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Comparison of soft tissue changes following orthodontic treatment with two different extraction patterns: Four first premolars vs. four second premolars

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Comparison of soft tissue changes following orthodontic treatment with two different extraction patterns: Four first premolars vs. four second premolars

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ABSTRACT

The purpose of this study was to compare the soft tissue changes in subjects with orthodontic treatment involving two different extraction patterns: four first premolars or four second premolars. Pretreatment and posttreatment orthodontic treatment records of 81 four premolar extraction patients were obtained and divided into two groups: (PM1) four first premolar extraction group (n= 48) and, (PM2) four second premolar extraction group (n=33). A comparison was made of the changes between the pre- and post-treatment measurements of nasolabial angle (NLA), upper and lower lips to E-plane(mm) using age, sex, upper lip thickness, convexity, and facial axis as variables. Correlation tests were also performed between changes in dental and soft tissue outcomes. The results showed that the NLA increased in both treatment groups indicating a reduction in soft tissue lip protrusion. However, there was no statistically significant difference between the two groups (p=0.99). The average change in lip position between the two groups was not statistically significantly different (p=0.68 and p=0.27 for the upper and lower lip to E-plane, respectively). The upper lip position was strongly correlated with the position of the upper incisor and the lower lip. **Conclusion:** There was no statistically significant difference between the change in the nasolabial angle or the retraction of the upper and lower lips between four first and four second premolar extraction orthodontic treatments. Furthermore, the change in the nasolabial angle was not significantly correlated with any dental or skeletal changes in either group. Clinically significant difference was found between the groups in some dental and soft tissue outcomes. Extraction pattern alone was not a significant predictor of the changes in soft tissues.

Key Words: premolar extraction, nasolabial angle, soft tissue

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Introduction:

The extraction of premolars in orthodontic treatment planning has been the subject of intense debate over the last 100 years. A principal concern regarding premolar extraction is the effect it may have on facial esthetics, especially soft tissue profile. The choice of whether to extract first or second premolars was not introduced until the second half of the past century when Nance[1] in 1949 presented numerous cases that were treated with second premolar extractions. In fact, prior to Nance's article, the term "extraction treatment" meant the removal of first premolars. Nance, however, presented the argument that the extraction of second premolars is an alternative if the esthetic profile was to be protected. Nance's suggestion was based mainly on subjective observations and despite the lack of scientific data, it established the notion that the extractions of second premolars would lead to less soft tissue changes than the extractions of first premolars.

The lips are the soft tissue structures that are most readily affected by orthodontic treatment. The Nasolabial Angle (NLA) and the Esthetic Line (E-line), suggested by Burstone[2] and Ricketts[3] , respectively, are two popular measures of the position of the lips relative to facial structures. The upper and lower lips are considered to be a major component of the soft tissue profile. It's, therefore, understandable that any treatment plan should take into consideration the possible effect on the lips. The nasolabial angle measures the protrusion of the upper lip relative to the inferior border of the nose. Burstone suggested that the nasolabial angle is an important measurement since the layman was more likely to evaluate the upper lip relative to the nose. In his original research[2], he found the average nasolabial angle to be 74°. However, studies on a more representative sample found that the average value for the nasolabial angle was 112° with a normal range of 91° to 139° [4,5] Women , on average had a larger angle but the difference was not statistically significant[4].

Since the nasolabial angle encompasses several components, the changes in those components due to growth were thought to affect the measurement. It is acknowledged that the facial profile components (nose, lips, soft tissue chin...etc) not only grow at different times, but also at different rates independent of bone growth[6,7] . Studies,

however, found that the angle didn't change with growth, at least over the early to late teen period which is the age during which people are more likely to seek orthodontic treatment[8,9]. Lo and Hunter[9] examined the changes in nasolabial angle in a group of orthodontically treated Class II div I subjects, and compared them to an untreated group of the same skeletal pattern. They confirmed that in the untreated sample, the nasolabial angle did not change with growth. They also reported that in the treated group, 90% of the changes in the nasolabial angle were due to Labrale Superius, and 10% was due to the lower border of the nose.

The protrusion of the lips could also be measured relative to the nose and the soft tissue chin by observing the distance of the upper and lower lips to the E-line. Ricketts[3] indicated the ideal distance for the upper and lower lips to the E-line in Caucasians was 4mm and 2mm, respectively. The long term effect of orthodontic treatment on those measurements is of particular importance. This is due to the fact that the upper and lower lips become significantly more retruded with respect to the E-line as people age due to growth of soft tissues at the nose and chin, regardless of orthodontic treatment.[10,11,12]

Research has shown that, on average, the NLA increases and the upper and lower lips become more retruded relative to the E-line when premolars are extracted as part of orthodontic treatments. Droboky et al[13] studied the changes in the nasolabial angle and the position of the upper and lower lips relative to the E-line in subjects with four premolar extractions during orthodontic treatment. The sample was composed of males and females between the ages of 10-30 years, with mixed skeletal patterns, who were randomly chosen from different sources. They found that 95% of the subjects had an average increase in the nasolabial angle of 5.2°. The upper and lower lips were retracted relative to the E-line by an average of 3.4mm and 3.6 mm, respectively. When the final position of the lips was compared to the norm, it was concluded that the extraction of four premolars didn't result in a "dished-in" profile. The study, however, made no distinction between whether first or second premolars were extracted. Bravo[14] studied a sample of 16 Caucasian females who had four premolar extractions as part of the orthodontic treatment. The author limited his study to subjects with Class II division I

malocclusion and did not differentiate between which premolars were extracted. He noted that the mean change in the nasolabial angle was an increase of 3.7°, and that the upper and lower lips were retracted an average of 1.6 and 2.3 mm to the E-line, respectively.

Other research investigating the changes in facial profile with extraction and non extraction orthodontic treatments also confirmed similar changes in the nasolabial angle and the position of the upper and lower lips after extractions of premolars, and allowed for comparison between the extraction and non extraction treatment modalities. Young and Smith[15] compared Drobocky et al's extraction sample to 198 patients treated with non extraction orthodontics. They found that although the average soft tissue change values were smaller in the non extraction sample, the variability of those changes among the sample was as great as that among the four premolar extraction sample. They concluded that undesirable soft tissue outcomes following orthodontic treatment could not be blamed on the extraction of premolars. Looi et al[16] compared 30 males and females with Class II div I malocclusion treated with four first premolar extractions to a group that was treated with no extractions. They noticed the nasolabial angle increased by 5.9° in the extraction group. However, they reported no difference between the extraction and the non extraction groups with regards to the final position of the upper and lower lips. Ismail et al[17] investigated the effect of extraction and non extraction orthodontic treatments in a small sample of 24 subjects using cephalograms and 3-D optical surface scans. The nasolabial angle increased by an average of 1.78° and 1.21° in the extraction and non extraction groups, respectively, with no significant difference between the groups. The upper lip to the E-line was retracted by an average of 1.31mm and 0.13mm in the extraction and non extraction groups, respectively with no significant difference between the groups. The lack of statistical significance may have been due to the small sample size, and the difference could indeed be clinically significant. The lower lip, however, was retracted by an average of 1mm in the extraction group while almost no change was reported in the non extraction group and the difference was statistically, and possibly clinically, significant. Again, there was no distinction reported between which teeth were extracted in the extraction group.

The effect of changes in the angulation and position of the upper and lower incisors on the soft tissue profile before and after orthodontic treatment has also received significant attention in an attempt to quantify the relation between the retraction of the incisors and the changes of the upper and lower lips, if any. There has been a wide range of reported results from no relation to a very significant correlation. The ratio of the upper lip retraction to the upper incisor retraction has also varied widely in the literature. Ratios as high as 1:2 and as low as 1:3.6 have been reported[18]. Caplan[19] found a weak correlation between the retraction of the upper lip and the retraction of the upper incisors in African Americans after extraction of maxillary and mandibular first premolars, but reported a significant correlation between mandibular incisor retraction and the retraction of the lower lip with a ratio of 1.2:1.

Kusnoto et al[20] studied the same effect on a sample of Indonesians and found a significant correlation between upper and lower incisor changes and the retraction of upper and lower lips to a vertical posterior reference line. Although the nasolabial angle significantly increased from pre to post treatment (mean increase was 7.75°), no significant correlation was found with the change in upper and lower incisor position. The study examined the effect of extracting the upper and lower first premolars. The same conclusion was made by another study with upper premolar extraction treatment[18] .Talass et al[8] studied 80 Class II division I females and compared them to 53 females in an untreated group. They found that the nasolabial angle had a strong correlation with the retraction of upper incisors. However, there was no difference between the extraction and the non extraction treatment groups. There was no distinction made for the pattern of extraction. Thus it appears from the literature that the data regarding such correlation is still inconclusive.

The thickness of the upper lip was thought to be an important factor that would determine the response of the soft tissue to the underlying osseous and dental changes. The effect of growth on the thickness of the upper lip appears to be minimal. Mamandras[21] reported a mild increase in the thickness of the upper lip (0.5m) for a sample of untreated girls between the ages of 10 to 12 years and an additional 0.3mm

between the ages of 12 to 14 years. Oliver[22] found strong correlations between osseous changes and soft tissue changes in Class II div I subjects with thin lips after orthodontic treatment with no extractions. Another study[8] found a significant correlation between the increase in nasolabial angle and thinner upper lips, but did not find that thinner lips retracted more. The effect of the lips thickness, therefore, remains controversial.

