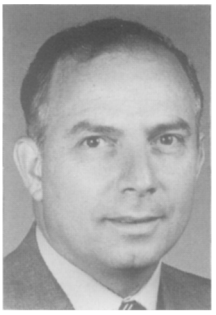

Dr. Bishara

Changes in facial dimensions and relationships between the ages of 5 and 25 years

Samir E. Bishara, B.D.S., D.D.S., D.Ortho., M.S.,*
Lawrence C. Peterson, B.S., M.S., and Edward C. Bishara*****
Iowa City, Iowa

The purpose of this study is to quantify the changes in facial dimensions and relationship as well as in standing height which occur between the age of 5 years and adulthood. The total change between the ages of 5 and 25.5 years was arbitrarily divided into three periods of growth: from 5 years to 10 years of age (GP I), from 10 to 15 years of age (GP II), and from 15 to 25.5 years of age (GP III). The subjects included twenty males and fifteen females for whom complete sets of data were available for the period of this study. All subjects had clinically acceptable occlusion and had undergone no previous orthodontic treatment. Descriptive statistics summarized the changes in standing height and the facial parameters for males and females at 5, 10, 15, and 25.5 years of age. The analysis of variance and Duncan's multiple-range test were used for posterior tests of significance in the comparisons between the three periods of growth for each of the parameters and for both males and females. The findings in this investigation indicated that (1) the timing and magnitude of change in the various facial parameters differ during the same growth period as well as between males and females; (2) in general, most of the changes in the various parameters in females occurred in GP I and GP II, whereas in males the changes were relatively distributed over the three periods of growth; (3) changes in GP III for some parameters were of clinically significant magnitude (for example, in females the ratio of anterior face heights decreased significantly in GP III whereas in males a significant increase occurred in Ar-Pog, SNB, and SNPog, while the maxillary and mandibular relationship, the ratio of anterior to posterior face heights, MP-SN angle, and the convexity of the soft-tissue profile continued to decrease significantly during GP III); (4) during GP III, with the exception of standing height and mandibular depth, there were no significant differences in the magnitude of change between 15 and 17 years of age and the change after 17 years of age; and (5) the data provided by this investigation are useful in describing mean trends, but *not* in *predicting* changes occurring in both the size and/or relationship of some facial parameters after 15 years of age; the magnitude of these late changes, at least in certain persons, could either beneficially or adversely influence the orthodontic and/or surgical treatment results.

Key words: Cephalometric, longitudinal, normal, face, anteroposterior, vertical

As orthodontists we are interested in understanding how the face changes from its embryologic form through childhood, adolescence, and adulthood. Of particular interest is an understanding of *how* and *where* growth occurs, *how much* growth is remaining in a person who needs orthodontic treatment, *in which direction* and *when* growth will express itself, *what* roles the genetic and environmental factors play in influencing facial growth and, in turn, how we can *influence* these factors with our treatment to achieve the optimal results within the potential of each individual patient.

By determining how much and when substantial amounts of growth do occur, one could treat persons with anteroposterior and/or vertical discrepancies either with different types of orthopedic appliances or by orthognathic surgery. The choice of treatment plans would depend, in part, on a thorough understanding of what happens during the various periods of growth and when facial growth can be considered complete.

Numerous investigators have described and quantified bodily and facial growth changes at various periods.[1-11] It is accepted that the growth of the various parts of the head neither proceed at the same rate nor follow the same pattern. According to Scammon and associates,[12] the cranium follows the neural growth curve while the middle and lower anterior parts of the face follow the bodily or general growth curve. They described the remaining growth between the ages of 10 and 20 years as 4% in the cranium and 35% in the

From the University of Iowa College of Dentistry.
*Professor of Orthodontics, Department of Orthodontics.
**Research Scientist, Dow's Institute of Dental Research.
***Research Assistant.

middle and upper parts of the face. Salzmann[13] asserted that at the age of 6 years the brain case is almost completed but the face is characteristically infantile. Accordingly, he believes that growth of the face is influenced to a relatively greater degree by environmental factors.

It is also accepted that, within the dentofacial complex, the changes in its various parts do not follow similar patterns. Meredith[14] found that, on the average, the indices of the upper face depth to upper face width remain practically constant (73%) throughout the childhood period between 5 and 11 years, but this average constancy is not found in all persons. On the other hand, the corresponding indices for the lower face increase from 80% at age 5 to 82% at age 11. Similarly, indices of upper face depth to anterior face height declined from 89% at age 5 to 85% at age 11. The corresponding indices of the lower face change from 78% at the age of 4 years to 84% at the age of 16 years. These findings, as well as those in other investigations,[1–13] indicate that the changes in facial dimensions and relationships do not proceed at a constant rate in the various parts of the face.

A number of longitudinal and semilongitudinal studies, described the change in various facial dimensions and relationships. Broadbent and associates[15] examined sixteen boys and sixteen girls between the ages of 1 and 18 years. They calculated yearly standards for various parameters and constructed average tracings for each year. Riola and colleagues[16] similarly presented data on a number of facial parameters between the ages of 6 and 16 years. Bishara and Jamison and their coworkers[17, 18] discussed the changes that occur in the face as they relate to standing height between the ages of 8 and 17 years.

Very few studies[19, 20] presented information concerning changes in facial parameters past the age of 17 or 18 years. One might presume that the lack of interest could be related to the fact that longitudinal data are not readily available or to the belief that facial growth is almost completed by that time. On the other hand, Björk[20] indicated that mandibular length (Ar-Pog) continued to increase in a number of persons past the age of 20 years. This, combined with the controversy[21] concerning the effect of "early" orthognathic surgery on the residual maxillary and/or mandibular growth, should encourage us to learn more about the overall changes in facial dimensions and relationships at different ages.

PURPOSE OF THE STUDY

The purpose of this study is to quantify the changes in the facial dimensions and relationships, as well as those in standing height, that occur between the age of 5 years and adulthood.

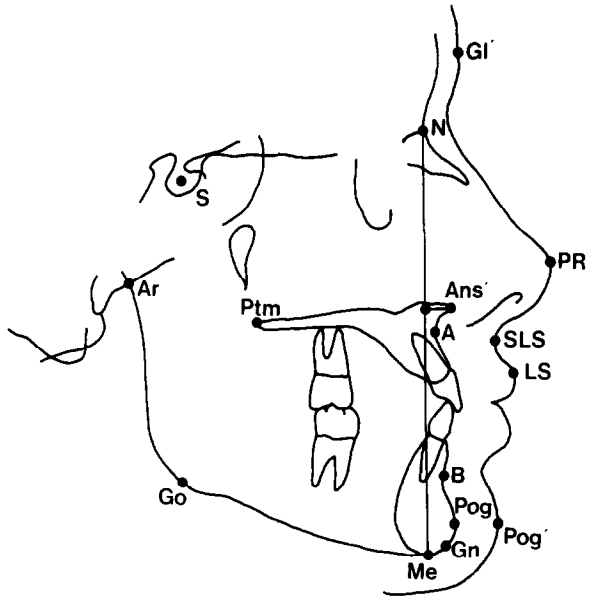

Fig. 1. Landmarks used.

The total change between the ages of 5 and 25.5 years was arbitrarily divided into three periods of growth: from 5 to 10 years of age (GP I), from 10 to 15 years of age (GP II), and from 15 years to early adulthood at a mean age of 25.5 years (GP III).

These periods correspond roughly to the times for what is considered to be "early" treatment, "adolescent" treatment, and "adult" treatment.

MATERIALS AND METHODS

Sample

The subjects in this investigation were participants in a longitudinal facial growth study at the University of Iowa. Lateral cephalograms were obtained biennially between the ages of 4.5 and 12 years and annually through age 17. A final set of records was also available at adulthood (mean age, 25.5 years). The cephalograms were obtained with the subject's head positioned in a cephalostat and oriented to the Frankfort horizontal plane.

