Norms of Size and Annual Increments of Seven Anatomical Measures of Maxillae in Boys from Three to Sixteen Years of Age*

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Introduction

For a better understanding of growth disorders, patterns of growth, and interrelations of bones within the facial complex it is essential that available data on growth rates and accelerations be descriptive of specific anatomical components of the face. The selection of facial dimensions on such a basis has been discussed for the mandible by Tracy and Savara (1966) and for the maxillae by Singh and Savara (1966).

This paper is one of a series of longitudinal studies on dentofacial growth and presents:

1. Norms of size of seven dimensions representing maxillary height, length and width in boys from three to sixteen years of age.
2. Norms of annual absolute and relative increments for each of the seven dimensions.
3. Circumpuberal growth for each of the dimensions.
4. Sex differences.
5. Comparison of findings with those reported by other investigators.

Material and Methods

Measurements were obtained from serial cephalograms of fifty-two boys of Northwest European ancestry and predominantly from middle socioeconomic status families. Each boy had been observed for six years or longer at the Child Study Clinic. Figure 1 presents the length of each subject's record, and the sample distribution which ranged from a minimum of ten subjects at sixteen years to a minimum of forty-six subjects at nine years.

Landmarks and Measurements:

The methodology and landmarks employed in this study are described in detail in a report on maxillary growth of girls (Singh and Savara, 1966). The dimensions listed below and illustrated in Figure 2 were selected as representing the maxillae:

Maxillary Height

1. Nasomaxillary suture to prosthion (NMS-PRO).
2. Nasomaxillary suture to anterior nasal spine (NMS-ANS).
3. Anterior nasal spine to prosthion (ANS-PRO).
4. Distal alveolar margin of second primary molar to infraorbital margin (DAM-IOM). Mean of distances of left and right sides.

Maxillary Length

1. Anterior nasal spine to pterygomaxillary fissure (ANS-PTM). Mean of distances of left and right sides.

Maxillary Width

1. Left to right pterygomaxillary fissure (L-R PTM).
2. Left to right zygomaticomaxillary suture (L-R ZMS).

Following the method of measuring face bone growth on cephalograms as

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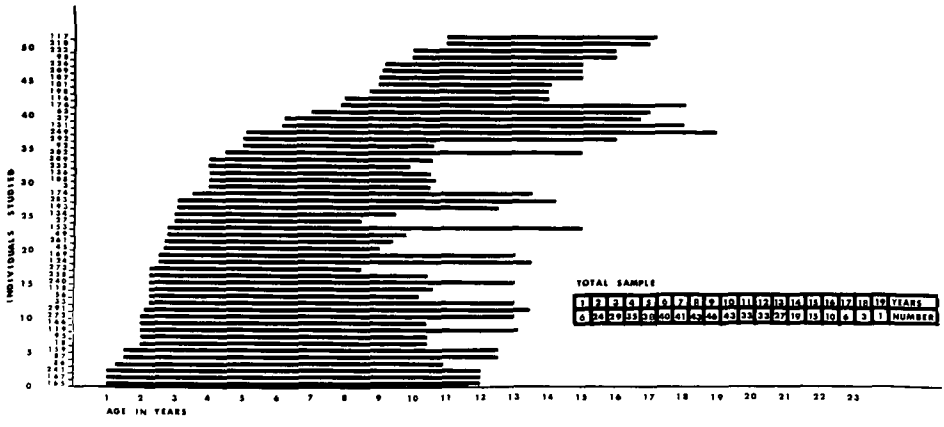


Fig. 1 Boys sample distribution, showing years of enrollment for each child.

described by Savara (1965), landmarks were located in three dimensions; the X and Z coordinates were obtained from lateral cephalograms and the Y coordinate from frontal cephalograms. Computer facilities were utilized to correct the coordinate values for magnification and distortion and to obtain anatomically accurate distances.

Measurement Errors:

A separate investigation by Miller, Savara and Singh (1966) estimated measurement and landmark location errors. They found that variability due to landmark location was the major source of error and was more than five times that of measurements; however, the cumulative errors were small enough to detect individual variability of the maxillary dimensions.

