Original Article

The Effects of Commonly Prescribed Premolar Extraction Sequences on the Curvature of the Upper and Lower Lips

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Abstract: The potential for premolar extractions to produce adverse facial effects after orthodontic treatment is still controversial. Detailed documentation of the predictability, or otherwise, of various soft tissue treatment effects would obviously be of assistance to clinical orthodontists in day-to-day treatment planning, by potentially refining the criteria for appropriate selection of various premolar extraction sequences. With this in mind, a retrospective lateral cephalometric study of 80 premolar extraction cases was undertaken to assess whether different patterns of premolar extraction do in fact produce predictably different lateral profile effects. A comparison was made of the changes in lip curvature after the extractions of all first premolars (4/4), all second premolars (5/5), or upper first and lower second premolars (4/5). Changes in the depths of curvature of both the upper and lower lips were not solely dependent on the selection of a particular premolar extraction sequence. Instead, there were wide ranges of individual variation in the changes in the depths of the lip curves. Therefore, in addition to the inherent soft tissue morphology of the lips in individual patients, it is the combined effect of the lip response to various dental and skeletal changes and the competent clinical management of extraction spaces that apparently affects the shapes of the lips within the lateral profile during treatment. In other words, it would seem possible for the clinician to carefully manage either first or second premolar extraction spaces while still protecting the facial profile. (*Angle Orthod* 2003;73:386–395.)

Key Words: Lateral facial profile; Premolar extractions; Lip curvature; Lip depth

INTRODUCTION

Facial appearance at the completion of treatment is obviously of paramount importance to contemporary orthodontists.[1] Accordingly, the detailed assessment of the lateral facial profile is an important part of routine diagnosis and planning.[2] Whether viewed dynamically or statically, individual facial harmony and profile balance are determined by the interaction of the inherent morphology of the soft tissues themselves, the characteristics of the underlying skeletal foundation, and the positions and angulations of the teeth. All these factors combine to provide the visual impact of each individual face.[3–5]

The ability of humans to recognize facial balance and harmony is apparently instinctive, and within any cultural group there seems to be a general consensus of what is accepted as an esthetically pleasing facial appearance.[6–8] The establishment of an objective method for assessment of profile features, however, has been difficult. Over the years, a number of analyses have been advocated in an attempt to quantitatively evaluate the esthetics of lateral facial profiles. Most of these methods appear to be based on the use of particular anterior reference lines, with which to compare the protrusion of one facial component relative to another. Such reference lines have included Merrifield's Z-angle, Ricketts' E-line, and Steiner's S-line.[9–11] When these well-known lateral cephalometric references are used, either for planning or for the assessment of changes with growth and treatment, the emphasis is placed on the anteroposterior positions of the profile components relative to each other, with little real focus being given to the vertical or transverse dimensions. Apparently, even less consideration was given to the depth and regularity of the tissue contours and their importance in the overall perception of the lateral facial profile. Interestingly, Holdaway's[2,12] soft tissue analysis is unique in this respect because it does include an assessment of the upper lip sulcus depth. Holdaway emphasized the need for the upper lip curve to be considered during planning to reduce the potential for the development of unpleas-

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ant expressions in this region, apparently as a result of excessive retraction of the upper and lower teeth during treatment. Holdaway recognized that the appropriate upper lip sulcus depth might vary amongst subjects with different underlying vertical facial patterns. For example, he recommended that for subjects with shorter faces, an upper lip sulcus depth of four mm might not be excessive. On the other hand, for subjects with longer faces, an appropriate upper lip sulcus depth might be as low as one mm. Although several other authors have considered the depths of the lip curves,[13–15] there is little information in the literature regarding changes in these depths, which might be associated with treatment involving various premolar extraction sequences.[14]

For more than a hundred years, the potential for premolar extractions to produce adverse facial effects after orthodontic treatment has been debated.[3,16] This concern for potential adverse effects remains a contemporary issue, both within the profession and in the community at large.[16,17] Fluctuations in extraction rates with time[18] and the widespread adoption of alternative premolar nonextraction treatment strategies[3] reflect an undercurrent of concern for the esthetic effect of orthodontic treatment involving premolar extractions. Apart from this long-standing extraction vs nonextraction debate, there are anecdotally based expectations of the esthetic benefit of one premolar extraction sequence over another. In 1949, for instance, Nance[19] stated that the term *extraction* had, at that time, become synonymous with the removal of all four first premolars. To protect the lips within the lateral facial profile, Nance promoted alternative extraction sequences such as upper and lower second premolars or second premolars from one arch and first premolars from the other. It, therefore, might be said that Nance's recommendations formed the basis of the still widely accepted clinical notion that to somehow protect the lateral lip profile, second premolars should often be extracted instead of first premolars. The accepted esthetic merit of the effects of different extraction sequences, however, was apparently based largely on clinical observation, with little scientific evidence to support the choice of one sequence over another.[20,21]

With all these things in mind, the present study was designed to evaluate the effects of three commonly prescribed premolar extraction sequences (4/4, 5/5, and 4/5) on the lateral facial profile, with particular reference to the depths of curvature of the upper and lower lips.

