Research Article

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Growth Changes in the Soft Tissue Facial Profile

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Successful evaluation of facial balance and harmony includes a study of the facial profile. The relationships of nose, lips and chin are important considerations. Cephalometric norms for well balanced and attractive faces have been suggested by Riedel^{1,2} and Peck and Peck.³ The selection of their sample could have been biased by facial distractors and/or sexual bias. Czarnecki⁴ constructed an androgynous young adult caucasian profile based on Burstone's⁵ assessment of integument thickness. Cephalometric measurements of the constructed facial profile were well within the range of normal.^{6,7} Assessment of facial profiles by varying the nose, lip and chin relations by dentists, orthodontists, oral surgeons, and pedodontists showed that more lip protrusion was acceptable for both males and females when either a large nose or a large chin was present. However, three times more lip protrusion was allowed with a large chin than was acceptable with a large nose. The most favored female profile exhibited four millimeters more lip protrusion than the most favored male profile. The data also demonstrated that a pleasing facial profile depends on the size of the chin. Profiles with marked facial concavity caused by a large nose and chin or when

the lips are retruded resulted in unfavorable facial esthetics. Czarnecki concluded that a balance between the size of the nose, lips and chin are essential to balanced facial appearance.

The relationship between nose, lips and chin can be altered by both growth and orthodontic treatment. It is imperative, therefore, that the orthodontist have an understanding not only of the changes incident to orthodontic treatment but also of the amount and direction of growth expected in the facial structures. Several authors⁵⁻⁸ have indicated the importance of considering both growth and treatment in predicting post-orthodontic facial changes.

The development of the soft tissue profile is a result of complex changes within the hard and soft tissue structures of the face. Altemus⁹ found great variability in the soft tissue thickness of individual faces. Growth changes in the integument of the face have also been described by Subtelny,¹⁰ Burstone,⁵ Chaconas and Bartroff¹¹ and Bishara et al.¹² The reference planes used in measuring growth changes were themselves subject to change and sometimes the data was cross-sectional or mixed longitudinal.

Abstract

Longitudinal growth changes in the soft tissue profile of 40 caucasians between the ages of 7 and 18 were studied. The sample consisted of 17 males and 23 females who had Class I dentitions and balanced faces at age 7 and 18 years. None of the subjects received any orthodontic treatment. Cephalometric radiographs were available, as a rule, on a yearly basis.

Soft tissue thickness, measured at the nose, upper lip, lower lip and chin, as well as the length of the upper and lower lip, all increased by varying amounts over the period of the study. Females acquired more growth as a percentage of their adult size (at age 18) than males in all variables except the angle of inclination of the skeletal chin which increased more in males. The largest increase in relative size was noted in the nose measurements. In males, the nose had not attained adult size even at age 18. Upper lip length growth, on the other hand, in both males and females was complete by the 15th year. The difference between male and female lip length growth was clinically significant; the average aggregate increase in upper and lower lips combined in males was 6.9 millimeters compared to 2.65 millimeters in females. The total gain in thickness at labrale superius was over four times as much in males as in females and continued to increase in males even at age 18. The change in thickness of the soft tissue at pogonion was not large, an average of 2.4 millimeters in males and 1.5 millimeters in females. The major contribution to the anterior growth of the chin was translatory, contributed largely by growth in the skeletal length from pogonion to pterygomaxillary plane.

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Key Words

Soft tissue profile • Longitudinal growth • Nose • Lips • Chin • Pterygomaxillary vertical plane
• Nasolabial angle • Mentolabial angle

The present investigation on longitudinal data was designed to measure soft tissue growth changes in reference to the pterygomaxillary vertical (PMV) plane drawn from the sphenoethmoid point (Se) to the pterygomaxillary (ptm) point. The sphenoethmoid synchondrosis is a stable landmark after the age of 4 years.^{13,14} Enlow, Kuroda and Lewis¹⁵ suggested that in craniofacial growth studies, the pterygomaxillary vertical plane may be relatively more stable for measurements.

Figure 1
The soft and hard tissue landmarks along with reference planes of the nose, lips and chin.

