Longitudinal study of cephalometric soft tissue profile traits between the ages of 6 and 18 years

Robert T. Bergman; John Waschak; Ali Borzabadi-Farahani; Neal C. Murphy

ABSTRACT

Objective: To study the longitudinal changes in 19 soft tissue cephalometric traits (according to the Bergman cephalometric soft tissue facial analysis).

Materials and Methods: Cephalograms and photographs of 40 subjects (20 male, 20 female, from the Burlington Growth Centre) that were obtained at ages 6, 9, 12, 14, 16, and 18 years were used. Subjects were orthodontically untreated whites and had Class I dentoskeletal relationships (ideal overjet and overbite). Images were obtained with the lips in a relaxed position or lightly touching.

Results: Three groups of soft tissue traits were identified: (1) traits that increased in size with growth (nasal projection, lower face height, chin projection, chin-throat length, upper and lower lip thickness, upper lip length, and lower lip–chin length); (2) traits that decreased in size with growth (interlabial gap and mandibular sulcus contour [only in females]); and (3) traits that remained relatively constant during growth (facial profile angle, nasolabial angle, lower face percentage, chin-throat/lower face height percentage, lower face–throat angle, upper incisor exposure, maxillary sulcus contour, and upper and lower lip protrusion).

Conclusion: Current findings identify areas of growth and change in individuals with Class I skeletal and dental relationships with ideal overjet and overbite and should be considered during treatment planning of orthodontic and orthognathic patients. (Angle Orthod. 2014;84:48–55.)

KEY WORDS: Cephalometry; Facial growth; Soft tissue profile

INTRODUCTION

The position and character of the teeth can have a significant effect on a patient’s facial appearance, a fact that was highlighted as early as 1834.4 Within this context, lines, angles, and measurements are used on cephalometric tracings for diagnosis and treatment planning; the soft tissue profile can then be used to determine the treatment needed to maintain or enhance facial esthetics. For instance, lip posture is intimately associated with the orthodontic objectives of esthetics, stability, and function.

Cephalograms are beneficial in quantifying skeletal and dental features, but extrapolation of skeletal relationships to soft tissue form can be challenging. Soft tissue features can vary significantly from the dentoskeletal structure depending on individual variation or radiographic technique,5 eg, the lips need to be in repose with the teeth in maximum intercuspation. Measuring the soft tissue profile establishes the ideal size and proportions of the nose and positions of the lips and chin, helping to quantify individual facial characteristics and norms. When measurements of facial features are outside the norm, there is often a decrease in facial attractiveness. Disproportionate soft tissue facial features, which are often obvious to patients and parents during orthodontic or cosmetic surgery consultation, should be identified and improved with orthodontic treatment or cosmetic surgery.6

Arnett and Bergman identified 19 soft tissue facial traits in profiles of white male and female patients.4–5
Facial esthetics were significantly improved by normalizing soft tissue traits. Subsequently, based on the two published papers4,5 two cephalometric analysis have been introduced by Arnett et al.6 and Bergman.7 The norms for those 19 soft tissue traits have been extrapolated for a few populations,3,8–10 but there is no information on the longitudinal changes of these traits, information that is critical to successful treatment. The present study used the Bergman Soft tissue analysis to assess soft tissue changes that occurred over time in a sample of white males and females. This study calculated average values for 19 traits of a standardized sample population and demonstrated the longitudinal changes that occurred in these values throughout growth.

**MATERIALS AND METHODS**

The cephalograms of 40 subjects (20 males and 20 females) were selected from the longitudinal growth.
data available at the Burlington Growth Centre using the following criteria: white, orthodontically untreated, Class I skeletal and dental relationships with ideal overjet and overbite, lips in relaxed position or lightly touching with no indication of mentalis strain, and plainly visible soft tissue profile. Sample radiographs were collected at ages 6, 9, 12, 14, 16, and 18 years. These ages were chosen because they had the most complete records. The soft tissue traits were measured as angles, linear dimensions, and proportions (percentages) from soft tissue landmarks along the facial profile and two points measuring upper and lower lip thickness. Tables 1 and 2 summarize the cephalometric landmarks and measurements used for the study.

The radiographs and photographs (Figures 1 through 3) were scanned; they were then digitized using Dolphin Imaging Software (Chatsworth, Calif), and the cephalometric data were superimposed on soft tissue facial photographs taken in a standardized procedure with the patient stabilized in a cephalostat. Tables 1 and 2 and Figures 4 and 5 summarize the cephalometric landmarks and measurements used for the study. All measurements were calibrated within the software program to correct for radiographic magnification (9.5%).

