Growth of the Mandible Relative to a Cranial Base Line

VIRGINIA B. KNOTT, Ph.D.

Reports from the Iowa Facial Growth Study have been published by Meredith[3] on change in a mandibular dimension, and by Knott[1,2] on change in cranial base measures. These reports presented analyses of longitudinal data from *norma lateralis* roentgenograms for pogonion-postgonion diameter at ages from 5 to 17 years, and for several segmental measures of the cranial base at ages from 6 years to early adulthood. The subjects were healthy American-born Caucasoid children largely of northwest European descent and above average socioeconomic level. It was found that, while mandibular depth continued to increase until at least age 17 years, some portions of the cranial base showed almost no change with age.

The aim of the present study is to investigate from age 6 years to early adulthood the change in size and position of pogonion-postgonion diameter relative to a dimension of the cranial base.

MATERIALS AND METHODS

Definitions of the four roentgenographic landmarks used are as follows:

1. Frontal sinus point (F): most posterior point of the frontal sinus.

2. Pituitary point (P): point of greatest convexity between the anterior contour of sella turcica and the sphenoid plane.

3. Pogonion (C): most anterior point of the mandible in a plane perpendicular to a base plane through menton and the lowest projection of the right and left mandibular bodies in their ramal regions.

4. Postgonion (R): midpoint of a transverse line between the posterior borders of the mandibular rami at points equidistant with pogonion above the base plane.

Measures of the quadrilateral formed by the four landmarks were taken. They were designated:

1. Cranial base segment, F to P
2. Mandibular depth, R to C
3. Anterior facial height, C to F
4. Posterior facial height, P to R

Four ages were selected for study: 6 years, 12 years, 15 years, and an early adult age (between 24 and 29 years). At the childhood ages, three films were used as a means of obtaining highly valid measures: for age 6 years, composite measures were used from films at 5.5, 6.0 and 6.5 years; for age 12 years, pooled values were secured from films at 11.5, 12.0, and 12.5 (or 13.0) years. When films were on file at ages 14, 15 and 16 years, these were used to determine the 15-year value; otherwise, films at the first two ages were used. One film was used for the adult value.

Satisfactory films with dental arches in occlusion at the specified ages were in the Growth Study files for forty individuals, 20 of each sex. For 11 males and 12 females an additional film at age 17 years was available. Seventy-five per cent of these subjects had fair to excellent occlusion; the remainder had received orthodontic treatment for diverse problems.

Two independent measures were made between the landmarks on each film; when differences were greater than 0.2 mm, measurements were repeated. The obtained values were corrected for roentgenographic enlargement and averaged to obtain a single

TABLE I

Means and Standard Deviations for Four Dimensions (mm) on 20 Males and 20 Females

Dimension	Sex		Age 6	12	15	17*	26**
Cranial Base Segment F-P	M	Mean	46.9	47.7	48.5	48.5	48.6
		S.D.	2.8		2.5		2.3
	F	Mean	46.3	47.2	47.5	47.5	47.5
		S.D.	2.0		2.1		2.2
Mandibular Depth R-C	M	Mean	63.7	73.2	77.9	80.0	80.8
		S.D.	3.3		4.3		4.7
	F	Mean	61.7	69.6	72.6	73.8	74.2
		S.D.	2.6		3.2		3.3
Anterior Facial Height C-F	M	Mean	90.3	102.9	110.3	114.6	117.6
		S.D.	4.9		6.1		6.4
	F	Mean	87.0	101.2	105.3	107.0	108.4
		S.D.	4.4		5.3		5.2
Posterior Facial Height P-R	M	Mean	58.2	68.8	75.7	81.8	86.0
		S.D.	4.5		5.5		6.7
	F	Mean	54.4	66.5	70.5	71.9	73.4
		S.D.	3.9		4.3		4.9

* Means at age 17 years estimated from changes for 11 males and 12 females.
** Ages between 24 years and 29 years.

value for each dimension at each specified age.

Data on two additional linear roentgenographic dimensions from a previous study[2] were available for multivariate analyses: (1) the distance from nasion (N) to point F, designated the frontal (or sinus) segment and (2) the distance from point P to the anteriormost point on the occipital condyle (O), the postsphenoid segment (posterior cranial base).

In addition to linear dimensions the angles of the quadrilateral were determined at ages 6 years, 15 years, and young adulthood. Repeated determinations were made on the several films, then averaged to obtain single angular values for the specified ages.

Linear Dimensions

Magnitude findings

Statistics for the four dimensions are presented in Table I and Figure 1. At ages 6 years, 12 years, 15 years, and in early adulthood, the same forty individuals are represented. The values listed as means for age 17 years are estimated from the dimensional changes found for 11 males and 12 females before and after this age.