Often, the orthodontist is faced with the dilemma of choosing between the extractions of four first or second premolars. Knowing the potential effect of one choice over the other on the soft tissue would certainly aid in making a better treatment decision. There exists an anecdotal belief that the extraction of first premolars has a more significant effect on the soft tissue profile compared to the extraction of second premolars. More specifically, clinicians believe that the extraction of first premolars will result in greater increase of the nasolabial angle and more retrusion of the lips relative to the E-line, compared to the extraction of second premolars. It has been suggested that the choice of which premolars to extract should be based on how much the upper incisors need to be retracted. Scientific data supporting this belief has been generally lacking. Steyn et al[23] indicated that the choice of premolar extraction pattern has an insignificant effect on the facial profile. The main objective of his study, however, was to generate regression models for the amount of incisor retraction with different extraction patterns including four first premolar and four second premolar extraction groups. Using the N-Pg plane as a reference line, they measured the upper incisor retraction in the four first premolar extraction group and the four second premolars extraction group and found that, on average, the first premolar group had less than 1mm greater retraction than the second premolar group, with the difference not being statistically significant. Although no soft tissue measurements were used, they concluded that the soft tissue appearance of patients in both groups after orthodontic treatment was "virtually the same".

Wholley et al[24] investigated the effect of four first premolar extraction and four second premolar extraction on the curvature of the upper and lower lips relative to a posterior reference plane. The mean change of the depth of the curvature of the upper and lower lips was minimally reduced in all groups with no difference between the different

extraction patterns. The study, however, acknowledged that a wide range of individual variations existed within each group, with both increases and decreases in the depth of the curvature as reflected by the reported large standard deviation. The study also found a significant correlation between the lip profile and incisor change in the four first premolar extraction group.

Moseling et al[25] repeated Wholley's et al[24] study and researched the changes in the upper and lower lip curvature after orthodontic treatment with extractions of four first premolars, four second premolars, or no extractions on females only. They studied subjects with Class I and Class II malocclusion and expanded their soft tissue indicators to include measurements such as the nasolabial angle. Their sample size was smaller and they also found no difference in the lip curvature between the different extraction patterns. They also reported no significant correlation between the position and the angulation of the upper incisors and the changes in the upper lip. Interestingly however, they reported that the position and the angulation of the upper incisors were more strongly correlated with the changes in the lower lip. The nasolabial angle was only used to determine any strong correlation with the pre-treatment curvature of the lip and the difference between the change in the nasolabial angle between the extraction groups was not investigated.

It's obvious from the lack of consistency in the preceding investigations that any information regarding any difference in soft tissue changes following first or second premolar extraction treatment would be valuable to the practitioner. Moreover, data of soft tissue and dental changes could provide further insight and aid in treatment planning. With that in mind, the purpose of the study was to determine if the extractions of four first premolars would lead to the same soft tissue changes when compared to the extraction of four second premolars, at the end of orthodontic treatment using dental, skeletal, and soft tissue measurements. The null hypothesis is that there is no difference between the soft tissue changes after the extraction of four first or second premolars

Subjects and Methods:

Sample:
Orthodontic patient records from the archives of the Department of Graduate Orthodontics at The University of Western Ontario were searched and subjects were chosen at random based on the following criteria:

1) Full written records of treatment
2) Full fixed orthodontic treatment including extractions of four first premolars or four second premolars
3) Availability of pre and post treatment lateral cephalograms
4) Patients between the ages of 10 and 16 years
5) No missing teeth (excluding third molars)

Exclusion Criteria:

1) Subjects who didn't meet the inclusion criteria
2) Subjects who had orthognathic surgery
3) Subjects with positive medical history of any craniofacial anomaly e.g. Clefts

The extraction pattern was confirmed using the extraction request letters and reconfirmed with confirmation letters from family dentists or oral surgeons. The subjects were divided into two groups based on either first or second premolar extractions. Group one (**PM1**) (four first premolar extraction treatment) included 48 patients (20 males, 28 females, average age 156.5±16.7 months, range 120-190 months). Group two (**PM2**) (four second premolar extraction treatment) included 33 patients (11 males, 22 females, average age 159±15.8 months, range 128-189 months) Table (1)

Radiographs:

Immediate pre- and post- treatment lateral cephalograms were taken using the same radiographic machine with Frankfort Horizontal parallel to the floor. The subjects' lips were subjectively judged to be in repose.

Cephalometric Analysis:

The radiographs were scanned into Dolphin Imaging System™, digitized, and the following soft tissue landmarks were identified (Figure I):

1. Labrale superius (LS) - The most anterior point on the convexity of the upper lip
2. Labrale inferius (LI) - The most anterior point on the convexity of the lower lip
3. Subnasale (Sn) - The point of convergence of the nose and the upper lip
4. Soft tissue A point (A') - The point of greatest concavity between LS and Sn
5. Pronasale (Pn) - The most anterior point of the nose tip
6. Columella (Cu) - a land mark on the inferior surface of the nose, representing the anterior delimiter of the nasolabial angle
7. Soft tissue Pogonion (Pg') - the most anterior point on the soft tissue chin

In addition, the following hard tissue landmarks were identified: Nasion (N), Basion (Ba), Pterygomaxillary point (Ptm), Orbitale (Or), Porion (Po), Sella (S), Upper Incisor Tip (U1), and Lower Incisor Tip (L1) as seen in Figure (1). From the above landmarks, the following dental, skeletal and soft tissue measurements were computed:

Dental: Figure (II)

1) Upper Incisor to NA line (mm)
2) Upper Incisor to NA line (deg)
3) Lower Incisor to A-Pg line (mm)

Skeletal: Figure (III)

1) Convexity (A-point to N-Pg) (mm)
2) Facial Axis (N-Ba to Ptm-Gn) (deg)

Soft tissue: Figure (IV)

1) Upper lip thickness (A' point – A point)
2) Upper lip to E-plane (mm)
3) Lower lip to E-plane (mm)
4) Nasolabial angle (deg)

The pre and post digitized radiographs for every subject were superimposed to ensure matching placement of landmarks.

Error Study:

Eighteen lateral cephalograms were randomly selected for the determination of measurement error. The landmarks were redigitized and the dental, skeletal, and soft tissue measurements were remeasured. The difference between the first and second measurements was subjected to a t-test to determine it was statistically significantly different from zero. The measurement error was then calculated using the following formula:

$$\text{Standard Deviation of Measurement Error (SE)} = \sqrt{\frac{\Sigma d^2}{2n}}$$

Where d is the difference between duplicate measurements and n is the number of repeat measurements. A coefficient of reliability (Interclass Correlation Coefficient) indicates the reproducibility of the cephalometric measurements.

Statistical Analysis:

Descriptive and inferential statistics were generated using the JMP v.4.0[1] statistical program. A p-value <0.05 was deemed to be statistically significant. Analysis of Covariance (ANCOVA) was used to determine the effect of the extraction pattern on the outcome variables. The primary outcome variable was the change in the nasolabial angle (NLA). Secondary outcome variables included the change of upper lip to the E-line and the change of the lower lip to the E-line. Facial convexity, facial axis, and upper lip thickness at base line were used as covariates, and age and sex were used as explanatory variables. For each outcome variable, a full model was used with treatment type,

[1] SAS Institute, Cary, NC

covariates, interaction terms and explanatory variables. If the interaction variables were not significant, they were removed from the model. The predictive ability of the model is donated by R^2. Least square means are used in calculating % difference and statistical significance.

Simple t-tests were used to determine whether any statistically significant difference was observed between the treatment groups means for each of the outcome variables and the correlation coefficient was used to determine the association between all pairs of outcome variables. Since multiple t-tests were performed, the Bonferroni adjusted p-value of 0.008 or less was used to determine statistical significance. The effect size of the difference between the treatment group means was also reported. An effect size of $\geq$15% was considered to be clinically significant.

Results:

The sample in this study consisted of two treatment groups: group one (**PM1**) had all four first premolars extracted, and group two (**PM2**) had all four second premolars extracted. Table (1) shows the distribution of age and gender for both groups. PM1 had more females than males (58% and 42%, respectively). PM2 showed similar distribution between females and males (67% and 33%, respectively) with the proportion of females being more than that of PM1. The average age of both groups was similar.

Table (2) presents the initial (pretreatment) skeletal characteristics of the treatment groups. The average convexity for PM1 and PM2 was 5.04mm±2.63 and 3.80mm±2.77, respectively. A positive value indicates a tendency for a Class II skeletal discrepancy. PM1 was slightly more Class II than PM2. The facial axis average showed a tendency for vertical growth pattern for both groups with PM1 being slightly more vertical than PM2 (-5.90° ±4.13 and -3.86°±4.03, respectively). The relatively large standard deviations for both of the skeletal measurements indicate a wide variation among the subjects with respect to the antero-posterior and vertical growth tendencies.

Table (3) presents the pretreatment and posttreatment skeletal characteristics of both treatment groups. The average change in convexity from initial to final for PM1 and PM2 was -2.28±1.31mm and -1.87±1.59mm, respectively. This indicates that both groups showed a decrease in convexity from pretreatment to posttreatment and an improvement in the antero-posterior dimension. The difference between the two groups was 0.41mm and this difference was not statistically significant ($p=0.21$). The average change in facial axis from pretreatment to posttreatment showed a small increase in the vertical dimension in both PM1 and PM2 (-0.54°±1.55 and -0.42°±1.51, respectively). The difference between the groups was also not statistically significant ($p=0.74$).

Table (4) presents the average initial and final upper lip thickness for PM1 and PM2. The initial values for PM1 and PM2 were 14.69mm±1.69 and 14.85mm±1.62, respectively. Those values were judged to be similar. The final values for the upper lip thickness were 15.60±2.13 and 15.76±1.61 for PM1 and PM2, respectively. An increase

of 0.91mm in the thickness was observed in both groups. The upper lip thickness was found to be a significant predictor of only the Upper lip to E-plane outcome ($p>0.002$). The entire model is reported in Table (6).