All subjects had clinically acceptable occlusion, with no apparent facial disharmony. All were white, and 97% of them were of northern European ancestry. None of the subjects had undergone orthodontic therapy.

The subjects included twenty males and fifteen females for whom complete sets of data were available for the period of this study. This criterion in the selection of the sample has the disadvantage of limiting the

Table I. Basic statistics on the absolute changes in the various parameters evaluated at four different ages—5 years, 10 years, 15 years, and 25.5 years

		5 years				*10 years*				*15 years*				*25.5 years*			
Variable	*Sex*	$\bar{X}$	*SD*	*Min.*	*Max.*	$\bar{X}$	*SD*	*Min.*	*Max.*	$\bar{X}$	*SD*	*Min.*	*Max.*	$\bar{X}$	*SD*	*Min.*	*Max.*
Height	M	110.6	4.6	99.0	119.3	139.1	5.6	125.4	148.6	169.5	7.5	154.7	185.7	180.1	6.6	169.3	197.5
(cm)	F	108.8	5.0	98.0	117.2	138.5	7.3	121.0	150.4	161.8	6.3	149.2	168.9	164.3	5.8	154.3	172.0
								Anteroposterior facial parameters									
Maxilla																	
A-Ptm (mm)	M	44.2	3.3	32.0	48.5	48.1	2.3	43.6	52.9	52.7	2.9	48.6	58.2	54.9	3.3	50.3	61.3
	F	42.9	1.6	40.4	46.0	46.4	2.0	42.6	49.4	48.8	2.0	44.0	51.2	50.1	2.7	44.2	53.5
SNA (°)	M	80.4	4.2	73.7	87.8	80.6	3.9	74.5	87.5	82.0	3.7	76.6	88.8	82.2	3.7	76.2	89.2
	F	80.1	3.2	76.6	87.9	80.0	3.7	74.3	89.2	80.3	3.8	73.4	89.4	80.6	3.7	74.4	89.1
Mandible																	
Ar-Pog	M	84.6	4.4	73.3	94.6	95.3	4.9	84.4	105.6	107.5	5.8	97.3	123.3	115.8	6.5	103.6	131.2
(mm)	F	81.5	3.7	74.6	86.1	91.4	4.5	83.5	98.0	100.2	4.9	92.1	108.8	102.4	4.5	95.0	111.0
SNB (°)	M	76.0	3.8	68.2	82.1	77.0	3.5	70.3	82.8	78.5	3.4	72.2	84.5	79.7	3.6	72.7	85.8
	F	75.4	2.7	71.3	81.9	76.1	3.0	71.5	83.2	77.3	3.3	70.8	83.6	77.3	3.4	71.8	83.6
SNPog (°)	M	75.1	4.0	66.3	81.9	77.2	3.9	68.9	84.4	79.2	3.8	71.4	86.4	80.9	4.2	71.9	88.4
	F	74.4	2.8	69.3	80.4	75.9	3.0	72.3	82.5	77.5	3.3	72.2	83.8	77.9	3.2	73.7	84.0
Maxilla-mandible																	
ANB (°)	M	4.1	2.0	−0.8	6.6	3.6	1.8	0	5.8	3.5	1.9	0.2	6.6	2.5	2.4	−1.9	6.2
	F	4.7	1.7	2.4	9.0	3.9	1.9	1.4	8.4	3.0	2.2	−1.4	6.7	3.3	2.0	−0.4	6.4
NAPog (°)	M	10.8	4.0	2.3	17.4	7.0	4.2	−0.1	12.1	5.9	5.1	−4.4	12.3	2.9	6.1	−9.8	11.8
	F	11.4	3.6	6.9	17.0	8.3	4.5	1.1	16.7	5.6	5.7	−6.9	17.3	5.8	5.6	−6.6	16.7
Overjet	M	3.0	1.3	1.2	6.3	3.4	1.3	1.8	6.1	2.9	1.0	1.8	6.1	2.8	0.8	1.0	5.2
(mm)	F	2.5	1.0	1.5	5.0	3.4	0.8	2.0	4.7	3.3	0.7	2.2	4.5	3.2	0.8	2.0	4.6
								Vertical facial parameters									
Anterior face heights																	
N-Ans'	M	38.8	3.9	24.7	43.1	46.0	2.5	40.5	50.6	51.8	2.9	45.7	58.2	54.2	2.9	48.2	59.6
(mm)	F	38.2	1.5	36.1	40.6	44.3	2.4	38.7	47.6	47.9	1.8	44.6	50.4	48.8	2.0	45.6	52.2
N-Me (mm)	M	92.6	8.7	58.4	100.6	104.6	4.2	97.5	111.4	116.2	5.9	106.4	128.5	121.9	6.0	112.9	135.2
	F	89.7	3.7	83.3	96.0	100.2	5.1	90.7	108.3	108.5	4.7	99.2	117.3	111.7	4.3	104.0	119.8
$\frac{\text{N-Ans'}}{\text{N-Me}}$ (%)	M	41.4	3.6	28.2	47.7	43.9	1.5	41.6	48.4	44.6	1.6	41.8	48.4	44.4	2.0	39.8	48.7
	F	42.6	1.7	38.9	45.2	44.3	1.6	40.9	47.1	44.2	2.2	40.3	50.1	43.8	2.2	39.3	49.2
Overbite	M	1.1	1.1	−1.1	3.3	3.2	1.5	0.2	5.8	3.6	1.3	1.3	5.4	3.1	1.4	0.5	5.5
(mm)	F	1.6	1.1	0.2	4.2	3.0	1.4	−0.5	5.0	3.0	1.6	−0.1	5.3	3.3	1.6	0.8	6.3
Posterior face heights																	
Ar-Go (mm)	M	40.1	4.0	28.3	48.6	45.7	3.5	40.5	52.4	53.3	5.0	44.8	63.5	60.5	6.4	48.1	73.5
	F	38.3	2.4	33.1	41.6	42.5	2.6	36.5	46.5	47.7	3.9	41.0	55.4	49.9	4.4	43.8	58.8
S-Go (mm)	M	60.8	6.0	41.8	70.9	71.0	4.9	62.7	78.8	81.6	5.4	71.1	91.7	89.9	6.8	80.0	102.3
	F	57.8	2.6	51.1	62.0	66.2	2.7	56.9	68.0	73.5	3.5	63.1	79.3	76.2	3.6	66.9	83.3
$\frac{\text{Ar-Go}}{\text{S-Go}}$ (%)	M	66.0	2.3	61.5	69.2	64.4	2.5	58.8	67.6	65.3	3.0	59.2	71.1	67.2	3.3	60.1	73.1
	F	66.3	2.3	61.9	70.9	64.2	2.6	60.5	69.0	64.9	3.4	60.8	71.1	65.4	3.9	59.4	73.2
Anterior-posterior face heights																	
$\frac{\text{S-Go}}{\text{N-Me}}$ (%)	M	66.2	4.4	60.0	75.0	67.9	4.6	60.6	76.4	70.3	5.0	60.3	79.2	73.9	6.5	61.1	87.0
	F	64.4	2.9	60.7	68.5	66.1	3.2	61.7	74.3	67.9	3.5	63.2	75.2	68.3	4.0	62.7	76.8
MP-SN (°)	M	34.5	6.0	18.4	42.3	33.1	5.0	24.1	41.2	30.8	5.6	21.1	43.6	27.8	7.2	12.7	43.4
	F	37.0	3.6	30.9	41.7	35.1	3.8	26.4	39.2	33.3	4.3	23.9	39.4	33.5	4.6	22.9	40.2
NSGn (°)	M	68.0	3.1	62.5	73.4	67.8	3.1	62.1	73.6	67.5	3.4	61.5	74.3	66.6	3.8	60.0	73.8
	F	68.2	2.5	64.4	74.3	68.6	2.6	63.7	72.5	68.3	3.0	62.7	73.6	68.4	2.8	62.7	72.3
								Soft-tissue profile									
Gl'-PR-Pog'	M	147.4	3.4	141.3	152.0	144.3	3.6	135.6	147.0	139.2	4.4	133.2	147.6	140.2	4.9	133.0	152.6
(°)	F	148.0	4.2	141.3	155.9	143.2	4.7	133.2	150.5	139.8	6.0	128.9	149.2	138.9	6.2	128.0	148.0
Gl'-SL-Pog'	M	169.7	4.1	159.7	175.9	168.1	3.3	162.2	173.4	166.9	4.7	160.0	177.0	173.0	5.9	163.9	182.4
(°)	F	170.3	4.0	164.8	178.3	167.4	4.2	160.7	175.3	169.6	6.0	158.0	183.3	171.3	6.5	158.9	184.9
Holdaway	M	15.0	3.9	3.4	21.2	13.6	3.8	4.6	19.7	13.2	4.8	2.2	20.2	8.1	5.5	−5.2	14.2
angle (°)	F	14.5	5.0	7.2	25.4	13.8	5.1	7.0	25.6	10.5	5.6	−1.1	19.2	9.1	6.0	−0.4	20.8

