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# Roentgen–cephalometric standards for a Swedish population. A longitudinal study between the ages of 5 and 31 years

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SUMMARY This study was performed to establish age- and gender-specific cephalometric normative data for a Swedish population. The material comprised 469 lateral cephalograms from two groups of subjects of Swedish origin between 5 and 31 years of age. All subjects (males and females) were diagnosed as 'normal' according to specified criteria and with no history of orthodontic treatment. Lateral cephalograms and body height measurements were taken at 5, 7, 10 and 13 years of age in one group (group E) (longitudinal follow-up). The same registrations were made in the other group (group U) at 7, 10 and13 years of age (mixed longitudinal type). Those 13 year olds were re-examined at 16, 19 and 31 years of age (longitudinal follow-up). No significant differences between age groups in the two samples were found. Therefore, subjects of the same age were combined. The study is hence regarded as a longitudinal follow-up from 5 to 31 years of age. The subjects were also grouped into dental development stages to widen the applicability of the cephalometric data.

The craniofacial distances were constantly larger in males than in females, while no statistical differences as regards angular measurements were seen between genders. Distances as well as angular measurements varied with the different developmental periods. The results clearly verify that facial pattern changes existed during the observation period, with a growth acceleration of most distances between the 13 and 16 year recordings.

## Introduction

Cephalometric analysis is used for orthodontic diagnosis and treatment planning in children and adolescents. In recent years the demand for orthodontic treatment even in adults has increased. As many of them require dentofacial orthopaedics or orthognathic surgery, cephalometric norms are of value for the optimal treatment alternative in these patients. Many different systems for analysis have been suggested, which can crudely be classified into two groups. Some evaluate the patient with regard to specific standards, which are also used to set the treatment goal, e.g. the analyses described by Tweed (1954), Steiner (1960) and Ricketts (1961). Other analyses are performed with the purpose of understanding the malocclusion, whether it is of dentoalveolar or skeletal origin. These analyses also attempt to explain the complex nature of the interplay between the craniofacial structures, e.g. those described by Björk (1947), Downs (1948), Enlow *et al.* (1971) and McNamara (1984).

It is well known from the literature that ethnic differences in facial traits exist, and that the dentofacial pattern will change during periods of active growth. Awareness of the normal dentofacial pattern of different ethnic groups of various ages will undoubtedly ensure greater success in orthodontic treatment. A large number of studies of cephalometric norms or standards for individuals of varying ethnic groups and ages have been published subsequent to the comprehensive 'Atlas of craniofacial growth' (Riolo *et al.*, 1974) and the classical study 'Bolton standards of dentofacial developmental growth' (Broadbent *et al.*, 1975). Some of these studies are presented in Table 1. Different criteria have been used in the selection of subjects, e.g. 'normal occlusion', 'acceptable occlusion' and 'Angle Class I with no facial deformity'. 'No history of orthodontic treatment' is mentioned in half of the studies. Both males and females have been analysed, usually in ages around puberty, and only a few of the investigations were longitudinal or mixed longitudinal.

In spite of the methodological differences mentioned above, a review of all these studies clearly verifies that great differences not only exist for specific variables among ethnic groups, but also between gender and age. Only a limited number of cephalometric variables have been presented for the Swedish population, and data from the early juvenile and adult periods are lacking. The purpose of the present study was to establish age- and gender-specific normative data for a Swedish population between the ages of 5 and 31 years.

## Material and methods

The material comprised 469 lateral radiographs from two different groups of subjects of Swedish origin (Figure 1).

**Table 1** Examples of studies of cephalometric standards of different ethnic groups.

| Ethnic group | Author(s) | Gender and age | Sample selection |
|---|---|---|---|
| American Caucasian | Bishara (1981) | m, f, 5–12 years | Acceptable occlusion, no deformity |
| | Bishara *et al.* (1994) | m, f, 26–46 years | Acceptable occlusion, no deformity |
| | Franchi *et al.* (1998) | m, f, adults | Ideal occlusion |
| African-American | Alexander and Hitchcock (1978) | m, f, 8–13 years | Class I, acceptable occlusion |
| | Fonseca and Klein (1978) | f, 20–30 years | Class I, acceptable occlusion |
| | Anderson *et al.* (2000) | m, f, 12–16 years | Normal occlusion |
| | Huang *et al.* (1998) | m, f, 6–18 years | Normal occlusion |
| Brazilian | Martins *et al.* (1998) | m, f, 6–18 years | Normal occlusion |
| Mexican | Garcia (1975) | m, f, 14–17 years | Normal occlusion |
| | Bishara and Garcia Fernandez (1985) | m, f, 11–14 years | Acceptable occlusion |
| | Swlerenga *et al.* (1994) | m, f, adults | Normal occlusion |
| Japanese | Uesato *et al.* (1978) | m, f, 11–18 years | Acceptable occlusion |
| | Engel and Spolter (1981) | m, f, 8–16 years | Normal occlusion |
| | Miyajima *et al.* (1996) | m, f, 20–25 years | Normal occlusion |
| Iranian | Davoody and Sassouni (1978) | m, f, 11–14 years | Normal occlusion |
| | Hajighadimi *et al.* (1981) | m, f, 12.5 years | Normal occlusion |
| Israeli | Gleis *et al.* (1989) | m, f, 11–16 years | Normal occlusion |
| | Ben-Bassat *et al.* (1992) | m, f, 11–13 years | Clinically acceptable occlusion |
| Egyptian | Bishara *et al.* (1990) | m, f, 12.5 years | Acceptable occlusion |
| Greek | Argyropoulos and Sassouni (1989) | m, f,12 years | Acceptable occlusion |
| English | Bhatia and Leighton (1993) | m, f, 5–17 years | Angle Class I, no deformity |
| Celtic | Kerr and Ford (1986) | m, f, 10–15 years | Acceptable occlusion |
| Finnish | Haaviko and Rahkamo (1989) | m, 7–18 years | Acceptable occlusion |
| Norwegian | El-Batouti *et al.* (1994) | m, f, 6–18 years | Acceptable occlusion, no deformity |
| Swedish | Thilander *et al.* (1982) | m, f, 7–16 years | 'Ideal', no deformity |

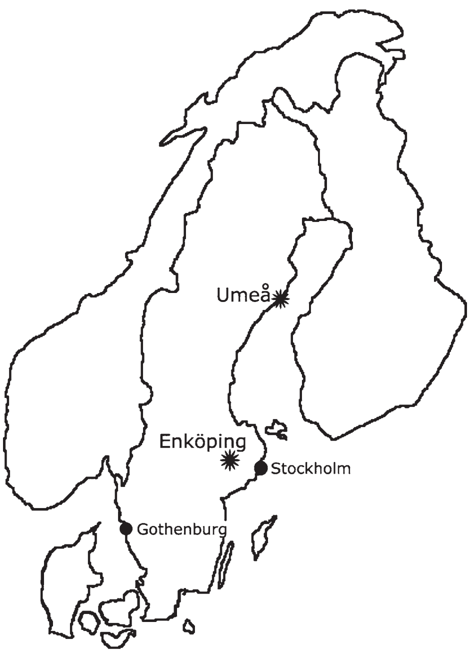


**Figure 1** Map showing the origins (asterisks) of the two samples, groups U and E.

The first group (group U) originated from Umeå (a university city in the northern part of Sweden), the other group (group E) from Enköping (an industrial town in the middle of the country).

### Samples

#### Group U.

All schoolchildren in the first, fourth and sixth grades, equivalent to 7, 10 and 13 years of age, were examined at the orthodontic department of the dental school in 1965, a total of 1559 children (791 males and 768 females). Of those children, 122 (7.8 per cent) (55 males and 67 females) were diagnosed as 'normal' according to the following criteria: Angle Class I molar/canine relationship, normal transverse occlusion, overjet and overbite 1–3 mm, dental arches without congenitally missing teeth or crowding, a 'straight' profile without any obvious asymmetry, and no history of orthodontic treatment (R1 in Table 2).

Photographs, study casts, lateral radiographs and body height measurements were taken of all 122 children, and repeated at re-examination 3 years later, i.e. at 10, 13 and 16 years of age (R2 in Table 2). The dropout of 12 children was due to moving from the city or refusal to be exposed to any further cephalometric radiation. The age at re-examination (R2) thus corresponded to the age at first examination (R1) for the subsequent age group. A Student's *t*-test, performed for 25 cephalometric variables, showed no differences between R1 and R2 for the 10- or 13-year-old children. Thus, these children were combined in the same age group.

From the 55 adolescents (16 years of age), 33 could be examined again at 19 years of age, and 30 at 31 years of age

**Table 2** Number of 'normal' children (7–16 years of age in group U) at the first (R1) and second registration (R2).

| Age (years) | Males | Total | Females | Total |
|---|---|---|---|---|
| 7 | 17 (R1) | 17 | 19 (R1) | 19 |
| 10 | 12 (R2)/11 (R1) | 23 | 12 (R2)/17 (R1) | 29 |
| 13 | 6 (R2)/27 (R1) | 33 | 11 (R2)/31 (R1) | 42 |
| 16 | 25 (R2) | 25 | 30 (R2) | 30 |

(Table 3). Dropout was due to temporary or permanent absence from the city at the time of the actual examination.

The period between 7 and 13 years of age is thus a mixed longitudinal study, while from 13 to 31 years of age it is a longitudinal follow-up (Figure 2).

### Group E.

From 898 children, 4–5 years of age, who came to the compulsory dental health control in Enköping during the period 1966–1968, 94 (10.5 per cent) were diagnosed as normal according to the criteria given for group U. These children were re-examined at 7, 10 and 13 years of age and registered with photographs, study casts, body height measurement and lateral cephalograms at each examination.

At the final examination, 47 children (20 males and 27 females) fulfilled the criteria for 'normality' described for the children in group U, i.e. 5.2 per cent of the original sample. Cephalograms from the age periods 5, 7, 10 and 13 years in these children represent a longitudinal study of normals from 5 to 13 years of age (Figure 2).

### Comparison between groups U and E.

A Student's *t*-test for 25 different cephalometric parameters in the age groups 7, 10 and 13 years showed no significant differences between the two groups. For that reason, subjects of the same age were combined (Table 3).

### Dental stages.

To widen the applicability of the cephalometric data, the subjects were also grouped into dental developmental periods (Table 4), based on dental stages according to the variation in tooth eruption described by Björk *et al.* (1964): primary teeth fully erupted (DS02); incisors erupting (DS1) and fully erupted (DS2); canines and premolars erupting (DS3) and fully erupted (DS4); first molars not fully erupted (DSM0) and fully erupted (DSM1); second molars fully erupted (DSM2); third molar(s) erupted (DSM3).

The 5-year-old children showed DS02 except for four children, in whom the tip of a cusp of one of the first permanent molars or the edge of one lower central incisor had just become visible, and hence characterized more as 'primary' than 'early mixed' dentition. Every 7-year-old child showed some combination, classified as 'early mixed dentition'. The 10-year-old children were registered with some of the combinations of dental stages given under 'late mixed dentition'. Among the 13-year-old children, DS4M2 was mostly found, except for a few, mostly males, with DS3M2 or DS4M1, here classified as 'early permanent dentition'. From the age of 16 years all subjects showed DS4M2, here referred to as 'adolescents' (16 years), 'young adults' (19 years) and 'adults' (31 years). The third molar had erupted in some young adults and adults (DS4M3).