Statistical Treatment of Data:

Most of the cephalograms used in this study were obtained within one month of each birthday. Occasionally observations were unequally spaced or missing due to a delayed visit or cancellation. Therefore, a three degree polynomial was fitted to the data adjacent to the missing or delayed value and the correct value interpolated (Milne, 1949). Thus

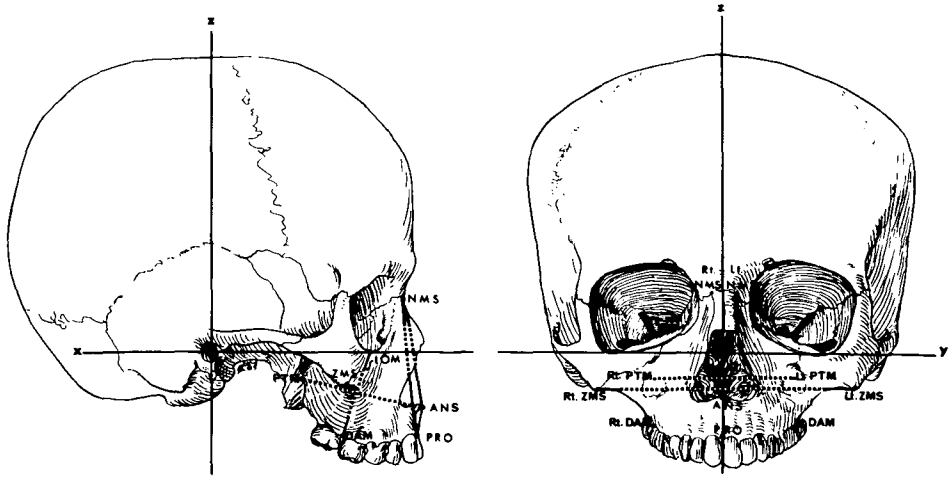


Fig. 2 Maxillary landmarks and distances.

all series of records were equally spaced. No extrapolations were made beyond the period of observation for any subject.

Annual increments were calculated for each child. Mean annual increments and standard deviations were then computed for each dimension from these data rather than from the mean size at each age since the standard deviation of the increments is different in the two procedures (Merrell, 1931; Shuttleworth, 1937).

Due to individual variability, calculation of mean adolescent growth from mean annual increments tends to spread out the growth spurt along the age axis and decreases its maximum magnitude (Tanner, 1965).

The time of the maximum circumpuberal increment was therefore located for each dimension for each child. Growth curves were then superimposed on their maxima during adolescence. Values at the time of the maximum increment (and for three years before and after) were computed and characteristic statistics derived (Table 4).

Findings

Mean size, standard deviations, and coefficients of variation of dimensions representing height, length and width of the maxillae are presented in Table 1. Mean annual increments, standard deviations, and coefficients of variation are presented in Table 2. Mean relative increments and standard deviations are presented in Table 3. Size and increment graphs are shown in Figures 3 and 4, respectively. Maximum circumpuberal growth rates are presented in Table 4 and plotted in Figure 5.

Measures of Maxillary Height:

1. *NMS-PRO*

This measurement represents the maximum height of the maxillae and increases from 4.99 cms at 3 years to 7.08 cms at 16 years. Increments from 3 to 7 years occur at a declining rate and reach a minimum from 6 to 7 years. This is followed by a period of acceleration which reaches a maximum from 8 to 9 years of age. The pattern of increments from 3 to 7 and from 7 to 9 years is due to prosthion being located on the alveolar border which is affected by loss of the primary and eruption of the permanent central incisors. The broken line in Figure 3 demonstrates the "catch up" growth which compensates for the loss from 3 to 7 years. The increments show a further decline from 9 to 13 years and an increase from 13 to 15 years. The period of acceleration from 13 to 15 years probably reflects adolescent changes. Variability for increments is maximum from 6 to 7 years. Relative to size, more increase takes place from 3 to 5 years than at any other time with a negative value occurring from 6 to 7 years.

2. *NMS-ANS*

This dimension represents the upper anterior part of the maxillae and increases from 3.71 cms at 3 years to 5.39 cms at 16 years. Increase in size is greater from 3 to 9 years than from 10 to 16 years. The increments decline gradually until 12 to 13 years of age and then show a small adolescent increase. An earlier peak in increments is observed from 6 to 7 years. Variability for both size and increments fluctuates but generally increases with age. Relative increments show a continuous decrease except for an adolescent increase from 12 to 15 years.