It is found:

1. The portion of the anterior cranial base behind the frontal sinus (F-P) averages near 46.5 mm for both males and females at age 6 years. There is an increase in this depth of approximately 1.5 mm over the next nine years, with no change after age 15 years.

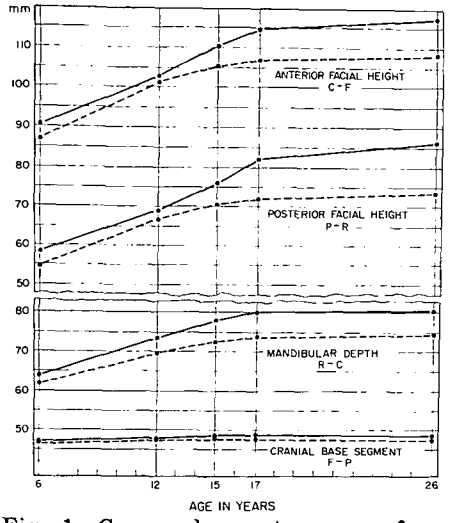

Fig. 1 Curves drawn to means from longitudinal data for four craniofacial dimensions. Means on males are connected by solid lines; means for females, by broken lines.

2. Mandibular depth (R-C) at age 6 years averages 63.7 mm for males and 61.7 mm for females. In early adulthood, the means are larger by 17.1 mm for males and 12.5 mm for females.

3. Both anterior and posterior sides of the facial quadrilateral yield greater absolute and relative increases in means from age 6 years to adulthood than does the mandibular depth dimension. At age 6 years, the anterior dimension (C-F) averages 90.3 mm for males and 87.0 mm for females; twenty years later these values are higher by 27.3 mm and 21.4 mm. The posterior dimension (P-R) averages, for males and females, respectively, 58.2 mm and 54.4 mm at age 6 years, 86.0 mm and 73.5 mm in early adulthood.

4. Accepting the hypothesis that means for males exceed means for females when the null hypothesis can be rejected at the .01 level of confidence, it is found that males show a larger mean posterior facial height at age 6 years, a larger mean pogonion-postgonion diameter at age 12 years, and larger means for both these dimensions at age 15 years. By early adulthood males also exceed females in anterior facial height. At none of the ages studied is the cranial dimension (F-P) significantly different for the two sexes.

5. In adulthood, the greatest difference in facial dimensions between the sexes is seen in the distance between the pituitary point P and the ramal point R. This posterior face height is less than 75.0 mm for 75 per cent of the females and greater than 85.0 mm for 50 per cent of the males. Dimensions of the cranial base which were found by Knott[2] to show a comparably marked sex difference are the frontal segment (N-F) and the postsphenoid measure (P-O).

6. Coefficients of correlation between adult dimensions for (a) anterior facial height (F-C) and posterior facial height (P-R), (b) cranial depth segment (F-P) and mandibular depth (R-C), (c) posterior cranial base (P-O) and posterior facial height (P-R), and (d) frontal base segment (N-F) and mandibular depth were computed for each sex. In no instance could the hypothesis of zero correlation be rejected at the .05 level of confidence.

7. Since it was found that sex differences in adult size were large for the dimensions P-R, N-F, and P-O, and that these dimensions varied independently, the discriminant function was computed to determine an estimated probability of misclassification of sex on the basis of size of these three dimensions. This was found to be 5.1 per cent; applied to the forty individuals of the present sample, three individuals were misclassified.

Increment findings

Table II exhibits the sex-specific distributions of change between ages 6 years and young adulthood for the four dimensions; Table III shows the

TABLE II

Distributions of Individual Change in Facial Dimensions for 11 Males from Age 6 Years to Early Adulthood*

Interval Midpoint (mm)	Cranial Depth F-P		Mandibular Depth R-C		Anterior Face Height C-F		Posterior Face Height P-R	
	M	F	M	F	M	F	M	F
39					1			
36					1		1	
33					1		3	
30					5		4	
27					5	2	5	
24			2		4	4	5	3
21			2		3	10	2	6
18			7	1		4		7
15			6	8				2
12			3	4				2
9				7				
6	1							
3	10	8						
0	9	12						
Mean (mm)	1.7	1.2	17.1	12.5	27.4	21.4	27.8	19.0
S.D.	1.39	0.93	3.86	3.29	3.67	2.33	4.45	2.72
S.E.	0.32	0.21	0.89	0.76	0.84	0.54	1.02	0.62
Sex difference (.01 level)	No		Yes		Yes		Yes	

* Between age 24 years and 29 years.

distributions of change occurring in the three facial dimensions after 15 years of age; and Table IV gives changes in the three facial dimensions after age 17 years.