### *Lateral cephalograms and analysis*

The cephalograms were taken in the maximal intercuspal position with the head fixed in a cephalostat. Throughout the investigation the distances, focus–film and film–midline plane, were kept constant at 155 and 14 cm, respectively. The enlargement factor of 10 per cent was not adjusted for in the linear distances.

The *skeletal* reference points and lines are in accordance with those described by Björk (1947)

**Table 3** Number of subjects in the age groups 5–31 years [mean (M) and standard deviation (SD)] in the total sample (groups U + E).

| Age groups | Males | | | | | Females | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Group U | Group E | Total | Age | | Group U | Group E | Total | Age | |
| | | | | M | SD | | | | M | SD |
| 5 | | 20 | 20 | 5.1 | 0.4 | | 27 | 27 | 4.9 | 0.3 |
| 7 | 17 | 20 | 37 | 7.4 | 0.4 | 19 | 27 | 46 | 7.4 | 0.4 |
| 10 | 23 | 20 | 43 | 10.4 | 0.5 | 29 | 27 | 56 | 10.4 | 0.4 |
| 13 | 33 | 20 | 53 | 13.1 | 0.4 | 42 | 27 | 69 | 13.0 | 0.4 |
| 16 | 25 | | 25 | 15.8 | 0.5 | 30 | | 30 | 15.8 | 0.5 |
| 19 | 16 | | 16 | 19.5 | 0.5 | 17 | | 17 | 19.1 | 0.6 |
| 31 | 11 | | 11 | 30.9 | 0.6 | 19 | | 19 | 31.1 | 0.5 |

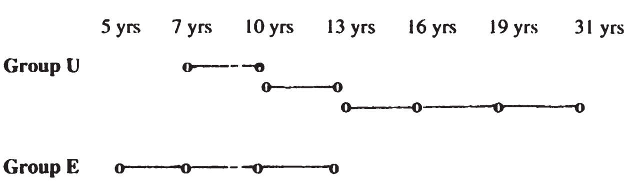


**Figure 2** Ages for the cephalometric recordings. Group U, 7–13 years (mixed longitudinal study) and 13–31 years (longitudinal study). Group E, 5–13 years (longitudinal follow-up).

**Table 4** Classification of age groups in developmental periods, based on their dental stages (DS), according to Björk *et al.* (1964).

| Age groups | | Developmental period | DS |
|---|---|---|---|
| Year | Range | | |
| 5 | 4.2–5.8 | Primary | DS02 |
| 7 | 6.6–8.2 | Early mixed | DS1M0, DS1M1, DS2M0 |
| 10 | 9.5–11.2 | Late mixed | DS2M1, DS3M1 |
| 13 | 12.3–13.8 | Early permanent | DS3M2, DS4M1 |
| 16 | 14.9–17.1 | Adolescents | DS4M2 |
| 19 | 18.4–20.5 | Young adult | DS4M2, DS4M3 |
| 31 | 29.7–32.2 | Adult | DS4M2, DS4M3 |

(Figure 3). In addition, the following landmarks were used:

sp′ = the intersection between the nasal line (NL) and the n–pg line;
tgo = the intersection between the mandibular line (ML) and the ramus line (RL).

The following *dental* reference points and lines were used:

is = the edge of the upper central incisor;
ii = the edge of the lower central incisor;
UIL = upper incisor line through edge and apex of the incisor;
LIL = lower incisor line through edge and apex of the incisor.

For the *soft tissue* profile (Figure 4), the following landmarks, described by Jacobson and Vlachos (1995), were used:

P (pronasale) = the tangency of a line through the tip of the nose and the chin;
Sn (subnasale) = the intersection between NL and the soft tissue profile;
SLS (superior labial sulcus) = the point of the greatest concavity of the upper lip;
Ls (labrale superius) = the most anterior point of the upper lip;
St (stomion) = the junction of the upper and lower lips;
Li (labrale inferius) = the most anterior point of the lower lip;

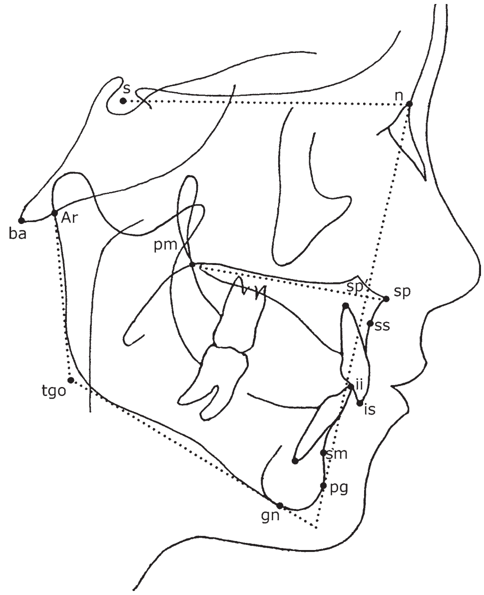


**Figure 3** Skeletal reference points and lines.

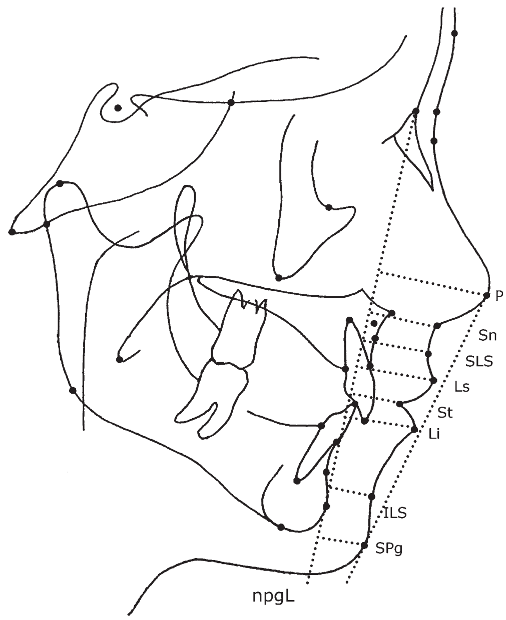


**Figure 4** Landmarks for the soft tissue profile. The perpendicular distances from these landmarks to the skeletal npgL have been used to represent the length of the nose, lips and chin.

ILS (inferior labial sulcus) = the point of the greatest concavity of the lower lip;
SPg (soft tissue pogonion) = the tangency of a line through the tip of the nose and the chin.

The perpendicular distances from these landmarks to the skeletal line, npgL were used to present the length of the nose, lips and chin.

In group U, all landmarks, given as co-ordinates, were digitized on the cephalograms. To improve the reliability in registration, the landmarks were localized in common by two of the authors (BT and MP). All co-ordinates from every cephalogram were stored in a computer file, and a special program was written to convert these filed data into the PC-DIG program (Databiten AB, Sandviken, Sweden).

In group E, all landmarks were digitized on the cephalograms using a digitizer (Scriptel®, Columbus, Ohio, USA) connected to a computer. The cephalometric computer program PC-DIG was used to file the data. All landmarks were localized and digitized by one author (UA).

*Statistic analyses*

To determine the degree of agreement with the registrations between groups U and E, 10 cephalograms from group U were digitized by one author (UA) and then compared with the filed data digitized by the authors BT and MP. To assess the importance of the method error, the magnitude of the error variance ($Se^2$) was studied in relation to the variance for group U. The error variance was less than 2 per cent of the total variance for each parameter, except for the inclination of the incisors (greater than 2 to less than 4 per cent), the degree of overbite/overjet (5.5 per cent), and sp´–pm (10.4 per cent). The results indicated a high degree of agreement in the digitizing procedure for all parameters, except sp´–pm.

## Results

The results are given in Tables 5–8 with the mean and standard deviation for males and females in the different developmental periods. The angular measurements are also presented graphically to illustrate changes during the observation period. The distances are presented as cumulative and velocity curves to illustrate the variation in growth rate at the developmental stages. The growth rate is defined as the mean difference between two adjacent registrations of the distance, and given at the chronological age centre.

*Overall findings*

Body height showed a growth spurt between the 10 and 13 year recordings in females and between the 13 and 16 year recordings in males (Figure 5). A growth acceleration, although of minor magnitude, was also registered during the mixed developmental period. A small residual growth increase was even observed in the young adult period. The velocity growth peak in males indicated the mean timing of the peak between the 13 and 16 year recordings, but due to great individual variation in skeletal maturation it may fall anywhere within the shaded area.

As seen from the cephalometric data (Tables 5–8), distances as well as angular measurements varied with the different developmental periods. A continuous increase in most distances up to the young adult period was observed, with a growth acceleration between the 13 and 16 year recordings. The craniofacial distances were constantly larger in males than in females, exemplified by Figure 6. However, no statistical differences as regards angular measurements were seen between genders. A more detailed analysis is given below, where the dynamic growth pattern between 5 and 31 years in males and females is evident.

*Cranial base*

During the total observation period, the length of the cranial base (s–n) increased 11.3 mm in females and 12.9 mm in males (Tables 5 and 6, Figure 7). One-third of the total increase was noted between 13 and 16 years of age, especially in males. An increase of 1.0–1.5 mm was even observed between the adolescent and young adult periods. The lateral cranial base (s–ar) increased with some acceleration in males during the adolescent period, but thereafter it was only negligible. The angle n–s–ar was stable in both genders from the primary until the adult period, in contrast to the angle n–s–ba, which decreased around 4 degrees during the observation period.

*Upper face (nasal–maxillary complex)*

The increase in the length of the maxilla (sp´–pm) between primary and adult ages was 8.5 mm in males and 7.2 mm in females (Tables 5 and 6, Figure 8), i.e. half the increase in height (n–sp´) (17.2 and 11.3 mm, respectively). Growth acceleration in height was observed between the 13 and 16 year recordings in males. The height of the nasal–maxillary complex related to total face height was constant during the longitudinal follow-up (44 per cent). Only small variations in maxillary rotation (NL/NSL) could be seen in both genders.

*Lower face (the mandible)*

The mean length of the mandible, represented by the distances ar–pg and tgo–gn, increased until the young adult period and more in males (Tables 5 and 6, Figure 9). A further increase (around 2 mm) was observed between the young adult and adult recordings, except for the distance ar–pg in females. The mean total increase for ar–pg was 33.1 mm in males and 27.9 mm in females, and for tgo–gn 25.5 mm in males and 23.9 mm in females. A growth acceleration was recorded between the 13 and 16 year recordings, especially in males.