M = Males; F = females; $\bar{X}$ = mean; SD = standard deviation; Min. = minimum value; Max. = maximum value.

number of persons to be included in the study. On the other hand, it has the advantage of giving a *purely longitudinal* set of data. With mixed longitudinal data, an increase or decrease in the number of persons included at different ages will cause the mean value to fluctuate between consecutive ages. Such variation is not an age-related change in either the size or the relationship of the parameter measured. The cause of such random variation can be eliminated by examining those subjects for whom complete sets of data are available.

Landmarks and measurements

The following landmarks were identified on each x-ray film (Fig. 1): sella turcica (S); nasion (N); point A (A); menton (Me); anterior nasal spine prime (Ans'), which is the point at which a perpendicular from the anterior nasal spine intersects N-Me; point B (B); pogonion (Pog); gnathion (Gn); gonion (Go); articulare (Ar); soft-tissue glabella (GL'); pronasale or tip of the soft-tissue nose (PR); superior labial sulcus (SLS); labrale superius (LS); and soft-tissue pogonion (Pog').

The definitions of the various landmarks have been published elsewhere.[16, 23, 24] From these landmarks, various linear and angular measurements have been derived. These measurements have been described in the cephalometric analyses published by Bishara,[19] Hession,[25] Riedel,[26] and Wylie.[27]

In addition to height, which is an indicator of the general body change, the twenty-one facial parameters evaluated were grouped as follows:

Anteroposterior facial parameters

1. Maxillary: A-Ptm and SNA
2. Mandibular: Ar-Pog, SNB, and SNPog
3. Maxillary to mandibular: ANB, NAPog, and overjet

Vertical facial parameters

1. Anterior face heights: N-Ans', N-Me, N-Ans'/N-Me, and overbite
2. Posterior face heights: Ar-Go, S-Go, and Ar-Go/S-Go
3. Anterior to posterior face: S-Go/N-Me, MP-SN, and NSGn

Soft-tissue profile

1. Total facial convexity, including the tip of the nose: Gl'-PR-Pog'
2. Facial convexity, excluding nose: Gl'-SLS'Pog'
3. Holdaway soft-tissue angle: LS-Pog'/N-B

The selection of these parameters was based on the fact that they are among the most commonly used by orthodontists, in both clinical practice and research, to diagnose and evaluate facial growth and/or orthodontic treatment.

The recorded value for a specific age was derived from the average of the measurements recorded before, at, and after the age in question. For example, the value of SNB at age 7 was actually an average of the value at 6 years 6 months, 7 years, and 7 years 6 months. All linear measurements were multiplied by the appropriate magnification factors, and the actual size will be reported in the findings.

Reliability

The landmarks on each cephalogram were pricked by one investigator and checked by another. When possible, the set of cephalograms belonging to an individual subject were pricked at the same sitting. Two investigators independently measured each parameter on each cephalogram twice.

Permissible intra- and interinvestigator disagreements were predetermined at 0.5° and 0.2 mm. When disagreements were greater than these limits, two new measurements were taken and the three in closest agreement were averaged.

Statistics used

The mean, standard deviation, minimum and maximum values were calculated for each parameter for the following ages: 5, 10, 15, and 25.5 years. The changes within the following growth periods were calculated: (a) 5 to 10 years of age (GP I); (b) 10 to 15 years of age (GP II); (c) 15 to 25.5 years of age (GP III); (d) 15 to 17 years of age; and (e) 17 to 25.5 years of age.

The yearly values between the ages of 5 and 17 years and at adulthood were also calculated but, because of space limitations, they will not be included in this article.

Similar descriptive statistics were calculated for the incremental changes between the different ages and are based on the individual change between consecutive ages.

The analysis of variance and Duncan's multiple-range test[28] were used for posterior tests of significance in the comparisons among the various periods of growth for each of the parameters, for both males and females. The level of statistical significance was predetermined at the 0.05 level of confidence.

FINDINGS

The mean, standard deviation, and minimum and maximum values for each of the parameters evaluated, at each age, for both males and females are presented in Table I. The incremental changes between the different periods of growth are presented in Table III. The means and standard deviations were derived by calculating the net change for each subject. The percentage change in each of the three growth periods is graphically illustrated in Figs. 2 to 9. When the change between the

Table II. Comparisons of the mean changes between the different periods of growth for each of the parameters

Variable	*Sex*	*GP I vs. GP II*	*GP II vs. GP III*	*GP I vs. GP III*	*15 to 17 years vs. 17 to 25.5 years*
Height	M	NS	S	S	S
	F	S	S	S	NS
		Anteroposterior facial parameters			
Maxilla					
A-Ptm	M	NS	S	S	NS
	F	S	S	S	NS
SNA	M	S	S	NS	NS
	F	NS	NS	NS	NS
Mandible					
Ar-Pog	M	NS	S	S	S
	F	S	S	S	NS
SNB	M	NS	NS	NS	NS
	F	NS	S	NS	NS
SNPog	M	NS	NS	NS	NS
	F	NS	S	S	NS
Maxilla-mandible					
ANB	M	NS	S	NS	NS
	F	NS	S	S	NS
NAPog	M	S	S	NS	NS
	F	NS	S	S	NS
Overjet	M	S	NS	NS	NS
	F	S	NS	S	NS
		Vertical facial parameters			
Anterior face height					
N-Ans'	M	S	S	S	NS
	F	S	S	S	NS

S = Significant at the 0.05 level of confidence.
NS = Not significant.
M = Male.
F = Female.
GP I = Growth period between 5 and 10 years.
GP II = Growth period between 10 and 15 years.
GP III = Growth period between 15 and 25.5 years.

ages of 5 and 25.5 years for any parameter was less than 1°, 1 mm, or 1%, no graphs were made for that particular parameter.

The results of the statistical comparisons between the changes in the various periods of growth are presented in Table II.

Changes in standing height

Changes in standing height were significantly different in the three periods of growth in both males and females, with the exception of the comparison between GP I and GP II in males. There was relatively less change in GP III for both males and females.

Changes in antero-posterior facial parameters

Maxilla. There is significantly more growth in maxillary depth (A-Ptm) in GP I and GP II in males. The magnitude of change in maxillary depth in females decreased significantly in each consecutive growth period. The greatest increase ($\bar{x}$ = 1.4°) in maxillary relationship (SNA) occurred in males in GP II. The total change in the SNA angle for females was 0.4°.

Mandible. Changes in mandibular depth (Ar-Pog) in males were not significantly different in GP I and GP II. The change was significantly less in GP III but was still of substantial magnitude ($\bar{x}$ = 8.4 mm or 26% of the total change). In females the changes in the three growth periods were significantly different, with the largest change in GP I ($\bar{x}$ = 10.0 mm) and the least change in GP III ($\bar{x}$ = 2.2 mm).