3. *ANS-PRO*

This dimension increases from 1.35 cms at 3 years to 1.79 cms at 16 years and mainly reflects growth changes in the alveolar bone. Growth rate decreases markedly from 3 to 7 years, increases from 7 to 9 years, and decreases gradually thereafter. Along with NMS-PRO, this dimension shows nega-

TABLE 1

MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIATION* FOR SEVEN MAXILLARY MEASUREMENTS OF BOYS AGE 3 TO 16 YEARS

DIMENSION		AGE IN YEARS													
		3	4	5	6	7	8	9	10	11	12	13	14	15	16
HEIGHT	$\bar{X}$	4.99	5.28	5.47	5.62	5.60	5.68	5.89	6.08	6.28	6.47	6.61	6.77	7.04	7.08
NMS - PRO	S.D.	0.32	0.33	0.29	0.37	0.41	0.37	0.37	0.43	0.45	0.45	0.39	0.40	0.44	0.43
	C.V.	6.43	6.22	5.33	6.58	7.30	6.45	6.26	7.03	7.11	6.96	5.92	5.98	6.21	6.04
	$\bar{X}$	3.71	3.87	4.02	4.19	4.36	4.51	4.60	4.71	4.81	4.91	5.03	5.17	5.39	5.39
NMS - ANS	S.D.	0.24	0.24	0.24	0.24	0.27	0.27	0.29	0.32	0.34	0.35	0.31	0.33	0.40	0.43
	C.V.	6.60	6.16	5.98	5.70	6.17	5.91	6.26	6.70	7.17	7.21	6.15	6.48	7.39	8.03
	$\bar{X}$	1.35	1.45	1.51	1.51	1.30	1.24	1.35	1.43	1.53	1.62	1.66	1.71	1.75	1.79
ANS - PRO	S.D.	0.21	0.20	0.17	0.25	0.30	0.20	0.21	0.22	0.23	0.24	0.24	0.26	0.26	0.24
	C.V.	15.98	13.45	11.28	16.77	22.89	16.46	15.50	15.34	14.90	11.64	14.37	15.03	14.80	13.67
	$\bar{X}$	2.65	2.88	3.01	3.14	3.26	3.38	3.50	3.63	3.74	3.91	4.04	4.25	4.46	4.47
DAM - IOM	S.D.	0.27	0.21	0.20	0.22	0.23	0.24	0.24	0.26	0.25	0.27	0.30	0.32	0.32	0.30
	C.V.	10.12	7.35	6.65	6.86	6.97	7.10	6.78	7.04	6.69	6.97	7.45	7.59	7.28	6.65
LENGTH	$\bar{X}$	4.83	4.99	5.12	5.26	5.36	5.45	5.53	5.63	5.72	5.80	5.87	5.99	6.08	6.08
ANS - PTM	S.D.	0.23	0.21	0.23	0.22	0.23	0.25	0.25	0.27	0.29	0.32	0.32	0.35	0.35	0.41
	C.V.	4.86	4.31	4.48	4.21	4.27	4.54	4.51	4.81	5.06	5.45	5.41	5.85	5.81	6.81
WIDTH	$\bar{X}$	3.79	3.97	4.11	4.27	4.41	4.49	4.58	4.67	4.76	4.88	4.93	5.02	5.17	5.06
L. PTM - R. PTM	S.D.	0.26	0.24	0.23	0.25	0.27	0.29	0.31	0.32	0.33	0.35	0.39	0.40	0.37	0.36
	C.V.	6.90	5.99	5.62	5.80	6.04	6.57	6.84	6.82	6.89	7.24	7.99	8.02	7.22	7.18
	$\bar{X}$	7.62	7.78	7.92	8.08	8.20	8.30	8.43	8.52	8.66	8.81	8.96	9.19	9.39	9.53
L. ZMS - R. ZMS	S.D.	0.37	0.39	0.39	0.40	0.44	0.45	0.48	0.44	0.44	0.47	0.47	0.48	0.54	0.67
	C.V.	4.89	4.98	4.89	4.96	5.41	5.41	5.65	5.21	5.13	5.39	5.30	5.25	5.79	6.99
	N	23	33	37	38	40	42	45	38	33	28	21	18	11	7

* measurements in cms.