From the tables and additional analyses it is found:

1. The distributions of change from age 6 years to early adulthood in cranial base depth (F-P) do not differ for the two sexes. In contrast, rather marked sex differences are found in increment distributions for the three facial dimensions shown in Table II.

2. During the childhood years from 6 to 12 years, increases in facial height were somewhat greater for girls than boys, while mandibular depth increased more for boys (9.5 mm) than girls (7.9 mm). The difference in mandibular depth change is statistically significant (.01 level).

3. Between age 12 years and young adulthood, males show a larger increase than females for each of the facial dimensions. The sex differences in mean increase are greater for the height dimensions. Females averaged around 7.0 mm increase in anterior and posterior facial heights, whereas males averaged increases over twice this amount. Overlap of corresponding distributions for the two sexes is small.

Pogonion-postgonion depth for females shows a mean increase of 4.6 mm, and dispersion of increments from

TABLE III

Distributions of Individual Change in Facial Dimensions for 20 Males and 20 Females from Age 15 Years to Early Adulthood

Interval Midpoint (mm)	Dimension: Mandibular Depth R-C		Facial Heights: Anterior F-C		Facial Heights: Posterior P-R	
	M	F	M	F	M	F
18	1				1	
16					2	
14					2	
12			1		2	
10			4		5	
8	1		6		4	1
6	2		3	2	2	3
4	8	4	5	8	2	3
2	5	11	1	9		10
0	4	5		1		3
Mean*	2.9	1.6	6.8	3.1	10.3	2.9
S.D.	2.04	1.07	2.54	1.51	3.89	2.11
S.E.	0.47	0.25	0.58	0.35	0.89	0.48
Sex difference (.01 level)	Yes		Yes		Yes	

* At the .01 level of confidence, the hypothesis of zero change may be rejected for each of the six means.

TABLE IV

Distributions of Individual Change in Facial Dimensions for 11 Males and 12 Females from Age 17 Years to Early Adulthood

Interval Midpoint (mm)	Dimension: Mandibular Depth R-C		Facial Heights: Anterior F-C		Facial Heights: Posterior P-R	
	M	F	M	F	M	F
8					1	
7						
6					2	
5			2		2	
4			2		1	
3			3	3	3	
2	3	1	2	3	1	8
1	4	3	2	4		1
0	4	8		1	1	3
-1				1		
Mean	0.8*	0.4	2.9*	1.5*	4.1*	1.5*
S.E.	0.24	0.17	0.37	0.36	0.65	0.28

* The hypothesis of no mean change is rejected at the .01 level of confidence.

1.0 and 9.0 mm; for males, the average is 7.6 mm and the range extends from 2.5 to 12.2 mm.

4. Table III shows that the longitudinal data after age 15 years on both males and females yield mean increases different from zero (.01 level of confidence) in the two facial heights and in mandibular depth. Least change is found in pogonion-postgonion diameter on females; however, three of four females increased between 1.0 mm and 4.0 mm.

5. For both males and females, hypotheses of no change between ages 15 years and 17 years may be rejected at the .01 level of confidence for the dimensions of mandibular depth and anterior facial height. For males, there is also a significant increase in posterior facial height.

6. Referring to Table IV on changes subsequent to age 17 years, it is seen that the three facial measures on both males and females show a change dependably different from zero except for mandibular depth on females. Largest average change is 4.1 mm in posterior facial height for males.

7. No relationship was found between changes from 6 years to early adulthood in (a) anterior and posterior facial height, (b) cranial and mandibular depth, (c) posterior cranial base and posterior facial height, or between (d) increase in frontal base segment (N-F) and mandibular depth.

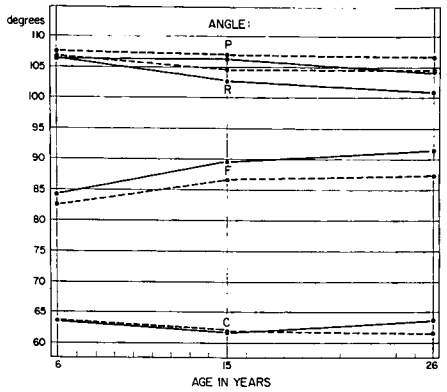

Fig. 2 Curves drawn to means from longitudinal data for four angles of a craniofacial quadrilateral (see text). Means on males are connected by solid lines; means on females, by broken lines.