MATERIALS AND METHODS

Study sample

The sample consisted of 80 premolar extraction cases, selected at random from completed premolar extraction cases in the practice of one experienced orthodontist. High-quality pre- and posttreatment lateral cephalometric radiographs with good soft tissue definition were available for all subjects. Radiographs were taken with lips relaxed, teeth in occlusion and using the same cephalostat. All 80 patients had been treated with preadjusted 0.018 by 0.028 inch edgewise appliances. No adjunctive appliances such as rapid maxillary expanders, headgears, transpalatal arches, or functional appliances were used as part of comprehensive orthodontic treatment. Interarch elastics, however, were used as required. Ages at commencement and duration of treatment are presented in Table 1.

TABLE 1. Study Sample

	Number	Age at Commencement of Treatment (mo)		Duration of Active Treatment (mo)	
		Mean	SD	Mean	SD
Group					
Total	80	162.3 (13 y 2 mo)	15.7	26.3	5.6
Males	38	166.8 (13 y 7 mo)	15.3	27.1	5.9
Females	42	160.1 (13 y 0 mo)	15.6	25.7	5.4
Extraction sequence[a]					
4/4	24	160.9 (13 y 0 mo)	16.6	26.7	3.5
5/5	26	161.5 (13 y 2 mo)	14.8	25.9	5.0
4/5	30	165.2 (13 y 5 mo)	15.8	26.0	7.1

[a] 4/4 indicates maxillary and mandibular first premolars; 5/5, maxillary and mandibular second premolars; 4/5, maxillary first premolars and mandibular second premolars.

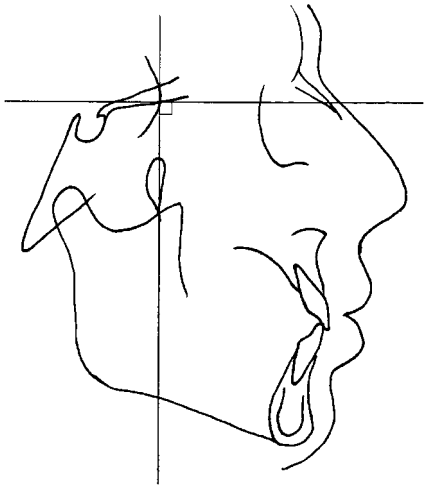

FIGURE 1. Pterygomaxillary (PM) line through Se and Ptm. Horizontal line constructed perpendicular to the PM line through Se.

Cephalometric analysis

All pre- and posttreatment cephalograms were traced by one examiner (Dr Wholley) and digitized with the aid of Westcef cephalometric software.* Measurements to both hard and soft tissue landmarks were made with reference to the pterygomaxillary (PM) line (Figure 1). To locate the

*A customized cephalometric analysis program written for the University of Melbourne by Mr Geoffrey West.

TABLE 2. Cephalometric Landmarks and Tissue Thickness Measurements Used in This Study

Landmark/Measurement	Definition
Upper vermilion point	Most anterior point on upper lip
Lower vermilion point	Most anterior point on lower lip
Soft tissue point A′	Deepest point on the outline of the upper lip, established by a tangent parallel to the PM line
Soft tissue point B′	Deepest point on the outline of the lower lip, established by a tangent parallel to the PM line
Upper lip—superior thickness	Distance between hard tissue point A and point of intersection with the outline of the upper lip, drawn perpendicular to PM line
Upper lip—vermilion thickness	Distance between vermilion point of upper lip and inner aspect of lip, drawn perpendicular to PM line
Lower lip—vermilion thickness	Distance between vermilion point of lower lip and inner aspect of lip, drawn perpendicular to the PM line
Lower lip—inferior thickness	Distance between hard tissue point B and point of intersection with the outline of the lower lip, drawn perpendicular to PM line
Pogonion soft tissue thickness	Distance between hard tissue pogonion and point of intersection with the outline of the soft tissue chin, drawn perpendicular to PM line

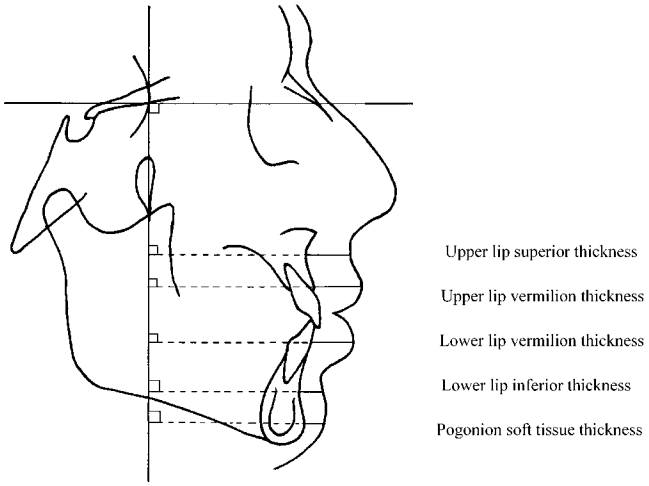

FIGURE 2. Soft tissue thickness.

