Effects of extraction of four premolars on vermilion height and lip area in patients with bimaxillary protrusion

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SUMMARY The purpose of this study was to evaluate the effects of orthodontic treatment, involving the extraction of four premolars, on vermilion height and lip area. Twenty-eight female patients (mean 21.9 ± 3.1 years) who were diagnosed with bimaxillary protrusion were selected for this study to be treated by extraction of four premolars. The control group consisted of 28 female volunteers (mean 25.0 ± 3.0 years) with Angle Class I normal occlusion. Frontal photographs of the patients were taken both before and after the orthodontic treatment in resting position. Thirty-five landmarks on the upper and lower lips were identified for the measurements of vermilion height and lip area. Lateral cephalograms were taken before and after active orthodontic treatment, and linear and angular measurements were performed. The mean pre-treatment values of vermilion height and lip area were significantly greater in the treatment group than those of the control group and decreased significantly after the orthodontic treatment towards the values in the control group. There were no significant differences in the vermilion height and lip area between the post-treatment and the control groups, except for lower lip area values. Significant correlations found between the changes in incisor position and the changes in vermilion height were few in number for the upper lip but greater in number for the lower lip. Thus, the results of this study show that bimaxillary protrusion cases can be treated by the extraction of four premolars to produce an aesthetic improvement in frontal facial features.

Introduction

The objectives of orthodontic treatment are not only to obtain functional occlusion but also to improve facial and dental aesthetics (Peck and Peck, 1970). The face plays a key role in the communication and interaction that involved in all social relationships among human beings (Ferrario et al., 2003; Matoula and Pancherz, 2006; Van der Geld et al., 2007). Farkas (1994) found a greater upper lip vermilion height at resting lip position in aesthetically pleasing men. Sforza et al. (2008) also reported that attractive adolescents had larger and more prominent lips than the average size. Moreover, a recent study reported that vermilion height played a very important role in determining smile aesthetics (McNamara et al., 2008). McNamara et al. (2008) concluded that the vertical thickness of the upper lip was an aesthetic determinant in a smiling face for both orthodontists and laypersons and that the vertical thickness of the lower lip was an aesthetic determinant in a smiling face for laypersons. Thus, vertical lip thickness was important in the determination of the attractiveness of a smile. Therefore, the relationship of incisor protrusion with upper lip thickness must be considered when planning orthodontic treatment.

It has been proposed that vermilion height could be large in bimaxillary protrusion cases due to the labially inclined anterior teeth (McNamara et al., 2008). These patients could be treated by extracting their premolars in order to straighten their profiles and make lip seal easier. Bills et al. (2005) had concluded in an earlier report that the extraction of four premolars would straighten the lips in patients with bimaxillary protrusion. This treatment modality might thus result in a decrease in vermilion height from a frontal view. Although studies on the relationship between the retraction of anterior teeth and profile changes have been reported (Oliver, 1982; Rains and Nanda, 1982; Drobocky and Smith, 1989; Bravo, 1994; Kusnoto and Kusnoto, 2001; Yasutomi et al., 2006; Hayashida et al., 2010), no reports can be found on changes in vermilion height and lip area as a result of the extraction of four premolars.

The purpose of this study was to evaluate the effects of orthodontic treatment by the extraction of four premolars on changes in vermilion height and lip area. The hypotheses of this study were that: 1. the vermilion height would be greater in bimaxillary protrusion cases than in those with normal occlusion, 2. the retraction of anterior teeth in the orthodontic treatment involving the extraction of four
premolars would decrease the vermilion height and the area of the upper and lower lips, and 3. the extent of anterior retraction would correlate to the decrease in vermilion height and the area of the lips.