TABLE 2

MEANS AND STANDARD DEVIATIONS OF ANNUAL INCREMENTS* FOR SEVEN MAXILLARY MEASUREMENTS OF BOYS AGE 3 TO 16 YEARS

DIMENSION		AGE PERIODS IN YEARS												
		3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16
HEIGHT	$\bar{X}$	0.27	0.19	0.16	-0.02	0.07	0.21	0.17	0.18	0.16	0.13	0.15	0.19	0.12
NMS - PRO	S.D.	0.17	0.12	0.20	0.29	0.28	0.12	0.10	0.10	0.11	0.08	0.09	0.10	0.07
	$\bar{X}$	0.16	0.15	0.16	0.16	0.14	0.11	0.10	0.10	0.10	0.11	0.13	0.15	0.09
NMS - ANS	S.D.	0.09	0.08	0.07	0.07	0.06	0.06	0.05	0.06	0.09	0.06	0.09	0.07	0.05
	$\bar{X}$	0.10	0.05	0.02	-0.21	-0.06	0.09	0.06	0.07	0.06	0.05	0.05	0.04	0.04
ANS - PRO	S.D.	0.08	0.09	0.15	0.28	0.27	0.11	0.06	0.05	0.04	0.04	0.04	0.04	0.04
	$\bar{X}$	0.20	0.13	0.14	0.12	0.10	0.12	0.11	0.12	0.12	0.15	0.19	0.12	0.15
DAM - IOM	S.D.	0.15	0.09	0.07	0.07	0.06	0.08	0.08	0.09	0.08	0.09	0.11	0.09	0.14
LENGTH	$\bar{X}$	0.18	0.14	0.13	0.10	0.09	0.07	0.09	0.08	0.06	0.09	0.11	0.07	0.08
ANS - PTM	S.D.	0.08	0.06	0.06	0.05	0.07	0.05	0.05	0.05	0.04	0.07	0.11	0.05	0.03
WIDTH	$\bar{X}$	0.17	0.16	0.16	0.12	0.09	0.07	0.06	0.08	0.07	0.06	0.08	0.07	0.05
L. PTM-R. PTM	S.D.	0.09	0.08	0.09	0.07	0.06	0.05	0.06	0.08	0.05	0.07	0.07	0.04	0.03
	$\bar{X}$	0.15	0.13	0.14	0.10	0.11	0.09	0.08	0.09	0.10	0.09	0.15	0.17	0.14
L. ZMS-R. ZMS	S.D.	0.08	0.07	0.09	0.07	0.06	0.05	0.07	0.05	0.06	0.05	0.09	0.11	0.06
	N	23	33	37	38	40	39	36	31	28	21	18	11	7

* measurements in cms.