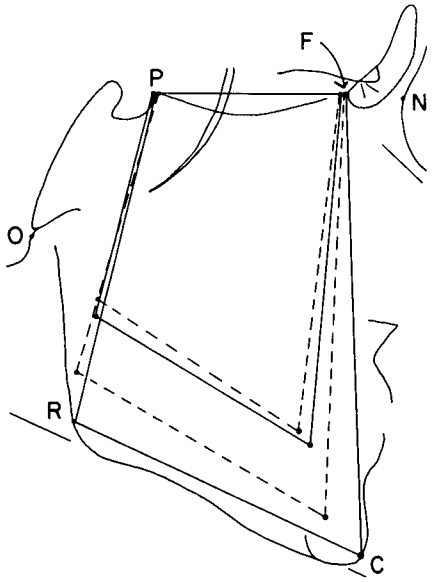

Fig. 3 Mean dimensions of craniofacial quadrilateral at age 6 years and near 26 years for 20 males (solid lines) and 20 females (broken lines).

Angular Measures

Magnitude findings

Figure 2 shows mean trend lines for the interior angles of the craniofacial quadrilateral on the twenty subjects of each sex studied at age 6 years, age 15 years, and in early adulthood. The means, together with standard deviations, are listed in Table V. It is found:

1. At age 6 years, there is no significant difference between boys and girls in magnitude of any of the four angles.

2. In adulthood, angle F (the angle between the cranial base segment and the anterior facial line) yields a greater average size for males than for females. Angle F was larger for 40 per cent of the males than for any female.

3. The trend lines drawn to the mean

TABLE V

Means and Standard Deviations of Angles of Craniofacial Quadrilateral (in Degrees) for 20 Males and 20 Females

Angle	Sex		Age in Years 6	15	26*
P	M	Mean	106.0	106.1	104.3
		S.D.	3.5	3.5	4.2
	F	Mean	107.4	107.0	106.8
		S.D.	3.9	4.7	4.4
R	M	Mean	106.2	102.7	100.9
		S.D.	3.3	4.7	5.8
	F	Mean	106.6	104.5	104.4
		S.D.	5.3	5.3	5.8
F	M	Mean	84.2	89.4	91.4
		S.D.	4.4	4.2	4.8
	F	Mean	82.4	86.6	87.2
		S.D.	3.2	4.0	4.1
C	M	Mean	63.6	61.8	63.4
		S.D.	2.1	3.0	4.1
	F	Mean	63.6	62.0	61.6
		S.D.	2.9	3.1	3.2

*** Median of ages ranging from 24 years to 29 years.**

for angles C and P are nearly horizontal over the twenty year period studied.

4. Increase in mean size of angle F is counterbalanced by decrease in angle R.

Figure 3 is presented to clarify change in mean values for linear and angular measures considered jointly. Four quadrilaterals are superimposed on line F-P. Inspection of this figure reveals differences and similarities between the sexes and between age 6 years and young adulthood.

Increment-decrement findings

Data on angular change between age 6 years and early adulthood presented in Table VI show:

1. On the average angle P (the angle between F-P and P-R) does not change with age. For 75 per cent of the subjects the change in this angle was less than 4 degrees.

2. The angle at postgonion (R) averaged less in adulthood than at age 6 years. The decrease was greater for males than for females. The maximum decrease for females was 6.2 degrees while 50 per cent of the males had decreases larger than this amount.

3. Both males and females yield a significant increase (.01 level) in angle F. The increase averages near 5.0 degrees for females and 7.0 degrees for males. All but two of the forty changes were in the direction of increase, ranging up to 13.0 degrees. Increase in this angle indicates a more forward placement in adulthood of pogonion (C) relative to the base line (F-P).

4. Change in the angle between

TABLE VI

Distributions of Individual Change for 20 Males and 20 Females from Age 6 Years to Adulthood in Four Craniofacial Angles

Midpoint (degrees)	Angle P		Angle R		Angle F		Angle C	
	M	F	M	F	M	F	M	F
12					5	1		
9					5	2		
6		1	1		5	8	2	
3	5	3		3	3	7	4	
0	5	10	3	4	3	2	9	11
-3	7	5	3	11			2	5
-6	2		8	3			3	4
-9	1	1	3					
-12			2					
Mean	-1.7	-0.6	-5.3*	-2.2*	7.2*	4.8*	-0.2	-2.0
S.E.	0.82	0.66	0.93	0.54	0.95	0.61	0.76	0.45

* The hypothesis of zero change may be rejected at the .01 level of confidence.