Table (5) presents the unadjusted (raw) initial, final and change in the means for the study outcome measures for each treatment group. The NLA increased in both treatment groups indicating a reduction in soft tissue lip fullness. However, there was no statistically significant ($p=0.99$) nor clinically significant (ES=0.4%) difference between the increase of NLA for PM1 and PM2. The upper lip position with respect to the E-plane showed a more retrusive position after treatment in both groups. The initial position of the upper lip in PM1 was relatively more protruded (-0.65mm ±2.31) compared with a more retruded initial position (-2.63mm±2.51) in PM2. The upper lips in both groups were found to be further retruded after treatment (-3.38mm ±2.39 and -5.20 mm ± 2.57 for PM1 and PM2, respectively). However, the average retraction of the upper lips between the two groups was not statistically significantly different ($p=0.68$) nor clinically significant (ES=7%). The lower lip position followed the same trend as the upper lip. Initially in PM1, the lower lip position was more protruded than that of PM2 (1.28mm±2.18 and -0.39mm ±2.95, respectively). The lower lip also finished in a slightly more protruded position (-1.39mm ±2.54) in PM1 compared to that of PM2 (-2.35mm ±3.19), with the difference between the groups being not statistically significant ($p=0.27$). This difference, however, was clinically significant (ES=21%).

Measuring U1-NA (mm) and U1-NA (deg) indicated the change in the upper incisor position. At the end of treatment in PM1, the upper incisors were retracted and uprighted an average of -1.68mm±2.43 and -2.42°±7.44 while in PM2, the upper incisors were retracted and uprighted an average of -0.76mm±2.19 and -0.33°±6.33. Although the upper incisors in PM2 were retracted less in millimeters and degrees, the difference between PM1 and PM2 was not statistically significant. ($p=0.10$) and ($p=0.20$), respectively. The difference, however, was also clinically significant. The lower incisor was retracted an average of 1.49mm±1.89 in PM1 while the average retraction in PM2 was 0.43mm±1.51. This difference between the groups was both statistically significantly

different (p=0.001) and clinically significant (ES=71%). This indicated that, on average, the lower incisors were retracted more when first premolars were extracted, compared with cases where the second premolars were extracted.

Table (6) presents the means for the outcome variables adjusted for the effect of extraction type, age, sex, initial facial axis, initial convexity, and upper lip thickness. The models for the primary and the secondary soft tissue outcomes showed no statistical significance (p>0.05). However, the lower incisor position model showed a statistically significant predictability (p=0.0002) and the difference between the extraction group means was clinically significant (ES=88%). Of the six variables used as covariates, only two were significant predictors of the outcomes. The upper lip thickness was a significant predictor of the retraction of the upper lip to E-plane (p=0.002). The thicker the upper lip, the greater the retraction. The facial axis was also a significant predictor of the retraction of the lower incisor relative to the APg line (p=0.0005). The more vertical the facial axis, the less the retraction of the lower incisors. Despite the statistical significance, the predictability of the covariates was low. The covariates examined in this study explained a maximum of 29% of the variability of the outcome as shown by the R^2 value.

Tables 7 and 8 display the association between the study outcome variables. A simple correlation was performed between the primary and secondary outcomes for both groups. The primary outcome (NLA) had no significant correlation with any other outcome (p>0.05) and r was generally weak. On the other hand, the retraction of the upper incisors was found to be positively correlated with the retraction of the upper and lower lips in PM1(r=0.49 and r=0.46, respectively). The more the upper incisors were retracted, the more the lips became retruded. The correlations between the upper incisor retraction and the retraction of the upper and lower lips relative to the E-plane were lower in PM2 (0.34 and 0.36, respectively).

Lower incisor retraction had a positive correlation with lower lip retraction in PM1 (r=0.34), but the correlation was negligible in PM2 (r=0.08). No significant correlation was found between lower incisor retraction and upper lip retraction in either group.

However, the retraction of upper and lower lips was highly correlated in both groups (r=0.68 and r=0.71 for PM1 and PM2, respectively).

Finally, Table (9) indicates the coefficient of reliability (R) and the error of measurement (SD) for all linear and angular measurements. In general, R was greater than 0.96 and the error of measurement was under 1mm or 1 degree for linear and angular measurements, respectively. Those values were determined to be acceptable.

Discussion:

The purpose of this study was to investigate the difference in the soft tissue response between orthodontic treatments involving the extractions of four first versus four second premolars. The study looked at the difference in the nasolabial angle, as well as the change of the upper and lower lips relative to the E-plane. The sample contained two groups that were similar in age and gender distribution but slightly different in base line skeletal characteristics. This difference was taken into consideration when the statistical model was constructed, and it was found that generally, those differences were not statistically significant and, with few exceptions, did not influence the model.

Convexity and Facial Axis:

The difference between the change in the vertical and antero-posterior tendencies of the maxilla and the mandible was investigated. It has been hypothesized that extraction treatment will decrease the vertical dimension by reducing the "wedge effect"[26] . The "wedge effect' concept assumes that premolar extraction treatment would allow the molars to move forward, resulting in bite closure. It follows that the extraction of second premolars would allow greater mesial movement and therefore, would cause greater reduction in the vertical dimension[27]. This investigation, however, found no signs of vertical dimension closure with premolar extraction treatment (Table 3). Furthermore, there was no significant difference between first and second premolar extraction groups which was in agreement with other studies[28,29] .There was, however, a slight increase in the vertical dimension in both groups at the end of treatment. Thus, the results from this study agreed with Staggers[30] that orthodontic treatment with four first premolar extraction produced an increase in the cephalometric vertical dimension.

The results of this study indicated that both groups showed a decrease in convexity from pretreatment to posttreatment and an improvement in the antero-posterior dimension (Table 3). It has been shown in previous studies that convexity tends to slightly improve with growth regardless of treatment modality[31,32]. The difference between the two groups was not statistically significant. It should be noted, however, that the relatively large standard deviations for the convexity and the facial axis

measurements indicate a wide variation among the subjects with respect to the antero-posterior and vertical growth tendencies.

The Nasolabial Angle:

The nasolabial angle (NLA) was the primary outcome to be investigated in this study (Table 5). The average initial NLA was very similar between the two groups but was slightly more acute than other average reported norm[4,33]. This study agreed with previous studies that the nasolabial angle increased following premolar extraction treatment[4]. The average increase was found to be 2.24° and 2.23° in the PM1 and PM2 groups, respectively which was less than the average increase reported by other studies[4,13,20,39]. The average change was not statistically or clinically significantly different between PM1 and PM2. The adjusted data also showed no statistically and clinically significant difference between the groups, and there were no significant predictors of this outcome. In fact, accounting for the variables measured in this study explained only 1% of the variability in NLA. The lack of significant difference between the two groups despite the clinically significant difference between the amount of lip and teeth retraction indicated the presence of other factors not measured in this study that may influence the nasolabial angle. One could argue that an accurate assessment of the soft tissue changes was difficult in a sample with different malocclusions. It has been shown, however, that changes in soft tissue profile were not related to the classification of the malocclusion[24,34].

The Upper and Lower Lips:

In this study, the soft tissue comparison and analysis between the first and second premolar extraction groups (Table 5) showed that the upper and lower lips were retracted relative to the E-plane when premolars were extracted, which is in agreements with previous studies that indicated that extraction treatment tended to retract the upper and lower lips[1,13,18]. The information from this study that was of particular importance to the orthodontists was that there was no statistically significant difference between the average change in the upper and lower lip position between the two groups. In other words, this study didn't find that extracting four first premolars would lead to more

retraction of the lips than extraction of four second premolars, which is in agreement with other studies[23,24,25] . However, the clinically significant difference between the average retraction of the lower lip in the two groups showed that there was some validity to the consideration of extracting the first premolars when it was desired to reduce lip protrusion.[29]

The Upper Lip Thickness:

The upper lip thickness was measured for all subjects in this sample to determine the possible influence on the NLA and the position of the upper and lower lips after treatment. Table (4) showed that the upper lip thickness increased over the course of treatment by 0.91mm for both groups. This is in agreement with another study investigating the effect of upper first premolar extraction[35]. This increase is probably due to growth[21] and to the reduction in lip strain as the incisors were retracted[36]. Other studies have reported a decrease in the upper lip thickness following extraction treatment that lead to retraction of the upper incisors[37,40]. The difference in those findings, in addition to the reported measurement error, is probably due to the method of measuring the upper lip thickness and which soft tissue point to mark. The upper lip thickness was included in the final ANCOVA as a possible covariate. This study found that the upper lip thickness affected the retraction of the upper lip. The results agreed with Talass et al's[8] observation that thicker upper lips tend to retract more and disagreed with Oliver's[22] conclusion that thinner lips demonstrated more retraction. However, all of the covariates measured in this study including the statistically significant upper lip thickness only explained 14% of the variability in the upper lip response.

The Upper and Lower Incisors:

In this study, the position of the upper incisors was measured relative to the N-A plane. Treatment planning based on the position of the upper incisor relative to the NA plane has been contemporarily promoted as a valid alternative[38]. The initial linear and angular measurements of the upper incisors relative to the NA plane were similar in both groups (Table 5). There was no statistically significant difference between the average change of the upper incisors to the NA plane between the two groups. Clinical

significance was present between the two means, as the upper incisors were retracted more in the first premolar extraction group. In this investigation, the average amount of the upper incisor retraction in PM1 was less than that in previous studies that used the NA as a reference plane[31,39]. Previous evidence for the average amount of retraction of the upper incisors in second premolar extraction cases was lacking in the literature. The lack of statistical significance in this study, despite evidence of clinical significance, was probably due to the small sample size. Thus, this study supports the concept that extraction of first premolars will result in more retraction and uprighting of the upper incisors as postulated by Nance[1]. Controlling for the variables measured (Table 6) revealed that there were no significant predictors of the upper incisor changes. In fact, the variables measured explained a maximum of 12% of the variability in the upper incisor response, indicating the presence of other factors that may influence this outcome. The adjusted results including the clinical significance were similar to the unadjusted data.