TABLE 3

MEANS AND STANDARD DEVIATIONS OF RELATIVE INCREMENTS* FOR SEVEN MAXILLARY MEASUREMENTS OF BOYS AGE 3 - 16 YEARS

DIMENSION		AGE PERIODS IN YEARS												
		3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16
HEIGHT	$\bar{X}$	5.50	3.68	2.83	-0.26	1.48	3.66	2.97	2.95	2.54	2.10	2.25	2.82	1.68
NMS - PRO	S.D.	3.70	2.48	3.55	5.35	5.09	2.27	1.78	1.71	1.88	1.27	1.48	1.53	0.90
NMS - ANS	$\bar{X}$	4.27	4.03	4.04	3.84	3.29	2.41	2.27	2.18	2.11	2.30	2.68	2.97	1.73
	S.D.	2.52	2.16	1.73	1.56	1.45	1.30	1.10	1.27	2.00	1.21	1.80	1.44	0.91
ANS - PRO	$\bar{X}$	8.36	3.96	1.02	-12.60	-1.68	7.97	4.97	5.07	3.93	2.91	3.09	2.78	2.01
	S.D.	7.08	7.37	10.56	19.76	19.69	10.05	4.81	3.98	2.71	2.52	2.71	2.36	2.00
DAM - IOM	$\bar{X}$	8.10	4.78	4.50	3.77	3.19	3.51	3.03	3.19	3.25	3.82	4.62	2.71	3.48
	S.D.	6.34	3.22	2.39	2.25	1.91	2.43	2.21	2.62	2.18	2.15	2.75	1.86	3.17
LENGTH	$\bar{X}$	3.69	2.88	2.55	1.88	1.61	1.30	1.58	1.41	1.09	1.59	1.81	1.11	1.34
ANS - PTM	S.D.	1.63	1.20	1.22	0.93	1.22	0.93	0.89	0.87	0.67	1.14	1.84	0.80	0.45
WIDTH	$\bar{X}$	4.52	3.98	3.94	2.85	2.00	1.60	1.34	1.76	1.54	1.31	1.72	1.39	1.07
L. PTM - R. PTM	S.D.	2.34	2.00	2.22	1.79	1.41	1.21	1.21	1.70	1.12	1.45	1.52	0.85	0.56
L. ZMS - R. ZMS	$\bar{X}$	1.92	1.69	1.83	1.28	1.29	1.08	0.94	1.03	1.18	1.07	1.68	1.79	1.45
	S.D.	1.08	0.94	1.11	0.78	0.72	0.64	0.87	0.61	0.68	0.56	0.94	1.22	0.61
	N	23	33	37	38	40	39	36	31	28	21	18	11	7

* measurements in percentages

TABLE 4

MEANS AND STANDARD DEVIATIONS OF ANNUAL INCREMENTS* DURING ADOLESCENCE AND AGE AT MAXIMUM CIRCUMPUBERAL INCREMENT FOR SEVEN MAXILLARY MEASUREMENTS OF BOYS

DIMENSION		AGE AT MAXIMUM INCREMENT	ANNUAL INCREMENTS						
			-3 yrs	-2 yrs	-1 yr	MAX INC	+1 yr	+2 yrs	+3 yrs
HEIGHT	$\bar{X}$	13.0	0.14	0.14	0.12	0.24	0.12	0.09	0.07
NMS - PRO	S.D.	1.63	0.12	0.14	0.06	0.08	0.04	0.06	0.05
NMS - ANS	$\bar{X}$	13.2	0.10	0.10	0.13	0.20	0.09	0.05	0.07
	S.D.	1.94	0.06	0.04	0.06	0.07	0.05	0.03	0.07
ANS - PRO	$\bar{X}$	11.8	0.06	0.06	0.06	0.12	0.05	0.04	0.03
	S.D.	1.63	0.03	0.06	0.06	0.04	0.04	0.03	0.03
DAM - IOM	$\bar{X}$	13.1	0.11	0.15	0.12	0.26	0.12	0.07	0.06
	S.D.	1.38	0.06	0.08	0.04	0.10	0.09	0.06	0.01
LENGTH	$\bar{X}$	12.1	0.10	0.08	0.09	0.17	0.08	0.06	0.06
ANS - PTM	S.D.	2.12	0.07	0.02	0.05	0.06	0.04	0.03	0.03
WIDTH	$\bar{X}$	12.4	0.06	0.06	0.09	0.16	0.07	0.04	0.04
L. PTM - R. PTM	S.D.	1.32	0.04	0.06	0.07	0.10	0.04	0.02	0.02
L. ZMS - R. ZMS	$\bar{X}$	12.8	0.10	0.08	0.10	0.18	0.14	0.10	0.08
	S.D.	1.94	0.05	0.05	0.04	0.05	0.05	0.04	0.06

* measurements in cms.