Materials and methods

Samples

A group of patients was selected from the case files of the Section of Orthodontics, Faculty of Dental Science, Kyushu University, Fukuoka, Japan. Inclusion criteria for the patient group in the present study were as follows:

1. Japanese female adults who were at least 18 years old at the beginning of the treatment;
2. Orthodontic treatment consisting of the extraction of four premolars, resulting in subsequent retraction of anterior teeth;
3. Pre- and post-treatment cephalometric radiographs of adequate diagnostic quality;
4. An ANB angle between 1 degree and 6 degree, Skeletal class I;
5. Pre-treatment Angle Class I molar relationship;
6. Pre-treatment upper incisor protrusion (U1-point A vertical line to occlusal plane) more than 6.0 mm;
7. Pre-treatment lower incisor protrusion (L1-APog) more than 4.9 mm;
8. Pre-treatment overjet less than 4.0 mm;

In the present study, records were obtained from 28 female patients (age range: 18–30 years; mean age ± standard deviation (SD): 21.9 ± 3.1 years). All patients were treated with edgewise appliances.

A control group was selected from dental students and staff members of Kyushu University. Twenty-eight female volunteers (age range: 20–30 years; mean age ± SD: 25.0 ± 3.0 years) with Angle Class I normal occlusion were included in this study. All volunteers in the control group were healthy and free from any craniofacial anomalies.

The research protocol was approved by the Ethics Committee of Kyushu University.

Facial photograph analysis

Frontal photographs of the control and patient groups were taken in resting position in a naturally seated posture with the head fixed by ear rods, at a distance of 1.5 m between the camera and the subject. The subject’s head was positioned so that the Frankfort horizontal (FH) plane was parallel to the floor, and the midsagittal plane of the head was aligned with the centre of the camera lens. Frontal photographs were taken of the patients with bimaxillary protrusion before and immediately after orthodontic treatment. All frontal photographs were scanned at the resolution of 300 dpi, printed on paper, traced by hand using tracing paper, and 35 facial landmarks were marked on the tracings.

The X-axis was drawn parallel to the line connecting the right and left irises through the subnasal point (Sn), whereas the Y-axis was drawn perpendicular to the X-axis through the Sn point (Figure 1). Two vertical lines were then drawn through the right and left superior vermilion points (9, 11). Both the right and left sides were divided into three equal parts from the superior vermilion point of the lip to the corners of the mouth (6, 14). Four more vertical lines were drawn through landmarks numbered 7, 8, 12, and 13. The landmarks numbered 6–14 and 15–21 were allocated for the upper lip, and 22–28 and 29–35 were allocated for the lower lip. We measured the vermilion height (7–15, 8–16, 9–17, 10–18, 11–19, 12–20, 13–21, 22–29, 23–30, 24–31, 25–32, 26–33, 27–34, and 28–35) and the lip area of both lips using the software program Winceph 5.5 (Rise, Sendai, Japan) and Adobe Photoshop 7.0 (Adobe systems, San Jose, CA). Details about the landmarks were reported earlier (Islam et al., 2009). Every landmark was digitized into X–Y co-ordinate values, and a statistical analysis was performed by using these values. To compare facial sizes, we measured the distance between the right and left irises of the patient and the control groups (Islam et al., 2009). Wilcoxon rank sum tests were used to test the differences in facial size between the patient and the control groups (JMP, SAS Institute INC, Cary, NC). We confirmed that there were no significant differences in facial size between the two groups.

Cephalometric analysis

Lateral cephalograms before and after orthodontic treatment were taken with lips in the relaxed position and teeth in occlusion (Ricketts, 1960; Burstone, 1967). The radiographs were taken with a DR-155-23HC (SSR-2B; Hitachi Medical Corporation, Tokyo, Japan) and exposed at 100 kV, 200 mA at the Dental Radiology Section of Kyushu University Hospital. All cephalometric radiographs were traced by hand on matte acetate sheets by one author (N.T.) to avoid any inter-investigator variability.

