Changes in Anterior Facial Height in Girls During Puberty

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One of the perplexing problems in the field of orthodontics is the prediction of craniofacial growth: the future size of a part, the future facial pattern, and the timing of growth events. Because growth does not proceed evenly, certain facial dimensions demonstrate marked changes in their velocity, or spurts. The difference in timing of these spurts enhances the difficulty of growth prediction. Knowledge of the onset, duration, and rate of growth during a spurt, especially during puberty, constitutes valuable information to the orthodontist.

The literature has demonstrated that the skeletal pattern of an individual can be modified by means of orthopedic forces in the presence of growth. One can see that prediction of not only the amount of growth, but also its timing and velocity, plays an important part in treatment planning. Despite the great interest and vast amount of research on the subject of craniofacial growth prediction, the methods employed are not the most sophisticated. Useful predictive procedures have evolved for most size measures of biologic meaning but very little is known about predicting velocity and onset of particular growth events as well as changes in the growth vector or direction of growth.

Ricketts' method was based on a detailed laminagraphic temporomandibular joint study combined with the analysis of lateral and frontal headfilms.[5] Special planes and references were explored to pursue the effects of growth on treatment or vice versa.

Johnston devised a method of predicting growth based on the addition of mean increments by direct superimposition on a printed grid.[3] Menarche and spurt of growth in height have often been utilized to evaluate the facial growth potential. Bambha concluded that the spurt of growth in height occurred slightly before the spurt of facial growth.[1] Shuttleworth found menarche to occur in the decelerative phase of growth in stature.[7]

In a longitudinal study of mandibular growth in 20 females, Tofani concluded that there was a significant difference in the amount of growth before and after menarche.[8] Although some growth did occur after menarche for most of the sample, the amount was greater before than after. The preceding findings were in agreement with those of Shuttleworth that menarche is an indication of growth deceleration.

This study was undertaken to find out: 1) if, in females, timing and amount of the pubertal spurt of growth in upper and lower anterior facial height vary within the same individuals for both dimensions; 2) if any relation can be demonstrated between timing and magnitude of the spurt of growth in the mandible and that of the anterior facial height at puberty; 3) at what time menarche or onset of epiphyseal-diaphyseal fusion occurs in regard to the peak of growth of the upper, lower, and total anterior facial heights for each of the patients.

Materials and Methods

The serial lateral cephalometric roentgenograms used in this study were obtained from the files of the Bolton Study at Case Western Reserve University. The apparatus used for this sample was the Broadbent-Bolton cephalometer with the standard 5 foot distance be-

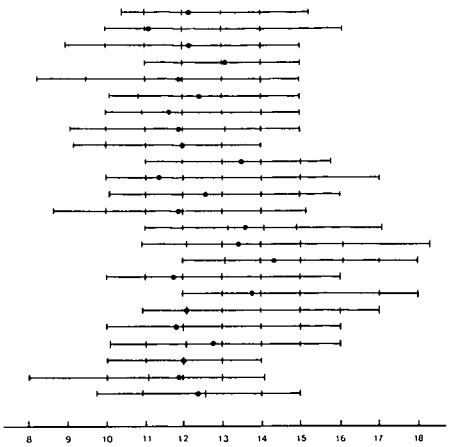

Fig. 1 Sample distribution. Availability of cephalograms (vertical lines) at different ages. Black dot represents time of menarche.

tween the target and the midsagittal plane of the patient with the head oriented in Frankfort. Since this study is concerned with growth changes, the magnification error is not important and therefore not reduced to zero. The sample consisted of 24 Caucasian females from whom records were taken approximately yearly. Figure 1 illustrates the sample distribution.

The criteria utilized for selection were: 1) availability of yearly lateral cephalometric radiographs where possible 2 to 3 years prior to and after menarche, 2) presence of normal anteroposterior and vertical skeletal relationships on the first cephalogram of the series according to the archial analysis,[6] 3) no permanent teeth congenitally missing or extracted, 4) absence of orthodontic treatment, and 5) availability of serial hand-wrist films.