Materials and methods

Longitudinal lateral head cephalograms of 17 males and 23 females were selected from the records of the Child Research Council, Denver.¹⁶ All of the 40 subjects were caucasian with North European ancestry. The following criteria were used for selection of the sample.

1. No orthodontic treatment performed.
2. Class I or an end-to-end molar relationship with normal overbite and overjet at the ages of 7 or 8 years; Class I molar relationship with normal overbite and overjet at 17 or 18 years of age.
3. A relaxed lip posture with the teeth in occlusion on all of the radiographs.
4. Six or more radiographs per individual distributed fairly even over ages 7 to 18 years. Each radiograph was taken at yearly intervals and was included only if it showed the soft tissue profile in repose without any strain. Case records with large age gaps between the serial radiographs were not included. In every instance the radiographs taken at 7 or 18 years had to be available.

All of the cephalometric radiographs were traced and the landmarks were digitized on a computer. Most of the landmarks were located according to the definition provided by Riolo et al.,¹⁷ Chaconas and Bartroff,¹⁸ and Legan and Burstone.¹⁹ Those not defined previously are given below.

Sphenoethmoidal point (Se): The intersection of the greater wings of the sphenoid with the floor of the anterior cranial fossa.

Pterygomaxillary point (ptm): The inferior and most posterior point on the anterior outline of the pterygomaxillary fissure.

Projected point nasion (n'): The point of intersection of the soft tissue profile by a line drawn perpendicular to the pterygomaxillary vertical plane through nasion.

Pronasale (prn): Point constructed with a line drawn parallel to PMV plane and tangent to the anterior profile of the nose.

Projected pronasale (prn'): The point of intersection of a line drawn parallel to the PMV plane from projected nasion (n') with a line drawn perpendicular to the PMV plane through pronasale (prn).

Columella (cm): The most anterior point on the columella of the nose.

Projected labrale superius (LS'): Point constructed where a line perpendicular to the PMV plane and passing through labrale superius intersects the hard tissue outline.

Projected labrale inferius (Li'): Point constructed where a line perpendicular to the PMV plane passing through labrale inferius intersects the hard tissue outline.

Project A point (A'): Point constructed where a line, perpendicular to PMV plane and passing through skeletal A point intersects the soft tissue outline.

Chin tangent point (Ct): The most anterior superior point on the soft tissue chin.

Projected supramentale point (B'): The point of intersection of the soft tissue profile with a line drawn perpendicular to PMV plane through supramentale (B point).

Projected pogonion' (Pg'): The point of intersection of the posterior border of the symphysis with a line drawn perpendicular to PMV plane through pogonion (Pg).

Soft tissue pogonion (Pgs): The point of intersection of the soft tissue profile of the chin by a line parallel to the PMV plane.

Projected soft tissue pogonion (Pgs'): The point of intersection of the anterior border of the mandibular symphysis with a line drawn perpendicular to the PMV through Pgs.

Location of the reference plane

On the first radiograph, at age 7 years, Se and ptm points were located. The tracing of the second radiograph was then superimposed on that of the first radiograph at the cribriform plate, trabecular pattern of the superior portion of the ethmoid bone as well as the lower portion of the anterior wall of sella turcica. Sphenoethmoidal (se) and pterygomaxillary (ptm) points were transferred from the first to the second radiographic tracing. This procedure was repeated for the third radiograph using the second as a guide. The Se and ptm

points were similarly located on all subsequent radiographs. Measurements made were related to the PMV plane on a parallel or perpendicular basis.

The cephalometric landmarks and the planes used in the study are shown in Figure 1 for the nose, lips and chin sections of the profile, respectively.

Error of method

A total of 54 lateral head radiographs of three male and three female subjects were retraced and redigitized two weeks after the first set of records was obtained. A combined error of tracing radiographs, landmark location and digitization was estimated. The mean measurement errors in excess of 0.5 millimeter or 0.5 degree were considered minimal. Exceptions were for the angle of lower nose inclination, nasolabial and mentolabial angles. The error in measurement of lower nose inclination ranged from 0.62 to 2.9 degrees and the error in measurement of nasolabial and mentolabial angles ranged from ± 2.9 to -4.3 degrees and -2.8 to 3.4 degrees, respectively. However, the mean measurement error did not exceed three percent of the mean values for these variables.