Statistical Analysis
The soft tissue traits were arranged into three groups: facial outline, upper lip positions, and lower lip positions. Means and standard deviations (SDs) for soft tissue traits were calculated. After the distribution of the data was assessed, appropriate statistical tests (ie, independent t-test) were used to detect any significant changes between the ages of 6 and 18 years in male and female subjects. Significance was set at $P < .05$.

RESULTS

Facial Outline
Facial outline measurements are summarized in Table 3.

Facial profile angle ($G'\cdot Sn-Pg'$). In males, a transition occurred; the angle decreased from $169^\circ$ to a minimum of $167^\circ$ at 14 years, and then it increased again to $169^\circ$ at 18 years. A similar transition occurred in females: this angle is a mean of $168^\circ$ at 6 years, decreases to $165^\circ$ at 12 years, and increases back to $168^\circ$ by 18 years. Overall, the trait remained constant ($P > .05$).

Nasal projection ($Sn-NT$). This measurement increased with age ($P < .05$). In males, the means were 10 mm at 6 years and 15 mm at 18 years, representing a mean increase of 5 mm. In females, the mean values were 10 mm at 6 years and 14 mm at 18 years.

Lower face height ($Sn-Me'$). In males at 6 years of age, lower face height averaged 62 mm. At 18 years of age, this increased by 12 mm to 74 mm. In females, the mean was 58 mm at 6 years and 69 mm at 18 years, an increase of 11 mm. This trait increased with age by an average of 11–12 mm ($P < .05$).

Lower face percentage ($Sn-Me' / G'-Me'$). In males, the average value was 56% at age 6, decreased to 55% at 12, and remained nearly constant thereafter. In females, the mean value was 55% at age 6 and decreased to 54% by age 18. However, the changes...
between the age of 6 and 18 were not significant and the mean remained at approximately 55% \( (P > .05). \)

Chin projection \( (B'-SnPg) \). In both genders, this distance increased, from 1.5 mm at age 6 to 3 mm at age 18, for a total mean increase of 1.5 mm \( (P < .05). \)

Lower face–throat angle. In males, the angle was 99° at age 6 and slowly increased to 103° by age 18. In females at age 6, the angle was a mean of 100°; it then increased to 103° by age 14 and decreased back to 100° by age 18. Overall, the changes were not significant \( (P > .05). \)

Chin-throat length \( (CP-Gn) \). This value increased in both sexes during the period observed \( (P < .05). \) In males, the mean at age 6 was 49 mm and increased to 56 mm by age 18. In females, this value was 47 mm at age 6, increased to 54 mm by age 12, and then followed a less dramatic rate of change, to 56 mm at age 18.

Chin-throat/lower face height %. The changes were not significant \( (P > .05). \) Males had a mean of 76% at age 6, which increased to 81% by age 14 and then returned to 75% by age 18. Females demonstrated a similar transition, but to a lesser degree: they started at a mean of 78% at age 6, increased to 82% by age 12, and then returned to 81% at age 18.

The Upper Lip

Upper lip measurements are summarized in Table 4.

Nasolabial angle \( (Col-Sn-ULA) \). This trait remained relatively constant \( (P > .05), \) decreasing only slightly between 6 and 18 years of age in females and remaining nearly constant in males. In males, the average at 6 years was 107° and at 18 years it was 108°. In females, the mean at 6 years was 107° and decreased to 102° by 18 years, for a mean decrease of 5°.

Upper lip length \( (Sn-ULI) \) and upper lip thickness \( (ULM-ULA) \). These two variables increased in both sexes \( (P < .05). \) The mean upper lip length increased in males, from 19 mm at age 6 to 23 mm at age 18, for an average increase of 4 mm. In females, the average length at age 6 was 18 mm, and at age 18 it was 21 mm. In males, the mean thickness of the upper lip increased from 11 mm at age 6 to 13 mm at age 18, a mean change of 2 mm. In females, the average thickness at age 6 was 11 mm and increased to 12 mm at 18 years of age, a mean increase of 1 mm.
Maxillary sulcus contour angle (ULA-A'-Sn). Minor variations were noted for this trait ($P > .05$). It began at 153° in males at age 6 and decreased to 151° at age 18. The mean for females at age 6 was 157°, and this decreased to 152° at age 18.