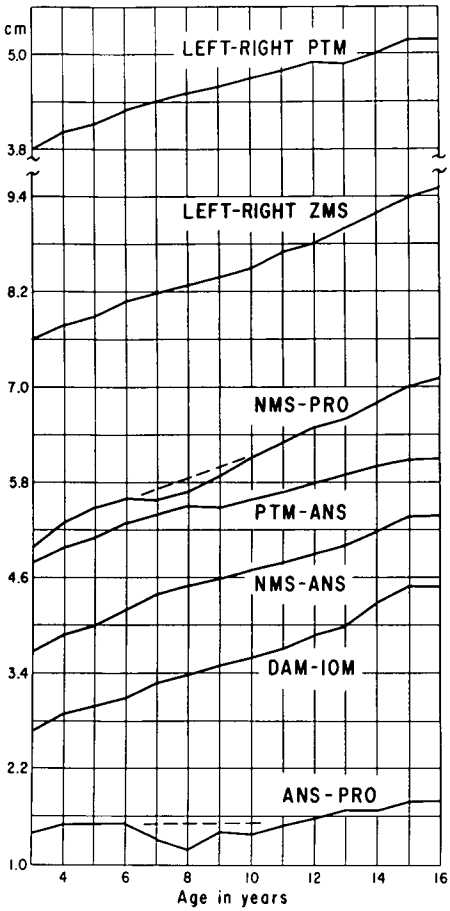


Fig. 3 Mean size of maxillary height, length, and width in boys from 3 to 16 years of age.

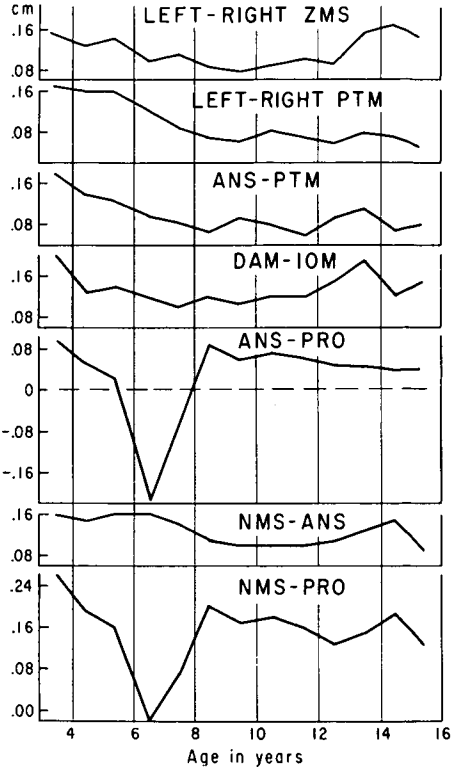


Fig. 4 Mean annual increments in maxillary height, length, and width in boys from 3 to 16 years of age.

tive increments from 6 to 8 years due to loss of primary central incisors. An acceleration is seen from 7 to 9 years which reflects rapid rebuilding of alveolar bone following eruption of the permanent central incisors. A distinct adolescent spurt is not seen and is probably masked by the variability in loss and eruption of central incisors. The broken line in the plot of this measurement in Figure 3 demonstrates the "catch up" growth associated with the eruption of permanent incisors. Variability for both size and increments is highest from 5 to 7 years. Growth changes relative to size are maximum from 6 to 7 years with negative values occurring from 6 to 8 years.