The reference line X was assigned as the plane parallel to the occlusal plane through sella, while the reference line Y was perpendicular to the reference line X, continuing through sella on the tracing of pre-treatment cephalograms. These X and Y axes were traced on the post-treatment tracing by superimposition with the pre-treatment tracing. Four linear measurements were determined to evaluate vertical dental changes (Figure 2), six linear and three angular measurements were constructed to evaluate horizontal dental changes (Figure 3). In addition, seven linear and one angular measurements were constructed for the skeletal and soft tissue measurements (Figure 2). The measurements of Sn–St and St–Me were constructed using the FH plane as the reference line.
treatment. All frontal photographs were scanned at the
protrusion before and immediately after orthodontic
photographs were taken of the patients with bimaxillary
was aligned with the centre of the camera lens. Frontal
positioned so that the Frankfort horizontal (FH) plane was
the head
Frontal photographs of the control and patient groups were
included in this study. All volunteers in the control group
3.0 years) with Angle Class I normal occlusion were
volunteers (age range: 20 – 30 years; mean age
9.7. Freedom from any craniofacial anomalies.
8. Pre-treatment overjet less than 4.0 mm;
7. Pre-treatment lower incisor protrusion (L1-APog) more
6. Pre-treatment upper incisor protrusion (U1-point A
5. Pre-treatment Angle Class I molar relationship;
4. An ANB angle between 1 degree and 6 degree, Skeletal
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Section of Orthodontics, Faculty of Dental Science, Kyushu
A group of patients was selected from the case
Materials and methods

Figure 1  Facial photograph analysis. Upper vermilion height 7–15, 8–16, 9–17, 10–18, 11–19,

Figure 2  Vertical linear measurements and soft tissue measurements. 1. tU1–X-axis (V–tU1) (mm), 2. cU1–X-axis (V–cU1) (mm), 3. tL1–X-axis (V–tL1) (mm), 4. cL1–X-axis (V–cL1) (mm), 5. cL1-thickness (mm), 6. cL-thickness (mm), 7. Chin thickness (mm), 8. Sn–St (mm), 9. St–Me (mm), 10. Interlabial gap (mm), 11. Nasolabial angle (°), and 12. N–Me (mm).

Figure 3  Horizontal linear and angular measurements. 1. tU1–Y-axis (H–tU1) (mm), 2. cU1–Y-axis (H–cU1) (mm), 3. tL1–Y-axis (H–tL1) (mm), 4. cL1–Y-axis (H–cL1) (mm), 5. tU1–Mo (mm), 6. tL1–Mi (mm), 7. U1–SN (°), 8. U1–FH (°), and 9. L1–Md (°).
Statistical analysis

The pre-treatment values were compared with the post-treatment values by using Wilcoxon signed-ranks tests, and Pearson’s correlation coefficients were calculated to assess the association between incisal position changes and vermilion height or lip area. In addition, Wilcoxon rank sum tests were used to test the differences between the patient and control groups. Stepwise regression analysis was used to determine the combination of variables that predict lip morphological changes during orthodontic treatment (JMP, SAS Institute INC). The minimum level of statistical significance was set at \( P < 0.05 \).

Sample size

A sample size calculation was undertaken using the nQuery Adviser software package (Version 6.01, Statistical Solutions, Cork, Ireland). The pilot study estimated that the effect size was 1.323. Based on a significance level of alpha 0.050, the sample size was calculated to achieve 90 per cent power. The sample size calculation showed that 14 subjects were necessary for statistically meaningful analysis.

Reliability

All facial photographs were traced and digitized on two separate occasions to evaluate intraobserver consistency for the measuring system. Intraclass correlation coefficients (ICCs) for the vermilion height and lip area measurements were used for detecting intraobserver agreement. As all ICC were greater than or equal to 0.84, the method error was considered to be negligible.

Facial photographs of 10 female volunteers were taken three times at 1-week intervals to assess test–retest consistency; the photographs were traced and digitized by one observer. One-factorial repeated analysis of variance was used to evaluate the reliability of the method. There was no statistically significant difference in vermilion height or lip area among the three facial photographs.

Results

Lip morphological changes

Upper vermilion height changes during the orthodontic treatment are shown in Figure 4.

Pre-treatment values of upper vermilion height were significantly greater than post-treatment values. The values of the pre-treatment upper vermilion height were significantly greater than those of the control group. There were no significant differences between the post-treatment and the control groups.

Lower vermilion height changes during the orthodontic treatment are shown in Figure 5. Pre-treatment values of lower vermilion height were significantly greater than post-treatment values. Pre-treatment values of lower vermilion height were significantly greater than those of the control group. There were no significant differences between the post-treatment and the control groups.

Lip area changes occurring during orthodontic treatment are shown in Figure 6. Pre-treatment values of the lip area were significantly greater than post-treatment values for both upper and lower lips. Pre-treatment values of the lip area were significantly greater than those of the control group for both upper and lower lips. Although there was no significant difference in the upper lip area between the post-treatment and the control groups, the post-treatment values of the lower lip area were still greater than those of the control group.