Statistical analysis of the data

All statistical analyses were conducted separately for males and females. To fill in the missing data where consecutive year radiographs were unavailable, a statistical technique described by Snedecor and Cochran¹⁹ was applied. The following statistical values of the sample were obtained:

- Means, medians, standard deviations and Q1 and Q3 ranges (25th and 75th percentile).
- Assessment of growth for all sagittal and vertical linear measurements were expressed as a proportion of their final size (100 percent) at age 18 years. The final size of the variable in this context refers to the value of the variable at 18 years and does not imply the eventual size of the dimension at the completion of growth.

Results

Nose height

At 7 years the median size of the upper nose height ($n'prn'$) was nearly the same in both sexes (Figure 2A). Both sexes showed a rapid increase between seven and eight years. The increase slowed down between 8 and 11 years, with prepubertal and pubertal accelerations in growth at 11 years and during 14 to 17 years.

The lower nose height ($prn'ans''$) (Figure 3A and B) increased more in males than the females. The major differential increase in this measurement for the males occurred at age 17. The female lower nose height attained adult size by age 15 as compared to the male group that was growing even at the age of 18. The upper nose to lower nose ratio was approximately 3:1 and remained nearly the same over the entire study period.

Figure 2
Growth changes in upper nose height for male and female subjects aged 7 to 18 years. A, median and Q ranges in millimeters. The median growth curves for males and females were parallel to each other. B shows the proportion of growth completed was 80 percent at 7 years, 90 percent at 11 years and 100 percent at 15 years for both sexes.

Figure 3
Growth changes in lower nose height for male and female subjects age 7 to 18. A, medians and Q ranges in millimeters. B, proportion of growth completed at each age.

Nose depth and sagittal depth of the underlying skeleton

Growth curves for nose depth (prn' to prn) show that from the age of 7 to 16 the median growth curves for males and females run parallel to each other (Figure 4). The size of the nose depth is approximately similar but the curves begin to diverge from age 16 to 18, the male group showing growth acceleration compared to the female group (nearly three millimeters gain from 17 to 18 years).

Sagittal displacement of the skeleton underlying the nose ($PMV-prn'$) was observed from 7 to 16 years in males and from 7 to 15 years in females (Figure 5). At 7 years, 85 percent of the proportionate growth in males and 90 percent in females had been completed. The male group showed a proportionately larger increase

particularly at puberty. Comparing Figures 4 and 5 for the sagittal depth of soft tissue nose and its underlying skeleton indicated that the sagittal growth of soft tissue nose was independent of the underlying skeleton, the former continuing to grow in the males even at the age of 18 years.

At 7 years the ratio of nose depth (prn-prn) to sagittal depth of the underlying skeleton (PVM-prn) was 1:2 in both sexes. By 18 years, this ratio had changed to 1:1.5 in males and 1:1.6 in females.

Inclination of the nose

The angle of the dorsum of the nose to the PMV plane is dependent on the sagittal growth of the nose. Figure 6 shows that the angle PMV-n-prn increase slightly with age in both sexes. Between ages 8 to 16, the size of this angle was nearly similar in both sexes. However, at 18 the male group showed an approximate 4.5 degree

increase. Since the nose depth in males showed continued growth, this angle would be even larger for the adult males.

Growth changes in the inclination of the base of the nose, angle PMV-ans-prn, were rather small. There was an average increase of five degrees in the female and an even smaller increase in the male sample (Figure 7) indicating that the inclination of the nasal base in the nasolabial angle changes little if any after seven years.

Upper lip height

The mean measurements from soft tissue subnasale (Sn) and upper lip stomion from ages 7 to 18 years increased from 19.8 millimeters to 22.5 millimeters in males and 19.1 millimeters to 20.2 millimeters in the females. The average increment was 2.7 millimeters and 1.15 millimeters in this measurement (Figure 8). A large part of this increment occurred between 9 and 13 years for females and 9 and 15 years for males and the percentage incremental changes after 11 years were similar in both sexes.