Menarche was recorded by interview. The error that can be introduced by this method of recording due to unreliability of memory was reduced since these girls were selected from a group of children who had been included in the long-term investigation of facial growth by the Bolton Study. Only when the exact age at menarche was known was it recorded.

In 4 cases, however, menarche was not recorded. In these cases onset of epiphyseal-diaphyseal fusion was utilized since its occurrence corresponds to the time when menarche takes place. Onset of fusion in the distal phalanges of the fingers was obtained through assessments of hand-wrist X-rays taken annually as a part of the many records gathered for each individual.

Whenever yearly absolute change was not available either due to a missing radiograph in the series or difficulty in locating landmarks on the cephalometric radiograph, the average behavior of the group with the peak at the same age was utilized to determine in the following way the behavior of the subject whose missing date existed: The amount of growth found in the corresponding two years was split into two values using a sharing key corresponding to the average behavior of the whole group (with peak at the same age). In the case of different missing data because of poor accuracy in the same series of one girl, the girl was disregarded for that particular measurement.

Twenty roentgenographic anatomic landmarks were identified. In this study only four linear measurements related to the topic will be reported (Fig. 2). The lower anterior facial height (LAFH) is defined as the distance between points ANS (anterior nasal spine) and Me (menton); the upper anterior facial height (UAFH) as the distance between points Na (nasion) and ANS; and the total anterior facial height (TAFH) as the distance between Na and Me. The mandibular length was measured as the distance between Ar (articulare) and Pog (pogonion). For the values of Ar-Pog of 20 out of the

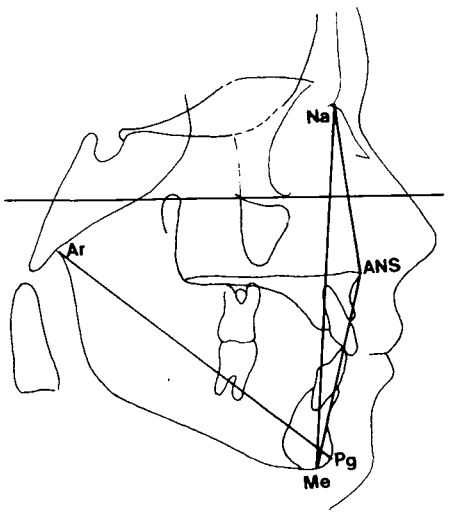

Fig. 2

24 patients we refer to the findings of an earlier publication[8] although these values were adapted to the accepted methodology for this paper.

Only when anatomic landmarks were accurately visible were they traced. Twenty measurements were done twice by each investigator to determine the error of the method and to check the reliability. None of the t-values was significant ($p < 0.05$).

When double images of bone contours appeared on the cephalogram, the midpoint of the two shadows was traced. The coordinates of each of the points were registered by means of a digitizer and transferred to an IBM 029 card punch machine. The punch cards were fed into the University of Pittsburgh PDP 10 computer system and stored on disk files. Individual incremental (growth) curves were plotted for each dimension measured with changes recorded in 0.1 mm and timing in chronological age.

Mean curves were derived by dividing the total sample into groups according to age at maximum pubertal growth increment. This method avoided loss of individual variability that would have occurred if one single average curve had been utilized.[7]

Findings

Timing (Table I)

In 7 (30%) of 23 girls the peak velocity occurred simultaneously for Na-ANS and ANS-Me. In 10 (43%) the Na-ANS peak velocity preceded the one for ANS-Me by approximately one year. In 2 (9%) of the girls the peak velocity for Na-ANS occurred within a year after the one for ANS-Me. In 19 (83%) girls there was either no difference or a maximum of one year difference between the peak velocity of these two dimensions of facial height (Na-ANS and ANS-Me).

For 6 (29%) of 21 girls the peak velocity occurred simultaneously for ANS-Me and Ar-Pog. In 3 (14%) the peak velocity for ANS-Me took place one year before that of Ar-Pog and in

TABLE I

Chronological age at peak velocity for the different parameters. Girls are identified by an alphabetic symbol.