The increase in lower posterior face height (ar–tgo) was 18.6 mm in males and 16.1 mm in females (Figure 10), especially in males between the 13 and 16 year recordings. Lower anterior face height (sp'–gn) increased 19.3 mm in

**Table 5** Mean (M) and standard deviation (SD) of *skeletal* cephalometric standards in Swedish *males* at 5, 7, 10, 13, 16, 19 and 31 years of age, i.e. in the primary, early mixed, late mixed, early permanent, adolescent, young adult, and adult developmental periods. Magnification factor 10 per cent.

| | 5 years Primary | | 7 years Early mixed | | 10 years Late mixed | | 13 years Early permanent | | 16 years Adolescent | | 19 years Young adult | | 31 years Adult | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| Cranial base | | | | | | | | | | | | | | |
| n–s–ar (°) | 121.9 | 4.4 | 122.3 | 5.0 | 122.2 | 4.5 | 121.9 | 4.6 | 121.9 | 4.6 | 122.3 | 3.8 | 120.7 | 4.5 |
| n–s–ba (°) | 131.4 | 4.4 | 131.3 | 4.6 | 130.5 | 4.5 | 129.4 | 4.5 | 128.4 | 4.1 | 128.3 | 4.2 | 127.3 | 4.3 |
| s–n (mm) | 65.5 | 2.7 | 68.1 | 2.8 | 70.8 | 2.9 | 73.0 | 3.0 | 76.9 | 2.9 | 77.9 | 2.3 | 78.4 | 3.7 |
| s–ar (mm) | 27.7 | 2.7 | 30.8 | 3.4 | 33.6 | 2.9 | 36.1 | 3.0 | 39.9 | 2.9 | 40.8 | 2.9 | 41.6 | 3.0 |
| Facial upper | | | | | | | | | | | | | | |
| s–n–ss (SNA) (°) | 81.8 | 3.0 | 81.3 | 3.2 | 81.2 | 3.2 | 82.3 | 3.4 | 82.7 | 3.7 | 82.5 | 3.9 | 82.2 | 3.3 |
| NL/NSL (°) | 6.9 | 2.6 | 6.3 | 3.3 | 6.7 | 2.8 | 6.3 | 2.7 | 6.8 | 2.5 | 6.6 | 2.6 | 6.4 | 2.5 |
| sp'–pm (mm) | 44.0 | 2.0 | 46.1 | 1.6 | 48.1 | 2.1 | 50.4 | 2.7 | 52.9 | 2.9 | 52.2 | 3.5 | 52.5 | 4.4 |
| n–sp´(mm) | 41.9 | 2.2 | 45.4 | 2.8 | 49.6 | 2.6 | 53.0 | 3.1 | 57.9 | 2.8 | 58.3 | 2.6 | 59.1 | 2.3 |
| n–sp´/n–gn (%) | 43.3 | 2.6 | 43.8 | 1.8 | 44.8 | 2.0 | 45.5 | 1.8 | 45.8 | 2.6 | 44.8 | 2.8 | 45.0 | 2.0 |
| Facial lower | | | | | | | | | | | | | | |
| s–n–sm (SNB)(°) | 77.2 | 3.0 | 77.7 | 3.1 | 78.5 | 3.1 | 79.7 | 3.0 | 80.6 | 2.9 | 80.8 | 3.7 | 80.9 | 2.8 |
| s–n–pg (°) | 77.1 | 2.9 | 78.1 | 3.3 | 79.4 | 3.4 | 80.9 | 2.9 | 82.1 | 2.8 | 82.1 | 2.6 | 82.7 | 3.2 |
| ML/NSL (°) | 35.2 | 4.1 | 33.5 | 5.3 | 32.2 | 5.3 | 30.7 | 4.3 | 28.6 | 3.9 | 28.8 | 4.6 | 27.8 | 5.1 |
| ML/NL (°) | 28.3 | 3.3 | 27.3 | 4.9 | 25.5 | 4.9 | 24.4 | 4.5 | 21.9 | 4.5 | 22.2 | 5.7 | 21.3 | 5.9 |
| RL/ML (°) | 132.1 | 2.9 | 128.4 | 4.6 | 126.6 | 4.6 | 125.1 | 4.2 | 121.4 | 4.9 | 121.0 | 3.8 | 120.2 | 5.9 |
| ar–tgo (mm) | 37.4 | 2.7 | 40.4 | 3.8 | 43.8 | 3.6 | 47.5 | 3.8 | 53.4 | 3.8 | 54.8 | 3.6 | 56.0 | 3.6 |
| tgo–gn (mm) | 62.3 | 2.6 | 67.5 | 3.6 | 73.0 | 3.8 | 77.5 | 4.1 | 84.6 | 4.2 | 86.7 | 4.1 | 87.8 | 4.0 |
| ar–pg (mm) | 89.4 | 3.6 | 95.6 | 4.3 | 102.7 | 4.5 | 108.8 | 5.2 | 118.2 | 6.3 | 120.0 | 5.9 | 122.5 | 3.9 |
| sp´–gn (mm) | 54.1 | 3.0 | 57.4 | 2.9 | 60.4 | 2.6 | 63.0 | 4.0 | 68.3 | 4.9 | 72.6 | 3.7 | 73.4 | 4.5 |
| sp´–gn/n–gn (%) | 55.9 | 2.3 | 55.3 | 1.8 | 54.6 | 2.1 | 54.1 | 1.9 | 54.0 | 2.3 | 55.2 | 1.9 | 54.8 | 2.1 |
| Facial upper/lower | | | | | | | | | | | | | | |
| ss–n–sm(ANB)(°) | 4.6 | 1.2 | 3.6 | 1.8 | 2.8 | 1.8 | 2.6 | 1.8 | 2.0 | 2.6 | 1.7 | 2.7 | 1.3 | 2.9 |
| s–ar–tgo (°) | 141.1 | 4.8 | 142.7 | 5.8 | 143.5 | 5.8 | 143.7 | 6.1 | 144.9 | 5.9 | 145.5 | 6.5 | 146.8 | 6.5 |
| n–ss–pg (°) | 170.2 | 3.4 | 173.5 | 4.5 | 176.3 | 4.7 | 177.2 | 4.3 | 178.8 | 5.9 | 179.2 | 4.5 | 181.2 | 7.7 |
| n–gn (mm) | 96.8 | 4.9 | 103.7 | 4.9 | 110.6 | 5.1 | 116.4 | 5.6 | 126.5 | 5.8 | 131.0 | 5.1 | 132.5 | 4.6 |
| s–tgo (mm) | 61.3 | 3.5 | 67.5 | 4.6 | 73.5 | 4.9 | 79.4 | 4.5 | 88.7 | 4.4 | 92.2 | 4.9 | 93.5 | 4.2 |
| n–gn/s–tgo (%) | 157.9 | 4.2 | 153.6 | 4.8 | 150.5 | 5.0 | 146.6 | 5.2 | 142.6 | 5.1 | 142.0 | 5.0 | 141.7 | 4.4 |

**Table 6** Mean (M) and standard deviation (SD) of *skeletal* cephalometric standards in Swedish *females* at 5, 7, 10, 13, 16, 19 and 31 years of age, i.e. in the primary, early mixed, late mixed, early permanent, adolescent, young adult, and adult developmental periods. Magnification factor 10 per cent.

| | 5 years Primary | | 7 years Early mixed | | 10 years Late mixed | | 13 years Early permanent | | 16 years Adolescent | | 19 years Young adult | | 31 years Adult | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| Cranial base | | | | | | | | | | | | | | |
| n–s–ar (°) | 123.9 | 5.0 | 123.8 | 5.0 | 123.5 | 4.1 | 123.2 | 4.1 | 123.2 | 4.8 | 122.4 | 4.6 | 122.3 | 3.5 |
| n–s–ba (°) | 133.3 | 4.6 | 132.0 | 4.1 | 130.9 | 4.1 | 130.7 | 3.8 | 129.8 | 4.7 | 129.4 | 4.8 | 129.5 | 3.8 |
| s–n (mm) | 62.7 | 1.8 | 65.8 | 2.4 | 68.5 | 2.7 | 70.3 | 3.1 | 72.9 | 3.5 | 73.9 | 2.1 | 74.0 | 3.9 |
| s–ar (mm) | 26.7 | 2.2 | 29.5 | 2.4 | 32.5 | 2.6 | 33.8 | 2.4 | 35.3 | 2.3 | 35.5 | 2.0 | 35.4 | 2.6 |
| Facial upper | | | | | | | | | | | | | | |
| s–n–ss (SNA) (°) | 82.6 | 2.7 | 81.8 | 3.0 | 82.6 | 2.7 | 83.4 | 3.0 | 83.5 | 4.1 | 83.1 | 2.8 | 83.2 | 3.0 |
| NL/NSL (°) | 7.3 | 2.5 | 7.5 | 2.9 | 7.7 | 2.8 | 6.8 | 3.2 | 5.9 | 2.7 | 6.0 | 2.6 | 5.3 | 2.7 |
| sp'–pm (mm) | 43.0 | 1.9 | 44.8 | 2.0 | 47.5 | 2.0 | 49.2 | 2.5 | 50.4 | 3.1 | 50.2 | 2.5 | 50.2 | 3.0 |
| n–sp´ (mm) | 40.8 | 1.7 | 45.0 | 2.4 | 49.1 | 2.8 | 50.8 | 2.5 | 52.3 | 2.7 | 52.9 | 2.6 | 52.1 | 3.5 |
| n–sp´/n–gn (%) | 44.3 | 2.6 | 45.2 | 1.8 | 46.1 | 2.0 | 45.8 | 1.8 | 44.9 | 2.6 | 44.6 | 2.8 | 44.0 | 2.0 |
| Facial lower | | | | | | | | | | | | | | |
| s–n–sm (SNB) (°) | 77.5 | 2.6 | 77.8 | 2.6 | 79.0 | 2.6 | 80.5 | 2.8 | 81.5 | 3.5 | 81.3 | 2.9 | 81.5 | 2.3 |
| s–n–pg (°) | 77.3 | 2.7 | 78.3 | 2.6 | 79.8 | 2.7 | 81.6 | 2.8 | 82.8 | 3.3 | 82.9 | 2.4 | 83.0 | 2.3 |
| ML/NSL (°) | 34.2 | 4.0 | 32.8 | 4.2 | 31.7 | 4.2 | 29.9 | 4.3 | 28.2 | 5.4 | 28.3 | 4.3 | 26.4 | 4.8 |
| ML/NL (°) | 26.8 | 4.0 | 25.2 | 4.6 | 24.0 | 4.2 | 23.1 | 4.4 | 22.3 | 5.1 | 21.3 | 4.2 | 21.1 | 4.9 |
| RL/ML (°) | 132.3 | 4.9 | 127.4 | 5.7 | 125.4 | 5.4 | 124.5 | 5.1 | 121.6 | 6.3 | 120.8 | 3.1 | 117.3 | 5.6 |
| ar–tgo (mm) | 36.7 | 3.3 | 39.4 | 3.1 | 42.3 | 3.5 | 46.2 | 4.1 | 50.1 | 3.9 | 51.1 | 3.6 | 52.8 | 4.3 |
| tgo–gn (mm) | 59.5 | 3.1 | 66.2 | 4.5 | 73.0 | 3.8 | 75.7 | 3.5 | 80.5 | 3.0 | 81.1 | 3.0 | 83.4 | 3.6 |
| ar–pg (mm) | 86.1 | 3.5 | 92.9 | 4.0 | 100.1 | 4.5 | 106.0 | 4.5 | 112.7 | 3.5 | 114.0 | 5.2 | 114.0 | 3.4 |
| sp´–gn (mm) | 50.5 | 2.3 | 54.0 | 2.9 | 57.1 | 3.4 | 59.8 | 3.9 | 64.0 | 4.5 | 64.9 | 3.2 | 65.9 | 4.8 |
| sp´–gn/n–gn (%) | 54.9 | 2.3 | 54.3 | 1.8 | 53.6 | 2.1 | 54.0 | 1.9 | 54.9 | 2.3 | 55.2 | 1.9 | 55.7 | 2.1 |
| Facial upper/lower | | | | | | | | | | | | | | |
| ss–n–sm (ANB) (°) | 5.1 | 1.7 | 4.0 | 2.3 | 3.6 | 1.8 | 2.9 | 1.7 | 2.0 | 1.7 | 1.9 | 1.2 | 1.7 | 2.1 |
| s–ar–tgo (°) | 138.0 | 6.7 | 141.6 | 6.5 | 142.8 | 5.8 | 142.2 | 5.1 | 143.5 | 5.0 | 145.5 | 6.4 | 146.8 | 5.1 |
| n–ss–pg (°) | 168.7 | 4.3 | 173.6 | 5.6 | 174.1 | 4.7 | 176.2 | 4.4 | 178.6 | 4.4 | 179.5 | 4.5 | 181.4 | 5.1 |
| n–gn (mm) | 92.0 | 2.6 | 99.5 | 4.0 | 106.5 | 4.6 | 110.8 | 4.9 | 116.5 | 5.1 | 118.0 | 4.9 | 118.3 | 6.0 |
| s–tgo (mm) | 59.2 | 3.6 | 65.1 | 4.1 | 70.8 | 4.7 | 75.8 | 4.4 | 81.2 | 3.8 | 82.8 | 3.5 | 84.6 | 4.3 |
| n–gn/s–tgo (%) | 155.4 | 3.1 | 152.8 | 4.0 | 150.4 | 4.2 | 146.2 | 4.6 | 143.5 | 4.5 | 142.0 | 6.6 | 139.8 | 5.2 |