reference line on the posttreatment tracing, the tracing was first superimposed on the cranial base landmarks on the pretreatment radiograph, according to Bjork's method.[22]

Sphenoethmoidale (Se) and Ptm were then transferred from the first to the second tracing to provide a consistent plane of reference for the subsequent evaluation of horizontal changes in landmarks. To provide a reference for the recording of vertical changes in landmarks, a horizontal reference line was constructed through sphenoethmoidale, perpendicular to the PM line. Absolute distances were measured from the digitized cephalometric points to the PM line or its horizontal construct, allowing the positions of all hard and soft tissue landmarks to be described with x and y coordinates. Cephalometric landmarks and tissue thickness measurements used in this study are presented in Table 2 and illustrated in Figure 2. Landmarks chosen for the study were based on the definitions suggested by Nanda et al.[23]

To quantify the soft tissue effects of the various premolar extraction sequences, the depths of the upper and lower lip curves were calculated in two ways.

- Relative to the PM reference line (Table 3, Figure 3). The depth of curvature for each lip was calculated as the difference in x coordinates between the respective vermilion point and the deepest point along the curvature of that lip (point A′ or point B′).
- Relative to constructed anterior soft tissue reference lines (Table 3, Figure 4). The upper lip depth was measured as the perpendicular distance to point A′ from a line joining the nasal tip to the upper vermilion point. The lower lip depth was measured as the perpendicular distance to point B′ from a line joining the lower vermilion point to soft tissue pogonion.

Statistical analysis

The x and y coordinates for all digitized landmarks were stored in an Excel spreadsheet.† Lip curve changes occurring during treatment were then calculated in preparation for statistical analysis using Minitab statistical software.‡ Linear measurements were then multiplied by a factor of 0.92 to take into account the 9% calculated cephalometric enlargement factor. Analysis of variance (ANOVA) was first used to search for statistically significant differences among the changes in depths of upper and lower lip curves for the three premolar extraction groups. Pearson's correlation coefficients (r) and associated levels of significance (P values) were then calculated to determine the levels of correlation between pretreatment depths of lip curvature and changes in the depths of lip curvature and various skeletal, dental, and soft tissue factors.

Error measurement. To evaluate likely tracing and measurement error associated with the study method, 20 radiographs from 10 patients were selected at random and traced and measured twice, four weeks apart. Results of the paired Student's t-test showed no significant differences between the two sets of measurements, at the 95% confidence level.

†Excel Microsoft Office 2000: Professional.
‡Minitab Statistical Software: Release 13 for Windows.

TABLE 3. Measurements of Depths of Upper and Lower Lip Curves

Relative to the PM line	
Depth to point A′	x-coordinate difference between distance from PM line to upper vermilion point and distance from PM line to soft tissue point A′
Depth to point B′	x-coordinate difference between distance from PM line to lower vermilion point and distance from PM line to soft tissue point B′
Relative to constructed anterior soft tissue reference lines	
Depth to point A′	The perpendicular distance from point A′ to a line drawn from the nasal tip to the upper vermilion point
Depth to point B′	The perpendicular distance from point B′ to a line drawn from the lower vermilion point to soft tissue pogonion.

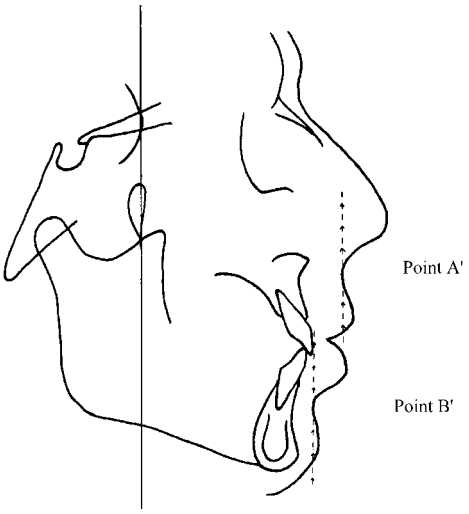

FIGURE 3. Soft tissue points A′ and B′ located by the lines drawn parallel to the PM line and tangent to the deepest points on the curvatures of the lips.

