tr>
</tbody>
</table>

SD, standard deviation; – not significant; *P < .01; **P < .05; ***P < .001. A paired t test was applied to compare Pr vs Po, while an unpaired t test was used for Pr vs Co and Po vs Co.

**Fig 4** Comparison of means and standard deviations of linear measurements among pretreatment, posttreatment, and control groups.
These results may be attributed to posterior movement of the upper and lower lips following retraction of the anterior teeth. All vermilion areas decreased due to reduced upper and lower vermilion height, while there were no significant changes in the lip widths (Fig 5).

Park and Hwang\textsuperscript{10} focused on a lateral evaluation with the addition of four frontal parameters. They found that nasolabial angle and philtrum length were increased, and vermilion length and lip width were decreased. Our findings were consistent with their results, except for the lip width. This may be explained by variations in the amount of posterior movement, operative techniques, lip thickness and strength, and amount of fatty tissue and musculature.\textsuperscript{10,23} Also, Park and Hwang\textsuperscript{10} used “6 months postsurgery” as the only inclusion criterion. However, our inclusion and exclusion criteria were more strict. These control subjects represented a normal untreated sample with which the experimental group was compared before and after treatment. Comparison with the pretreatment subjects demonstrated their deviation from standard soft tissue values, while comparison with the posttreatment subjects determined the effectiveness of ASO in improving soft tissue measurements to normal esthetic standards.

Total and lower vermilion areas in our pretreatment group were significantly larger than in the control group, but these differences were resolved after treatment (Figs 5 and 6). Posttreatment results showed that the upper lip height in the experimental group became significantly longer than in the controls (Fig 4). This increase was probably caused by the full retraction of the anterior teeth combined with surgery.
Kang et al\cite{18} made an esthetic comparison of frontal measurements on professional female models and nonmodels, and concluded that the models had fuller lower and thinner upper vermilion areas. In the present study, the upper vermilion area improved from 279.5 units\textsuperscript{2} to 223.9 units\textsuperscript{2} following ASO. Also, full lip width in the posttreatment group was 12.9 units, which was close to the 13.2 reported by Kang et al\cite{18} for the models. The results suggest that posttreatment values for some measurements approach the esthetic standards for models.

However, concerning the use of models as a control group, the present study did not include them because the model samples from magazine and Internet photographs would have made standardization very difficult due to variation in angulation and magnification from one photograph to another. Also, the makeup worn by the models under different light conditions would have made it even more challenging for valid comparison. As a result, our study utilized nonmodels as a control group. Standardizing the process of photography allowed more accurate comparisons among the groups. In addition, to control the magnification variation, evaluations were made by measuring linear dimensions divided by intercanthal width to provide standardized results.\cite{21} This is recommended because it is important to consider proportion as well as absolute values when comparing different groups.

ASO has been indicated in bimaxillary protrusion patients for maximum retraction in a shorter treatment time, but with the introduction of mini-implants, the procedure has decreased in popularity. Since use of skeletal anchorage allows distalization of the buccal segment as well as full retraction of anterior teeth, the amount of soft tissue improvement may be maximized compared to ASO alone. A future study comparing the effectiveness of ASO vs mini-implants or ASO assisted with mini-implants might be worthwhile.

Further study comparing a model sample under standardized photographic conditions rather than an untreated control group would be helpful to evaluate the esthetic norms for better diagnosis and treatment planning.

CONCLUSION

Treatment combined with ASO significantly improved the frontal soft tissue dimensions. Therefore, it is recommended that clinicians use this data to predict frontal soft tissue changes of the lower facial portion in diagnoses and treatment planning for better esthetic results.

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REFERENCES