**Table 7** Mean (M) and standard deviation (SD) of cephalometric standards for *dental relationship* and *soft tissue* profile (in mm) in Swedish *males* at 5, 7, 10, 13, 16, 19, and 31 years of age, i.e. in primary, early mixed, late mixed, early permanent, adolescent, young adult and adult developmental periods. Magnification factor 10 per cent.

| | 5 years Primary | | 7 years Early mixed | | 10 years Late mixed | | 13 years Early permanent | | 16 years Adolescent | | 19 years Young adult | | 31 years Adult | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| Dental relationship | | | | | | | | | | | | | | |
| UIL/NL (°) | 99.6 | 5.4 | 106.2 | 6.0 | 110.4 | 5.3 | 110.7 | 5.4 | 111.5 | 4.7 | 107.2 | 7.9 | 109.1 | 8.4 |
| LIL/ML (°) | 86.0 | 5.8 | 90.1 | 6.7 | 91.3 | 6.8 | 94.5 | 6.2 | 95.6 | 7.1 | 92.2 | 6.1 | 91.6 | 7.0 |
| UIL/LIL (°) | 146.1 | 8.4 | 137.1 | 9.1 | 130.7 | 8.3 | 130.4 | 8.4 | 131.0 | 8.3 | 134.5 | 8.7 | 137.9 | 8.9 |
| UIL/n–ss (°) | 10.9 | 6.2 | 18.6 | 6.1 | 22.5 | 5.1 | 22.1 | 5.9 | 22.0 | 5.2 | 19.7 | 6.8 | 20.5 | 8.2 |
| LIL/n–sm (°) | 18.4 | 5.8 | 21.2 | 5.8 | 24.0 | 5.8 | 24.9 | 6.1 | 24.9 | 7.0 | 23.1 | 5.1 | 20.3 | 8.0 |
| UIL/n–ss (mm) | –0.2 | 1.6 | 1.3 | 2.3 | 3.9 | 2.0 | 4.1 | 2.0 | 4.0 | 2.2 | 4.1 | 2.8 | 3.7 | 2.7 |
| LIL/n–sm (mm) | 2.3 | 1.3 | 2.8 | 1.6 | 4.2 | 1.6 | 4.4 | 2.4 | 4.4 | 2.8 | 5.1 | 2.1 | 3.1 | 2.7 |
| Soft tissues | | | | | | | | | | | | | | |
| P–npgL | 24.4 | 2.2 | 26.5 | 2.5 | 28.4 | 2.7 | 30.6 | 3.5 | 34.9 | 3.1 | 35.8 | 2.6 | 36.5 | 2.6 |
| Sn–npgL | 14.8 | 2.1 | 15.8 | 2.2 | 16.9 | 2.7 | 17.8 | 3.1 | 19.4 | 3.4 | 20.6 | 2.6 | 18.1 | 5.3 |
| SLS–npgL | 15.8 | 2.0 | 16.1 | 2.2 | 17.3 | 2.3 | 17.5 | 3.0 | 18.2 | 3.7 | 18.4 | 2.7 | 15.3 | 4.7 |
| Ls–npgL | 18.9 | 2.2 | 19.1 | 2.8 | 20.4 | 2.7 | 20.8 | 3.3 | 21.5 | 4.3 | 22.2 | 2.9 | 17.7 | 5.2 |
| St–npgL | 11.4 | 1.2 | 12.2 | 2.2 | 13.6 | 2.6 | 13.9 | 2.8 | 14.3 | 3.7 | 14.6 | 2.6 | 10.9 | 3.9 |
| Li–npgL | 15.6 | 1.8 | 15.6 | 2.2 | 17.3 | 2.1 | 17.2 | 2.8 | 17.5 | 3.4 | 18.5 | 2.4 | 15.5 | 4.2 |
| ILS–npgL | 9.2 | 1.1 | 9.4 | 1.7 | 9.9 | 1.7 | 9.6 | 1.9 | 9.6 | 2.2 | 10.1 | 1.8 | 8.9 | 2.7 |
| SPg–npgL | 10.1 | 1.4 | 10.4 | 1.7 | 10.8 | 1.8 | 11.2 | 1.2 | 11.5 | 2.2 | 11.6 | 1.6 | 12.3 | 1.7 |

**Table 8** Mean (M) and standard deviation (SD) of cephalometric standards for *dental relationship* and *soft tissue* profile (in mm) in Swedish *females* at 5, 7, 10, 13, 16, 19, and 31 years of age, i.e. in primary, early mixed, late mixed, early permanent, adolescent, young adult and adult developmental periods. Magnification factor 10 per cent.

| | 5 years Primary | | 7 years Early mixed | | 10 years Late mixed | | 13 years Early permanent | | 16 years Adolescent | | 19 years Young adult | | 31 years Adult | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| Dental relationship | | | | | | | | | | | | | | |
| UIL/NL (°) | 102.0 | 4.7 | 108.2 | 5.1 | 110.9 | 4.8 | 110.6 | 5.0 | 109.4 | 4.4 | 110.0 | 4.7 | 107.9 | 5.3 |
| LIL/ML (°) | 88.9 | 4.6 | 93.5 | 4.1 | 96.0 | 4.4 | 95.1 | 5.1 | 93.4 | 5.3 | 90.9 | 6.7 | 96.3 | 5.1 |
| UIL/LIL (°) | 142.3 | 6.6 | 133.3 | 7.5 | 129.2 | 6.8 | 131.2 | 7.6 | 134.8 | 7.5 | 132.9 | 7.7 | 134.6 | 6.1 |
| UIL/n–ss (°) | 12.0 | 5.1 | 18.8 | 5.7 | 20.6 | 5.4 | 20.4 | 4.9 | 20.1 | 4.8 | 19.9 | 6.0 | 18.5 | 4.3 |
| LIL/n–sm (°) | 20.5 | 3.9 | 24.1 | 4.3 | 26.6 | 4.1 | 25.5 | 4.8 | 23.1 | 5.4 | 22.9 | 5.0 | 24.2 | 4.9 |
| UIL/n–ss (mm) | 0.2 | 1.5 | 1.6 | 2.1 | 3.1 | 2.0 | 4.6 | 1.7 | 4.0 | 1.8 | 3.2 | 2.0 | 3.4 | 1.7 |
| LIL/n–sm (mm) | 2.8 | 1.8 | 3.5 | 1.6 | 4.7 | 1.5 | 4.5 | 1.8 | 4.1 | 1.9 | 3.7 | 1.8 | 4.5 | 2.0 |
| Soft tissues | | | | | | | | | | | | | | |
| P–npgL | 23.9 | 1.7 | 25.7 | 1.9 | 28.0 | 2.2 | 30.3 | 2.5 | 31.3 | 2.4 | 33.2 | 2.8 | 34.0 | 5.5 |
| Sn–npgL | 14.7 | 1.3 | 15.3 | 2.0 | 16.8 | 2.3 | 17.5 | 2.4 | 17.4 | 1.9 | 17.8 | 2.0 | 16.5 | 2.8 |
| SLS–npgL | 15.6 | 1.6 | 15.8 | 2.1 | 16.8 | 2.2 | 16.7 | 2.4 | 15.8 | 1.9 | 15.0 | 2.1 | 14.7 | 1.8 |
| Ls–npgL | 18.3 | 1.8 | 18.6 | 2.2 | 19.5 | 2.4 | 19.7 | 2.4 | 19.0 | 2.0 | 18.6 | 2.2 | 17.5 | 1.9 |
| St–npgL | 11.3 | 1.9 | 11.8 | 2.1 | 13.1 | 2.2 | 13.2 | 2.3 | 12.5 | 2.0 | 11.8 | 2.1 | 11.2 | 2.2 |
| Li–npgL | 15.0 | 1.9 | 14.9 | 2.1 | 16.3 | 2.3 | 16.7 | 2.1 | 16.5 | 1.8 | 16.8 | 2.1 | 16.3 | 1.9 |
| ILS–npgL | 8.6 | 1.3 | 8.5 | 1.5 | 9.2 | 1.8 | 9.3 | 1.5 | 9.7 | 1.4 | 9.5 | 2.6 | 9.9 | 1.7 |
| SPg–npgL | 9.8 | 1.6 | 9.7 | 1.6 | 10.5 | 1.7 | 11.3 | 1.5 | 11.7 | 1.3 | 12.2 | 2.0 | 12.3 | 1.7 |

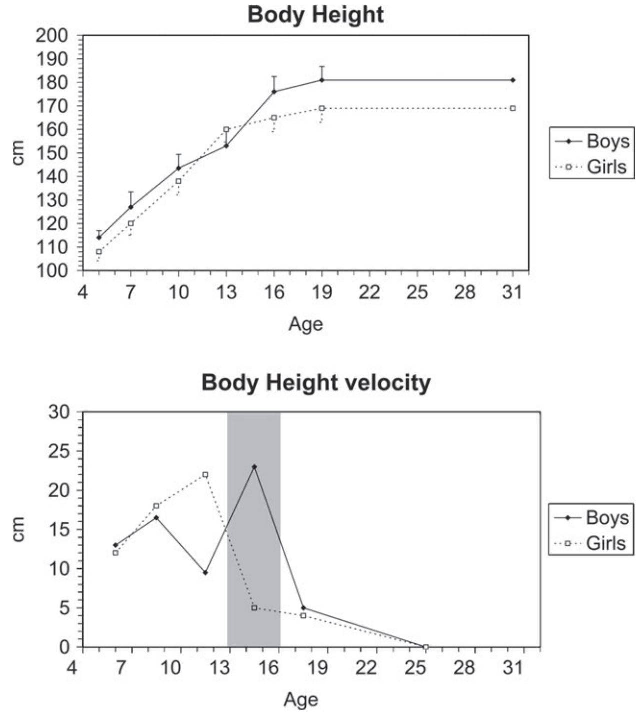


**Figure 5** Increase in body height (cm) in males and females from 5 to 31 years of age, with the mean and standard deviation. Growth velocity between two adjacent recordings is given at the chronological age centre.

males and 15.4 mm in females, also with a growth acceleration between the 13 and 16 year registrations for both genders. The height of the lower face related to total face height was constant during the follow-up (55 per cent).