Subjects in PM1 were shown to have more statistically and clinically significant retraction of the lower incisors than subjects in PM2 (Table 5). Despite the mixed skeletal sample in this study, the average distance of lower incisor retraction was similar to studies with Class I malocclusion[39]. Thus, this study supported Nance's suggestion that the orthodontist should extract first premolars to retract the lower incisors to a greater degree, but should consider second premolar extraction if only a minor change in the position of the lower incisors is desired[1]. There was, however, a wide variation within each individual group as indicated by the standard deviation. The difference between PM1 and PM2 was also statistically and clinically significant when controlling for the variables measured. Moreover, the facial axis was found to be a significant predictor of the lower incisor retraction. The lower incisors in the dolichofacial subjects were retracted less. This was probably due to the observation that the initial position of the lower incisors in the dolichofacial subjects was more retruded as a natural way to compensate for the vertical pattern and therefore, less retraction was necessary during treatment. However, all of the other covariates measured in this study including the statistically significant facial axis only explained 29% of the variability in the lower incisor response.

Correlations between Dental and Soft Tissue Changes:

In PM1, there was a significant positive correlation between the change in the upper incisor position and the change in the lower incisor position indicating that on average, whenever the upper incisor was retracted, the lower incisor was retracted as well. This correlation was also significant in PM2. This correlation was possibly due to the nature of four premolar extraction orthodontic treatment that tended to retract the incisors to decrease protrusion or to close extraction spaces[29]. The change in the upper incisor position in millimetres was strongly correlated with the angular position of the incisors in both groups. This was an expected finding as the two measurements tend to generally change together [8,39].

This study also found a significant positive correlation between the change in the upper incisor position and the change in the position of upper and lower lips in PM1. This is in agreement with previous research that indicated the presence of strong correlation between the retraction of the upper incisors and the retrusion of the upper and lower lips when the first premolars were extracted [18,20]. Weak correlation was found in PM2 and it was not statistically significant. Furthermore, the lower incisor position was found to have a statistically significant correlation with the retrusion of the lower lip in PM1. This is in agreement with Caplan et al[19]. The results indicated that the lower lip position was affected by the position of the lower incisors when the first premolars were removed. No such correlation was found in PM2. Therefore, this study agreed with the previous suggestion that the upper lip position was not influenced by the extraction of second premolars[1]. It could be hypothesized that other factors –e.g. relief of crowding and mesial movement of the molars-account for the use of space in PM2 but those were not examined in this study.

The correlation between the change in the NLA angle and any dental or skeletal changes in the PM1 and the PM2 groups was very weak and was not statistically significant. This finding was in agreement with previous studies investigating different extraction treatment[18,20,40]. This study, however, disagreed with the significant correlation between the change in the NLA and the retraction of the upper incisors[8,9,22,23]. The weak

correlation between the NLA and other parameters in this study including the change in upper incisor position suggested that the minor changes observed in the NLA following treatment were probably due to other factors including growth. Studies with an untreated control group are needed to determine the full effect of growth on the change of NLA.

In both groups, the change in the upper lip was very strongly correlated with the change in the lower lip, suggesting that the position of the lips influences each other. The wide variation in the lip response to the dental changes, however, suggested that lip posture could be affected by many factors such as the superimposed growth, the adaptation of the lips to the incisors, and the changes in vertical dimension[2]. Other factors include the complex anatomy of the lips, the interrelation between the muscles of the upper lip and the muscles of the nose, and lip posture and its inaccurate representation on the lateral cephalograms.

The Limitations of the Study:

The limitations of this study must be taken into consideration when interpreting the results. The retrospective nature of the study introduced a bias since no randomization of case selection was possible. Moreover, the relative inability to confirm the repose position of the lips on a cephalogram was a deficiency in the study[6]. Although the subjects' lips in this investigation were judged to be in the relaxed position, the reliability of some soft tissue landmark identification remained questionable[41]. Another shortcoming of this retrospective study was that the reason for the choice of the premolar extraction could not have been known with certainty. Many factors must be considered prior to specifying the extraction pattern which could include, but not limited to, molar relations, crowding, appliances, and anchorage. On the other hand, the orthodontist's own belief regarding the relationship between a certain extraction pattern and the changes in the soft tissues or the effect on the vertical dimension may have been a factor in the decision of which premolars to remove. Finally, the difference between some outcomes was clinically, but not statistically,significant which may have been due to the small sample size.

Conclusions:

The results of this study sample suggested the following:

1) There was no statistically or clinically significant difference in the mean change in the nasolabial angle from pre- to post-orthodontic treatment between the group with the four first premolar extractions and the group with the four second premolar extractions.
2) The change in the nasolabial angle from pre- to post-orthodontic treatment was poorly correlated with any dental or skeletal changes in both extraction groups.
3) The mean retraction of the upper incisors from pre- to post-orthodontic treatment was clinically significantly different between the two extraction groups. On average, the upper incisors were retracted more in the first premolar extraction group.
4) The mean retraction of the lower incisors from pre- to post-orthodontic treatment was clinically and statistically significantly different between the two extraction groups. On average, the lower incisors were retracted more in the first premolar extraction group.
5) The upper and lower lips were retracted from pre- to post-orthodontic treatments in both extraction groups. There was no statistically significant difference in the mean amount of retraction between the two extraction groups. There was, however, a clinically significant greater retraction of the lower lips in the first premolar extraction group.
6) In both extraction groups, the thicker the upper lip, the more it was retracted.
7) The retraction of the upper incisor was strongly correlated with the retraction of the upper and lower lips in the four first premolar extraction group only.
8) In both groups, the more vertical the facial axis, the less the retraction of the lower incisors.
9) The change in the soft tissue profile following orthodontic treatment is highly variable and depends on many other factors in addition to the ones measured in this study.

Table (1): Sample groups age and sex

	Males (%)	Females (%)	Total	Age (Months)
PM1	20 (42)	28 (58)	48	156.5±16.7
PM2	11 (33)	22 (67)	33	159 ±15.8

Table (2): Pretreatment skeletal pattern by treatment group

	Convexity	Facial Axis
PM1	5.04±2.63	-5.9±4.13
PM2	3.80±2.77	-3.86±4.03

Table (3): Pretreatment, posttreatment and the change in skeletal pattern by treatment group

	Convexity			Facial Axis		
	Initial	**Final**	**Change**	**Initial**	**Final**	**Change**
PM1	5.04±2.63	2.75±2.56	-2.28±1.31	-5.9±4.13	-6.44±4.29	-0.54±1.55
PM2	3.80±2.77	1.93±3.22	-1.87±1.59	-3.86±4.03	-4.28±4.40	-0.42±1.51
Group Diff (p-value)			-0.41(NS)*			-0.12(NS)*

*NS: The difference is not statistically significant (p>0.05)

Table (4): Groups Initial and Final Upper Lip thickness

	Initial Upper Lip Thickness (mm)	Final Upper Lip Thickness (mm)
PM1	14.69±1.69 (18.0-10.3)	15.60±2.13 (20.5-11.8)
PM2	14.85±1.62 (18.4-12.0)	15.76±1.61 (19.4-12.9)

Table (5) Pretreatment and posttreatment dental and soft tissue measurements, by Treatment group

Outcome Variable	PM1			PM2			Group Diff (p-value)	Effect Size (ES) %
	Initial	Final	Change	Initial	Final	Change		
NLA	110.38 ±10.21	112.7 ±7.9	2.24 ±7.69	110.9 ±9.14	113.13 ±7.76	2.23 ±7.00	0.01° (0.99)	0.4
U Lip to E Plane	-0.65 ±2.31	-3.38 ±2.39	-2.75 ±1.90	-2.63 ±2.51	-5.20 ±2.57	-2.56 ±2.21	-0.19 mm (0.68)	7
L Lip to E Plane	1.28 ±2.18	-1.39 ±2.54	-2.59 ±2.05	-0.39 ±2.95	-2.35 ±3.19	-2.05 ±2.33	-0.54 mm (0.27)	21
U1-NA(mm)	4.77 ±2.33	3.02 ±2.14	-1.68 ±2.43	4.61 ±2.10	3.79 ±219	-0.76 ±2.19	-0.92 mm (0.10)	55
U1-NA(deg)	23.89 ±5.76	21.31 ±6.16	-2.42 ±7.44	24.06 ±5.18	23.72 ±6.99	-0.33 ±6.33	-2.09° (0.20)	86
L1-AP (mm)	3.24 ±2.03	1.64 ±1.95	-1.49 ±1.89	2.3 ±2.31	1.87 ±2.08	-0.43 ±1.51	-1.06 mm (0.001)*	71

* Statistical Significance ($p<0.008$)

Table (6): Analysis of Covariance (ANCOVA) Models by Outcome Variable

Outcome Variable	Whole Model R^2	Whole Model P-Value	Covariate P-Value						% Difference Least Square Group Means (Effect Size)
			Sex	Age	Extraction Pattern	Convexity	Facial Axis	Upper Lip Thickness	
NLA	.01	0.98	0.72	0.98	0.90	0.80	0.79	0.48	10
U Lip to E-plane	0.14	0.07	0.54	0.16	0.83	0.49	0.56	0.002*	3
L Lip to E-plane	0.09	0.33	0.70	0.60	0.20	0.58	0.47	0.06	25
U1-NA (mm)	0.08	0.39	0.14	0.53	0.14	0.43	0.91	0.46	56
U1-NA (deg)	0.12	0.13	0.23	0.61	0.27	0.18	0.90	0.70	99
L1-Apg (mm)	0.29	0.0002*	0.08	0.16	0.0006*	0.06	0.0005*	0.98	88