![Figure 4](image-url) Changes in upper vermilion height during the orthodontic treatment.
Cephalometric analysis

The upper and lower incisors were significantly moved, posteriorly and lingually (Table 1), from the horizontal measurement of H–tU1, H–cU1, H–tL1, H–cL1, U1–SN, U1–FH, L1–Md, tU1–Mo, and tL1–Mi. Skeletal and soft tissue analysis revealed significant increases in the N–Me, Sn–St, and nasolabial angle (Table 2). Cephalometric analysis of V–tU1 and V–cU1 measurements revealed that the upper incisors extruded significantly due to the orthodontic treatment (Table 2).

Relationship between incisor position and lip morphology

We found only a few significant correlations between the changes in incisor position and changes in vermilion height for the upper lip (Table 3). However, several significant correlations were found between the changes in incisor position and changes in the vermilion height or lip area for the lower lip (Table 4).

Stepwise multiple regression analysis

Using the variables for stepwise multiple regression analysis (Supplementary Table 1, available as online supplementary material), stepwise regression models were developed for vermilion height and lip area (Supplementary Table 2, available as online supplementary material). The predictability of changes in upper vermilion height and lip area was relatively low although changes in upper (Up) 7–15 vermilion height were predicted by three variables
with 43 per cent confidence. Up 10–18 (centre of upper lip) vermilion height was predicted by six variables with 55 per cent confidence. However, the changes in lower (Lo) 23–30 vermilion height were predicted by 10 variables with 75 per cent confidence. Lo 24–31 vermilion height was predicted by six variables with 51 per cent confidence. Lo 25–32 vermilion height was predicted by seven variables with 61 per cent confidence, and Lo 26–33 vermilion height was predicted by three variables with 49 per cent confidence. Lo 27–34 vermilion height was predicted by eight variables with 70 per cent confidence, whereas Lo 28–35 vermilion height was predicted by four variables with 46 per cent confidence. Moreover, lower lip area was predicted by eight variables with 66 per cent confidence. Thus, vermilion height and lip area were predicted by variables, such as changes in incisor position as well as initial skeletal and soft tissue variables, with relatively high level of confidence.

### Discussion

Facial aesthetics is one of the most important matters of concern for both orthodontists and their patients. Individuals mainly focus on another person’s eyes and mouth during interpersonal interaction (Evans et al., 2005). Therefore, facial appearance is fundamental for communication and interaction in human society. To date, studies have reported antero-posterior evaluation of the aesthetic features of lip position in the lateral view (Farrow et al., 1993; Ioi et al., 2005; McKoy-White et al., 2006; Chan et al., 2008). However, morphological lip changes need to be studied from the frontal view, as patients tend to judge their facial aesthetics in the mirror. The present report is the first study to evaluate the effects of orthodontic treatment by the extraction of four premolars on changes in vermilion height and lip area.

On separate occasions, the reliability test showed that ICCs were greater than or equal to 0.84 for the vermilion

### Table 1  Horizontal incisor position changes in the orthodontic treatment.

<table>
<thead>
<tr>
<th>Pre-treatment</th>
<th>Post-treatment</th>
<th>Significant</th>
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<tbody>
<tr>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td></td>
</tr>
<tr>
<td>H–tU1 (mm)</td>
<td>89.45 ± 3.53</td>
<td>84.65 ± 3.19</td>
</tr>
<tr>
<td>H–cU1 (mm)</td>
<td>85.27 ± 3.24</td>
<td>82.90 ± 3.19</td>
</tr>
<tr>
<td>H–cL1 (mm)</td>
<td>86.25 ± 3.77</td>
<td>81.37 ± 3.33</td>
</tr>
<tr>
<td>H–cL1 (mm)</td>
<td>83.93 ± 3.43</td>
<td>80.65 ± 3.45</td>
</tr>
<tr>
<td>U1–SN (°)</td>
<td>112.84 ± 4.48</td>
<td>100.26 ± 5.93</td>
</tr>
<tr>
<td>U1–FH (°)</td>
<td>120.54 ± 3.92</td>
<td>108.00 ± 6.26</td>
</tr>
<tr>
<td>L1–Md (°)</td>
<td>98.82 ± 8.19</td>
<td>88.50 ± 9.11</td>
</tr>
<tr>
<td>L1–Md (°)</td>
<td>98.82 ± 8.19</td>
<td>88.50 ± 9.11</td>
</tr>
</tbody>
</table>

*P < 0.05, **P < 0.01, and ***P < 0.001.