A continuous average decrease in the angles ML/NSL and ML/NL (7.5 and 6.5 degrees, respectively) was noted in both genders (Figure 10), indicating an upward anterior growth rotation of the mandible. The jaw angle (RL/ML) also decreased during the follow-up period (11.9 degrees in males and 15.0 degrees in females) (Figure 11).

*Jaw relationship*

The s–n–ss angle (SNA) remained constant during the different dental developmental periods (83 degrees in females and 82 degrees in males) (Tables 5 and 6, Figure 12). The s–n–sm angle (SNB) increased continuously during the observation period, from 77 to 81 degrees. Thus, the mean n–ss–sm angle (ANB) decreased from 5 degrees among the young children, to 2 degrees for the 16-year-old individuals, and to 1.3 degrees for adult males and 1.7 degrees for adult females. A continuous increase for the s–n–pg angle was noted during the total observation period (from 77 to 83 degrees).

*Upper/lower facial relationship*

Anterior face height (n–gn) increased continuously until the young adult period (34.2 mm in males and 26.0 in

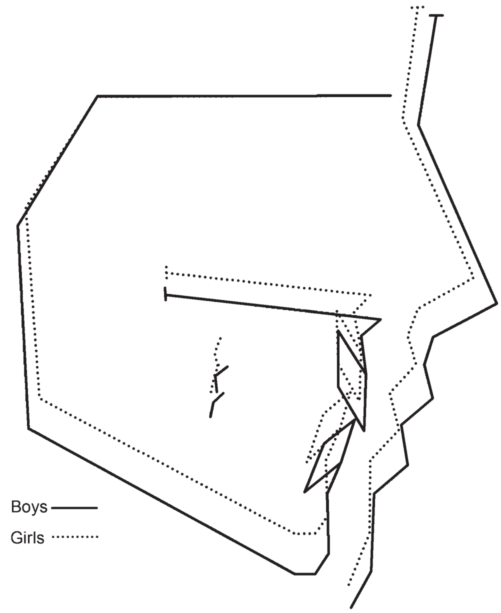


**Figure 6** Mean differences in craniofacial dimensions in 16-year-old males and females.

females) as did posterior face height (s–tgo) (32.2 and 25.4 mm, respectively) with a growth spurt between the 13 and 16 year recordings, especially in males (Tables 5 and 6, Figure 13). No further increase was observed between the 19 and 31 year recordings. The anterior/posterior face height relationship (n–gn/s–tgo) decreased continuously (approximately 16 per cent), coinciding with an upward rotation of the mandible.

The angle s–ar–tgo, representing the upper/lower posterior relationship, increased in both genders (5.7 degrees in males and 8.8 degrees in females). The mean facial convexity (n–ss–pg) changed from slight convexity to straight, and in adults even to slight concavity (Figure 14).

*Dental relationships*

In spite of difficulties in measuring the inclination of the primary incisors, they were estimated as rather vertically positioned. The permanent incisors related to their apical bases (UIL/NL and LIL/ML) continuously achieved a more proclined position up to the 16 year recordings (Tables 7 and 8, Figure 15). In the young adult and adult periods, great individual variations were observed. The mean interincisal angle (UIL/LIL) was approximately 130 degrees in both genders at the 10 year recordings, followed by a continuous increase up to the adult recordings (5.4 degrees in females and 7.2 degrees in males).

*Soft tissues*

The soft tissue profile changed with age (Tables 7 and 8). As illustrated in Figure 16, the prominence of the nose (P–npgL) increased continuously up to the young adult

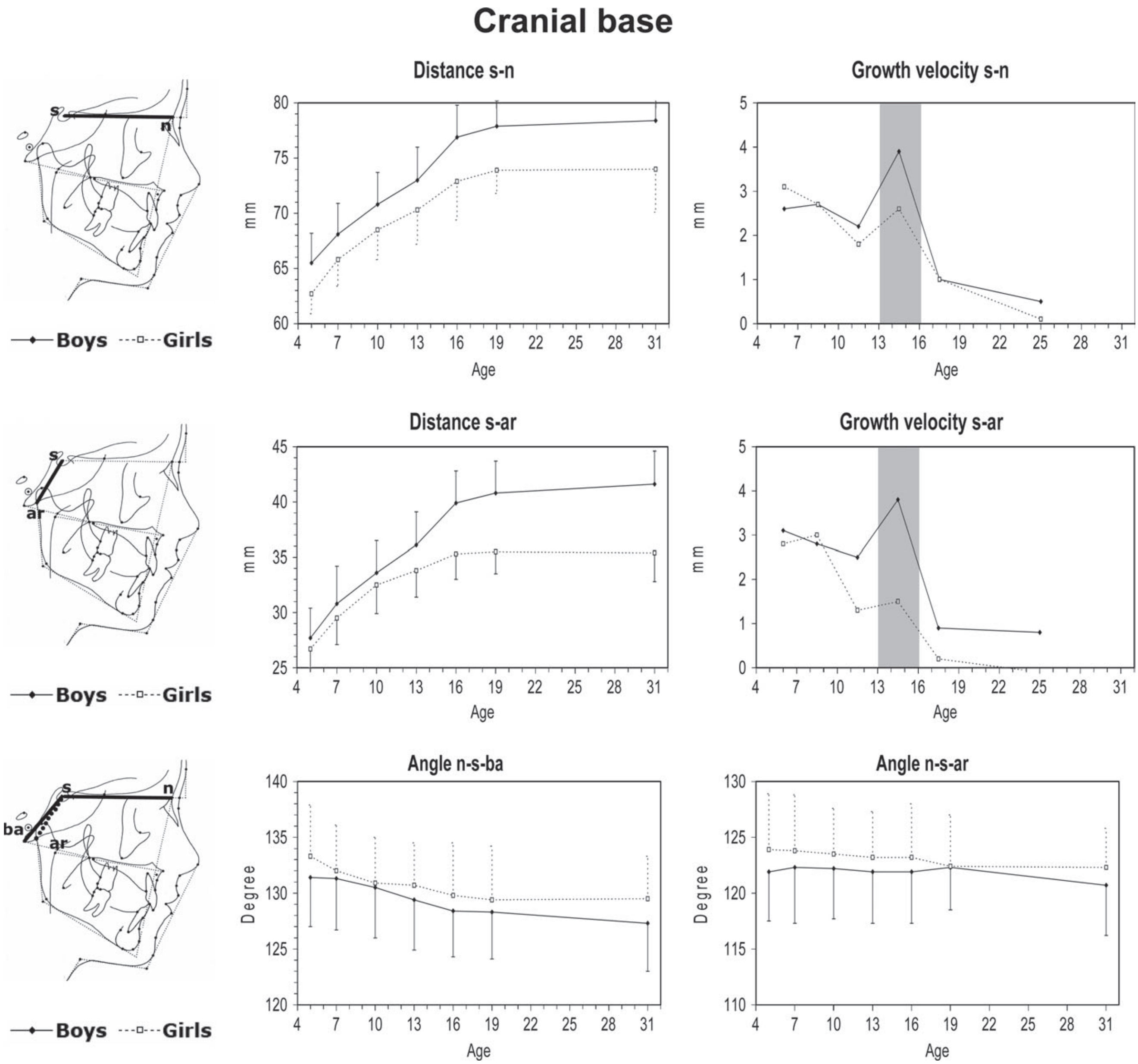


**Figure 7** Length (mm) and growth velocity of the cranial base (s–n and s–ar) and cranial base angles (n–s–ba and n–s–ar)(degrees). Mean and standard deviation for each recording.

period, with an acceleration between the 13 and 16 year recordings, especially in males. A further slight increase was even noted between the 19 and 31 year recordings. The upper lip, represented by the distances from the landmarks Sn, SLS, Ls and St to npgL, increased in thickness up to the 13 year recordings in females and the 19 year recordings in males. Thereafter, however, an evident decrease was observed in both genders. The thickness of the lower lip (Li–npgL and Ils–npgL) followed the growth pattern for the upper lip, but not to the same magnitude. The soft tissue of the chin (Pg–npgL) increased slightly up to adult age in both genders.

## Discussion

The cephalograms in the present study were obtained from subjects of a Caucasian Swedish population of different ages, living in two different regions of the country. The criteria for selection of the samples were normal/ideal dental arches, no facial asymmetry, a straight profile, and no history of orthodontic treatment. The samples were collected between 1965 and 1989, and cephalometric registrations with 3 year intervals were sanctioned by the ethical committees of the medical faculties of Umeå and Göteborg Universities. It is, however, questionable whether the collection of similar samples would be approved today, due

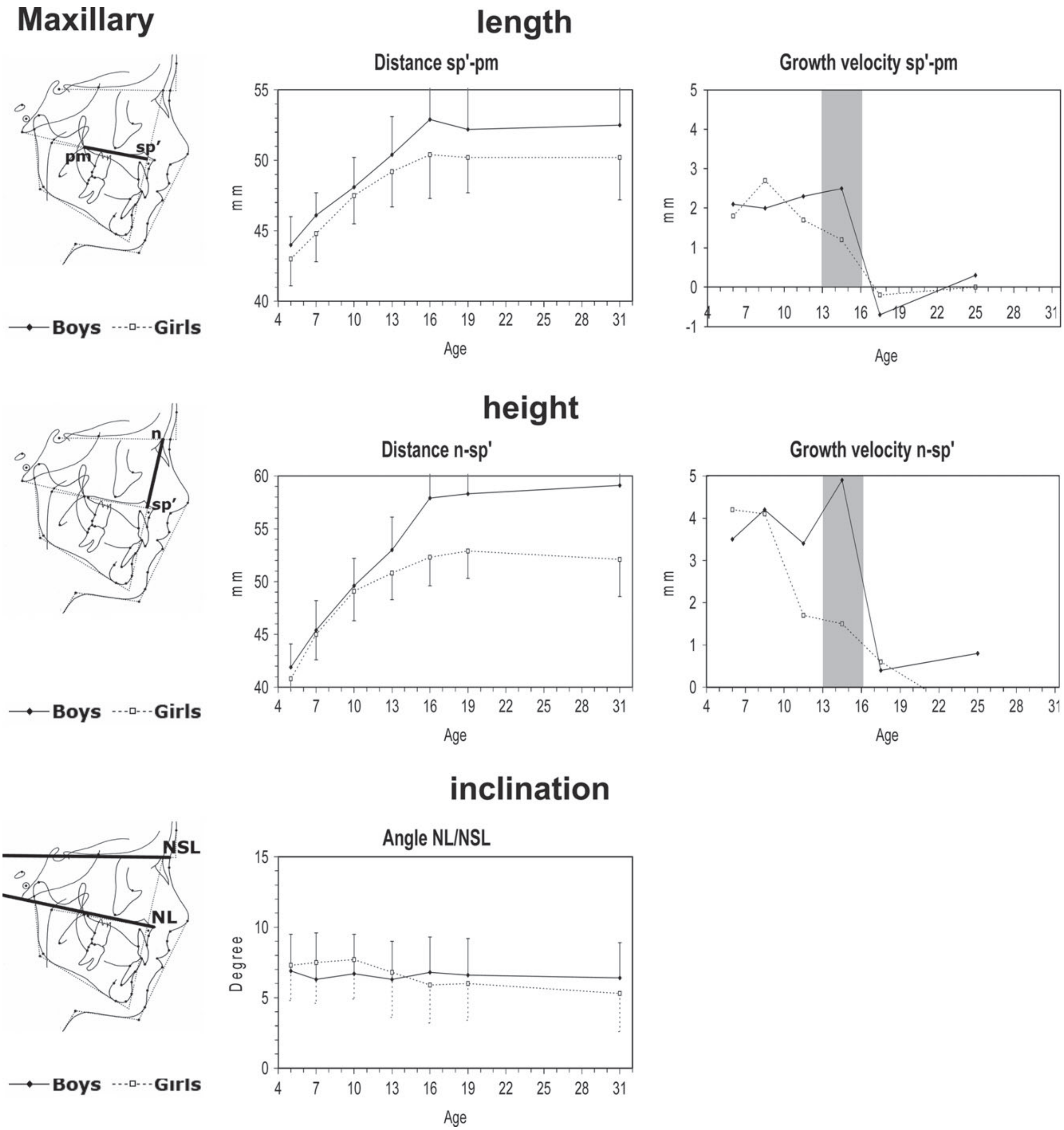


**Figure 8** Maxillary length (sp'–pm) and height (n–sp') and growth velocity (mm) and maxillary inclination to the cranial base (NL/NSL) (degrees). Mean and standard deviation for each recording.

to the change in views on exposure of 'healthy' individuals to radiation. Ironically, this is one of the merits of this sample of 'normal' individuals. Annual recordings, instead of 3 year intervals, would have been preferable in a study of growing individuals, but such frequent radiographic registrations in 'healthy' individuals are not justifiable for ethical reasons.