Figure 4
Growth changes in the nose depth for male and female subjects age 7 to 18. A, medians and Q ranges in millimeters. Whereas the female group had achieved its adult size at age 16 years, the male group indicated continued growth. B, proportion of growth completed at each age.

Figure 5
Growth changes in sagittal depth of skeletal base underlying the nose for male and female subjects age 7 to 18. A, medians and Q ranges in millimeters. B, proportion of growth completed at each age.

Figure 6
Growth changes in upper nose inclination for male and female subjects age 7 to 18. The graph shows median and Q ranges in degrees.

Figure 7
Growth changes in lower nose inclination for male and female subjects age 7 to 18. The graph shows median and Q ranges in degrees. The relatively larger change in the females would reflect a large nasolabial angle in the adult female.

Lower lip height

Lower lip height was measured from lower lip stomion to the soft tissue B' point. The lower lip in the males increased 4.2 millimeters but only 1.5 millimeters in females. Standard deviations within the samples were small. The major increase in lower lip length in the male group occurred between 10-11 years and 13-18 years. The females, however, experienced major growth increment from 11-13 years (Figure 9). The predictive quadratic regression equation showed $R^2=0.72$, which was interpreted to suggest that a reasonable prediction of adult lip size can be made even at age 7. This can assist in treatment planning because estimated growth changes can project the most esthetic and functional vertical and sagittal position of the incisors.

Thickness of the lips

Along with the lip length, the thickness of the lips adds another dimension to the study of lip growth. The variability in thickness of the upper and lower lips can

Figure 8
Growth changes in upper lip height for male and female subjects age 7 to 18. A, medians and Q ranges in millimeters. B, proportion of growth completed at each age.

Figure 9
Growth changes in lower lip height for male and female subjects age 7 to 18. Left graph shows medians and Q ranges in millimeters. Right graph shows proportion of growth completed at each age.

affect the degree of facial convexity. Due to the variability of lip thicknesses at various points along the facial profile, upper and lower lip thicknesses were determined at four points.

1. Upper lip thickness at point A (A-A') (Figure 10):

There was an average increase of 4.7 millimeters in males and 3.5 millimeters in females, i.e. from 12.5 millimeters at 7 years to 17.2 millimeters at 18 years and from 11.4 millimeters at 7 years to 14.9 millimeters at 18 years, respectively.

2. Upper thickness at labrale superius (Ls to Ls'):
The mean thickness of the upper lip at labrale superius increased from 13.9 millimeters to 17.1 millimeters in the males and 11.8 millimeters to 12.5 millimeters in the females from 7 to 18 years. The increase in thickness for the males was relatively much larger than the increase in females (3.2 millimeters

Figure 10
Growth changes in upper lip thickness at A point for male and female subjects age 7 to 18. A, medians and Q ranges in millimeters. Females as a group, attained their adult size by 13 years in contrast to the male sample that indicated continued growth even at 18. B, proportion of growth completed at each age.

Figure 11
Growth changes in upper lip thickness at labrale superius for male and female subjects age 7 to 18. A, medians and Q ranges in millimeters. B, proportion of growth completed at each age.

to 0.7 millimeter). From the growth of this dimension in the males, it appeared that the thickness was still increasing at age 18 years as compared to the female growth curves that had levelled off at 14 years (Figure 11).

3. Lower lip thickness at labrale inferius (Li-Li'): The mean thickness of the lower lip at labrale inferius at 7 years was 13.3 millimeters in males and 11.4 millimeters in females. This increased by 2.4 millimeters and 1.4 millimeters in the two sexes, respectively. Females, as a rule, displayed thinner lips at labrale inferius than males and reached a peak in thickness at 13 years as compared to 18 years for males (Figure 12).
4. Lower lip thickness at B point (B-B'): The mean increase in thickness at B point was 2.8 millimeters in males and 1.6 millimeters in females. Males had thicker lips at B point than females. This became more pronounced after the age of 14 (Figure 13).

Figure 12
Growth changes in lower lip thickness at labrale inferius for male and female subjects age 7 to 18. A, medians and Q ranges in millimeters. B, proportion of growth completed at each age.