* Statistical Significance ($p<0.05$)

Table (7): Correlation Coefficient (r) among outcomes in PM1

	U1-NA(mm)	U1-NA(deg)	L1-APg(mm)	U lip-E plane	L lip-E plane	NLA
U1-NA(mm)	_____	0.84*	0.46*	0.49*	0.46*	0.02
U1-NA(deg)	_____	_____	0.39*	0.39*	0.45*	0.14
L1-APg(mm)	_____	_____	_____	0.18	0.35*	0.16
U lip-E plane(mm)	_____	_____	_____	_____	0.68*	0.003
L lip-E plane(mm)	_____	_____	_____	_____	_____	0.08
NLA	_____	_____	_____	_____	_____	_____

* Statistical Significance ($p<0.05$)

Table (8): Correlation Coefficient (r) among outcomes in PM2

	U1-NA(mm)	U1-NA(deg)	L1-APg(mm)	U lip-E plane	L lip-E plane	NLA
U1-NA(mm)	_____	0.91*	0.53*	0.17	0.16	0.04
U1-NA(deg)	_____	_____	0.58*	0.14	0.16	0.11
L1-APg(mm)	_____	_____	_____	0.03	0.31	0.09
U lip-E plane	_____	_____	_____	_____	0.71*	0.04
L lip-E plane	_____	_____	_____	_____	_____	0.27
NLA	_____	_____	_____	_____	_____	_____

* Statistical Significance ($p<0.05$)

Table (9) Error of measurements and Coefficient of Reliability (R)

	R	Measurement Error
U1-NA (mm)	0.975	±0.42mm
U1-NA (deg)	0.986	±0.79°
L1-Apo (mm)	0.982	±0.30mm
Convexity	0.96	±0.64mm
Facial Axis	0.963	±0.78°
Upper lip thickness	0.96	±0.43mm
U lip to E-plane	0.99	±0.30mm
L lip to E-plane	0.99	±0.32mm
Nasolabial Angle	0.99	±0.37°

Figure (I)
Land marks used in the cephalometric analysis

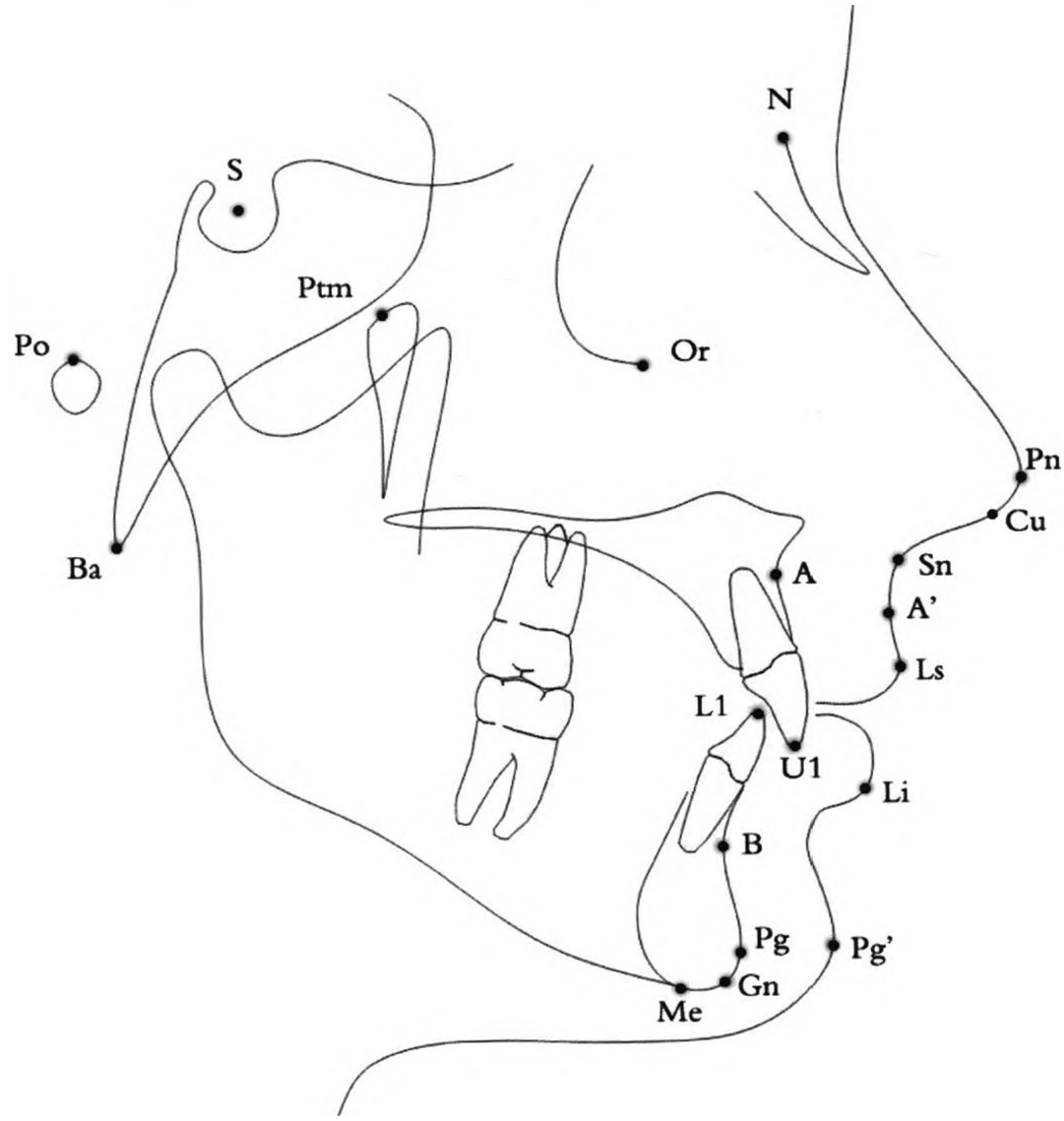


Figure (II)
Dental Measurements: (1) U1-NA (mm), (2) U1-NA (deg), (3) L1-APg(mm)