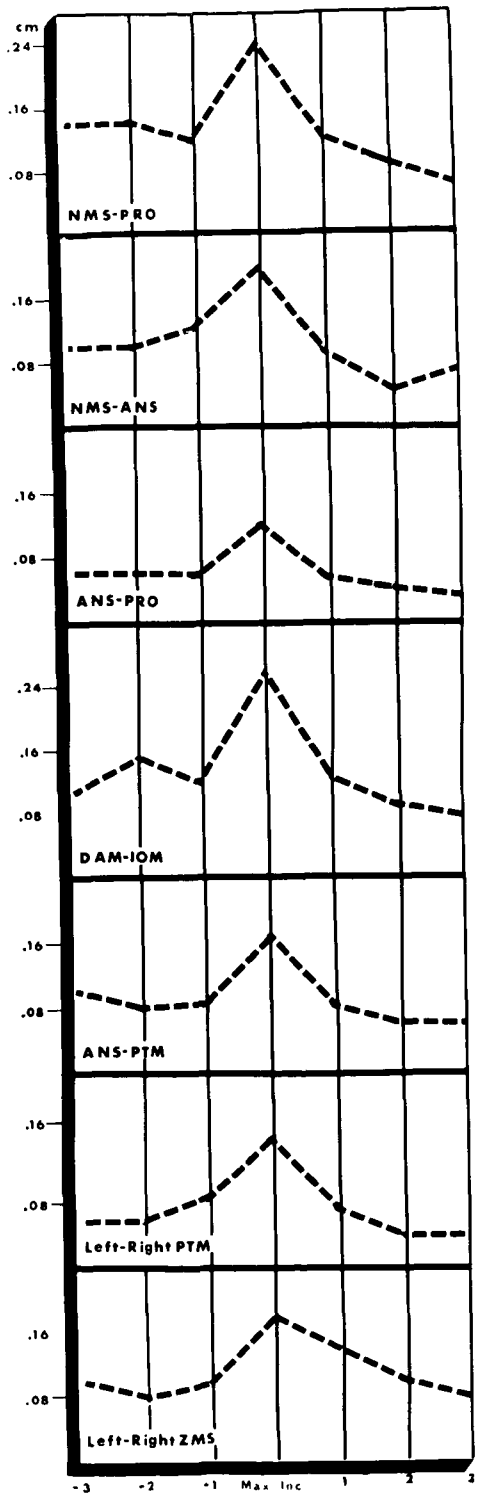
4. *DAM-IOM*

The mean size increases from 2.65 cms at 3 years to 4.47 cms at 16 years. Increments for this distance decrease from 3 to 12 years, show an adolescent increase to 14 years, and decline thereafter. The curve for increments is similar to that of NMS-ANS which is another measure of maxillary height. Variability fluctuates very little for both size and increments throughout the age span. Relative increase in size is more from 3 to 4 years than any other yearly interval.

Measure of Maxillary Length:

1. *ANS-PTM*

Maxillary length increases from 4.83



cms at 3 years to 6.08 cms at 16 years. It presents a slowly declining rate of growth from 3 to 9 years which is similar to the distance DAM-IOM. A slight acceleration is seen from 9 to 10 years. Except for an adolescent increase from 13 to 14 years, the rest of the age period shows fairly constant increments. Almost two thirds of the total growth for the fourteen-year period occurs from 3 to 9 years. Variability for size increases with age and for increments is highest for the 13-14 year period. Relative increments show a steady decrease from 3 to 9 years, an increase from 9 to 10, and from 12 to 14 years.

Measures of Maxillary Width:

1. *Left to Right PTM*

This dimension increases from 3.79 cms at 3 years to 5.06 cms at 16 years. Increments show a gradual decrease with age except for slight accelerations from 10 to 11 years and 13 to 14 years. The acceleration from 13 to 14 years may reflect an adolescent spurt. Variability of increments is maximum for 3, 4, 5 and 6 year periods and, except for a slight increase from 10 to 11 years, shows a decrease with age. Variability for size tends to increase with age, reaching a maximum at 14 years and declining thereafter. Relative increments show a steady decrease from 3 to 10 years, after which increases are seen at 10 to 11, and 13 to 14 years.

2. *Left to Right ZMS*

This dimension, the maximum distance between the maxillae, increases from 7.62 cms at 3 years to 9.53 cms at 16 years. The increments decline from 3 to 10 years and accelerate thereafter until 15 years of age. The increase from 14 to 15 years reflects the maxi-

Fig. 5 Mean age of maximum circumpuberal increments, showing growth curve for three years preceding and following, in maxillary height, length, and width in boys from 3 to 16 years of age.

mum gain during the adolescent spurt. Variability for increments fluctuates, being highest at 14 years. Size variability increases with age. Relative increments decline with age except from 10 to 12 years and from 13 to 15 years.

Adolescent Period:

Three dimensions representing maxillary height (NMS-PRO, NMS-ANS, DAM-IOM) show a later maximum circumpuberal increment than the dimensions representing length (ANS-PTM) and width (L-R PTM and L-R ZMS) (Table 4, Figure 5). However, one dimension of height (ANS-PRO) shows the earliest maximum increment which occurs at a mean age of 11.8 years. For the other measures of height, the mean age at the time of maximum increment is about 13.0 years. Maxillary length (ANS-PTM) has a mean age of 12.1 years at time of maximum circumpuberal increment. The mean ages of maximum increment for measures of width are at 12.4 years for L-R PTM and 12.8 years for L-R ZMS. NMS-ANS is the last of the seven dimensions to reach its maximum circumpuberal increase.

Two dimensions of height (NMS-PRO and ANS-PRO) show the largest and smallest maximum circumpuberal increments, respectively. NMS-PRO also exhibits the greatest variability of all dimensions; this occurs two years prior to the age of maximum circumpuberal increment.