Changes in mandibular relationship (SNB and SNPog) in the three growth periods were not significantly different in males. The least amount of increase in mandibular relationship occurred in GP III in females.

Maxilla-mandible. The least amount of change in

Table II. (Cont'd)

Variable	*Sex*	*GP I vs. GP II*	*GP II vs. GP III*	*GP I vs. GP III*	*15 to 17 years vs. 17 to 25.5 years*
N-Me	M	NS	S	S	NS
	F	S	S	S	NS
N-Ans'/N-Me	M	S	NS	S	NS
	F	S	NS	S	NS
Overbite	M	S	S	S	NS
	F	S	NS	S	NS
Posterior face heights					
Ar-Go	M	NS	NS	NS	NS
	F	NS	S	S	NS
S-Go	M	NS	NS	NS	NS
	F	NS	S	S	NS
Ar-Go/S-Go	M	S	NS	S	NS
	F	S	NS	S	NS
Anterior-posterior face heights					
S-Go/N-Me	M	NS	NS	S	NS
	F	NS	S	S	NS
MP-SN	M	NS	NS	S	NS
	F	NS	S	S	NS
NSGn	M	NS	NS	NS	NS
	F	NS	NS	NS	NS
			Soft-tissue profile		
Gl'-PR-Pog'	M	S	S	S	NS
	F	S	S	S	NS
Gl'-SLS-Pog'	M	NS	S	S	NS
	F	S	NS	S	NS
Holdaway angle	M	NS	S	S	NS
	F	S	S	NS	NS

maxillary-mandibular relationship (ANB and NAPog) in males was in GP II. In effect, more than one third of the total change in this relationship occurred after the age of 15 years.

In females, it was interesting to note that in GP III there was a tendency for these two angles to reverse their earlier trend.

There was a small overall change in overjet in both males ($\bar{x} = -0.2$ mm) and females ($\bar{x} = 0.8$ mm) during the 20-year period.

Changes in vertical facial parameters

Anterior face height. The increase in upper face height (N-Ans') was significantly greater in GP I in both males and females and significantly smaller in GP III.

The increase in total face height (N-Me) was similar to those in upper face height in females.

Most of the increase in the ratio of anterior face heights (N-Ans'/N-Me) and in overbite occurred in GP I in both males and females.

Posterior face heights. The magnitude of the increase in the posterior face heights (ArGo and S-Go) in males was not significantly different in the three growth periods. In females, however, there was a significantly greater increase in these parameters in GP I than in the other two periods of growth.

The changes in the ratio of posterior face heights (Ar-Go/S-Go) were similar in both males and females; that is, the ratio decreased in GP I and increased in GP II and GP III.

Anterior-posterior faces. The ratio of S-Go/N-Me and the SN:MP angle changed the most in males, and the least in females during GP III.

The changes in NSGn were not significantly different in the three growth periods for either males or females.

Changes in soft-tissue profile

The angle of total facial convexity (Gl'-PR-Pog'), which includes the tip of the nose, continued to increase significantly in the three periods of growth in both males and females, with the greatest increase in GP I and GP II.

The angle of facial convexity (Gl'-SLS-Pog'), which excludes the nose, decreased significantly in GP III in males, but there was little overall change in females.

Table III. Basic statistics on the incremental changes in the various parameters evaluated during four periods of growth—5 to 25.5 years or total change, 5 to 10 years or GP I, 10 to 15 years or GP II, and 15 to 25.5 years or GP III