Upper lip protrusion (ULA-SnPg'). This trait showed little variation ($P > .05$). In both sexes, average upper lip protrusion was 4.5 mm at age 6 and had decreased to 4.0 mm by the age of 18.

Upper incisor exposure (StI-U1). In both sexes, this variable remained constant from ages 6 to 18 ($P > .05$). The mean value for males at age 6 was 2.5 mm, and by age 18, it measured 3.0 mm. For females, the average upper incisor exposure was 2.3 mm at age 6 and 3.0 mm by age 18.

The Lower Lip

Lower lip measurements are summarized in Table 5.

Interlabial gap (StS-Stl). A significant decrease was noted in both sexes ($P < .05$). In males, the average values were 4.0 mm at age 6 and 2.0 mm at age 18. In females, the average values were 3.0 mm at age 6 and 2.0 mm at age 18.

Lower lip–chin length (Stl-Me'). This variable showed a significant increase in both sexes ($P < .05$). In males, the lower lip–chin length increased from a mean of 39 mm at age 6 to a mean of 49 mm at age 18, an overall increase of 10 mm. In females, the lower lip–chin length increased from a mean of 37 mm at age 6 to a mean of 46 mm at age 18, an overall increase of 9 mm.

Lower lip thickness (LLM-LLA). This variable increased significantly from 6 to 18 years ($P < .05$). The lower lip thickness in males averaged 10 mm at age 6 and 13 mm by age 18, an increase of 3 mm. In females, the average thickness was 10 mm at age 6 and had increased to 12 mm at age 18, an increase of 2 mm.
Mandibular sulcus contour angle (LLA-B’-Pg’). In males, the mean was 138° at age 6 and decreased to 135° at age 18 (P < .05). In females, the mean was 141° at age 6 and decreased to 134° by age 18 (P < .05).

Lower lip protrusion (LLA-SnPg’). Taken as a whole, the mean value remained constant, at approximately 3.0 mm, from ages 6 to 18, and changes were not significant (P > .05).

DISCUSSION

Soft tissue characteristics have attracted the attention of many scientists and prominent orthodontists. These characteristics can guide tooth placement, occlusal correction, and be assessed objectively as one factor that determines the need for orthodontic treatment, substituting some subjective treatment need assessment methods. Furthermore, they can be a diagnostic feature in some craniofacial anomalies. However, it is important to have an objective standard as a reference. Various facial planes have been recommended as treatment objectives for the soft tissues; however, none works in all cases, because each provides only limited information for esthetic goals. The lateral cephalometric tracing can identify the limits of normal variations or rank the severity of a dentoskeletal malocclusion. Burstone introduced the first useful system of soft tissue cephalometric analysis and stressed its use as an integral part of orthodontic case analysis. His premise was that, as inclinations, contours, and proportions approached the average (norm) esthetic ideal, they became more harmonious and esthetically more appealing, and vice versa. He maintained that variation is possible and that the final evaluation of esthetics depended on the individual observer. Peck and Peck used three concepts to discuss facial attractiveness: (1) facial symmetry and balance, (2) facial harmony, and (3) facial proportions. The frontal view is generally described by the degree of facial symmetry and balance. The state of facial equilibrium describes the size, form, and arrangement of the facial

Table 3. Summary (Means and SDs) of Facial Outline Measurements

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Patient age (y)</th>
<th>Sig. changes (6–18 y)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sex</td>
<td>6</td>
</tr>
<tr>
<td>Face height (%</td>
<td>Male</td>
<td>107 (4)</td>
</tr>
<tr>
<td>(CS-Sn) (%)</td>
<td>Female</td>
<td>107 (9)</td>
</tr>
<tr>
<td>Upper lip projection (Sn-U1) (mm)</td>
<td>Male</td>
<td>19 (1)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>18 (2)</td>
</tr>
<tr>
<td>Lower face height (Sn-P) (mm)</td>
<td>Male</td>
<td>11 (1)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>11 (1)</td>
</tr>
<tr>
<td>Lower lip protrusion (ULA-SnPg') (mm)</td>
<td>Male</td>
<td>4.5 (1)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>4.5 (1)</td>
</tr>
<tr>
<td>Nasolabial angle (G-Sn-Pg') (°)</td>
<td>Male</td>
<td>107 (4)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>108 (4)</td>
</tr>
</tbody>
</table>