Spurt at Parameter	10y	11y	12y	13y	14y	15y	16y
ANS-Me		ABCD	EFGH IKLM	NOPQ RSTU	VWX		
Na-ANS	LM	BDEF GHIT	ACKN PQSU	ORV	WX		
Na-Me	L	DHG	ABCEFI KMQSUY	OPRTX	N	V	W
Ar-Pog		FTY	ABGHK LNOQU	MPSVX	DRW		

7 (33%) one year after it. In 16 (76%) girls there was either no difference or a maximum of one year difference between the peak velocity of these two dimensions (ANS-Me and Ar-Pog).

For Na-ANS and Ar-Pog in 9 (43%) of 21 girls the peak velocity occurred simultaneously. Na-ANS peak preceded the peak velocity of Ar-Pog within a year in 6 (29%) patients and occurred one year after in 2 (10%) of the girls. In 17 (81%) girls there was either no difference or a maximum of one year difference between the peak velocity of these two dimensions (Na-ANS/Ar-Pog).

In 12 (52%) out of 23 girls the peak velocity occurred simultaneously for Na-ANS and Na-Me. Na-ANS peak preceded the peak velocity of Na-Me in 5 (22%) of the girls. In 18 (87%) of the 23 girls there was either no difference or a maximum of one year difference between the peak velocity of these two dimensions (Na-ANS and Na-Me).

For ANS-Me and Na-Me in 10 (43%) of 23 girls the peak velocity occurred simultaneously. ANS-Me peak preceded the peak velocity of Na-Me in 5 (22%) girls and occurred one year after it in 6 (26%).

The maximum increment occurred from as early as 10 to as late as 14 years for upper anterior facial height; however, in the great majority it took place between 11 to 12 years of age. For lower anterior facial height the timing of the maximum increment was between 11 and 14 years with most falling between 12 and 13 years of age.

For Na-Me the peak of growth was registered as early as 10 to as late as 16 years of age although most of the girls had their peak of growth between 11 and 13 years of age. In 12 (50%) of the girls it occurred at the age of 12.

The maximum increment of growth of Ar-Pog varied from 11 to 14 years of age mostly between 12 and 13 years of age.

Menarche and onset of epiphyseal-diaphyseal fusion occurred before as well as after the maximum pubertal increment. In most cases it occurred within 3 to 5 months of the peak varying from as early as 25 months before to as late as 20 months after it.

The coefficients of correlation between age at peak for the 3 measurements and age at menarche were significant at the 0.05 level, being the highest for Na-ANS ($r = 0.670$, $n = 23$) and the lowest for ANS-Me ($r = 0.419$, $n = 23$) with Ar-Pog being 0.538 ($n = 21$).

Magnitude

The mean magnitude of growth at peak velocity for Na-ANS and ANS-Me was similar, reading 2.1 mm and 2.0 mm, respectively. No significant correlation could be demonstrated between magnitude at peak for both variables ($r = 0.276$). The total amount of growth during the investigative period varied from female to female; however, the mean amount for Na-ANS and ANS-Me was similar, 4.5 mm and 4.9 mm, respectively. No significant correlation was present between the two dimensions for the whole period of the investigation ($r = 0.201$). In 83% of the cases Na-Me had the greatest magnitude at peak, which was expected.

It has to be emphasized that the total anterior facial height (TAFH), measured in this sample as Na-Me, does reflect to a certain degree changes in the upper anterior facial height and the lower anterior facial height, although it is not the sum of both since point ANS is not involved in the measurement of the total anterior facial height. Within total anterior facial height, lower anterior height had the greatest magnitude at peak in 10 cases

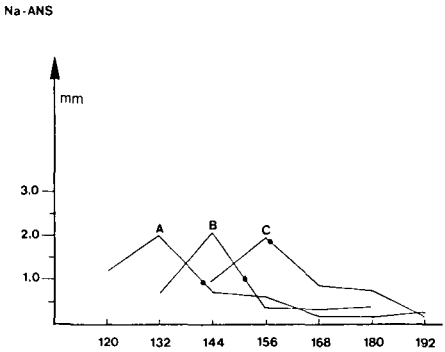

Fig. 3 Average curves for the upper anterior facial height. X-axis, chronological ages in months. Y-axis, growth increments in mm. Average time of menarche for the different groups is indicated by a black dot.