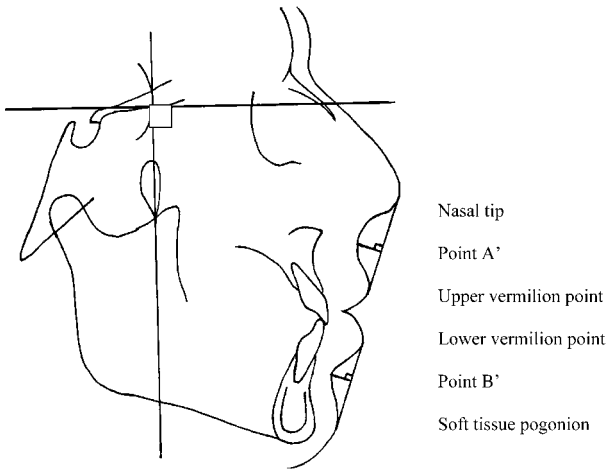

FIGURE 4. Constructed anterior soft tissue reference lines.

RESULTS

Upper lip depth changes at soft tissue point A′

Changes in relation to the PM line. Mean changes in the depths of upper lip curves at point A′ are presented in Figure 5 and Table 4. The depths of the lip curves were found to have reduced, on average, after treatment in all three groups. ANOVA demonstrated that the differences among the mean changes (−0.48 mm, 4/4; −0.47 mm, 5/5; −0.85 mm, 4/5) were not statistically significant ($P < .05$). Within each extraction subgroup, however, there was a wide range of individual variation, with both increases and decreases in the depths of upper lip curves.

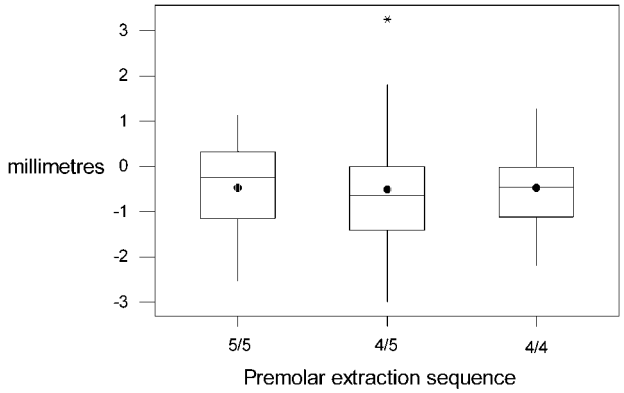

FIGURE 5. Changes in depths of upper lip curves at point A′, perpendicular to the PM line.

TABLE 4. Changes in the Depths of the Upper Lip Curves (mm)[a]

	Mean	SD	Maximum	Minimum
In relation to PM line				
4/4	−0.48 NS	0.93	+1.26	−2.2
5/5	−0.47 NS	0.97	+1.12	−2.52
4/5	−0.85 NS	2.3	+3.25	−2.79
In relation to constructed anterior soft tissue reference line				
4/4	+0.15 NS	1.8	+3.1	−3.1
5/5	+0.01 NS	0.95	+1.7	−2.0
4/5	−0.08 NS	1.26	+3.6	−2.6
Correlation of both sets of results at soft tissue point A′[b]				
4/4				0.82 ●●
5/5				0.68 ●●
4/5				0.75 ●

[a]ANOVA: NS, not significant ($P \leq .05$);
[b]Student's *t*-test: ●, $P \leq .05$; ●●, $P \leq .001$.

Changes in relation to the constructed anterior soft tissue reference line. Mean changes in the depths of upper lip curves from point A′ to the constructed soft tissue line are presented in Figure 6 and Table 4. ANOVA demonstrated that the differences among the mean changes (0.15 mm,

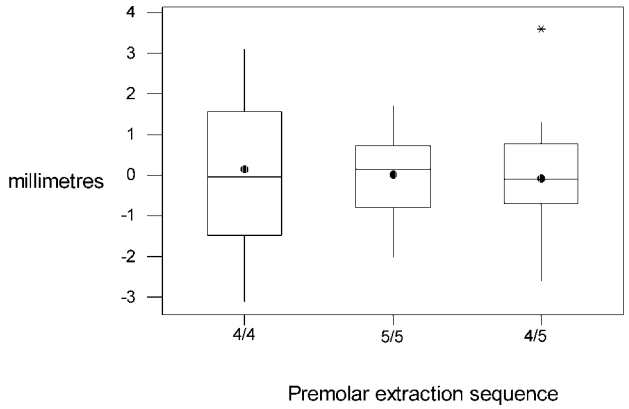

FIGURE 6. Changes in depths of upper lip curves measured from point A′ to the constructed soft tissue line from upper vermilion to the nasal tip.

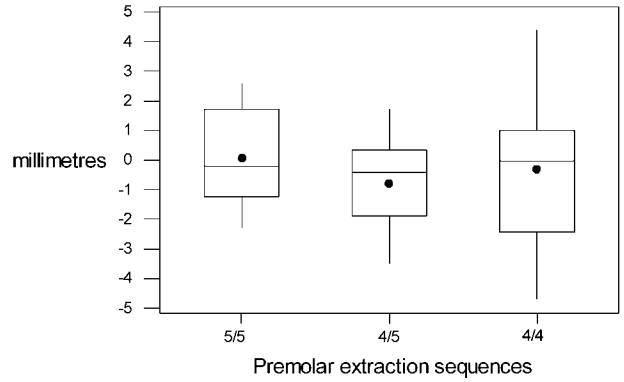

FIGURE 7. Changes in depths of lower lip curves at point B′, perpendicular to the PM line.