Parameter	Sex	Total change				Change in GP I				Change in GP II				Change in GP III			
		$\bar{X}$	SD	Min.	Max.	$\bar{X}$	SD	Min.	Max.	$\bar{X}$	SD	Min.	Max.	$\bar{X}$	SD	Min.	Max.
Height (cm)	M	69.5	3.4	61.9	78.2	28.5	2.0	25.8	31.9	30.4	3.4	24.2	37.1	10.6	4.8	2.4	19.2
	F	55.5	3.2	48.9	59.9	30.0	4.0	22.2	37.1	23.3	3.8	16.9	28.4	2.6	2.2	0.3	9.5
Anteroposterior facial parameters																	
Maxilla																	
A-Ptm (mm)	M	10.6	4.2	6.3	24.0	3.9	3.8	1.0	19.3	4.5	2.0	0.8	10.5	2.2	1.3	0.6	5.8
	F	7.2	2.1	3.8	11.7	3.5	1.3	−0.1	5.1	2.4	1.6	0.2	6.1	1.3	1.3	−1.5	4.1
SNA (°)	M	1.8	1.5	−0.5	4.6	0.2	0.8	−1.2	2.5	1.4	0.9	−0.4	3.0	0.2	0.6	−1.0	2.0
	F	0.4	1.8	−2.6	2.9	−0.1	1.5	−2.7	2.9	0.2	1.1	−2.0	1.9	0.3	0.8	−0.8	2.0
Mandible																	
Ar-Pog (mm)	M	31.2	4.8	20.4	38.3	10.6	2.1	7.0	14.2	12.1	2.6	6.4	17.7	8.4	3.8	2.6	16.1
	F	21.0	2.8	16.2	26.2	10.0	1.6	7.5	12.4	8.7	1.6	5.4	11.0	2.2	1.4	1.0	6.3
SNB (°)	M	3.6	2.4	−1.1	8.8	1.0	1.2	−1.1	3.6	1.4	1.1	−0.5	3.8	1.2	1.2	−1.2	5.1
	F	1.8	2.0	−1.6	5.4	0.6	1.3	−1.9	2.6	1.2	1.0	−0.7	3.0	0	0.6	−1.0	1.1
SNPog (°)	M	5.7	2.3	0.9	10.6	2.1	1.0	0.3	4.8	1.9	1.1	−0.1	3.2	1.7	1.4	−0.7	6.0
	F	3.4	2.1	0.2	6.5	1.4	1.4	−0.8	3.5	1.7	0.9	−0.1	3.2	0.3	0.6	−0.8	1.9
Maxilla-mandible																	
ANB (°)	M	−1.6	2.0	−5.3	2.8	−0.5	1.4	−2.5	3.4	−0.1	0.9	−1.8	1.4	−1.0	0.8	−3.1	0.3
	F	−1.4	1.5	−5.5	0.5	−0.8	0.8	−3.0	0.4	−1.0	1.1	−3.5	0.7	0.4	0.6	−0.5	1.6
NAPog (°)	M	−7.8	4.8	−14.8	3.1	−3.8	2.5	−8.8	0.7	−1.1	2.4	−4.7	3.9	−2.9	2.0	−8.0	−0.2
	F	−5.6	3.8	−15.8	−0.3	−3.1	2.1	−8.1	−0.3	−2.7	2.4	−8.0	0.6	0.2	1.1	−1.4	−0.3
Overjet (mm)	M	−0.2	1.4	−3.8	1.2	0.4	1.3	−4.3	2.1	−0.5	0.9	−2.9	0.9	−0.1	0.7	−2.2	0.8
	F	0.8	1.1	−1.0	2.2	1.0	1.0	−0.8	2.8	−0.2	0.4	−1.4	2.8	0	0.4	−1.0	0.8
Vertical facial parameters																	
Anterior face heights																	
N-Ans' (mm)	M	15.4	3.4	11.3	21.2	7.2	2.6	4.4	17.7	5.8	1.6	3.3	9.3	2.4	1.2	−0.2	5.0
	F	10.6	1.8	8.2	15.3	6.2	1.4	2.6	9.0	3.5	1.2	1.6	6.6	0.9	0.6	0.1	2.5
N-Me (mm)	M	29.8	6.9	20.9	54.5	12.6	6.4	8.2	39.1	11.6	2.9	4.8	17.1	5.6	2.1	1.6	10.1
	F	21.9	1.9	17.8	24.4	10.5	2.9	1.5	15.4	8.2	2.2	4.3	14.8	3.2	1.2	1.9	7.0
$\frac{\text{N-Ans'}}{\text{N-Me}}$ (%)	M	3.0	3.8	−0.3	17.8	2.5	3.1	0.7	15.3	0.6	0.9	−0.9	2.1	−0.1	0.7	−2.0	1.2
	F	1.2	1.4	−1.4	4.9	1.7	0.8	0.2	2.6	0	1.0	−1.4	3.3	−0.5	0.3	−1.0	0.1
Overbite (mm)	M	2.0	1.1	0.1	3.6	2.1	1.2	−0.3	4.2	0.3	1.3	−1.9	3.0	−0.4	0.7	−2.2	0.5
	F	1.7	1.7	−1.6	4.8	1.4	1.7	−3.3	4.6	0	0.8	−1.6	1.4	0.3	0.8	−1.3	2.0
Posterior face heights																	
Ar-Go (mm)	M	20.4	6.4	8.7	37.4	5.6	3.8	1.1	18.8	7.6	2.5	3.6	11.4	7.2	3.4	2.5	14.8
	F	11.6	3.7	2.2	18.6	4.1	1.4	1.2	6.8	5.3	1.9	1.7	9.1	2.2	1.3	−0.7	4.6
S-Go (mm)	M	29.1	6.0	20.0	48.1	10.1	4.6	0	27.9	10.6	2.5	4.7	14.0	8.3	3.4	2.4	16.9
	F	18.5	2.6	11.7	22.5	8.4	1.7	5.8	11.8	7.4	1.7	5.2	11.8	2.7	1.2	0.5	5.1
$\frac{\text{Ar-Go}}{\text{S-Go}}$ (%)	M	1.1	3.6	−5.5	10.3	−1.6	2.0	−4.0	3.9	0.9	1.7	−2.5	3.5	1.9	1.5	−0.4	5.8
	F	−0.8	3.2	−7.6	4.4	−2.1	1.8	−5.8	2.6	0.1	1.0	−2.5	3.0	0.5	1.0	−1.3	2.1
Anterior-posterior face heights																	
$\frac{\text{S-Go}}{\text{N-Me}}$ (%)	M	7.7	3.4	−0.5	15.1	1.7	1.8	−0.9	5.3	2.4	1.3	−0.3	5.0	3.6	2.5	−0.8	9.7
	F	3.9	2.7	−2.7	8.7	1.7	2.0	−2.0	6.1	1.7	0.9	0.1	3.4	0.5	1.0	−1.4	2.3
MP-SN (°)	M	−6.7	4.7	−15.1	3.3	−1.4	3.0	−0.5	9.3	−2.3	1.7	−5.0	2.4	−3.0	2.3	−9.0	−0.2
	F	−3.5	2.6	−8.5	−0.5	−1.8	1.8	−5.0	1.2	−1.7	1.3	−3.7	0.4	0.1	0.9	−1.9	1.2
NSGn (°)	M	−1.5	2.3	−6.1	2.8	−0.2	1.1	−2.7	1.6	−0.4	1.2	−2.7	2.2	−0.9	1.2	−4.6	1.5
	F	0.2	1.9	−3.1	3.5	0.4	1.4	−1.8	2.9	−0.3	0.9	−1.9	2.0	0.1	0.7	−1.7	0.8
Soft-tissue profile																	
Gl'-PR-Pog' (°)	M	−7.3	4.6	−16.7	3.2	−3.2	2.3	−5.9	2.7	−5.1	2.9	−11.5	−1.4	1.0	2.8	−2.5	9.6
	F	−9.2	3.4	−15.3	−4.5	−4.9	1.5	−8.1	−2.7	−3.4	2.4	−9.4	−0.4	−0.9	1.3	−3.3	1.2
Gl'-SL-Pog' (°)	M	3.3	4.7	−6.2	12.2	−1.6	3.2	−5.7	7.4	−1.2	3.2	−7.4	4.6	6.1	2.5	1.9	10.6
	F	1.0	4.7	−6.4	9.8	−2.8	2.2	−6.3	2.1	2.1	2.6	−3.0	8.0	1.7	2.3	−2.4	7.1
Holdaway soft-tissue angle (°)	M	−6.9	3.4	−14.8	−2.0	−1.3	2.6	−7.5	2.8	−0.4	2.7	−4.6	6.2	−5.2	2.6	−9.8	−1.3
	F	−5.4	3.7	−13.1	1.2	−0.8	2.4	−7.0	2.9	−3.2	2.7	−9.0	1.6	−1.4	2.5	−6.3	3.5

M = Males; F = females; $\bar{X}$ = mean; SD = Standard deviation; Min. = minimum value; Max. = maximum value.

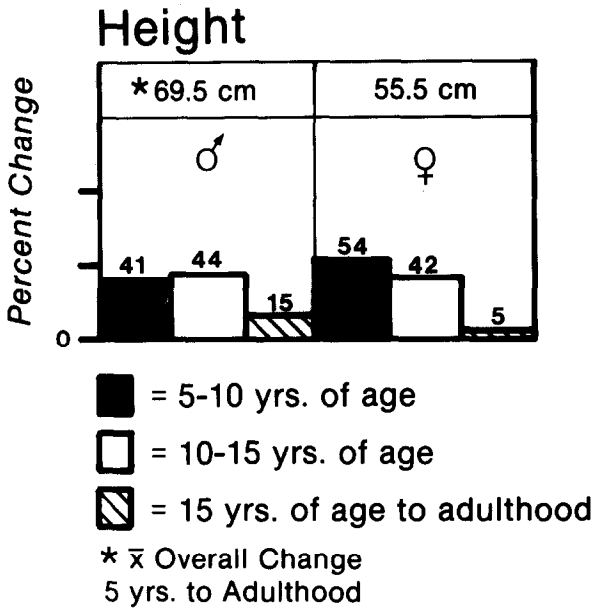

Fig. 2. Changes in standing height in three periods of growth.

The Holdaway soft-tissue angle decreased significantly in GP III in males and during GP II in females.

Changes within GP III (15 to 25.5 years)

The comparisons between the changes from 15 to 17 years and those from 17 to 25.5 years are presented in Table II. The findings indicate that the changes in two parameters—standing height and mandibular depth (Ar-Pog)—in males were significantly greater in the 15- to 17-year period than in the 17- to 25.5-year period. The changes in all other parameters for both males and females were not significantly different.

DISCUSSION

The data from this investigation provide basic information on the changes in size and relationship of various facial parameters between the ages of 5 and 25.5 years.

Most investigators involved in growth studies are acutely aware that longitudinal data are hard to collect. In the research that we have conducted on the Iowa Growth Study, we have made a conscious decision to report on a purely longitudinal sample rather than a mixed longitudinal one. It is true that implied in such a decision is a reduction in the size of the sample used. On the other hand, it greatly enhances the validity as well as the accuracy of interpreting the data on a longitudinal basis. The addition or deletion of subjects at different ages can influence both the mean values and the standard deviations from one year to another.[16] Hence, one is unable to determine whether the trends are a reflection of changes in the facial relationships

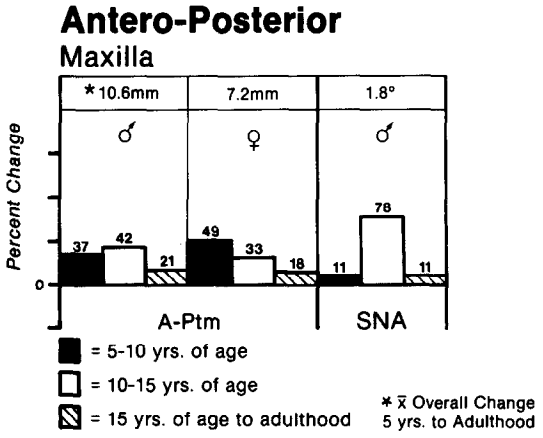

Fig. 3. Changes in maxillary anteroposterior parameters.

and dimensions or whether they are a reflection of the changes in the composition of the sample.