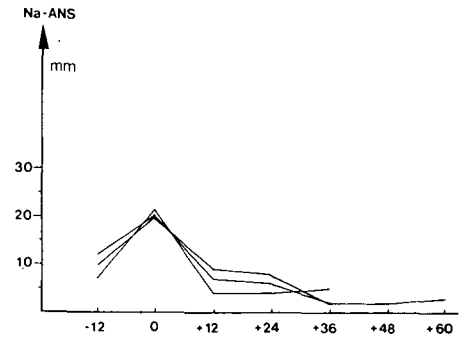

Fig. 4 Average curves for the upper anterior facial height, superimposed on their peaks of growth. X-axis, chronological age in months before (—) and after (+) peak. Y-axis, growth increments in mm.

(43%). In 13 cases (57%) upper anterior height presented the largest increment. When comparing magnitude of growth at peak velocity of upper and lower facial height with mandibular length (Ar-Pog), it was found that in 74% of the cases (n = 19) the amount of growth at peak velocity was greatest for Ar-Pog. No correlation could be demonstrated between the magnitude at peak velocity of Ar-Pog and the magnitude at peak velocity of the other variables measured (r Ar-Pog/Na-Me — 0.193, r Ar-Pog/Na-ANS = 0.295, and r Ar-Pog/ANS-Me = 0.242 (n = 19).

Average Curves

The individual incremental curves were grouped according to age at maximum increment and average curves were then derived for each dimension.

Upper anterior facial height (Figs. 3 and 4). Three average curves were derived: Group A with peak velocity at 11 (n = 8), Group B with peak velocity at 12 (n = 8), and Group C with peak velocity at 13 years of age (n = 3). In two girls the peak velocity took place at age 10 and at 14 in two others. Because of the small numbers they were not considered as groups. The three average curves (Fig. 4) presented a great similarity in duration, velocity and magnitude. Menarche occurred after the peak, within less than a year of it. The later the maximum increment occurred, the closer menarche occurred to the peak velocity.

Lower anterior facial height (Figs. 5 and 6). Four average curves were derived: Group A (n = 4), Group B (n = 8), Group C (n = 8), Group D (n = 3), with peak velocity at ages 11, 12, 13 and 14, respectively.

Here velocity and duration of the spurt were similar. However, magni-

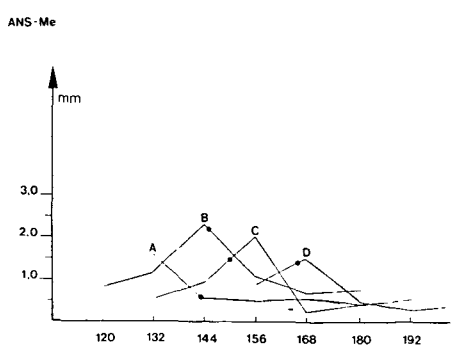

Fig. 5 Average curves for the lower anterior facial height. X-axis, age in months. Y-axis, growth increments. Average time of menarche indicated by a black dot.

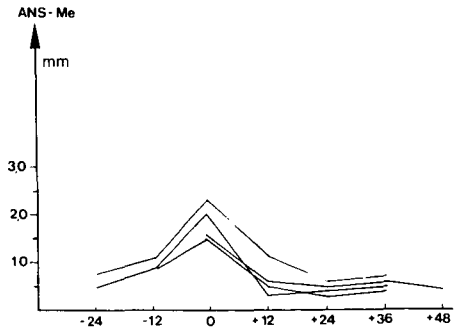

Fig. 6 Average curves for the lower anterior facial height, superimposed on their peaks of growth. X-axis, age in months before (—) and after (+) peak. Y-axis, growth increments.

tude was variable with Group B having the greatest magnitude at peak followed by C, A and D, respectively. In Groups A and B menarche occurred after the maximum increment and within a year of it whereas in Groups C and B it occurred before and within a year of it. Another observation was that the greater the magnitude of growth at peak, the greater was the amount of growth that followed excepting Group C (Fig. 6).