4/4; 0.01 mm, 5/5; −0.08 mm, 4/5) were not statistically significant ($P < .05$). Once again, within each extraction subgroup, there was a wide range of individual variation, with both increases and decreases in the depths of upper lip curves being observed.

Comparison of the upper lip results obtained with the two reference lines. Strong coefficients of correlation were found for the two different sets of upper lip depth changes at point A′ (Table 4).

Lower lip depth changes at soft tissue point B′

Changes in relation to the PM line. Mean changes in the depths of the lower lip curves at point B′ are presented in Figure 7 and Table 5. The depths of the lip curves were found to have reduced, on average, after treatment in all three groups. ANOVA demonstrated that the differences among the mean changes (−0.31 mm, 4/4; −0.07 mm, 5/5; −0.86 mm, 4/5) were not statistically significant ($P < .05$). Within each extraction subgroup, however, there was a wide range of individual variation, with both increases and decreases in the depths being observed.

Changes in relation to the constructed anterior soft tissue reference line. Mean changes in the depths of lower lip curves from point B′ to the constructed soft tissue line are presented in Figure 8 and Table 5. ANOVA demonstrated that there was some difference between the changes for the various subgroups. Further assessment of these results in relation to the constructed soft tissue reference line uncovered no significant differences between the changes for lower lip curves for the 4/4 and 5/5 groups. Changes in the 4/5 group, however, differed from the 4/4 and 5/5 groups (Table 5). Within each extraction subgroup, there was a wide range of individual variation with both increases and decreases in the depths being observed (Figure 8).

Comparison of the lower lip results obtained with the two reference lines. Strong coefficients of correlation were found for the two different sets of lower lip depth changes at point B′ (Table 5). Correlation of the results for the 4/5 group using the two reference lines is presented in Figure 9.

TABLE 5. Changes in the Depths of the Lower Lip Curves (mm)

	Mean	SD	Maximum	Minimum
In relation to PM line				
4/4	−0.31 NS	2.31	+4.38	−4.69
5/5	−0.07 NS	1.52	+2.57	−2.31
4/5	−0.86 NS	1.7	+1.7	−5.83
In relation to constructed anterior soft tissue reference line				
4/4	+0.66 *	1.02	+2.4	−1.2
5/5	+0.89 *	1.50	+5.7	−1.2
4/5	−0.18 *	1.18	+2.1	−2.8
Isolation of significant difference in lip curve changes between groups				
Group 1	Group 2			
4/4	5/5 NS			
4/5	4/4 **			
4/5	5/5 **			
Correlation of results at point B′				
4/4				0.48 ●
5/5				0.55 ●●
4/5				0.78 ●

[a]ANOVA: NS, not significant (* $P \leq .05$, ** $P \leq .005$);
[b]Student's *t*-test: ● $P \leq .05$, ●● $P < .005$.

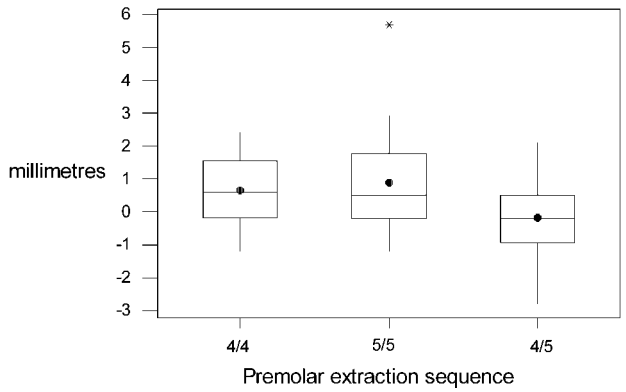

FIGURE 8. Changes in the depths of lower lip curves measured from point B′ to the constructed soft tissue line from lower vermilion to pogonion.

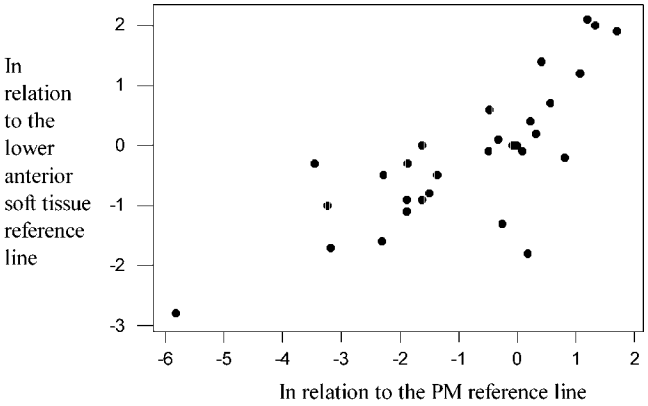

FIGURE 9. Correlation of lower lip depth changes obtained using the PM line and the constructed lower anterior soft tissue line for the 4/5 extraction subgroup.