Figure 13
Growth changes in soft tissue thickness at B point. Left graph shows medians and Q ranges in millimeters. Right graph shows proportion of growth completed at each age.

Sagittal depth of the mandible at B (B to PMV)

The skeletal measurement at 7 years for both the male and female samples was the same, however, due to larger growth increments in the males during the pubertal spurt, the size at 18 years was 59.2 millimeters for males and 53.6 millimeters for females. Females achieved their final size at 15 years whereas males continued to grow until 18 years (Figure 14).

The relative size of the skeletal depth at B point and the thickness of the soft tissue integument (B-B') was 82 percent to 18 percent in males and 84 percent to 16 percent in females throughout the age period studied.

Growth at the chin

The soft tissue thickness at the chin was measured along two points: Pgs, the soft tissue pogonion and Pg', a point at the level of skeletal pogonion (Pg).

The soft tissue thickness at the level of the soft tissue pogonion showed a total increase of 2.7 millimeters in males and 2.0 millimeters in females.

Sagittal measurements along the pogonion line

The perpendicular line drawn to PMV through pogonion (Pg) touches the soft tissue profile at Pg' and the posterior border of the symphysis at point pg''). Three linear measurements were made: soft tissue thickness at pogonion (pg to pg'); thickness of the symphysis (pg-pg''); and skeletal length of the mandibular corpus from posterior border of the symphysis (pg'') to the PMV plane (Figures 15, 16 and 17). The latter measurement reflects the amount of anterior displacement of pogonion.

In both sexes all three distances increased continuously, males showing larger increments than females. Over the period studied, the total growth increments for Pg'' to PMV, Pg to pg' and pg to pg'' were 16.1 millimeters, 2.4 millimeters and 1.5 millimeters for the male group and 11.7 millimeters, 1.5 millimeters and 0.8 millimeter for the female group, respectively. The largest increments recorded were for displacement of the symphysis in the

Figure 14
Growth changes in sagittal depth of mandible at B point for male and female subjects age 7 to 18. Left graph shows medians and Q ranges in millimeters. Right graph shows proportion of growth completed at each age.

sagittal direction and the smallest for thickness of the mandibular symphysis.

The corpus measurement from the posterior border of the symphysis (Pg'') to the PMV plane (Figure 17) showed a steady increase between 7 and 18 years. The size for both sexes was approximately similar at 7 years,

Figure 15

Growth changes in soft tissue thickness at Pg for male and female subjects age 7 to 18. Left graph shows medians and Q ranges in millimeters. Right graph shows proportion of growth completed at each age. The thickness of the soft tissue chin at pogonion decreased about one millimeter in both sexes between 7 and 9 years, but thereafter showed increase. Pubertal growth in females occurred between 10 and 13, and in males between 12 and 15. In contrast to females who achieved the adult size of the thickness at 15 years, the male group growth curve indicated continued growth even at age 18 years.

Figure 16

Growth changes in symphyseal thickness underlying Pg for male and female subjects age 7 to 18. Left graph shows medians and Q ranges in millimeters. Right graph shows proportion of growth completed at each age. Only small changes are noticed on the thickness of the symphysis in the female. For the male group a two millimeter increase in thickness was recorded between 14 and 17. These changes are largely due to surface remodelling.

and the curves progressed parallel to each other until 15 years when the male sample had larger increments than the female sample. The relative sizes of these three dimensions expressed as percentage of the total length from PMV to Pg' at ages 7 and 18 years are given in Table 1.

The figures show that the corpus length of the mandible Pg'' to PMV plane experienced larger proportionate increase than Pg to Pg'' and Pg to Pg''.

Inclination of the hard tissue chin (Pg-B-PMV) and soft tissue chin (Pgs-B'-PMV)

Both of the angles show considerable amount of variation at all age periods (Figures 18 and 19). The central trend indicates that these angles increased by approximately seven degrees over the period of this study, which indicates that the slope to the chin became more oblique. Although the inclination of the hard tissue chin was greater in males than females, the soft tissue chin inclination was approximately the same in both sexes.