The size of the sample reported in this investigation compares favorably with other longitudinal studies. As an example, the Bolton longitudinal standards, derived from the Bolton study of 5,000 persons, were based on sixteen individuals from each sex.[15] Even then, some of these cases had voids which necessitated selective substitution from other cases with similar size and morphology. These comments are not meant to be critical in nature, or to detract in any way from the efforts of the persons involved in their collection. On the contrary, they point to the difficulties encountered by most of us in obtaining and reporting on the changes in dentofacial relationships in large numbers of persons between childhood and adulthood.

The change in facial dimensions and relationships during the various growth periods is one of the many important parameters that should be understood by the clinician who is planning the appropriate therapy for an individual with anteroposterior and/or vertical skeletal discrepancy.

When the data from this study are compared with previously published semilongitudinal and longitudinal data, certain similarities and differences are observed in the behavior of some of the parameters. As an example, SNA in males decreased by 0.5° between the ages of 6 and 16 years in one study,[16] while it increased by 3.3° between the ages of 5 and 18 years in another study[15] and by 1.8° in the present study. The respective changes for ANB were −2.1°, −1.0°, and −1.6° in males and −2.1°, −0.9° and −1.4° in females.

The differences in the magnitude of change in the various parameters in the three investigations could be attributed in large part to the composition of the sample (that is, longitudinal versus semilongitudinal).

One of the interesting findings in this investigation is related to the changes in SNB and SNPog. The total

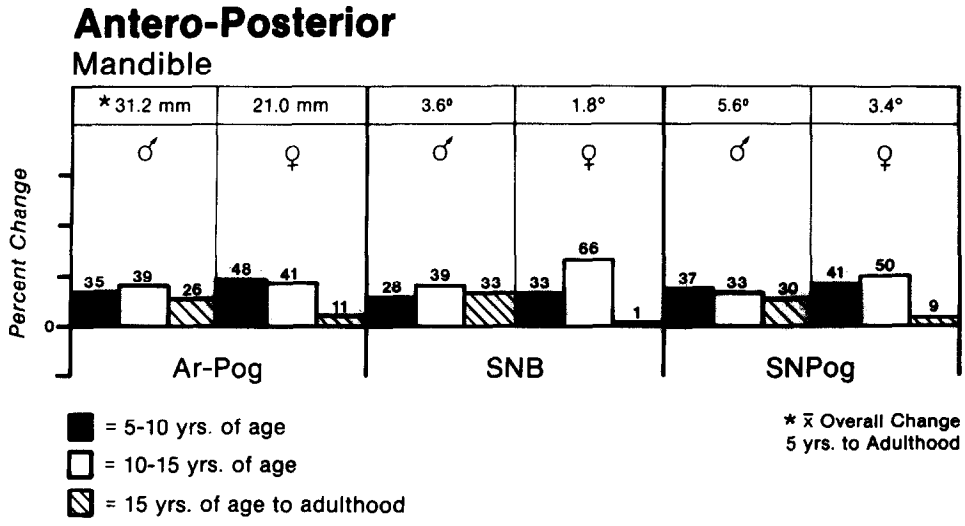

Fig. 4. Changes in mandibular anteroposterior parameters.

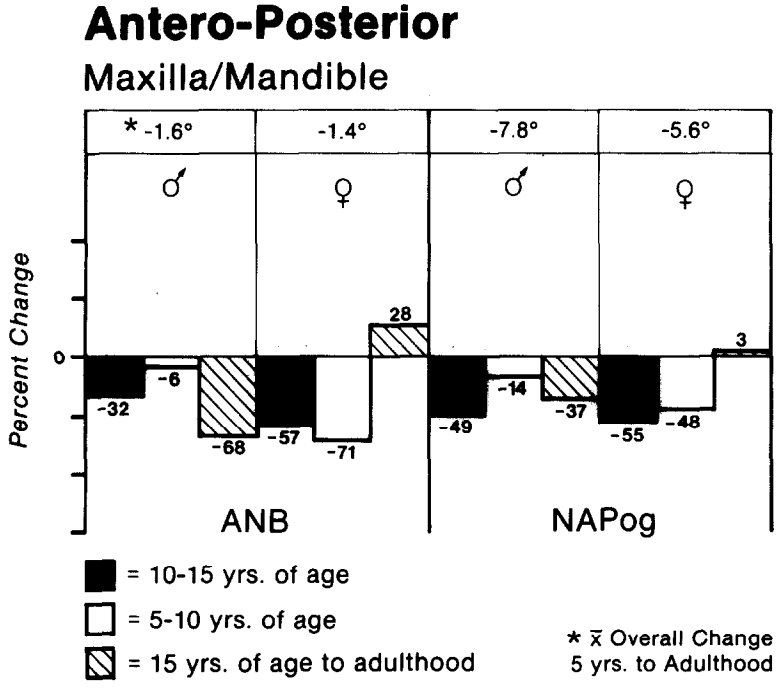

Fig. 5. Changes in maxillary-mandibular anteroposterior parameters.

changes in SNB in males and females were 3.6° and 1.8°, respectively, while those for SNPog were 5.7° and 3.4°, a difference of 2.1° in males and 1.6° in females. Since both angles are related to the same reference line SN, the difference in the magnitude of increase indicates a change in the position of point B and pogonion relative to each other and to the reference line. Both Björk[20] and Enlow[29] indicated that the area at point B is resorptive in nature while the area at pogonion is relatively more depository. With this in mind, one might explain the difference between the magnitude of increase in SNB and SNPog as being partly the result of the remodeling activity which accompanies the overall translation of the mandible forward and downward.

Orthodontists are interested in learning about the growth of the various parts of the face, not only as to where it occurs but also as to when it occurs or ceases to occur. Traditionally, most of the interest was concentrated on those periods during which maximum

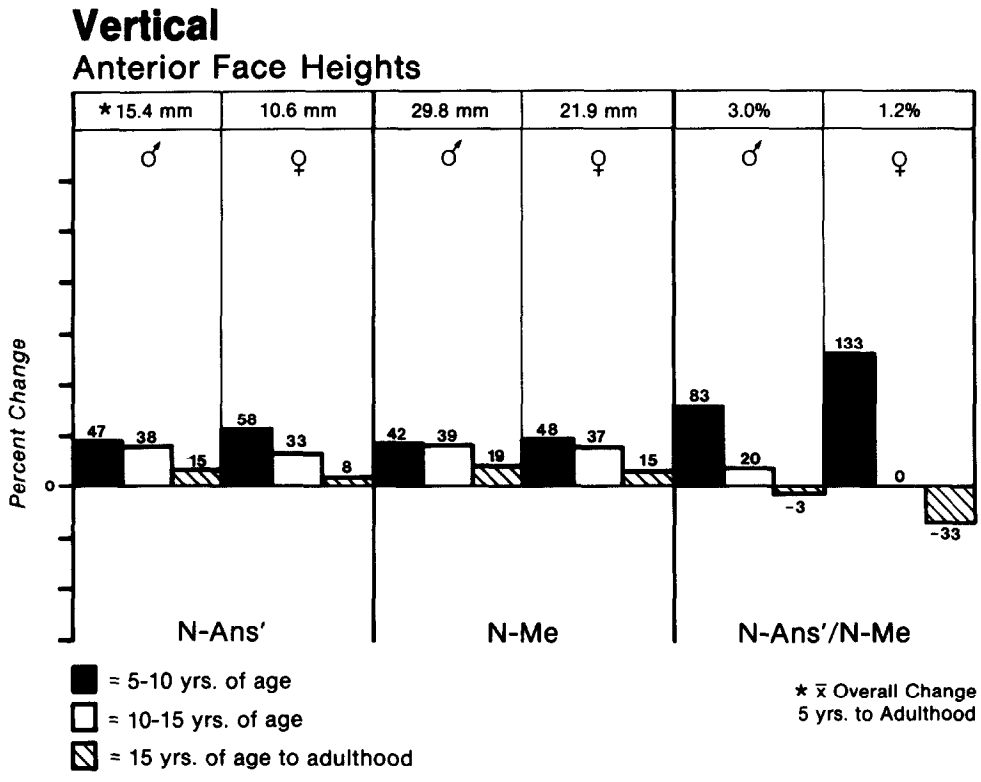

Fig. 6. Changes in anterior vertical parameters.

changes were evident. In the last 10 years there has been a significant increase in the number of patients undergoing orthognathic surgical procedures, and there is an ongoing debate[21] regarding the effects of orthognathic surgery in the adolescent patient. Therefore, it is important to have a better understanding of the overall changes that occur in the face during growth. Such an understanding should help the orthodontists and other clinicians plan the best treatment for their patients. With this in mind, some of the present findings can be of particular relevance to this discussion.