Individual variation in lip curve depth change

In light of the wide range of changes in depth of curvature for both upper and lower lips within all three extraction groups, the records of 12 individual cases, exhibiting extreme changes in lip curve depth, were reviewed in detail to see whether any potential associated factors could be elicited. From an analysis of the data presented in Table 6, a relationship between changes in mandibular incisor protrusion and changes in the depths of the lower lip curves appears to exist. Within each group, an increase in mandibular incisor protrusion with treatment appeared to be associated with an increased depth of lower lip curvature (eg, subjects C, G, K), whereas a reduction in mandibular incisor protrusion with treatment appeared to be associated with a reduced depth of lower lip curvature (eg, subjects D, H, L). Furthermore, an association between pretreatment upper lip vermilion thickness and changes in the depths of the upper lip curves also seemed to be present. For instance, a relatively thicker vermilion appeared to be associated with an increase in the depths of upper lip curves with treatment, (eg, subjects A, E, I), whereas a relatively thinner vermilion appeared to be associated with a reduction in the depths of upper lip curves (eg, subjects B, F, J). No obvious association was present between extreme changes in the depth of lip curves and changes in the ANB angle, the mandibular plane angle, or mandibular incisor inclination.

Further correlations amongst various skeletal, dental, and soft tissue factors and lip curvature

Pre- and posttreatment skeletal, dental, and soft tissue factors and their associations with changes in depth of lip curvature are presented in Table 7.

DISCUSSION

In this study, changes in the depths of lip curvature have been assessed using two different frames of reference. A posterior skeletal line, the PM line as proposed by Enlow et al,[24] was first used as a reference line. Constructed anterior soft tissue reference lines, based on the most anterior points of the upper lip and nose and lower lip and soft tissue pogonion, were then used to assess changes in the depths of the upper and lower lip curves. Foley and Duncan[25] recommended that there is a need to separate those soft tissue studies that include nasal changes from those that do not. Accordingly, the assessment of data in this study was made in relation to both the constructed anterior soft tissue reference lines and the posterior skeletal reference line. This was done because the components of the lateral facial profile between nasion and pogonion are accepted to grow at differential rates and times.[4,23,26–29] Soft tissue changes with growth are also acknowledged to occur independent of underlying hard tissue changes.[5,30–33]

Measurements from both the posterior hard tissue line and the constructed anterior soft tissue reference lines demonstrated that, on average, there were no significant differences in the changes in depths of upper or lower lip curves within the three different premolar extraction subgroups. For example, it can be seen in Figure 8 that there was considerable overlap in the ranges of lip curve changes in the three groups, with the 4/5 group demonstrating a distribution of results toward a reduction in the depth of the lower lip curve at the completion of active treatment. This reduction in the 4/5 group might be explained by the fact that, with a reduction in incisal overjet, there was less need for the lower lip to roll out to form a deep lower lip curve.

The extractions of premolar teeth may at times be appropriate and necessary to deal with crowding, increased overjet, tooth and lip protrusion, molar and anteroposterior skeletal discrepancies, or skeletal asymmetry.[20,21,34–38] Despite this acceptance, Bravo[39] and Bowman and Johnston[16] found that facial appearance appeared worse after treatment in some patients, regardless of whether premolar extractions had been performed.

The pretreatment curvature of the lips is another important contributor to the facial esthetic effects of treatment.[2,36] For example, the pretreatment depth of the upper lip curve was nominated by Bravo[39] as one variable that might significantly influence the appropriateness of premolar extractions in any individual orthodontic patient. In contrast to Bravo's conclusions, however, the results of the present study have demonstrated that, regardless of whether first or second premolars were extracted, there were often minimal changes in upper or lower lip curvature with treatment. This is consistent with the results of other studies[40–42] and would suggest that the skeletal and dental factors listed above should perhaps take precedence over the pretreatment depth of lip curves when deciding which, if any, premolars to extract. This suggestion would also be consistent with Bowman and Johnston's[16] statement that given the surprisingly minor average effect of premolar extractions on the lateral facial profile, crowding, midline deviation, and molar re-

TABLE 6. Pretreatment Vermilion Thickness and Various Hard and Soft Tissue Changes in 12 Individual Subjects