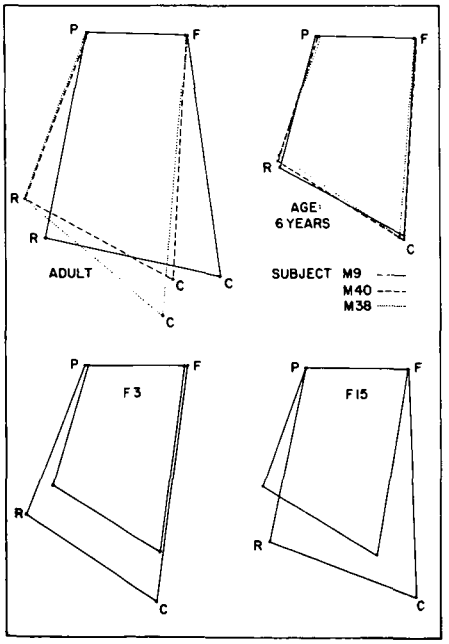

Fig. 4 Craniofacial quadrilaterals at age 6 years and in young adulthood: (top row) three males with good occlusion; (bottom row) two females who received orthodontic treatment for Class II, Division 1 malocclusion.

F-C and C-R was positive for 50 per cent of the male subjects, while none of the female subjects showed an increase in this angle.

Figure 3, as indicated previously, shows the mean trends of change in the facial quadrilateral for the twenty-year age span under study. To illustrate variation of change among individuals, two additional figures are presented.

Figure 4, upper section, depicts three males differing by relatively small amounts at age 6 years and differing considerably in changes with age: e.g., measure R-C increased 18.1 mm for subject *M* 9 and 10.8 mm for subject *M* 40; C-F increased 20.5 mm for *M* 9 and 38.0 mm for *M* 38; angle R decreased 12.2 degrees for *M* 9 38 and increased 5.2 degrees for *M* 38. Changes from age 6 years to age 27 years for two females are contrasted in the lower portion of Figure 4. The occlusion of each of these individuals was considered to be Class II, Division 1 at age 6 years; each received orthodontic treatment including removal of the upper first premolar teeth.

Figure 5 shows the change between

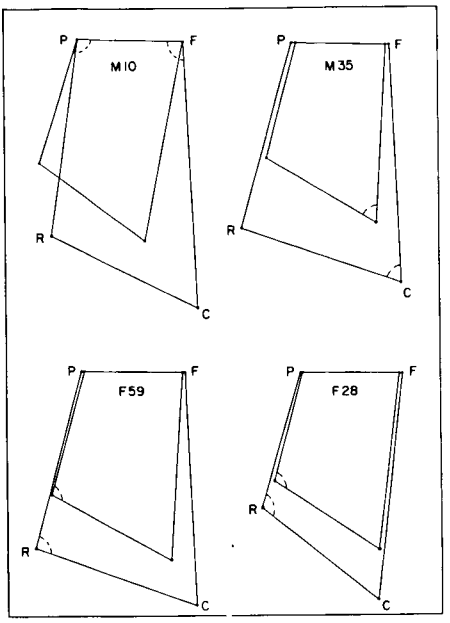

Fig. 5 Craniofacial quadrilaterals at age 6 years and in young adulthood on four individuals with varied patterns of growth.

age 6 years and early adulthood in four individuals. These individuals were selected to illustrate, with respect to the sample studied, the greatest increase in angle C (M 35), the greatest decrease in angle P and increase in angle F (M 10), the female (F 28) with the most increase in angle R, and the female (F 59) with the most decrease in angle R.

Summary

The change in size and position of a mandibular diameter relative to a cranial dimension was investigated using longitudinal roentgenographic data from age 6 years to age near 26 years for twenty individuals of each sex. Measures were made of the sides and angles of the quadrilateral formed by the cranial segment, the mandibular dimension, and the lines connecting their respective anterior and posterior endpoints.

Over the full age period studied, increase in the cranial depth dimension averaged 1.7 mm for males and 1.2 mm for females in contrast to mean change in depth of the mandible of 17.1 mm on males and 12.5 mm on females. Larger increases were registered in anterior and posterior facial heights (27.4 mm and 27.8 mm for males; 21.4 mm and 19.0 mm for females).

After age 15 years no change in magnitude was found for the cranial dimension but the three facial dimensions showed significant mean increase for both males and females. Increases were also found after age 17 years in the three measures on males and for the two facial heights on females.

Individual variation of change in size and angles is shown in tables and presented in figures by means of quadrilaterals at age 6 years and in early adulthood with superimposition on the cranial base segment.

University of Iowa
Institute of Child Behavior and Development
Iowa City, Iowa 52240

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