Measurements of the lips to the esthetic plane

An evaluation of the upper lip relative to the esthetic plane (Ls-E) indicated a gradual retrusion of the lip relative to this plane in both sexes (Figure 20). In males, the means were -0.8 millimeter at 7 years and -4.2 millimeters at 18 years. In the females, the means were -0.9 millimeter at 7 years and -5.4 millimeters at 18 years.

Figure 17

Growth changes in sagittal depth of mandible underlying Pg for male and female subjects age 7 to 18. Left graph shows medians and Q ranges in millimeters. Right graph shows proportion of growth completed at each age.

Table 1

Percentage growth changes in the three component measurements constituting the sagittal length of the mandible from PMV to Pg'

Sex	Age	Pg-Pg'	Pg-Pg''	Pg''-PTV
Male	7 years	18%	24%	58%
	18 years	17%	20%	63%
Female	7 years	18%	22%	60%
	18 years	16%	21%	63%

Figure 18
Growth changes in inclination of hard tissue chin for male and female subjects age 7 to 18. The graph shows median and Q ranges in degrees. The Q ranges are large for this measurement.

Figure 19
Growth changes in inclination of soft tissue chin for male and female subjects age 7 to 18. The graph shows median and Q ranges in degrees. The Q ranges are large for this measurement.

The amount of retrusion of upper lip in both sexes was nearly the same.

The lower lip to esthetic plane (Li-E) measurement in the males was -0.4 millimeter at 7 years and -2.7 millimeters at 18 years, whereas in the females it was -0.6 millimeter at 7 years and -2.5 millimeters at 18 years (Figure 21).

The means for upper and lower lip to the esthetic plane values suggest an increasing retrusion of the lips relative to the nose and chin with age. These changes can be accounted for by the increase in nasal depth and height accompanied by anterior growth displacement of the chin. It is reasonable to assume that the mean values of this variable at age 18, as indicated in this study, should not be considered final. It is apparent from this work that growth of mandible, nose and chin was not completed by age 18 years especially in the male group. Any additional anterior movement of the nose and chin is

Figure 20
Growth changes in the upper lip to esthetic plane for male and female subjects age 7 to 18. The graph shows median and Q ranges in millimeters.

Figure 21
Growth changes in the lower lip to esthetic plane for male and female subjects age 7 to 18. The graph shows median and Q ranges in millimeters.

likely to increase the linear measurements from the lips to the E-plane.

Nasolabial angle (Cm-Sn-Ls)

The nasolabial angle decreased slightly from 7 to 18 years in both sexes (Figure 22). The means at 7 years were 107.8 ± 9.4 degrees for males and 114.7 ± 9.5 degrees for the females. At 18 years the means were slightly reduced to 105.8 ± 9.0 and 110.7 ± 10.9 degrees. The growth changes in this measurement are small in view of the large Q ranges.

Mentolabial angle (Li-B-Ct)

The mean in the males at 7 years was 125.3 ± 8.4 and 18 years 125.1 ± 12.9 degrees. In the females, it was 136.1 ± 11.6 at 7 years and 127.1 ± 12.9 degrees at 18 years.

The Q ranges of these angles highlight the variability (Figure 23). Much of the variability could also be due to the measurement error inherent in the angular measurements of soft tissue structures. The slightest change in the posture of the lips can cause large variations. The amount of decrease in these angles is not significant in view of the large standard deviation. It will suffice to note that the growth changes noted are small over the period of this study.

The position of the lips is largely dependent upon the incisor inclination. Uprighting the maxillary and mandibular incisors enlarges the nasolabial and mentolabial angles. The inclination of the columella (Cm) and tip of the nose can profoundly affect the nasolabial angle.

Discussion

A predictable change in facial esthetics can only be achieved if the predetermined treatment objectives are adequately realized and if the amount and direction of expected growth can be estimated. Several investigators have noted that predictability of facial changes following growth and orthodontic treatment based on dentofacial evaluation is negated by extreme variability in soft tissue dimensions.^{5,10,20,21,22,23} It is imperative that clinical

Figure 22
Growth changes in naso-labial angle for male and female subjects age 7 to 18. The graph shows median and Q ranges in degrees.

Figure 23
Growth changes in mentolabial angle for male and female subjects age 7 to 18. The graph shows median and Q ranges in degrees.

cephalometric analyses include a consideration of soft tissue measurements.