The defined criteria for 'normality' might have given a limited number of individuals included in the study. However, a Student's *t*-test showed no significant difference between the cephalometric parameters in 7-, 10- and 13-year-old subjects in the two groups. Therefore, subjects of the same age were combined, a procedure that increased the number of subjects in the different age groups. Longitudinal follow-ups were performed between 5 and 13 years in one group, and between 13 and 31 years in the other group. Thus, the present study is regarded as a longitudinal cephalometric

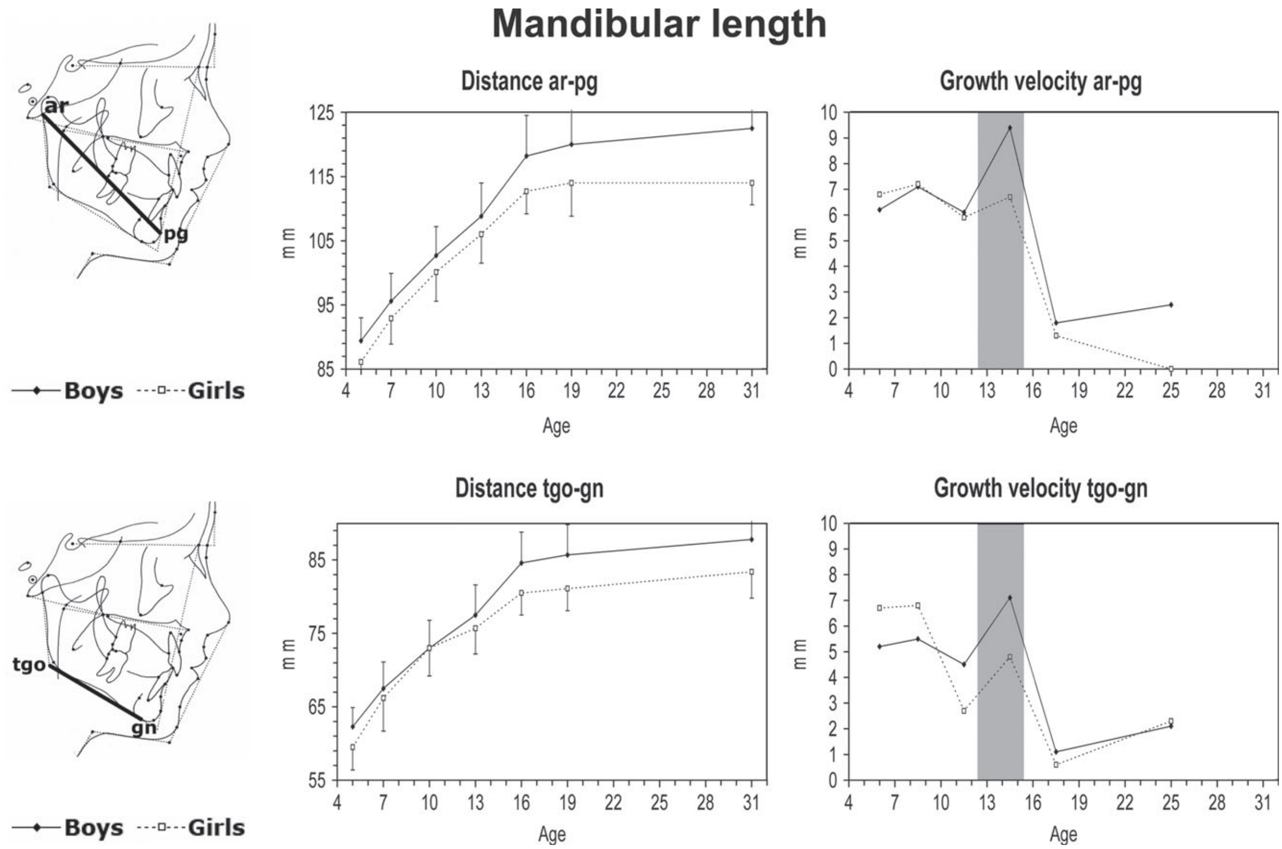


**Figure 9** Mandibular length (ar–pg and tgo–gn) and growth velocity (mm). Mean and standard deviation for each recording.

study of Swedes from 5 to 31 years of age, which can offer the orthodontist normative standards for both gender and age.

It is well known that developmental differences exist between individuals of the same chronological age; some are 'early' and some are 'late'. Therefore, the subjects were grouped not only by age but also by their dental stage to increase the use of the cephalometric data. Thus, data for the 7 year olds are applicable for children in the early mixed dentition; data for the 10 year olds can be used for children in the late mixed dentition, and so on, as presented in the tables.

Cephalometric measurements involve errors of identification of landmarks and errors of projection. In the present study, the error variance was low or negligible for all parameters, except for the distance sp'–pm. It is well known that the landmark pm is difficult to locate and, hence, the exact length of the maxilla, represented by sp'–pm, may be questioned.

As regards errors of projection, linear measurements are often given in millimetres, without paying attention to the magnification factor, which usually varies between 5 and 14 per cent, mainly due to variation in the focus–object distance. In contrast to distances, angular measurements are not sensitive to the changes in magnification of the cephalometric radiograph (10 per cent in this study).

It should be noted that all the distances calculated between cephalometric landmarks in the mid-sagittal plane call the reliability of their dimensions into question. For instance, there are problems in quantifying mandibular length in a lateral view. Due to its anatomy, this section is angulated approximately 30 degrees to the mid-sagittal plane, resulting in a marked shortening of the cephalometric distance ar–pg relative to its anatomical equivalent of $2a/\sqrt{3}$. Thus, the magnification factor and the error projection have to be considered when describing the effect of orthodontic treatment (e.g. activator, Herbst appliance) in millimetres on mandibular growth. The individual growth potential during the treatment period is also included in this effect, while it is difficult to give an exact value of the effect of the appliance.

The use of velocity curves was a complement to illustrate the craniofacial growth dynamics. All diagrams illustrate a growth acceleration between the 13 and 16 year recordings for both genders, although considerably more evident in males. The growth rate, defined as the mean difference between these two recordings, is given with the peak point at the chronological age centre (14.5 years). Due to

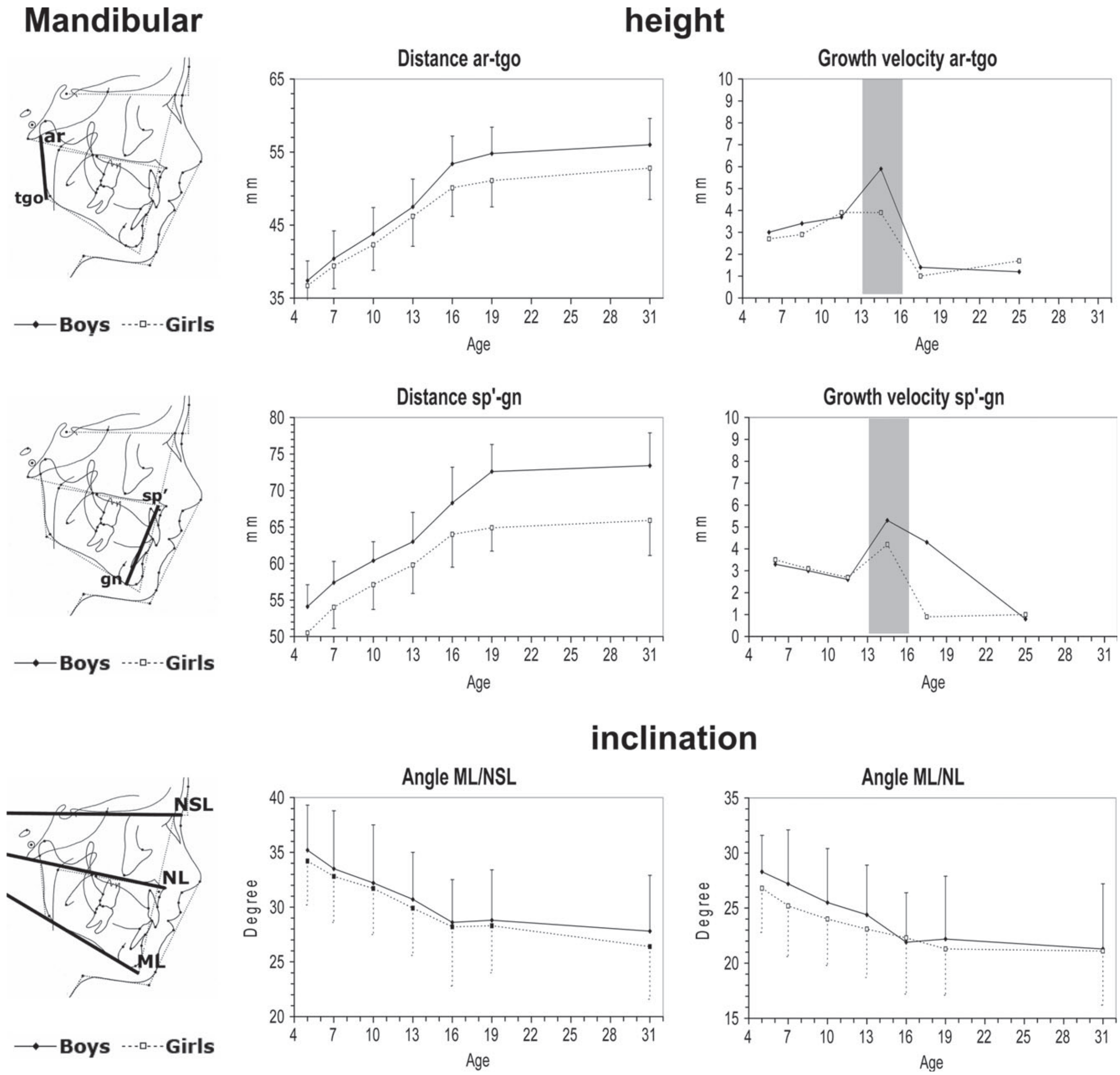


**Figure 10** Mandibular height (ar–tgo and sp'–gn) and growth velocity (mm), and mandibular inclination to the cranial base (ML/NSL) and to the maxilla (ML/NL) (degrees). Mean and standard deviation for each recording.