### Table 2  Vertical incisor position and soft tissue changes in the orthodontic treatment.

<table>
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<tr>
<th>Pre-treatment</th>
<th>Post-treatment</th>
<th>Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
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<tr>
<td>V–tU1 (mm)</td>
<td>65.69 ± 4.64</td>
<td>66.93 ± 5.20</td>
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<tr>
<td>V–cU1 (mm)</td>
<td>53.44 ± 4.69</td>
<td>54.18 ± 5.11</td>
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<tr>
<td>V–tL1 (mm)</td>
<td>64.21 ± 4.24</td>
<td>64.47 ± 5.05</td>
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<tr>
<td>V–cL1 (mm)</td>
<td>75.26 ± 4.38</td>
<td>75.67 ± 4.92</td>
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<td>cU-thickness (mm)</td>
<td>13.29 ± 1.73</td>
<td>13.31 ± 1.76</td>
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<tr>
<td>CL-thickness (mm)</td>
<td>13.52 ± 2.63</td>
<td>13.30 ± 2.14</td>
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<tr>
<td>Chin-thickness (mm)</td>
<td>10.76 ± 2.00</td>
<td>11.17 ± 2.04</td>
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<tr>
<td>Sn–St (mm)</td>
<td>23.66 ± 2.42</td>
<td>24.69 ± 2.66</td>
</tr>
<tr>
<td>St–Me (mm)</td>
<td>54.95 ± 3.42</td>
<td>55.34 ± 3.71</td>
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<tr>
<td>Interlabial gap (mm)</td>
<td>0.63 ± 1.90</td>
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<td>Nasolabial angle (°)</td>
<td>99.76 ± 8.02</td>
<td>102.94 ± 11.01</td>
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<tr>
<td>N–Me (mm)</td>
<td>130.30 ± 5.53</td>
<td>131.18 ± 5.78</td>
</tr>
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</table>

*P < 0.05, **P < 0.01, and ***P < 0.001, NS, no significant.