The comparisons between the three growth periods in this study indicated that, in general, most of the changes in females occurred in GP I and GP II, whereas in males the change was more distributed over the three periods. Only two parameters decreased significantly during GP III in females; these were the ratio of upper to total anterior face height and the Holdaway soft-tissue angle.

On the other hand, a number of parameters showed significant changes in GP III in males; while standing height increased by an average of 15% in GP III, there was a 20% increase in maxillary depth (A-Ptm) and an increase of only 11% in SNA. Changes of greater magnitude occurred in the mandibular parameters examined; for example, there was a 26% increase in mandibular depth (Ar-Pog) and approximately a 30% change in mandibular relationship (SNB, SNPog). Similarly, almost one third of the decrease in maxillary-mandibular relationship occurred during GP III. There was a greater average increase (28%) in the posterior face height (S-Go) than in the anterior face (19%), the combined effects of which could explain the fact that 45% of the total decrease in the MP:SN angle and 50% of the decrease in the ratio of the anterior to posterior face heights (S-Go/N-Me) occurred in GP III. Significant reduction in the convexity of the soft-tissue profile (tip of the nose excluded) occurred during GP III in males.

In previous publications[17, 18] on the same group of persons, the changes in GP I and GP II were discussed in detail. Of particular interest in this investigation is when, during GP III, does most of the change occur; that is, when does growth "end"? A comparison of the changes between the ages of 15 and 17 years with those occurring between the ages of 17 and 25.5 years indicated that, with the exception of standing height and mandibular length, in males there were no significant differences between the changes in the 15- to 17-year period and those that occurred between the ages of 17 and 25.5 years in all the other parameters evaluated. This, in turn, indicates that for those facial parameters

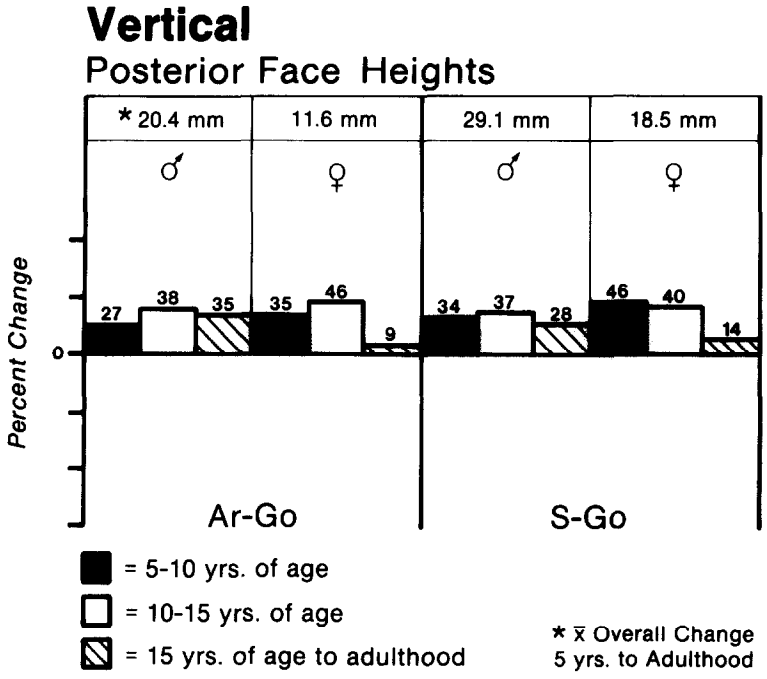

Fig. 7. Changes in posterior vertical parameters.

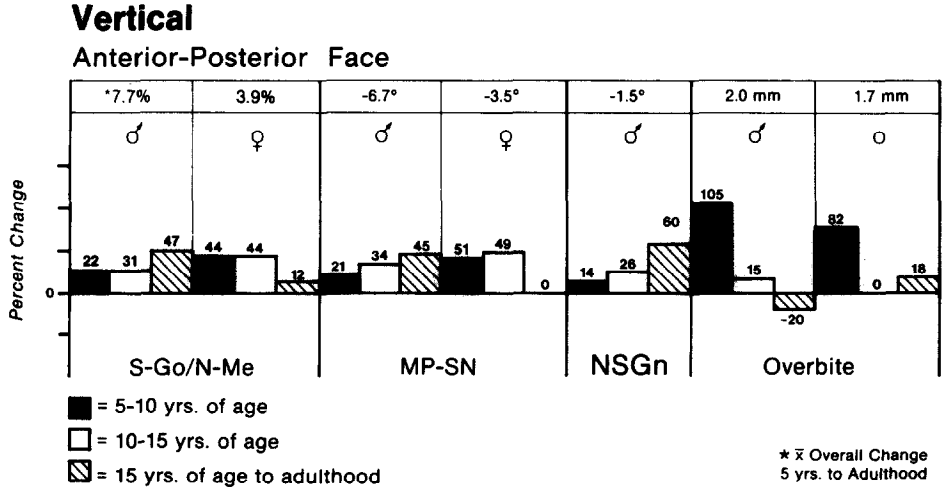

Fig. 8. Changes in anterior-posterior vertical parameters.

which continue to change significantly after the age of 15 years, there is as much change before age 17 as there is after that age. However, since the persons examined in this investigation did not have yearly records between the ages of 17 and 25 years, it is obviously impossible to determine when growth has effectively "stopped" between those ages.

These age-related changes in the skeletal, dental, and soft-tissue relationships emphasize the need to use age- and sex-matched cephalometric standards for the diagnosis and treatment of persons with malocclusion. Five such standards have been developed[19] and can be obtained from one of the authors (S.E.B.). For the vast majority of cases, only one of these standards need be used by the clinician to evaluate an individual patient before, during, and after orthodontic treatment.