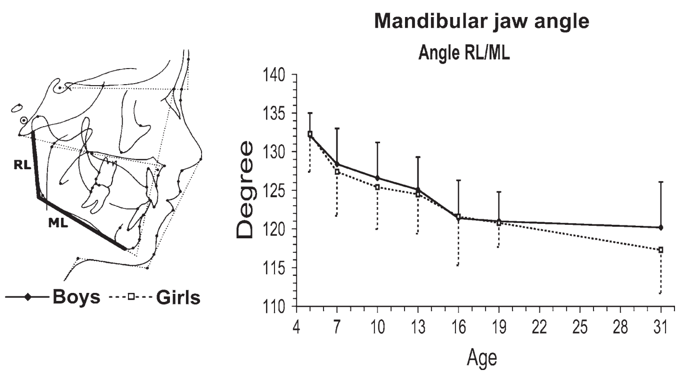


**Figure 11** Jaw angle (RL/ML) (degrees). Mean and standard deviation for each recording.

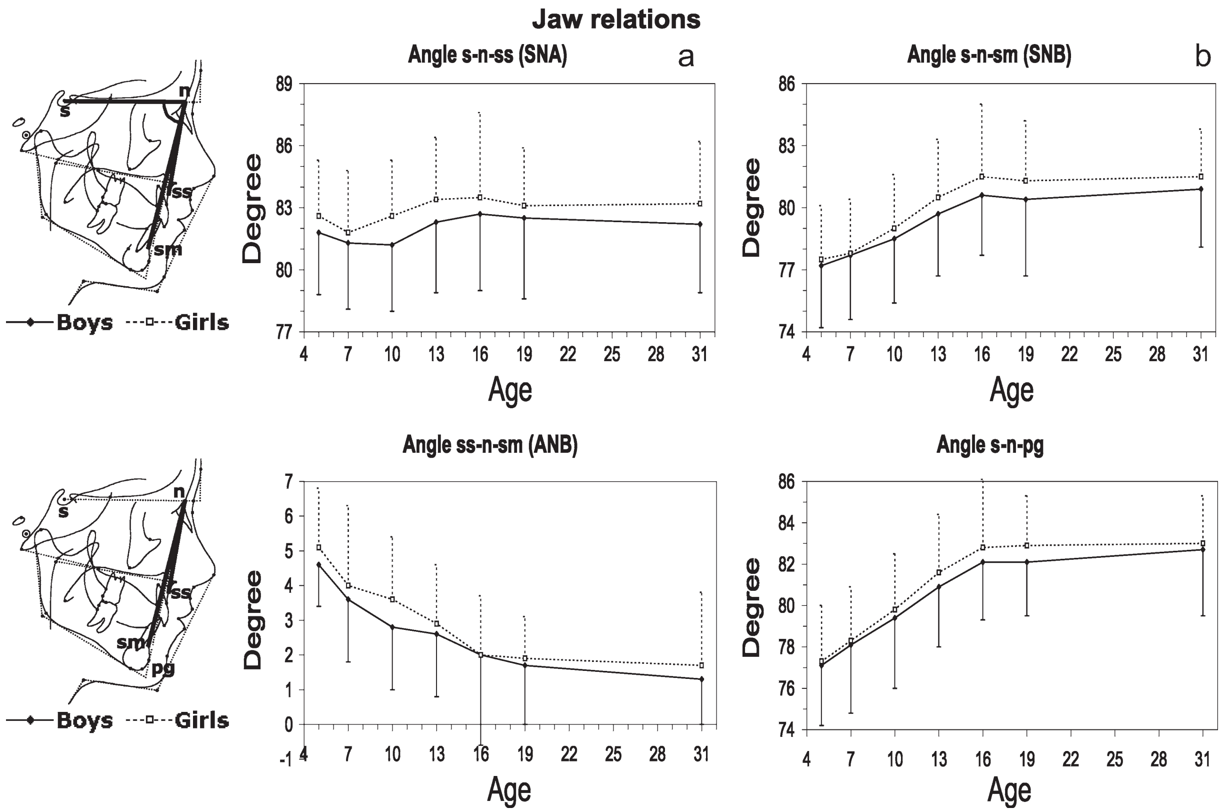


**Figure 12** Upper and lower jaw related to the cranial base (SNA, SNB and s–n–pg)(degrees) and to each other (ANB). Mean and standard deviation for each recording.

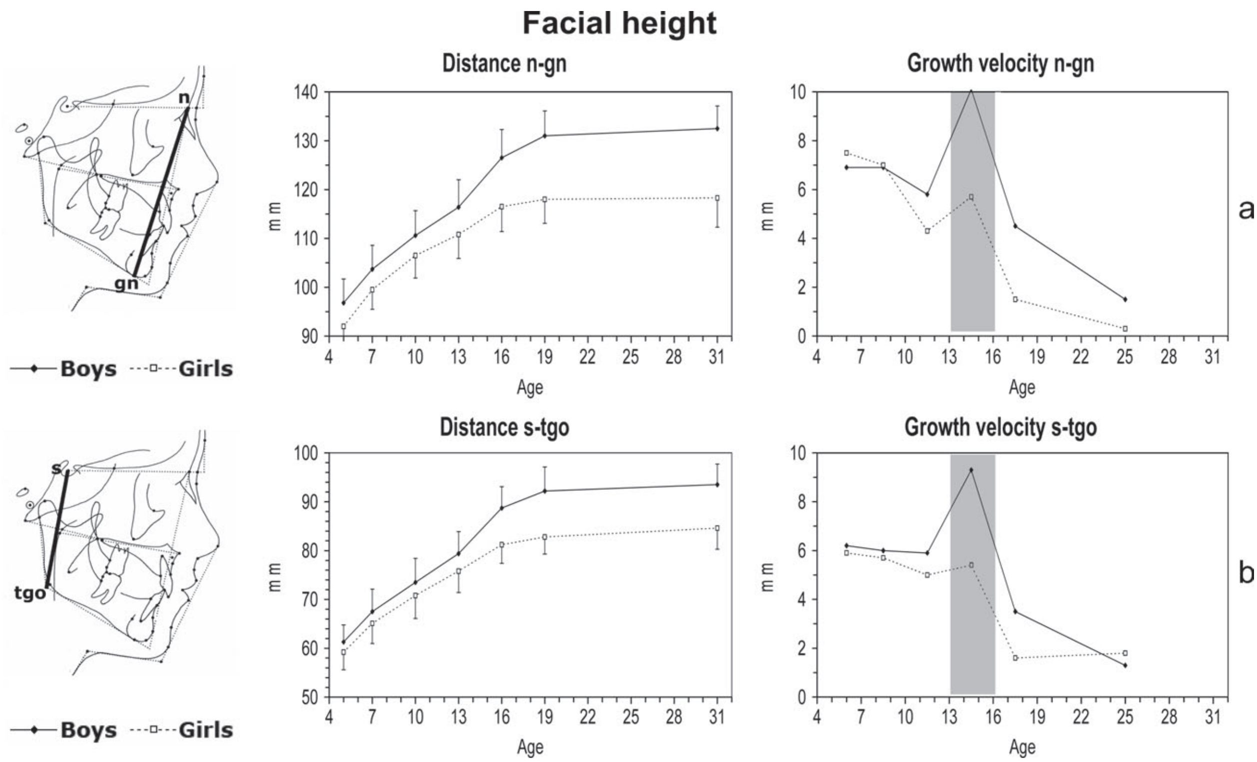


**Figure 13** Anterior (n–gn) and posterior (s–tgo) face height, and growth velocity (mm). Mean and standard deviation for each recording.

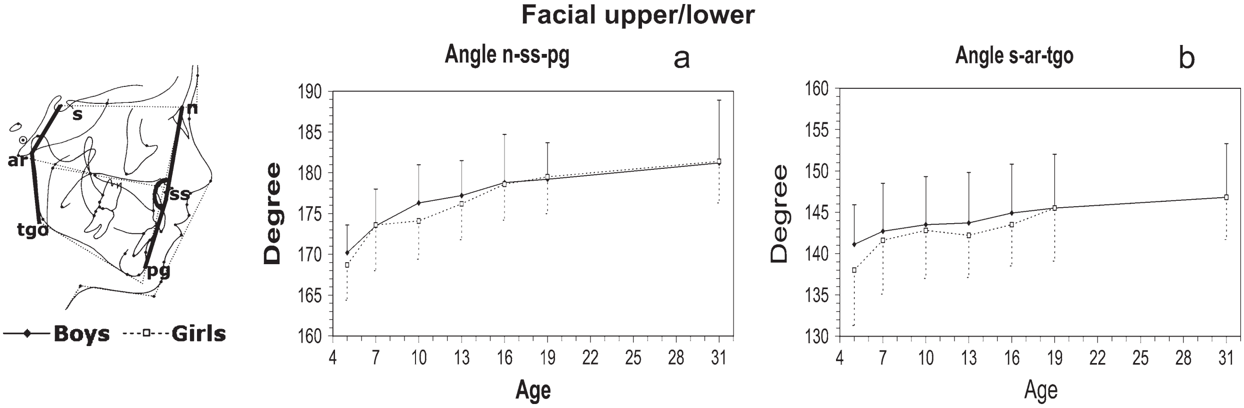


**Figure 14** Anterior (n–ss–pg) and posterior (s–ar–tgo) facial relationship (degrees). Mean and standard deviation for each recording.

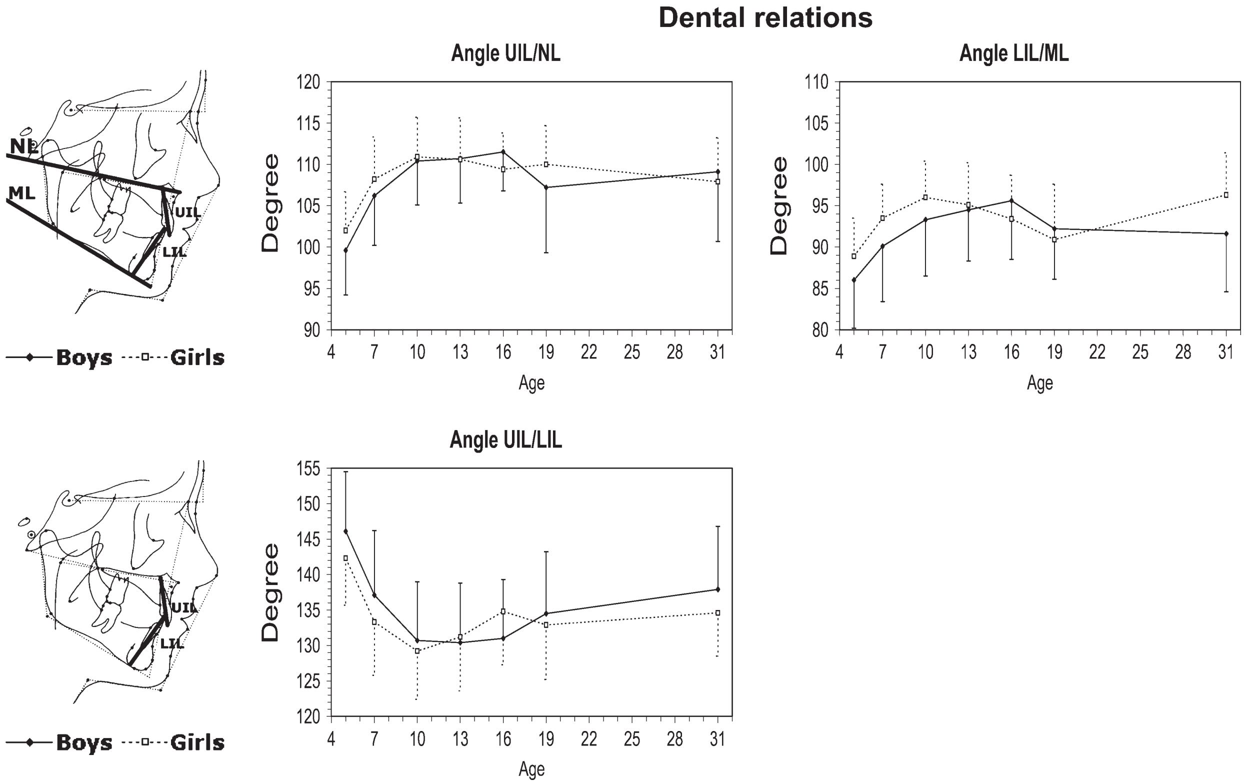


**Figure 15** Inclination of the incisors to their alveolar bases (UIL/NL and LIL/ML) and to each other (UIL/LIL)(degrees). Mean and standard deviation for each recording.