The relationships and proportions of the nose, lips and chin determine the balance and harmony of the face. Czarnecki⁴ found that a larger lip protrusion is acceptable with a large nose and/or chin. Adequate information on the growth changes of these structures will assist in diagnosis and treatment planning.

Selection of the sample

For inclusion in this investigation, longitudinal cephalometric radiographs were carefully selected from the files of the Child Research Council, Denver. Selection of the sample was based on completeness and quality of the records with minimum number of missing radiographs or radiographs with strained posture of the soft tissues. The subjects included in this study had normal overjet, Class I molar relationship at 18 years and a fairly normal facial profile. The rigid criteria used for selection of the sample excluded many subjects that might otherwise have been included. Due to the selection criteria, the sample is small; for longitudinal studies of this type, it was deemed to be sufficient.

Reference planes

Several investigators used palatal plane to orient vertical and sagittal measurements of the soft tissues.^{5,10,22,24,25} Although the palatal plane has been shown to be fairly stable, its angulation with anterior cranial base may vary,²⁶ the position of the plane may be altered by orthodontic treatment,^{8,27,28} and its orientation to the neutral head position may also change.

Chaconas and Bartroff¹¹ made soft tissue profile measurements from a line joining glabella and soft tissue pogonion. Burstone,²² Legan and Burstone,¹⁸ and Park and Burstone,²¹ recommended the use of a line joining subnasale to soft tissue pogonion to measure lip protrusions.

To provide a stable, reproducible reference plane to study the changes in the soft tissue profile, the pterygomaxillary vertical plane (PMV) was used. Both the pterygomaxillary (ptm) and sphenoethmoidal (Se) points are regarded to be relatively stable during growth.^{13,14} Enlow et al.¹⁵ noted that the pterygomaxillary vertical plane is approximately perpendicular to the line of vision and is consistent with anatomically neutral position of the head.

Large fluctuations in the size of soft tissue measurements are to be anticipated. Any change in posture and movement in the facial musculature can affect the length and thickness of tissues particularly at the lips and chin. The findings, however, provide consistency even with a fairly large variance at each age. Orientation of the measurements, either along a vertical plane parallel to the PMV plane or along a plane perpendicular to PMV plane provide stability.

Growth changes in the facial profile

Vertical dimension of the nose increased until 18 years

of age. Whereas about 80 percent of the upper nose height had been completed for both sexes at age 7 and only a small sex difference in its ultimate size was noticed, the lower nose height at age 7 was 90 percent complete for the female group as opposed to 67 percent for the male group. The males showed larger increments in growth of the lower nose height at 17 years. It was apparent from the data that the upper nose height increased three times more than the lower nose height, thereby maintaining a ratio of upper nose height to lower nose height of 3:1.

Nose depth (prn'prn) was 70 percent completed at 7 years in the females and 63 percent in the males. Similar to nose height, nose depth also showed significant increase at age 17 in males.

The soft tissue height and depth of the nose appears to be still growing at 18 years in males. However, the skeletal base to the nose measurement from prn' to the PMV completed its growth by 17 years in both the males and females.

Lip length and thickness are important elements of the facial profile. Lip position is affected by the placement and inclination of the maxillary and mandibular incisors and hence is responsive to orthodontic treatment. It was significant to note that average increase in upper and lower lip length in males was more than two times that of females. Figure 24 gives the total increments in the size of various measurements in millimeters from age 7 to 18 years. It is also important to note that, whereas aggregate increase in upper and lower lip lengths in the males is 6.9 millimeters, in the females it is only 2.65 millimeters. It is obvious from the small growth changes in the female upper and lower lip lengths that a protruding dentition at 7 years will not change much relative to the lips during growth. The treatment of choice, if so indicated, may require extraction of first premolars. However, with growth in the lip lengths of the males, some accommodations are possible.

Small changes in the upper lip length and the prediction equations suggesting a linear relationship indicate a probability that those with a short upper lip at 7 years will continue to have a short upper lip even at age 18 years. The impact of this finding on treatment planning is significant because the excessive display of upper

Figure 24
The total increments of the size of various measurements in millimeters for male and female subjects age 7 to 18.