Table 4. Summary (Means and SDs) of Upper Lip Cephalometric Measurements

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Age (y)</th>
<th>Sig. changes (6–18 y)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sex</td>
<td>6</td>
</tr>
<tr>
<td>Nasolabial angle (°)</td>
<td>Male</td>
<td>107 (4)</td>
</tr>
<tr>
<td>(Col-Sn-U1A) (°)</td>
<td>Female</td>
<td>107 (9)</td>
</tr>
<tr>
<td>Upper lip length (mm)</td>
<td>Male</td>
<td>19 (1)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>18 (2)</td>
</tr>
<tr>
<td>Upper lip thickness (mm)</td>
<td>Male</td>
<td>11 (1)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>11 (1)</td>
</tr>
<tr>
<td>Maxillary sulcus contour angle (°)</td>
<td>Male</td>
<td>153 (9)</td>
</tr>
<tr>
<td>(ULA-A’-Sn)</td>
<td>Female</td>
<td>157 (6)</td>
</tr>
<tr>
<td>Upper lip protrusion (mm)</td>
<td>Male</td>
<td>4.5 (1)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>4.5 (1)</td>
</tr>
<tr>
<td>Nasolabial angle (°)</td>
<td>Male</td>
<td>107 (4)</td>
</tr>
<tr>
<td>(Col-Sn-Pg') (°)</td>
<td>Female</td>
<td>108 (4)</td>
</tr>
</tbody>
</table>

Angle Orthodontist, Vol 84, No 1, 2014
Features on the opposite side of the median sagittal plane. The term facial harmony is commonly used to express true beauty in orthodontics. Harmony, when referring to human beauty, is the "due observance of proportions." Peck and Peck defined facial harmony as the orderly and pleasing arrangement of the facial parts in profile. The harmonious profile flow is described as a series of waves. Irregularities in the profile flow create attention in that area of the face. Facial proportions are the comparative relationships of the facial elements in the profile.

Today there is greater emphasis on the use of three-dimensional analysis\(^\text{[30]}\), however, two-dimensional profile analysis, using profile photos and lateral cephalograms, is still the most commonly used method of analysis for everyday planning of orthodontic or orthognathic cases. Throughout the orthodontic literature, two terms predominate for describing facial esthetics: facial harmony and facial proportion. The harmony values consist of the facial profile, maxillary and mandibular sulcus contours, interlabial gap, and the lower face–throat angle. Facial proportions are the lower face percentage and chin-throat length/lower face percentage. The linear trait values are measured with reference to the subnasale-pogonion line. These traits are upper and lower lip protrusion, chin projection, and chin-throat length. The values are used to evaluate the size of each facial trait.

The overall pattern of changes was similar to those seen in previous studies.\(^\text{[31–37]}\) Soft tissue variables showed three distinct patterns of change. Some traits increased in size with growth, such as nasal projection, lower face height, chin projection, chin-throat length, upper and lower lip thickness, upper lip length, and lower lip–chin length. Changes in the nose and chin projections as well as lip position and thickness are important, as they can affect facial stability after orthodontic treatment or orthognathic/cosmetic surgery. A trend similar to the data of Hamamci et al.\(^\text{[37]}\) was observed, ie, the average thickness of the soft tissue of the lips in males were greater than in females, but not to a statistically significant extent. There were also variables that decreased in size with growth, such as the interlabial gap and, in females only, the mandibular sulcus contour. The mandibular sulcus contour angle in males showed a tendency to decrease with age, but this was not significant. This could be a result of the relatively small sample size, which may have meant that significant changes went undetected. The third group of measurements remained constant during growth: facial profile angle, nasolabial angle, lower lip contour angle in males showed a tendency to decrease with age, but this was not significant. This could be a result of the relatively small sample size, which may have meant that significant changes went undetected. The third group of measurements remained constant during growth: facial profile angle, nasolabial angle, lower lip contour angle in males showed a tendency to decrease with age, but this was not significant. This could be a result of the relatively small sample size, which may have meant that significant changes went undetected.

### CONCLUSIONS

- Based on this study of subjects with Class I skeletal and dental relationships with ideal overjet and overbite, all soft tissue facial traits could be placed into three general categories depending on whether they increased, decreased, or remained the same between the years of 6 and 18.
- Traits that increased in size over the years were nasal projection, lower face height, chin projection,
Traits that decreased in size with growth were interlabial gap and mandibular sulcus contour (in females only).

Many traits remained constant during growth: facial profile angle, nasolabial angle, lower face percentage, chin-throat/lower face height, lower face–throat angle, upper incisor exposure, maxillary sulcus contour, and protrusion of both the upper and lower lips.

REFERENCES