A quantitative method of evaluating the changes that occur in the face between the ages of 5 and 25.5 years, as well as the changes in the different growth periods, is given in Table III. The difficulty that is encountered in predicting the growth of the face is partly reflected by the magnitude of the difference be-

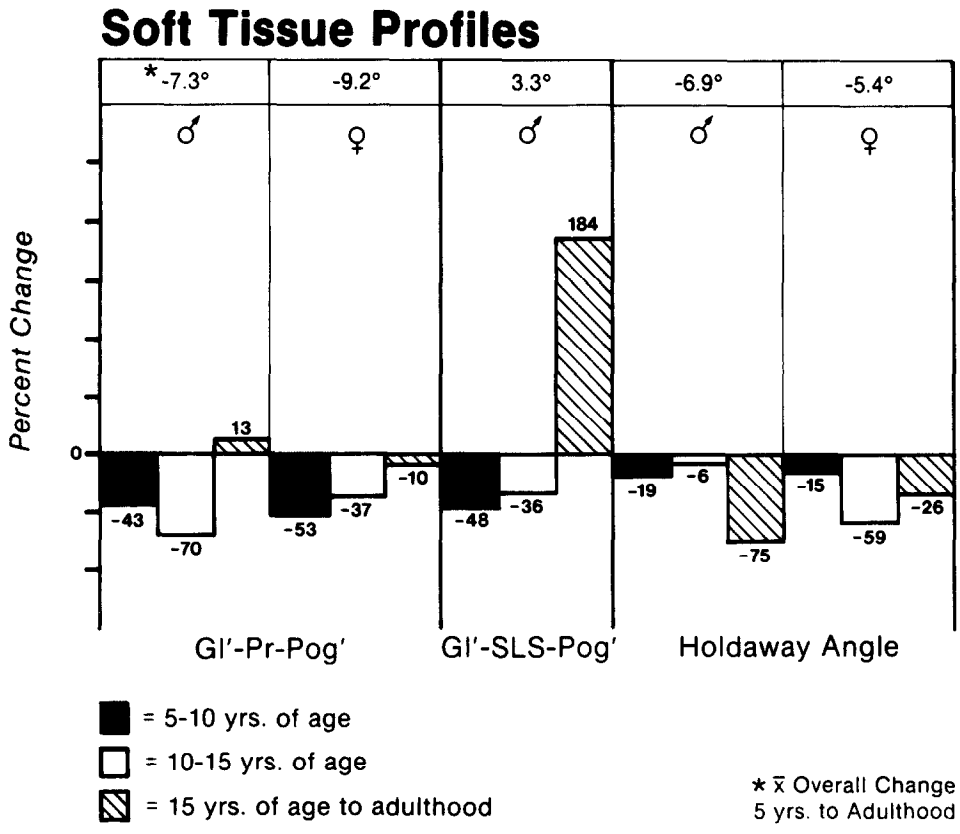

Fig. 9. Changes in soft-tissue parameters.

tween the minimum and maximum values as well as by the standard deviations of the mean changes in the various parameters.

A qualitative, and partly subjective, way of appreciating the changes that occur in the face is to examine the photographs of the ten persons presented in Fig. 10. The photographs of each person were taken at the ages of approximately 5, 10, 15, and 25.5 years. There is an obvious resemblance as well as an obvious difference between the various photographs of any one person. Once again it is of particular interest to examine the faces of both males and females at 15 and 25 years.

The presence of clinically significant growth in certain facial parameters in GP III, particularly in males, presents us with the dilemma of how to deal with it from an orthodontic and/or surgical viewpoint. This dilemma is, in part, based on the following constraints: (1) our inability to predict accurately how much a person will grow, in which direction, and for how long and (2) the question of the effects of surgery on the magnitude and/or the timing of the remaining growth.

In a study comparing various methods of predicting facial growth, Greenberg and Johnston[30] concluded that the accuracy of long-range forecasting is not significantly different from adding the average yearly incremental change for each facial dimension examined.

The works of Bayley and Pinneau,[31] as well as that of Tanner,[32] regarding our ability to accurately predict body growth were based on changes in standing height and weight. Unfortunately, facial dimensions and relationships are not as predictable within clinically useful limits.[17–19] As practitioners of orthodontics, we find that most of our estimates of future changes in facial dimensions are no better than adding average values[30] and our prediction of changes in growth direction is to a great extent, based on the pretreatment morphologic characteristics rather than on any accurate prediction of future change.[17, 18]

Since the amount and direction of change in the "later" stage of development is not accurately predictable, at least at this point, both the patient and the clinician should be aware of its presence since in certain individuals the change could either beneficially or adversely influence the orthodontic and/or surgical treatment results.

CONCLUSIONS

In addition to providing some basic information on the age-related changes in the size and relationships of a number of facial parameters between the ages of 5

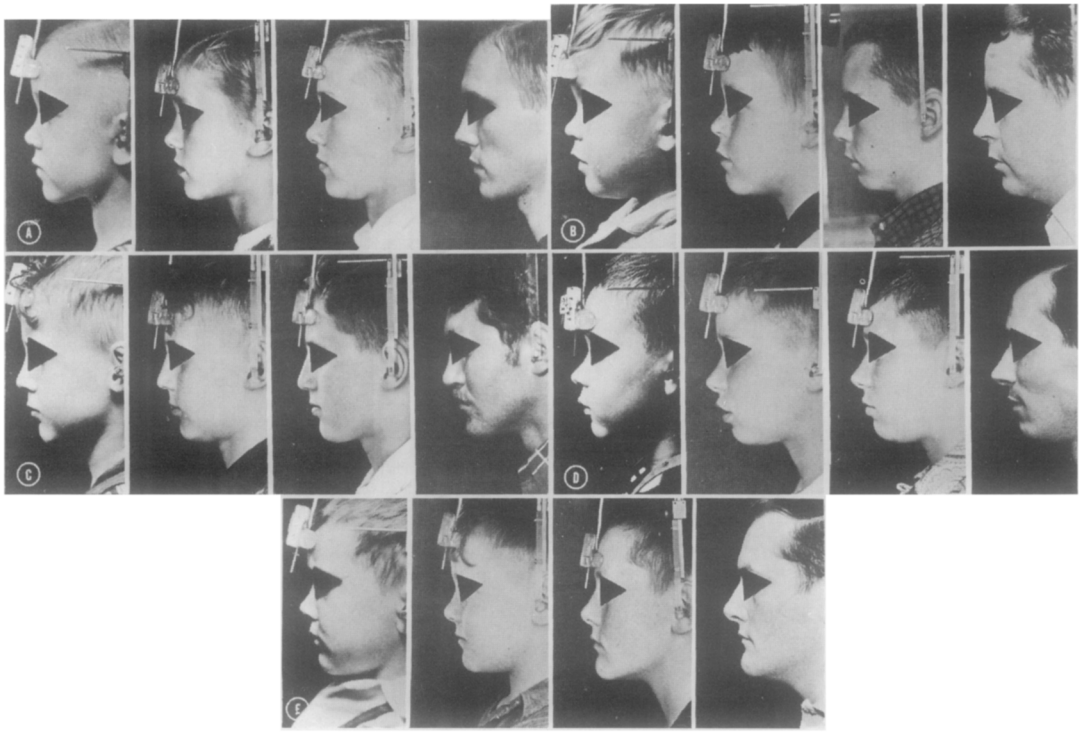

Fig. 10. Photographs of five males and five females taken at ages of approximately 5, 10, 15, and 25.5 years. No attempt was made to standardize face size of photographs at different ages.

Fig. 10, F-J. For legend, see Fig. 10, A-E.

and 25.5 years, the findings in this investigation support the following conclusions:

1. The timing and magnitude of change in the various facial parameters differ during the same growth period, as well as between males and females.

2. In general, most of the changes in the various parameters in females occurred during GP I and GP II while in males the changes were relatively distributed over the three periods of growth.

3. Changes in GP III for some parameters were of clinically significant magnitude; that is, in females the ratio of anterior face heights decreased significantly in GP III, whereas during GP III in males a significant increase occurred in Ar-Pog, SNB, and SNPog, while the maxillary-mandibular relationship, the ratio between anterior and posterior face heights, MP-SN angle, and the convexity of the soft-tissue profile continued to decrease significantly.

4. During GP III, with the exception of standing height and mandibular depth, there were no significant differences in the magnitude of change between the ages of 15 and 17 years and the change after age 17.

5. The data provided by this investigation are useful in describing mean trends but *not* in *predicting* changes for any one person. The trends indicate that there are significant changes occurring in the size and/or relationship of some facial parameters after the age of 15 years. The magnitude of these late changes, at least in certain individuals, could influence the orthodontic and/or surgical treatment results either beneficially or adversely.

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Reprint requests to:
Dr. Samir E. Bishara
Department of Orthodontics
University of Iowa
Iowa City, Iowa 52242