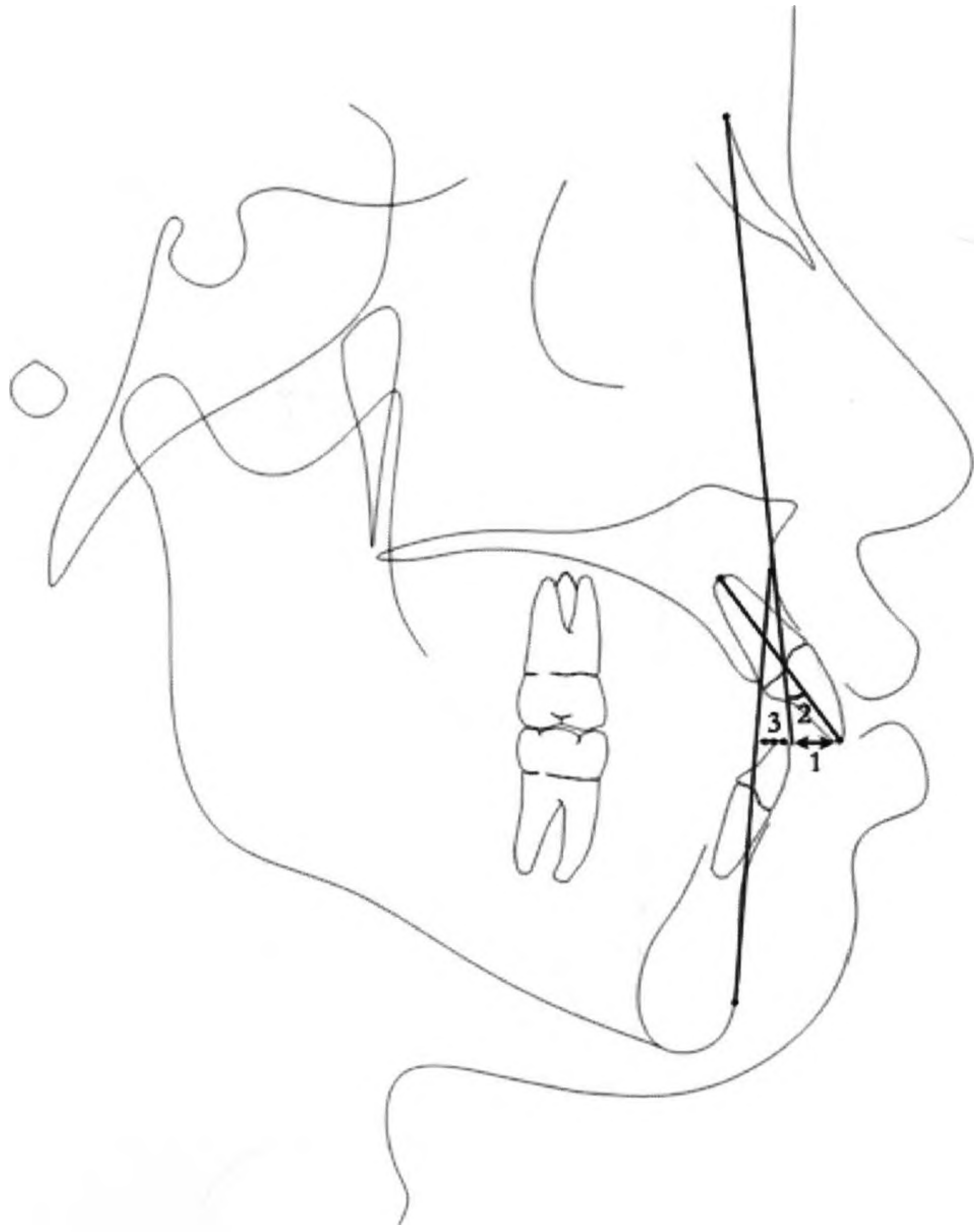


Figure (III)
Skeletal Measurements: (1) Convexity (mm), (2) Facial Axis Angle

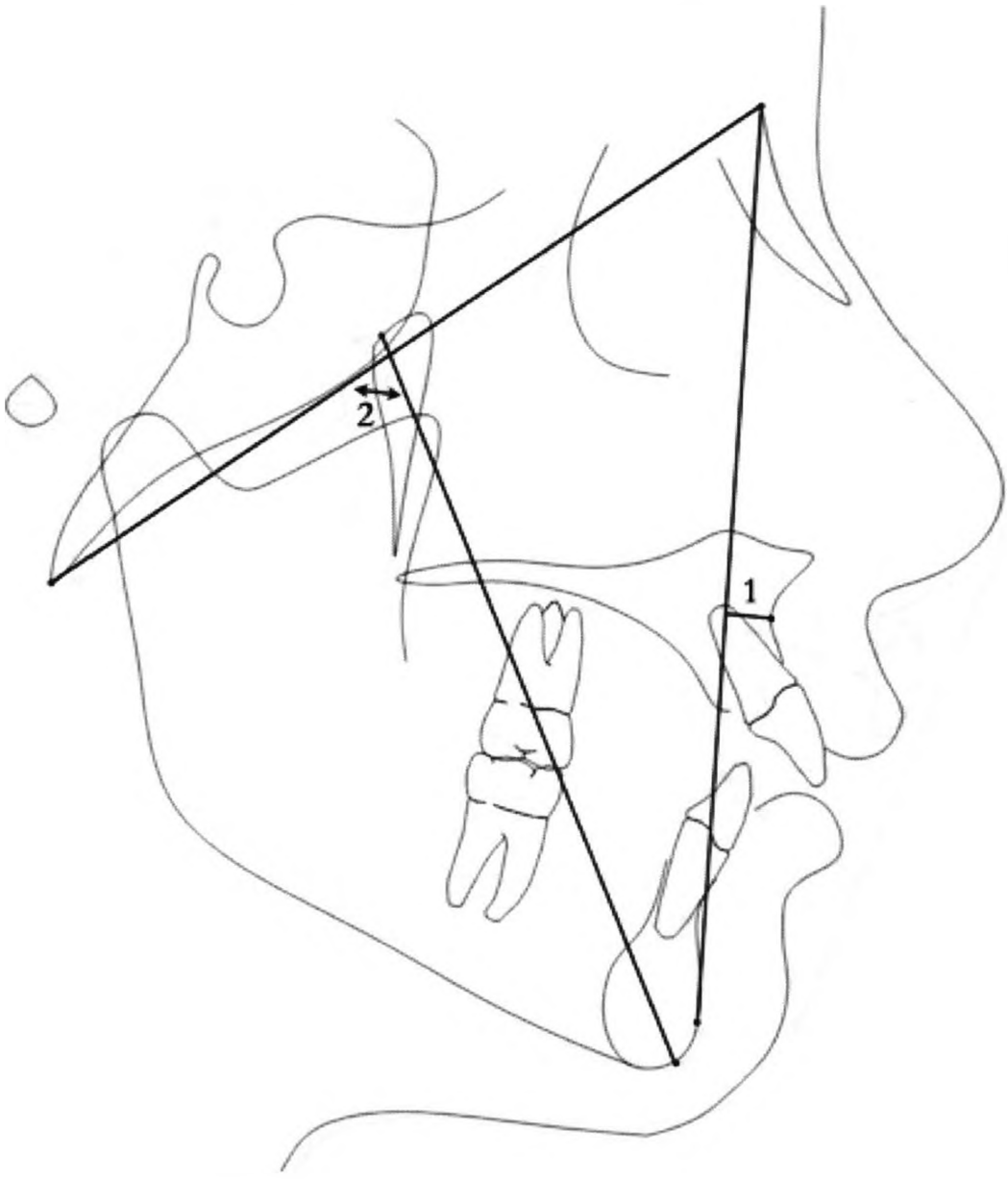
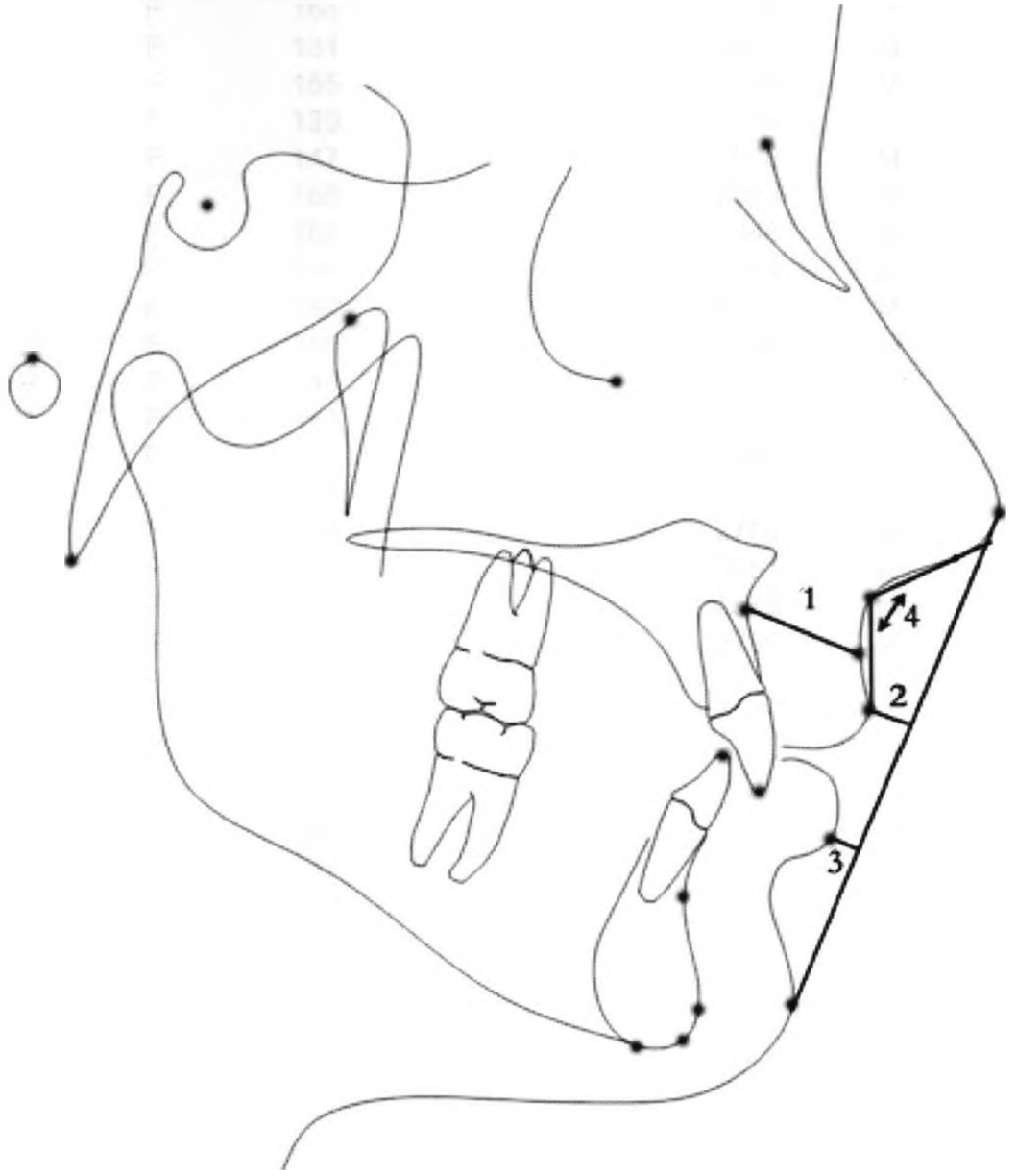


Figure (IV)
Soft tissue measurements: (1) Upper lip thickness, (2) Upper lip to E-plane, (3) Lower lip to E-plane, (4) Nasolabial Angle



Appendix I

Subjects in Group (PM1): Four First Premolar Extraction (n= 48)

Subject	Sex	Age(mon)	Subject	Sex	Age(mon)
1938	F	149	2140	M	154
1606	F	141	1727	M	185
1380	F	164	1726	M	135
1051	F	131	1608	M	168
3119	F	155	3138	M	156
3036	F	120	3115	M	133
1715	F	147	2976	M	190
1861	F	158	3024	M	160
1647	F	158	1646	M	153
1645	F	144	1694	M	183
K. N.	F	147	R. S.	M	179
G. W.	F	155	H. W.	M	151
M. V.	F	146	E. A.	M	184
A. B.	F	141	J. C.	M	164
A. H.	F	181	3255	M	138
N. H.	F	177	3098	M	160
3345	F	144	2704	M	189
3005	F	140	3081	M	156
2706	F	145	2575	M	149
2488	F	156	2790	M	183
2509	F	167			
2437	F	148			
2399	F	140			
2404	F	169			
2608	F	169			
2590	F	147			
2797	F	139			
2530	F	165			

Appendix II

Subjects in Group (PM2): Four Second Premolar Extraction (n= 33)