Extraction Sequence	Lip	Depth of Lip Curvature[a] (mm)	Mandibular Incisor Inclination[b](°)	Mandibular Incisor Protrusion[c] (mm)	Maxillary Incisor Inclination[d] (°)	Maxillary incisor Protrusion[e] (mm)	Mandibular Plane Angle (°)	ANB Angle (°)	Pretreatment Vermilion Thickness Upper Lip (mm)	Pretreatment Vermilion Thickness Lower Lip (mm)
4/4										
Individual A	Upper	1.48	9.2	2.19	−11.8	−0.68	−1.21	−0.7	18.94	15.61
Individual B	Upper	−2.88	9.3	0.49	9.5	−1.12	−0.12	−0.9	15.13	15.72
Individual C	Lower	2.67	−8.1	3.1	−24.8	−7.56	5.38	−1.8	17.52	15.19
Individual D	Lower	−4.36	19.7	−4.25	−15.8	−5.21	−0.94	−1.8	10.29	12.41
5/5										
Individual E	Upper	2.55	−4.9	−2.12	4.2	−2.75	−1.59	−0.3	16.08	18.37
Individual F	Upper	−2.88	4.7	−1.27	−1.0	−2.07	1.65	−1.1	13.23	11.31
Individual G	Lower	2.13	4.5	3.7	6.2	2.03	0.16	−2.1	19.99	15.79
Individual H	Lower	−5.79	−2.1	−3.84	−1.7	−1.84	0.15	−3.1	13.72	14.9
4/5										
Individual I	Upper	3.4	−3.8	0.82	−12.4	−1.71	−1.97	1.6	24.63	16.79
Individual J	Upper	−2.2	2.2	−1.94	1.4	−3.6	−0.27	0.2	16.01	11.02
Individual K	Lower	2.17	3	7.26	9.1	5.86	3	0.8	18.04	15.55
Individual L	Lower	−3.18	13.4	−1.57	−8.4	−5.48	−1.01	−3.7	13.7	14.72

[a] Negative value represents lip becoming flatter as measured from PM reference line.
[b] Mandibular incisor angulation to APo line.
[c] Measured to PM reference line.
[d] Maxillary incisor angulation to APo line.
[e] Measured to PM reference line.

lation may still be the most important factors affecting the extraction decision.

In this study, more dental factors than skeletal factors were found to have statistically significant relationships with lip profile changes. For instance, significant correlation coefficients were found between lip profile and incisor changes in the 4/4 group. Changes in the inclination of mandibular incisors to the APo line and in the interincisal angle also had significant relationships with the lip curve changes in the same 4/4 group. As noted by Young and Smith,[43] most studies involving the assessment of soft tissue responses to incisor retraction have been directed at particular types of malocclusion. Battagel,[44] however, suggested that the type of malocclusion might not be a relevant predictor of changes in lip profile. In this study, correlation coefficients varied between the extraction groups. This might be explained, at least in part, by treatment changes in the mandibular incisor angulation to the APo line and the interincisal angle in the 4/4 group that are dependent on the control of both molar anchorage and incisor inclination during extraction space closure.

Although it is acknowledged that techniques for the control of tooth movements in three dimensions have improved, the results of this study could reflect that it may be comparatively more difficult to provide such control, without the use of auxiliary devices, after the removal of all four first premolars than with the other premolar extraction sequences.[37] Any bias toward the choice of the 4/4 extraction sequence, however, was also present in pretreatment factors such as incisor angulation and depth of lip curvature. Thus, the type of presenting malocclusion may indeed influence the potential for a particular skeletal or dental change to be associated with an alteration in the lip profile. In any case, the results of this study, which have suggested a lack of significant correlation between either the pretreatment incisal overjet and the depths of lip curves or changes in the overjet and the lip curves, are consistent with the findings of other authors.[45,46]

Of all the soft tissue factors that demonstrated significant correlation with lip profile changes, the pretreatment thickness of lip tissue at the vermilion level appeared to exert the greatest influence. Any change in depth of the lower lip curvature, for instance, seemed to be influenced by the pretreatment vermilion thickness in at least two of the extraction groups (5/5 and 4/5). This is not unexpected because the morphological characteristics of the lip tissues themselves may influence responses of the lips to orthodontic tooth movement.[47–49] In this study, soft tissue parameters, as a group, exerted the greatest influence on treatment changes in the lip profile. This would be consistent with the concept that the overlying soft tissues are the ultimate compensators for growth and treatment in any facial profile. The overlying soft tissues have the capacity to mask any underlying skeletal discrepancy.[1,32,50,51]

Apparently, the finding that there was no significant difference, on average, in the changes in depths of upper or lower lip curves, in the various extraction sequence groups, is consistent with contemporarily accepted concepts. Steyn

TABLE 7. Significant Coefficients of Correlation Between Lip Curvature and Various Skeletal, Dental, and Soft Tissue Factors