### Table 3  Correlation coefficients between changes of incisor position and vermilion height or lip area in upper lip.

<table>
<thead>
<tr>
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<tr>
<td>H–tU1 (mm)</td>
<td>0.203</td>
<td>0.368</td>
<td>0.202</td>
<td>0.162</td>
<td>0.253</td>
<td>0.146</td>
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<tr>
<td>H–cU1 (mm)</td>
<td>–0.048</td>
<td>–0.008</td>
<td>0.005</td>
<td>0.116</td>
<td>0.155</td>
<td>0.078</td>
<td>–0.069</td>
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<tr>
<td>H–tL1 (mm)</td>
<td>–0.133</td>
<td>–0.950</td>
<td>–0.074</td>
<td>–0.093</td>
<td>0.082</td>
<td>–0.110</td>
<td>0.150</td>
</tr>
<tr>
<td>H–cL1 (mm)</td>
<td>–0.023</td>
<td>0.210</td>
<td>–0.092</td>
<td>–0.034</td>
<td>0.035</td>
<td>0.083</td>
<td>0.246</td>
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<tr>
<td>V–tU1 (mm)</td>
<td>–0.194</td>
<td>–0.313</td>
<td>–0.078</td>
<td>–0.194</td>
<td>–0.130</td>
<td>–0.083</td>
<td>0.246</td>
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<tr>
<td>V–cU1 (mm)</td>
<td>–0.137</td>
<td>–0.338</td>
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<td>–0.340</td>
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<tr>
<td>V–tL1 (mm)</td>
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<td>–0.0330</td>
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<td>–0.095</td>
<td>0.011</td>
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<tr>
<td>V–cL1 (mm)</td>
<td>–0.111</td>
<td>–0.196</td>
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<tr>
<td>U1–SN (°)</td>
<td>0.323</td>
<td>0.429*</td>
<td>0.184</td>
<td>–0.072</td>
<td>0.085</td>
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<td>U1–FH (°)</td>
<td>0.274</td>
<td>0.402*</td>
<td>0.178</td>
<td>–0.038</td>
<td>0.097</td>
<td>0.089</td>
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<tr>
<td>L1–Md palne (°)</td>
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<td>–0.106</td>
<td>0.074</td>
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<tr>
<td>tU1–Mo (mm)</td>
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<td>–0.014</td>
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<td>–0.285</td>
<td>–0.118</td>
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*P < 0.05, **P < 0.01, and ***P < 0.001.
Table 4  Correction coefficients between changes of incisor position and vermilion height or lip area in lower lip.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>H–tU1 (mm)</td>
<td>0.153</td>
<td>−0.288</td>
<td>−0.405*</td>
<td>−0.310</td>
<td>−0.493**</td>
<td>−0.296</td>
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<td>H–cU1 (mm)</td>
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<td>−0.278</td>
<td>−0.371</td>
<td>−0.476*</td>
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<tr>
<td>H–tL1 (mm)</td>
<td>0.349</td>
<td>0.207</td>
<td>0.015</td>
<td>0.111</td>
<td>0.228</td>
<td>0.075</td>
<td>0.197</td>
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<tr>
<td>H–cL1 (mm)</td>
<td>0.349</td>
<td>0.207</td>
<td>0.015</td>
<td>0.111</td>
<td>0.228</td>
<td>0.075</td>
<td>0.197</td>
<td>0.132</td>
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<tr>
<td>V–tU1 (mm)</td>
<td>−0.288</td>
<td>−0.405*</td>
<td>−0.310</td>
<td>−0.493**</td>
<td>−0.296</td>
<td>−0.027</td>
<td>−0.160</td>
<td></td>
</tr>
<tr>
<td>V–cU1 (mm)</td>
<td>−0.438*</td>
<td>0.058</td>
<td>0.111</td>
<td>0.044</td>
<td>0.129</td>
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<td>V–tL1 (mm)</td>
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<td>−0.036</td>
<td>0.156</td>
<td>0.168</td>
<td>0.143</td>
<td>0.160</td>
<td>0.034</td>
<td>0.072</td>
<td>0.117</td>
</tr>
<tr>
<td>U1–SN (°)</td>
<td>−0.049</td>
<td>−0.152</td>
<td>−0.114</td>
<td>0.078</td>
<td>−0.057</td>
<td>−0.010</td>
<td>−0.018</td>
<td>0.021</td>
</tr>
<tr>
<td>U1–FH (°)</td>
<td>−0.020</td>
<td>−0.146</td>
<td>−0.144</td>
<td>−0.042</td>
<td>−0.133</td>
<td>−0.044</td>
<td>−0.028</td>
<td>0.033</td>
</tr>
<tr>
<td>L1–Md palate (°)</td>
<td>−0.186</td>
<td>−0.147</td>
<td>0.015</td>
<td>0.033</td>
<td>−0.008</td>
<td>−0.023</td>
<td>−0.059</td>
<td>−0.009</td>
</tr>
<tr>
<td>tU1–Mo (mm)</td>
<td>0.167</td>
<td>−0.011</td>
<td>−0.200</td>
<td>−0.235</td>
<td>−0.434*</td>
<td>−0.092</td>
<td>−0.163</td>
<td>−0.016</td>
</tr>
<tr>
<td>tL1–Mi (mm)</td>
<td>0.030</td>
<td>0.046</td>
<td>0.107</td>
<td>0.122</td>
<td>−0.023</td>
<td>0.248</td>
<td>−0.001</td>
<td>0.218</td>
</tr>
</tbody>
</table>

*P < 0.05, **P < 0.01, and ***P < 0.001.

height and lip area measurements. This result demonstrated that the measurement system in this research protocol was quite reliable, and therefore, that the method error could be considered to be negligible. Moreover, morphological differences were minimal on three different occasions and therefore, lip morphology appeared to be a stable and reliable parameter for evaluation.