Subject	Sex	Age (mon)	Subject	Sex	Age (mon)
2144	F	168	2764	M	149
2651	F	170	2637	M	180
2325	F	128	2256	M	153
2394	F	144	2124	M	130
2146	F	167	1922	M	156
2136	F	164	2313	M	171
1985	F	167	2198	M	151
1950	F	151	2395	M	165
1867	F	146	3050	M	171
1817	F	170	3336	M	175
1813	F	147	W. L.	M	135
1548	F	132			
1346	F	189			
1067	F	156			
S. T	F	147			
K. R	F	188			
M. M.	F	157			
2724	F	167			
2350	F	156			
2982	F	158			
3319	F	155			
E. C	F	184			

Appendix III

Group (PM1): Initial and Final Convexity and Facial Axis

Subject	Convexity Initial	Convexity Final		Facial Axis Initial	Facial Axis Final
2140	6.9	3.5		-12	-9.7
1938	6	4.5		-5.1	-6.5
1727	6.9	3.6		-8.2	-7.4
1726	5.7	5.5		-7.3	-10
1606	6.1	2.1		-8.5	-7.2
1608	-0.8	-1.5		-0.7	0
1380	6.1	1.3		-11.2	-11
1051	9.9	7.3		-9.4	-10.2
3138	1.5	-2.8		-6.6	-7.5
3119	5.9	2.9		-8.3	-9.2
3115	3.2	1.3		-10.6	-9.8
2976	6.7	5.5		-7.6	-6.8
3024	6.1	3.8		-4.6	-6.3
3036	5.2	1.4		-11.7	-13.1
1715	3.2	1.3		-5.5	-6.2
1861	11	6		-7.4	-9.2
1647	5.7	3.6		-3.7	-2.1
1645	6.4	2.7		-6	-5.9
1646	6.9	2.9		-3	-1.4
1694	2.5	0.3		-0.3	-1
K. N.	5.2	4.5		-11.6	-16.1
G. W.	3.2	3.8		-10.2	-11.9
M. V.	6.5	5		-5.3	-7.6
R. S.	4.2	0.5		-1.3	-5.3
H. W.	7.9	4.2		-8.2	-7.4
A. B.	7.4	5.3		1.1	2
E. A.	0.9	-1		-3.2	-4.5
A. H.	0	-2.1		3	-0.3
N. H.	9.2	7.1		-5.8	-6.9
J. C.	4.9	1		-5.3	-6.8
3345	7.2	4.6		-3.1	-4.2
3255	6.5	3.5		-0.6	-1.3
3098	3.9	2.5		-8	-8.5
3005	5.8	6		-10.4	-11.8
2706	2.1	0.5		-9.6	-9.4
2704	6	3.1		-14.5	-13.7
3081	2.7	1.5		-11.2	-13
2488	8.7	7.2		2.5	4.5
2509	4.8	5		-8.7	-8.8
2437	5.7	3.3		-6.2	-5
2399	6.8	4.5		-4.5	-5.1
2404	4.2	1.9		-4.3	-3.2
2608	1	-0.9		0.4	-1.2
2590	4.1	3.4		-1	-3.5
2575	1	-2.5		-2.5	-4.4
2790	7	4.3		-8	-6.8
2797	-0.1	-1.2		-2.2	-1.1
2530	4	2		-7.1	-7.4

Appendix IV

Group (PM2): Initial and Final Convexity and Facial Axis

Number	Convexity Initial	Convexity Final		Facial Axis Initial	Facial Axis Final
2144	-0.2	0.3		-1.1	-5.8
2764	-0.6	-5.7		1.3	4.1
2651	5.9	4.7		-5.2	-4.5
2325	5	2.4		-8.1	-8.1
2394	2.4	-1.3		-4.3	-4
2637	1.4	-0.3		-4.9	-3.1
2256	6.6	3.6		-3.4	-5.2
2146	6.4	4.5		-7.9	-8.7
2124	6	2.1		-4.6	-6.4
2136	-3.4	-3.3		-3.7	-4.2
1985	-0.3	-4.3		3.8	6.1
1950	5.1	4.2		-9	-8.7
1922	5.7	2.4		-3.1	-2
1867	4.4	3.6		-2.2	-2.3
1817	4.3	1.7		0.2	0.4
1813	3.8	-2.5		-4.8	-4.6
1548	1.8	1.5		-2.6	-3.9
1346	6.2	5.6		-10.2	-10.5
1067	2.3	1.8		-6.6	-8.5
S. T	8.4	8.1		-4.9	-6.7
K. R	1.8	0.4		0.7	-1.7
M. M.	1.5	-1.3		-6.5	-6.1
2724	3.4	2.6		1.6	1.4
2313	6.4	6		-7.1	-8.9
2350	2.7	0.4		7.4	6.5
2198	3.3	1.8		-3.7	-5.3
2395	6.7	3.4		-4.2	-3.5
2982	2.9	0		-5.7	-5.7
3050	7.2	6.5		-11.4	-12.9
3319	0	-0.2		-6.6	-5.9
3336	6.2	4.4		-3.9	-2.7
W. L.	6.4	5.1		-7.1	-8.3
E. C	5.9	5.5		0.3	-1.6

Appendix V

Group (PM1): Initial and Final Dental Measurements

Subject	U1-NA(MM) Initial	U1-NA(mm) Final		U1-NA(deg) Initial	U1-NA(deg) Final		L1-Apo Initial	L1-Apo Final
2140	1.5	2.1		14.1	22.3		3.5	1.6
1938	3.3	1.6		21.7	20.2		1.9	2.9
1727	9.2	2.8		36.2	20		4	1.2
1726	4	0.4		20.1	11		5.2	2
1606	8.5	7.5		32.1	27		4.3	4.3
1608	6	7.1		27.9	29.8		-1.6	2.2
1380	5.7	3.6		28.4	24.5		-0.1	-2.3
1051	4.4	3		23.7	20.9		4.7	4.5
3138	12.2	8.1		26	33.4		2.4	3.2
3119	7.3	5.3		32.2	25.1		5.4	4.1
3115	5.2	2.1		24.3	17.1		1.1	-0.2
2976	3.1	3.3		21.8	26.3		6.3	4.7
3024	5.3	4		23.9	24.1		3	3.3
3036	2.7	3.4		17.7	18.2		0.3	2.4
1715	3	3.9		22.1	22.4		2.9	2.3
1861	3.5	2.1		23.3	17.3		4.5	3.5
1647	4.2	-0.2		24.1	13.4		4	-0.8
1645	2.9	0.2		19.1	16.9		0.6	-1.1
1646	0.1	1		14	20.6		1.4	-0.6
1694	3.7	3.3		19.8	28.3		2.4	0
K. N.	3.8	3.5		23.2	22.9		5.4	1.9
G. W.	4.4	2.7		23	20.5		4.2	2.1
M. V.	5.1	1.2		25.5	19.6		3.5	1.8
R. S.	2.9	6		19.3	29		2.3	2.2
H. W.	6.5	3.3		28.7	21.9		3.1	2.6
A. B.	5.5	1.2		30.3	17.7		4.7	0.8
E. A.	5	4.2		24.9	20.5		1.2	0.5
A. H.	6.9	8.1		29.5	34.4		6.2	3.3
N. H.	1.6	1.9		14.7	18		5.6	2.6
J. C.	4.3	4.8		23.8	22.2		5.3	3
3345	6.4	0.8		27.7	8.1		5.4	3.1
3255	3.5	4.6		19.8	25.2		6.5	3.1
3098	5.3	1.5		23.4	14.6		2.4	-0.1
3005	3.7	2.8		18.6	21.3		3.2	3.4
2706	6.5	2.9		29.9	24.1		3.7	1.1
2704	5.7	2.7		22.3	14.9		1.7	1.5
3081	2.6	2.6		16.2	17.6		1.1	1.8
2488	4.9	1.5		22.2	19.1		6.9	3.2
2509	4.6	4.8		24.3	26.8		3.9	5.8
2437	2.9	0.9		22.6	13.7		-0.7	0.4
2399	3	1.2		18.2	12.4		3	1.2
2404	2.5	1.8		20.4	18.2		1.8	-0.6
2608	9	-1.3		34.3	10.5		1.7	-4.6
2590	4.8	2.7		25.5	19.4		4.1	0.3
2575	7	4.5		29.3	33.1		1.1	-0.8
2790	1.1	2.4		14.3	23.6		1.1	0.4
2797	3.9	4.8		24.5	33.1		2	0.5
2530	10.2	6.1		41.8	33.4		6.2	3.6

Appendix VI

Group (PM2): Initial and Final Dental Measurements

Subject	U1-NA(MM) Initial	U1-NA(mm) Final		U1-NA(deg) Initial	U1-NA(deg) Final		L1-Apo Initial	L1-Apo Final
2144	3.4	2.1		23.9	18.5		-0.1	-1
2764	9.4	5.9		36.7	34.1		-1	-1.1
2651	3.6	4.1		22.4	25.1		3.4	4.4
2325	6.2	3.7		25.3	24.5		1.1	0.9
2394	3.3	4.1		23.6	24.5		0.2	0.9
2637	4.8	7.9		24.6	34		2.3	3.9
2256	-0.8	1.3		17.4	21.2		0.4	0.9
2146	6	1.9		27.1	15.1		5.6	2.9
2124	8.5	4.5		33.6	23.5		-0.1	-1.1
2136	6.9	6.5		32.9	32.5		2	1.7
1985	5.7	8.2		27.4	36.4		2.3	1.2
1950	0	0.8		11.2	20.3		-0.7	1.8
1922	2.8	4.4		21.4	26.2		1.6	3
1867	7.3	2.8		28.9	20.2		5.5	3.3
1817	3.8	5.5		22.6	26.8		3	1.6
1813	3.7	6.4		19.4	25.9		1.7	3.7
1548	4.8	1.4		24.1	15.9		-0.1	-0.2
1346	6.2	0.4		23.8	12.7		3.1	1.4
1067	2.5	-0.1		17.1	10.1		-0.5	-1.4
S. T	3.7	2.1		17.7	13.6		7	6.7
K. R	5.8	3.1		25.9	20.4		3.7	0.6
M. M.	3.5	7.3		22.1	31.5		2.6	2.6
2724	4.7	2.2		23.7	17.8		2.8	-0.2
2313	5.2	3.4		24.4	19		5.4	4.8
2350	5	4.6		26.6	27.6		3	0.5
2198	3.4	6.1		18.1	26.1		2.3	1.9
2395	4.2	2		23.1	19.3		4.6	1.4
2982	6.3	3.8		29.9	25.8		1.2	0.9
3050	4.9	4.9		24.3	25.7		5.1	6.2
3319	2.2	2.2		19.3	22.9		-1.9	-0.9
3336	5.8	6		28.1	39.9		3.3	3.4
W. L.	3.6	1.9		19.9	18		1.7	2.9
E. C	5.8	3.7		27.4	27.7		5.4	4