Variable 1	Variable 2	Extraction Group/Location	*r*-value[a]
1. Dental factors			
a. Pretreatment			
Mandibular incisor to mandibular plane angle	Depth of lip curve—pretreatment	4/4 lower lip	−0.55**
		5/5 upper lip	0.334
		5/5 lower lip	−0.36
		4/5 upper lip	−0.332
Interincisal angle	Depth of lip curve—pretreatment	4/4 lower lip	−0.657***
		5/5 lower lip	−0.334*
Maxillary incisor angle to APo	Depth of lip curve—pretreatment	4/4 lower lip	0.498**
		5/5 upper lip	−0.391*
Pretreatment angle—mandibular incisor to APo	Depth of lip curve—pretreatment	4/4 lower lip	−0.59**
b. Change with treatment			
Maxillary incisor protrusion	Depth of lip curve—change with treatment	4/4 upper lip	0.462*
		4/4 lower lip	0.356*
		4/5 lower lip	0.342*
Mandibular incisor protrusion	Depth of lip curve—change with treatment	4/4 upper lip	0.396
		4/4 lower lip	0.342
		5/5 upper lip	0.322
2. Skeletal factors			
a. Pretreatment ANB angle	Depth of lip curve—pretreatment	4/4 lower lip	0.36
		5/5 upper lip	−0.47**
		4/5 lower lip	0.355*
b. Change with treatment			
ANB angle	Depth of lip curve—change with treatment	5/5 upper lip	0.353
		4/5 lower lip	0.41*
Hard tissue point A	Depth of lip curve—change with treatment	5/5 upper lip	−0.35
		5/5 lower lip	0.365
Mandibular plane angle	Depth of lip curve—change with treatment	5 5 upper lip	−0.56**
3. Soft tissue factors			
a. Pretreatment—Lip thickness	Depth of lip curve—pretreatment	4/4 upper lip vermilion level	0.44*
		4/4 lower lip vermilion level	0.545**
		5/5 upper lip superior level	0.377*
		5/5 upper lip vermilion level	0.777***
		5/5 lower lip vermilion level	0.515*
		4/5 upper lip vermilion level	0.359*
		4/5 lower lip vermilion level	0.751***
Lip thickness	Depth of lip curve—change with treatment	5/5 lower lip vermilion level	−0.49*
		4/5 lower lip vermilion level	−0.5**
b. Change with treatment—Lip thickness	Depth of lip curve—change with treatment	4/4 lower lip vermilion level	0.376
		5/5 upper lip vermilion level	0.507*
		5/5 lower lip vermilion level	0.596***
		4/5 upper lip vermilion level	0.501**
		4/5 lower lip vermilion level	0.713***

[a] ANOVA: * $P \leq .05$, ** $P \leq .005$, *** $P \leq .001$.

et al,[35] for instance, suggested that, on average, for the same patient, the choice of which premolars to be extracted would eventually be of little consequence to the overall soft tissue facial appearance of that patient. Similarly, Boley et al[13] reported that most premolar extraction subjects in their sample commenced treatment with satisfactory facial profiles. Having been treated with extractions to enhance health and stability of the intraoral tissues, the profiles were still apparently most satisfactory.

Limitations of the study

As in any retrospective lateral cephalometric study, the potential for voluntary and involuntary muscle activity to occur during the taking of radiographs may affect the accuracy of measurements subsequently made from these radiographs. The relative inability to quantify such measurement error is a shortcoming of all retrospective cephalometric studies.[45,52,53] As noted by Yogosawa,[33] the contrac-

tion of the mentalis muscle generally results in an increase in soft tissue thickness over point B and a decrease over pogonion. Interestingly, in this study, no significant correlation was found between a change in tissue thickness at the level of pogonion and a change in depth of the lower lip curve. The lack of such a significant correlation might suggest that contraction of the mentalis muscle did not generally lead to significant distortion of lip profiles in the subjects whose radiographs were used for this study.

CLINICAL CONCLUSIONS

Although it is acknowledged that extreme changes in the dental or skeletal factors, such as excessive retraction of the anterior teeth, may lead to adverse facial profile changes, the results of this study would suggest that it is not the routine outcome. Instead, it would seem possible for the clinician to carefully manage either first or second premolar extraction spaces while still protecting the lateral profile. Taking into account the limitations of any lateral cephalometric study, the following conclusions can be drawn.

- A similar range of changes in depths of upper and lower lip curves should be expected, regardless of the chosen premolar extraction sequence.
- Many skeletal, dental, and soft tissue factors may be associated with changes in depth of lip curves in individual orthodontic patients. No single factor is likely to influence changes in depths of upper or lower lip curves on its own.
- As a group, soft tissue factors are more likely to be associated with lip curve changes than dental or skeletal factors.
- The pretreatment thickness of the upper and lower lips, at the level of the vermilion tissue, is likely to be the pretreatment characteristic with the greatest potential to influence changes in depths of lip curvature. An increased pretreatment vermilion lip thickness would seem to provide some protection against a significant reduction in the depth of lip curvature, even in the presence of potentially adverse skeletal or dental changes.
- If dental and skeletal factors have been well managed during treatment, the posttreatment depths of lip curvature are likely to be satisfactory. This soft tissue compensation will be influenced by the pretreatment vermilion thickness of the upper and lower lips.
- Extraction choices in orthodontic practice are made for a number of reasons and, the choice of a particular extraction sequence does not imply that there will be an inevitable direct change in the overlying lip profile.

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