individual differences, this peak may fall anywhere within the shaded area, i.e. in some subjects closer to the age of 13 years, while in others close to 16 years or even later. The craniofacial growth acceleration in males thus seems to coincide with that of body height. In females, however, the craniofacial growth spurt seems to occur somewhat later than that of body height. The explanation for these differences can only be speculated on. Although knowledge of craniofacial growth and development in normal and pathological conditions has increased during recent times, it is still incomplete, especially in relation to the theory of the regulation of growth.

The present study has clearly shown that marked age-related changes occur. Figure 17 illustrates the craniofacial growth pattern during the different developmental periods in males, with acceleration in growth between the 13 and 16 year recordings, and even between the 5 and 7 year recordings. The change in growth pattern is especially notable for the mandible, even with a residual growth potential in young adult males, which was also noted for

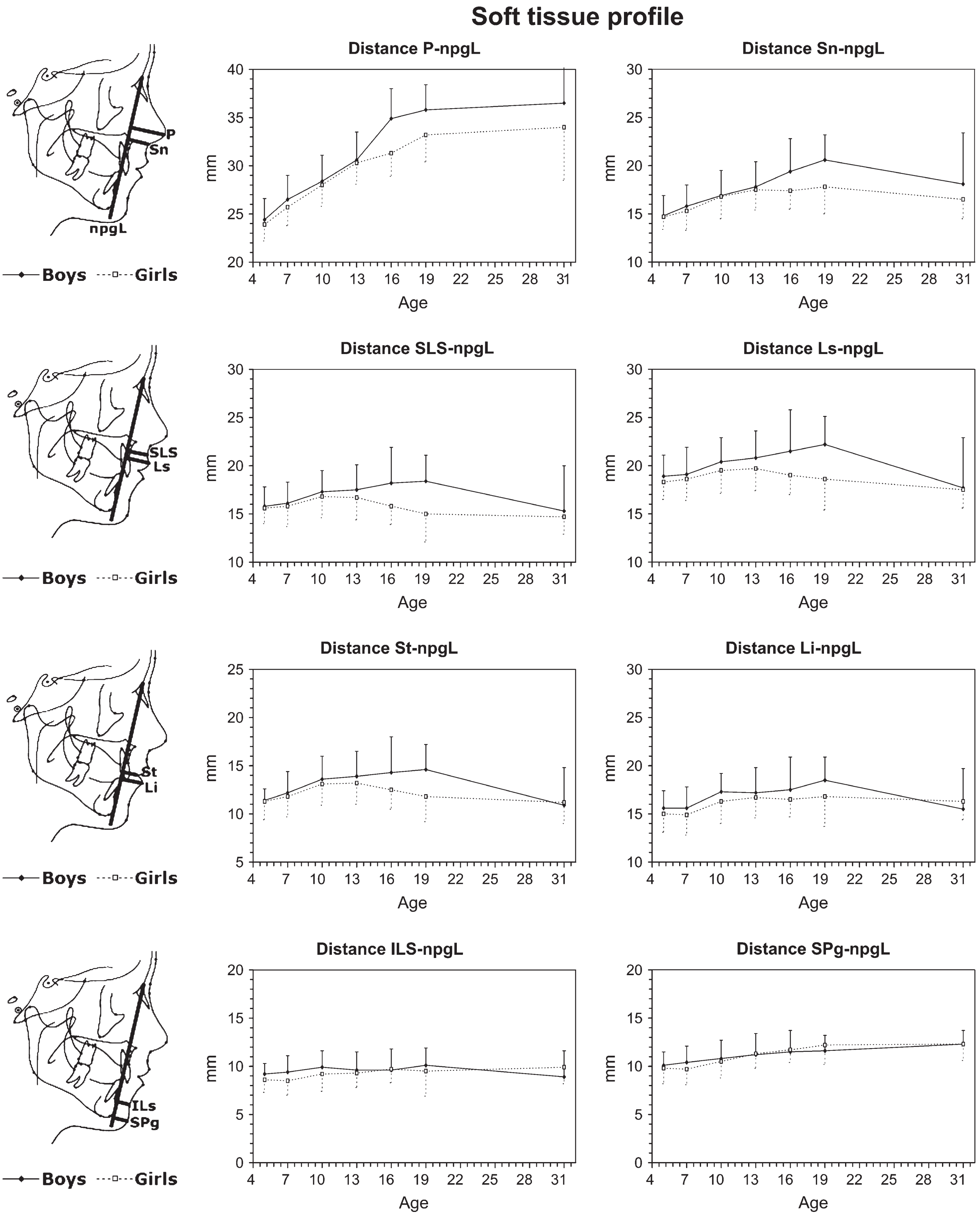


**Figure 16** Length and growth velocity (mm) of the nose (P–npgL); upper lip (Sn–npgL, SLS–npgL, Ls–npgL and St–npgL); lower lip (Li–npgL and ILS–npgL); and the soft tissue chin (SPg–npgL). Mean and standard deviation for each recording.

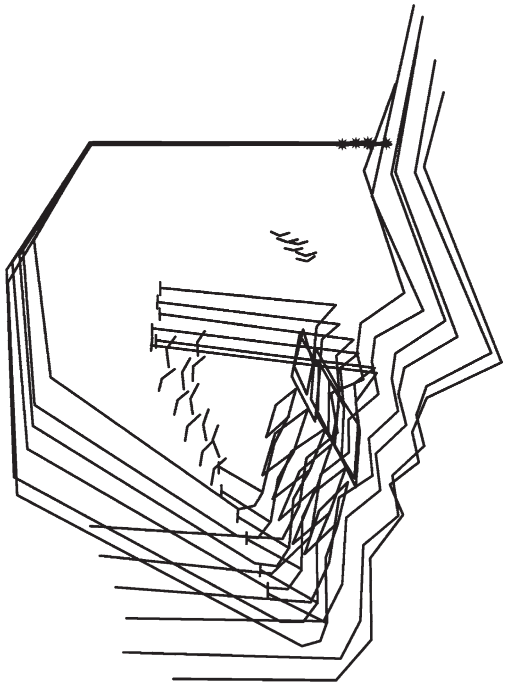

**Figure 17** The mean craniofacial growth patterns in 5-, 7-, 10-, 13-, 16-, 19- and 31-year-old males. There was no difference between the 19 and 31 year recordings.

body height. No further increase was observed between the 19 and 31 year recordings. This growth pattern was the same for females, although not of the same magnitude in the different developmental periods. Hence, the differences in growth rate in the various developmental stages are of importance for the clinician to consider in treatment planning.

The increase in cranial base length (n–s) in adolescents and adults suggests an apposition on glabella, as pointed out by Björk (1947). This may involve a movement of point n, even in the vertical dimension, which has to be considered in superimpositioning of cephalograms (Björk and Skieller, 1983). The use of the ethmoid and sphenoid bones are more reliable structures (Melsen 1974; Thilander and Ingervall, 1976). Those authors also observed remodelling in the basion area, which may explain the continuous decrease in n–s–ba angle.

The increase in the height of the maxilla in the present study was approximately double the size of its length, which is in accordance with the findings of Björk and Skieller (1977), due to suture growth and remodelling of the maxillary bone (resorption of the nasal and apposition on the oral sites). This growth pattern may explain the small changes in SNA angle and the slight rotation of the maxilla (NL/NSL) from primary to adult ages.

Studies with metal markers in combination with radiographic cephalometry have served, above all, to illustrate the complexity of craniofacial growth. This especially applies to the rotational changes of the jaws during growth (Björk and Skieller, 1983). Rotation in this context means a change in the inclination of the mandible and/or maxillary body relative to the anterior cranial base. The decrease in the angles ML/NSL and ML/NL indicates an anterior, upward rotation of the mandible. Synchronous remodelling of the jaw angle region and along the inferior margin of the mandible reduces the apparent effect of this rotation on facial morphology. An upward rotation will have an influence on the relationship between the upper and lower jaws, resulting in a decrease in the ANB angle. An increase in the dimensions in the lower jaw was noted up to the 19 year recordings. A further increase, of slight magnitude at the 31 year recording, was only observed for the distance ar–pg, due to bone apposition on the chin, which describes how the profile angle (n–ss–pg) changes from convex to straight and even to concave.

The residual growth potential of the mandible in young and adult subjects, especially in males, has to be considered in patients who need orthognathic surgery in conjunction with orthodontic treatment. This residual growth may also influence the long-term stability of the occlusion (Henrikson *et al.*, 2001). Furthermore, the variation in inclination of the incisors, shown in the present study, and the slow continuous eruption of teeth, even after developmental stage DS4M2 (Iseri and Solow, 1996; Thilander *et al.*, 2001), illustrate the dynamic dental development and, hence, have to be considered in the discussion on relapse after orthodontic treatment versus post-retention development (Thilander, 2000).

The changes in soft tissue growth with age, especially at the nose and upper lip, suggest sexual dimorphism, which is in accordance with the findings of Nanda *et al.* (1990). These age changes in the lip profile followed the skeletal age changes, from a convex to a straight and even to a slightly concave face. Furthermore, upward rotation of the mandible will result in a relative decrease in lower face height simultaneous with growth acceleration of the nose and the remarkable decrease in the thickness of the lips, especially the upper lip. These skeletal and soft tissue changes will result in a sunken profile with age. This fact is worthy of attention in subjects treated with retroclination of the incisors after extraction of four first premolars.

As mentioned in the introduction, it is well known from the literature that ethnic differences in facial traits do exist, and that the dentofacial pattern will change with age, which was verified in the present study. Thus, cephalometric standards for gender and age of ethnic groups are important in orthodontic diagnosis, treatment planning and evaluation of treatment, even after the post-retention period. The purpose of the present study was not to make a comparison between these data and those from earlier investigations as regards ethnic differences. However it was of special interest to compare the present results with those from 6-, 9-, 12-, 15- and 18-year-old Norwegians (El-Batouti *et al.*, 1994). Skeletal angular measurements, used in both studies, showed remarkably good agreement for both males and females. This good agreement indicates that the cephalometric data in the present study are representative of a Caucasian Scandinavian population.

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