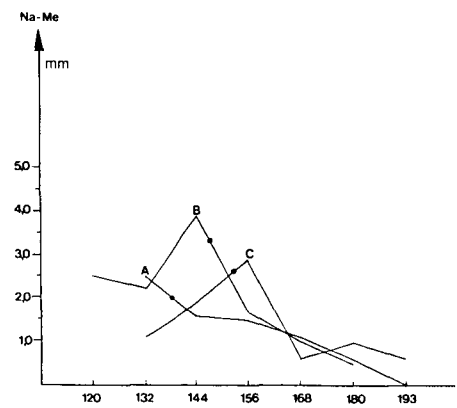

Fig. 7 Average curves for the total anterior facial height. X-axis, age in months. Y-axis, growth increments. Average time of menarche indicated by a black dot.

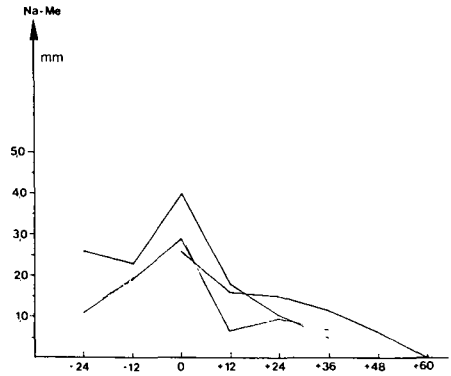

Fig. 8 Average curves for the total anterior facial height, superimposed on their peaks of growth. X-axis, chronological age in months before (—) and after (+) peak. Y-axis, growth increments in mm.

Total anterior facial height (Figs. 7 and 8). Although the total anterior facial height does approach the sum of the lower and upper anterior facial heights, it must be repeated that the total anterior facial height is measured without involving point ANS. A forward movement of point ANS, for example, does reflect an increase in upper and lower anterior facial height but does not affect the total anterior facial height as it is measured in this sample.

Three average curves were derived with maximum increment at ages 11 (Group A), 12 (Group B), and 13 years (Group C) with n = 3, 11 and 5, respectively. The greatest magnitude at peak occurred in Group B and was followed by C and A. Menarche occurred after the peak velocity and, within less than a year of it, in Groups A and B and before it in Group C. Velocity and duration of the spurt were somewhat similar but magnitude was the most variable of the dimensions measured (Fig. 8).

Mandibular length (Ar-Pog). For the average curves of this parameter we refer to an earlier publication.[8]

Discussion

From the morphology of the different individual growth curves it can be deducted that extreme variability exists in the amount and timing of growth as well as in their configurations for the different variables measured. This is in agreement with Hunt's statement that height increments during growth have no individual predictability.[2] However, some relation could be demonstrated between the growth spurts of the UAFH and the LAFH. In 83% of the cases there was either no difference or a maximum of 1 year difference between the timing at which both peaks were registered. No specific pattern was found indicating that the peak of growth of UAFH most often precedes the peak of growth of LAFH or vice versa. Table I indicates that the spurt of growth of the UAFH was registered mostly between 11 and 12 years of age whereas the spurt of growth for the LAFH most often was observed at the ages 12 and 13. These findings have to be understood within the framework of a sample size of 23 females.

Significant coefficients of correlation were found between the timing at which the maximum spurt of growth of LAFH as well as the UAFH occurred and the timing of menarche (r ANS-Me/Men = 0.413; n = 23 and r Na-ANS/Men = 0.670; n = 23). The following tendency seems to exist: the earlier menarche occurred, the earlier the peak of growth was observed and vice versa for dimensions UAFH and LAFH. However, from the individual curves it can be deducted that, although most of the growth was found within a year of menarche, significant growth can be expected before as well as after that event. It is also obvious that the amount of growth before menarche is usually greater than after menarche. This conclusion confirms the findings of Tofani which expressed the same tendency for the mandibular growth.[8]