Appendix VII

Group (PM1): Initial and Final Upper Lip Thickness

Subject	Upper Lip Thickness Initial	Upper Lip Thickness Final
2140	15.3	16.2
1938	15	14.9
1727	16.4	14.4
1726	12.8	15.9
1606	14.9	18.4
1608	14	16.2
1380	13.1	13.5
1051	14.7	16.3
3138	15.6	19.7
3119	15	13.9
3115	16.7	19
2976	15.9	15.7
3024	16.5	14.3
3036	10.3	13
1715	13.9	14.4
1861	12.6	15.8
1647	14.3	11.8
1645	15.6	14.1
1646	13.6	16.3
1694	18	17.1
K. N.	11.9	14.2
G. W.	12.8	13
M. V.	13.2	14.9
R. S.	14.4	16.9
H. W.	13.6	17.6
A. B.	14	14.6
E. A.	18	18.9
A. H.	15	17.1
N. H.	12.7	14.8
J. C.	14.6	20.5
3345	16.9	15.4
3255	14.4	18.9
3098	17.9	17
3005	17.5	18.8
2706	12.1	17.7
2704	15.2	13.8
3081	13.5	13.6
2488	14.1	13.2
2509	13.9	12.3
2437	13.5	15.7
2399	15.6	14.6
2404	14.5	13.6
2608	15.9	12.3
2590	14.2	13.2
2575	14.7	16.6
2790	17.8	18
2797	14.5	14.1
2530	14.5	16.4

Appendix VIII

Group (PM2): Initial and Final Upper Lip Thickness

Subject	Upper Lip Thickness Initial	Upper Lip Thickness Final
2144	14.5	13
2764	15.8	15.8
2651	17.3	17.3
2325	14.5	13.8
2394	13.2	14.1
2637	17.9	19.4
2256	14.7	15.5
2146	14.4	14.3
2124	13.4	17
2136	13.3	15
1985	16.9	19.3
1950	12.9	14.9
1922	15.5	17.3
1867	14.9	14.3
1817	14.7	15.9
1813	12	16.6
1548	15	15.4
1346	15.1	14.8
1067	15.1	14.9
S. T	16.8	17.8
K. R	13.4	14.4
M. M.	18.4	17.6
2724	15.3	18
2313	16.5	15.1
2350	12	14.8
2198	13.4	15.4
2395	14.8	16.9
2982	14.8	14.7
3050	14.6	15.5
3319	14.3	12.9
3336	17.6	17.1
W. L.	13	16
E. C	14.1	15.3

Appendix IX

Group (PM1): Initial and Final Soft Tissue Measurements

Subject	U Lip-E plane Initial	U lip-E Plane Final	L Lip-E plane Initial	L Lip-E plane Final	NLA Initial	NLA Final
2140	-0.5	-4	1	-0.7	119.2	112.5
1938	2.4	-1.3	2.6	-1.2	119.8	119.2
1727	3.4	-5	5.2	-7	111.1	110.9
1726	-2.5	-3.1	2.2	-1.2	132.1	132.8
1606	4	-0.1	3.8	1.2	101.8	104.6
1608	-2.6	-2.7	0.3	-0.9	105.9	114.1
1380	-1.7	-5.9	-1.3	-2.9	108.3	117.5
1051	2.7	-1.4	3.2	1.3	107.8	115
3138	-1.8	-4.6	0.8	-1.8	134.1	119.3
3119	2.1	-2	4.3	0.7	118	107
3115	-0.4	-2.7	1.4	0.3	120.3	111.8
2976	-5.1	-5.5	-0.9	-1	124.3	119.4
3024	-0.5	-6.2	1.3	-1.9	109.8	108.4
3036	-1.9	-3.5	0.3	1.2	91	108.2
1715	-1	-3.4	-1.6	-3.3	104.1	117.7
1861	2.7	-0.4	2.8	1	98.7	103.3
1647	-2.3	-6.2	-0.8	-4.1	111.8	110.5
1645	-0.8	-6.4	-2.7	-6.7	130.8	128.9
1646	2.2	0.8	2	0.7	104.9	108.4
1694	0.2	-5.1	0.6	-3.7	111	115.8
K. N.	0.2	-1.9	4.3	0.7	115.9	116.8
G. W.	-3.4	-2.9	0.7	0	102.1	106.1
M. V.	0.2	-2.7	-0.1	-0.8	116.1	113.8
R. S.	-3.7	-5.4	-1.6	-2.2	106.9	105.9
H. W.	1.5	0	4.4	2.5	104.8	110.9
A. B.	0.2	-2.7	1.7	-1.2	110.6	116
E. A.	-4.9	-7.1	-2.6	-3.8	116.8	114.5
A. H.	-4	-3.4	1.3	0.4	110.7	116
N. H.	-1.9	-2.5	2.3	-2.2	108.6	122.7
J. C.	-0.6	-2.3	3.2	0.3	113.1	110.6
3345	1.7	-2.5	4.6	-0.4	97.7	111.3
3255	2.4	0.2	4.7	0.8	98.3	114
3098	-0.4	-3.7	1.3	-2.6	107.8	125.8
3005	1.9	2.2	3	2.5	104.4	103.5
2706	-1.6	-8.3	1.7	-3.3	88.2	93.1
2704	-1.5	-5.6	0.3	-3.1	121.3	120.1
3081	-1.7	-5.5	0.8	-2.4	114.5	115.8
2488	4.1	2.1	4.8	5	101.6	100.5
2509	-4.4	-4.7	1.2	1.3	119.3	109.1
2437	-2.1	-4.3	-1.2	-4	124.6	124.7
2399	-1.3	-4.9	0.6	-3.2	107.9	95.2
2404	-3.1	-5.6	-0.5	-3.3	114.4	114.8
2608	-1.1	-6.5	-0.5	-5.3	95.9	110.3
2590	-0.5	-1	3.2	-0.2	107.2	102.5
2575	-0.3	-3.2	-1.4	-2	118.4	119.5
2790	-0.5	-2.4	0	-2.8	101.6	111.6
2797	-3.5	-6.6	-2.8	-5.2	119.6	121.9
2530	0.6	-1.3	4.8	2.7	94.5	102.9

Appendix X

Group (PM2): Initial and Final Soft Tissue Measurements

Number	U Lip-E plane Initial	U lip-E Plane Final		L Lip-E plane Initial	L Lip-E plane Final		NLA Initial	NLA Final
2144	-4.9	-8.8		-3.5	-7		92.8	112.2
2764	-2.9	-11.1		-4.6	-9.5		118.4	119.2
2651	-0.5	-2.4		3.2	2.2		109.5	114.4
2325	-0.5	-4.5		-0.5	-1.5		106.3	106.8
2394	-6.8	-10.6		-2.9	-8.7		123	110.9
2637	-4.2	-7.2		-0.9	-3.8		108.3	110.8
2256	-0.3	-4.1		1	-2.8		127.1	132.7
2146	-1.4	-4.8		1.7	-1		123	132.2
2124	-0.7	-4.6		2.6	-0.6		120.8	118.4
2136	-9.8	-7.8		-7	-6.9		95.2	94.8
1985	-2.7	-3.4		0	-2.9		103.9	109
1950	-1.9	-4.8		0.4	-1.4		115	117
1922	-2	-4		-0.5	-2.4		119.5	119.1
1867	-1.9	-4.4		0	-3.3		113.4	111.7
1817	-2.6	-5.4		-1.1	-1.1		116.6	107
1813	-4.2	-5		-0.7	-0.7		110.8	113.6
1548	-2.9	-4.9		-2.8	-4.8		115.8	112
1346	-1.8	-2.9		0.5	-1.1		116.4	113.2
1067	-5.4	-7.6		-3.7	-5.5		116.7	119
S. T	2	-5.2		5	0.5		96.2	95.8
K. R	-7.1	-9.9		-3.1	-7.5		106.8	109.5
M. M.	-3.1	-8.2		-1.9	-3.6		108.5	114.3
2724	-2.6	-3.7		1.5	-0.3		109.8	115.1
2313	0.3	-3.2		1.9	-0.2		103.9	108
2350	-3.4	-4		-0.5	-2.8		113.5	117
2198	-4.7	-4.5		-1	-1.3		112.6	113.1
2395	-0.8	-4.4		3.1	-2.7		119.7	114.7
2982	0.1	-5.6		1.3	-2.9		99	117.2
3050	-0.3	-1		4.4	4.6		109.4	112.4
3319	-3.7	-6.1		-3.2	-3.8		95.8	101.2
3336	1.3	-1.5		5.7	2.3		123.5	117.8
W. L.	-2.5	-0.3		-4.5	2.2		97.2	116
E. C	-5	-5.6		-2.9	-2.4		111.3	107.3

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