Table 2
Attainment of adult size for the various soft tissue variables
and three skeletal base measurements.

Variable	% growth completed at 7 years		Growth ending at or before 15 years		Growth completed past 15 and before 18 years		Growth continuing at 18 years	
	Male	Female	Male	Female	Male	Female	Male	Female
Upper nose height	80	82			X	X		
Lower nose height	67	90		X			X	
Nose depth	63	70		X			X	
Nose skeletal base at prn'-PMV	85	90			X	X		
Upper nose inclination	87	90		X			X	
Lower nose inclination	92	89		X	X			
Upper lip length	88	95	X	X				
Lower lip length	78	91				X	X	
Upper lip thickness at A	73	76		X			X	
Upper lip thickness at LS	82	93		X			X	
Lower lip thickness at LI	85	89		X	X			
Lower lip thickness at B	80	85		X	X			
Sagittal length of mandible at B	75	84		X			X	
Chin thickness at Pgs	80	83			X	X		
Chin thickness at Pg	83	88				X	X	
Symphyseal thickness	92	95		X	X			
Skeletal base at Pg"-PMV	66	74		X			X	
Inclination of skeletal chin	44	27		X	X			
Inclination of chin integument	72	66					X	X

gingiva, if present, should be corrected early to establish a more favorable tooth/lip relationship.

Lip thickness at points A and B increased more than at the vermilion borders. The increase in lower lip thickness at vermilion border was very small for the females. These changes lead to thicker, longer lips for the males. The males' lips increased approximately seven millimeters in length and therefore accommodate more protrusion of incisors than the female lips.

The esthetic plane E drawn tangent to the tip of the nose and chin, when measured against the upper and lower lips gives the esthetic position of the lips. When the

lips were posterior to the E plane the distances were expressed with a negative sign and when in an anterior position, with a positive sign. In this study, the average upper lip to the E plane distance increased 3.4 millimeters in males and 5.4 millimeters in females and the lower lip to the E plane 2.7 millimeters in males and 1.9 millimeters in females. All these increases were in the negative direction. Longitudinal observations of Bishara et al.¹² correspond closely to the findings of this study. The lower lip to the esthetic plane in females showed a fairly strong predictability for adult size ($R^2=0.67$) and only a marginal predictability in males ($R^2\pm 0.49$). The level

of predictability for the upper lip in the males was also good ($R^2 \pm 0.62$); for females it was non-predictive ($R^2 \pm 0.35$). Bishara et al.,¹² however, obtained more significant predictive equations in both males and females.

The esthetic plane relationship to the lips is exceedingly complex; the E plane judges only the resultant growth in the regions of nose, lips and chin. This growth is not just that of the soft tissue drape but also the translation forward of the entire facial profile due to growth in the facial skeleton. The forward growth of the facial skeleton also varies, with more growth occurring in the mandibular region than in the maxillary region. The differential growth changes in the soft and hard tissue determine the final form of the face and hence the relationship of the facial features.

Most of the soft tissue growth changes at the nose, lips and chin suggest sexual dimorphism. Males had greater increase over a larger time span than females (Figure 24). Table 2 summarizes the observation on all the measurements in terms of percentage of growth completed at 7 years and the attainment of adult size. Most of the measurements in females had attained their adult size at 15 years, whereas, in males several measurements appeared to be on the increase even at 18. The period of study covered only 7 to 18 years, and therefore, could not predict the adult size of several of the male soft tissue measurements.

Mamandras,²⁷ also reported that pubertal growth spurts in females occurred two years earlier than males. In the present study, it was found that fewer female measurements had childhood growth spurts. Males demonstrated prepubertal, circumpubertal, and post pubertal growth spurts for five of the six soft tissue dimensions.

A graphic evaluation of the percentage of growth completed at each age relative to the size of the variable at 18 years also demonstrated differences in proportionate development of the various facial dimensions between the males and females.

Sex differences in size of the soft tissue measurements, suggest that the age at which orthodontic treatment is commenced will be important, especially in patients requiring orthognathic surgery in conjunction with orthodontic treatment.

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