The total anterior facial height peak velocity, measured as the distance Na-Me, occurred at the same time or within a year of the peak of growth of Na-ANS (UAFH) in 78% of the cases. In 91% of the girls there was either no difference or a maximum of 1 year difference between the peak of growth of ANS-Me and Na-Me. The coefficient of correlation between timing of the spurt in total anterior height and menarche was significant (r = 0.726; n = 23). Comparing the findings of this investigation with those of an earlier study[8] in which 20 females were used out of the 23 girls of this sample, the same trend is found in 76% of the cases. There was either no difference or a maximum of 1 year difference between the peak of growth of Ar-Pog and the peak of growth of the LAFH. When comparing the timing of maximum growth increase for Ar-Pog and Na-ANS, the same was observed in 81% of the subjects. The coefficient of correlation between timing of maximum growth for Ar-Pog and timing of menarches was also significant (r = 0.538; n = 21) but not as high as was found for anterior facial height.

It can be concluded that the timing of the spurt of growth for each of the vertical dimensions measured in this sample can be expected to occur usually within one year intervals from each other. Although no rigid pattern was found between the timing of menarche and of peak growth for the measured vertical dimensions, one can state that the timing of menarche can be used to a certain degree as an indicator for the timing of the anterior vertical growth spurt.

A few conclusions can be made concerning the amount of growth. The amount of growth at peak velocity for Na-ANS/ANS-Me is on the average very similar. It was also observed that

the upper anterior facial height grew approximately the same as the lower anterior facial height if we compare both variables during the entire investigative period. It can be concluded that, on the average, neither the amount of growth at peak velocity nor the total amount of growth during the whole period of investigation are different for the upper and lower anterior facial heights. No correlation could be demonstrated between the amounts of growth at peak for these heights. Regarding the amount of growth for both variables, the individual subjects seem to behave differently.

When comparing the magnitude of growth at peak velocity for the total anterior facial height and mandibular length (Ar-Pog), no correlation was found.

The average curves for upper anterior height (Figs. 3 and 4) reveal no specific differences in their pattern; neither the height nor the morphology of the curves was significantly different. The average timing of menarche followed the age of maximum increment for all groups; on the average the peak of growth for upper anterior height can be expected before menarche. The later the peak of growth for UAFH, the closer menarche will be to the timing of the peak.

The average curves for lower anterior facial height were similar in morphology. However, their heights were different (Fig. 6). The timing of menarche was observed within a year of the timing of peak velocity for all four groups (Fig. 5). In groups A and B, menarche follows the maximum increment; in groups C and D it precedes it; and the earlier the peak of growth, the later menarche. In females with early menarche the spurt of growth of LAFH precedes it; the reverse occurs in females with late menarche.

The picture for the total facial height (Na-Me) was not so clear as it was for the UAFH and LAFH; no specific pattern could be demonstrated. The amount of growth at peak was the largest for group B. Menarche and timing of peak growth velocity showed similar behavior, as was also observed for LAFH and UAFH. When menarche occurred early, it preceded the maximum increment in total height, while late menarche (13 years) preceded the peak velocity. The peak of growth occurred within a year from the timing of menarche in all cases. These conclusions do confirm prior findings for mandibular growth.

Although a significant amount of growth can be expected after, as well as before menarche, the timing of menarche, in general, can be used as an indicator for timing of the anterior vertical growth spurt.

Conclusions

The following conclusions can be made:

1. Extreme variability exists in amount and timing of growth for the variables measured.

2. Peak growth velocity for upper anterior facial height occurred most often at ages 11 and 12 and for lower and total anterior facial height at ages 12 and 13.

3. Menarche was significantly correlated with the timing of peak growth velocity: the earlier the menarche, the earlier the peak and vice versa for all the measured dimensions.

4. Most of the anterior vertical growth occurred before menarche in the majority of cases.

5. Peak growth velocity for ANS-Me, Na-ANS and Na-Me occurred within one year of each other.

6. The average amount of growth at peak velocity and during the whole period of this investigation was similar for upper and lower anterior heights.

7. The magnitude at peak velocity for Ar-Pog was not correlated with the magnitude at peak for Na-Me, Na-ANS or ANS-Me.

8. The later the peak of growth, the closer menarche occurs to the timing of the peak.

9. When menarche occurs rather early (11 and 12 years of age) it usually *follows* the peak of the anterior facial height, while a later timing of menarche (13 years) *precedes* the timing of the peak.

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