We found that pre-treatment values of vermilion height and lip area in the patient group were significantly greater than those of the control group for both upper and lower lips. This finding is in agreement with the clinical observation that flared incisors have a tendency to roll the upper and lower lips out, exposing more of the mucocutaneous lip and increasing the vermilion height and lip area (McNamara et al., 2008). McNamara et al. (2008) also reported a positive correlation between the vertical thickness of the upper lip and the position of the maxillary incisor. By extracting the four premolars, values of vermilion height and lip area significantly decreased towards corresponding values in the control group. However, post-treatment values of vermilion height and lip area in the patient group were not lower than those of the control group. It is very important for bimaxillary protrusion patients to improve their profiles by posterior movements of their anterior teeth, particularly in the Japanese population as Japanese young adults prefer a retracted profile (Shimomura et al., 2011) even though Japanese profiles have ethnically been characterized by more convex facial features (Nezu et al. 1982). In addition, lip morphology from a frontal view is another matter of concern. McNamara et al. (2008) stated that the vermilion height of the upper lip was an aesthetic determinant for orthodontists and laypersons, whereas the vertical thickness of the lower lip was an aesthetic determinant for laypersons. Our results suggest that the clinicians could decrease the vermilion height towards average values while concomitantly improving their profiles. There is no distinct evidence regarding the vermilion height that would be preferred by orthodontists and orthodontic patients. In general, treatment objectives for orthodontic treatment are set to be in the average range in the absence of any apparent contradiction against physiological function. Langlois and Roggman (1990) reported that attractive faces were only average and that the notion of attractiveness is consistent with evolutionary pressures that favour characteristics close to the mean of the population and with cognitive processes that favour prototypical category members. Thus, average vermilion height would be one desirable treatment objective of orthodontic treatment; the desirable values for vermilion height need further investigation.

Only a few significant correlations were found between changes in incisor position and changes in vermilion height for the upper lip, whereas several significant correlations were found between the above changes for the lower lip. These results suggest that changes in frontal lip morphology cannot be predicted only by changes in incisor positions. Hayashida et al. (2010), who investigated the effects of retraction of the anterior teeth and initial soft tissue variables on antero-posterior lip changes, reported that the predictability of lip position increases by including not only the incisor position but also the initial soft tissue variables. In the present study, the predictability for vermilion height and lip area increased significantly when the incisor position as well as the skeletal and soft tissue variables were included as independent variables, particularly for the lower lip. Seven variables (Lo 23–30, Lo 24–31, Lo 25–32, Lo 26–33, Lo 27–34, Lo 28–35, and Lo Lip Area) of eight for the lower lip were highly predicted by changes in incisor position as well as by the initial skeletal and soft tissue variables. The lower vermilion height and lip area might be predicted by the changes in incisor position in combination with the initial skeletal and soft tissue variables.

Retraction of the anterior teeth leads to the reduction of tongue space. These changes might result in the relapse of
the anterior teeth. Thus, a re-examination of these patients is necessary after the retention period to evaluate the stable positions of both hard and soft tissues.

The current study demonstrated that the post-treatment values of vermilion height and lip area in the patient group decreased towards the values in the control group after the extraction of the four premolars. The lower values of vermilion height and lip area might be predicted by changes in incisor position and the initial skeletal and soft tissue variables. We found that, to correctly predict post-treatment changes, each subject must be carefully observed by evaluating individual soft tissue patterns.

Conclusions
1. Pre-treatment values of vermilion height and lip area were significantly greater in the patient group than in those of the control group for both the upper and lower lips.
2. The values of vermilion height and lip area in the patient group significantly decreased towards the corresponding values in the control group as a result of the orthodontic treatment.
3. Only a few significant correlations were found between changes in the incisor position and changes in the vermilion height for the upper lip, whereas several significant correlations were observed between the above changes for the lower lip.
4. The values of lower vermilion height and lip area could be predicted by including the variables of the changes in incisor position as well as the initial skeletal and soft tissue variables. However, certain parameters, such as lower facial height, should be added to improve the predictability.
5. Clinicians can treat patients with bimaxillary protrusion by decreasing vermilion height towards the average values while concomitantly improving their profiles.

Supplementary material
Supplementary material is available at European Journal of Orthodontics online.

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