Sex Differences

Boys are expectedly larger in each dimension throughout the age period studied with the greatest size differential occurring at 15 and 16 years of age. Boys show greater increments from 13 to 14 years and maintain this difference thereafter. The adolescent spurt in boys occurs two to three years later than in girls. Sex differences for each dimension are:

Maxillary Height:

1. *NMS-PRO*

Boys are larger than girls at 3 years by 0.30 cms and at 16 years by 0.74 cms. Increment patterns are similar until 8 to 9 years when boys exhibit a peak which is followed by an adolescent peak at 14 to 15 years; girls exhibit the adolescent peak at 11 to 12 years. For both boys and girls, variability is greatest at 6 to 7 years. Relative to size, both boys and girls show more increase from 3 to 5 years than during any other age interval. Both show an increase from 8 to 9 years.

2. *NMS-ANS*

Comparison with girls shows boys to be larger by 0.26 cms at 3 years, the difference increasing to 0.41 cms at 16 years. Increments for boys peak at 6 to 7 years with a marked adolescent peak at 14 to 15 years. For girls, marked peaks occur at 5 to 6 years and at 11 to 12 years (the adolescent increase) with minor peaks at 7 to 8 years and 9 to 10 years. Maximum variability for boys occurs at 3 to 4 years, at 11 to 12 years, and at 13 to 14 years and for girls at 4 to 5 years of age. Relative increments show greatest increase for girls from 5 to 6 years and for boys from 3 to 4 years.

3. *ANS-PRO*

Boys are larger in size throughout the 14 year period with a sex difference of 0.09 cms at 3 years and 0.32 cms at 16 years. Both boys and girls show negative increments in this dimension, the boys from 6 to 8 years and the girls from 5 to 7 years. A distinct adolescent spurt is not seen for either boys or girls. Variability is greatest from 6 to 7 years for both boys and girls. Relative to size, both boys and girls show greatest increase from 6 to 7 years.

4. *DAM-IOM*

Size in boys and girls is similar at 3 years (boys, 2.65 cms; girls, 2.62 cms). The sex difference in size increases

gradually with age resulting in a difference of 0.47 cms at 16 years. Boys' increments show a peak at 5 to 6 years and a marked adolescent increase at 13 to 14 years. Increments for girls are fairly constant until 14 to 15 years when a marked peak is seen; because of its late appearance, however, this may be questionable as an adolescent spurt. Variability for boys is greatest at 3 to 4 years and for girls at 3 to 4 years and 10 to 11 years. Relative increments show greatest increase from 3 to 4 years in both boys and girls.

Maxillary Length:

1. *ANS-PTM*

Boys are larger than girls at 3 years by 0.18 cms and show a size difference of 0.24 cms at 16 years. However, the difference in total increase from 3 to 16 years is slight (boys, 1.25 cms; girls, 1.19 cms). Increments for boys show a peak at 9 to 10 years and an adolescent increase from 13 to 14 years. The adolescent peak for girls occurs from 10 to 11 years of age. Time of greatest variability is very different for boys and girls (boys, 13 to 14 years; girls, 3 to 4 years). A general decrease with age is seen in relative increments. Both boys and girls show greatest increase from 3 to 4 years.

Maxillary Width:

1. *Left to Right PTM*

Boys are larger than girls throughout the fourteen-year period. A size differential of 0.11 cms at 3 years increases to 0.36 cms at 16 years. Increment patterns are similar until 10 to 11 years when girls exhibit a marked adolescent peak followed by smaller increment peaks at 12 to 13 years and at 14 to 15 years. An adolescent increase for boys occurs from 13 to 14 years and is preceded by a peak from 10 to 11 years. Variability is greatest in boys from 3 to 4 years and 5 to 6 years and in girls from 3 to 4 years and 10 to 11 years. Relative increment for boys is maximum from 3 to 4 years, and in girls from 5 to 6 years.

2. *Left to Right ZMS*

Boys are larger than girls at 3 years by a difference of 0.21 cms. This size differential increases to 0.58 cms at 16 years. Small increment peaks for boys are seen from 5 to 6 years, 7 to 8 years and 11 to 12 years, and a well-marked adolescent peak is seen from 14 to 15 years. Increment peaks for girls occur from 4 to 5 years, 9 to 10 years and 12 to 13 years; the last is not distinct but appears to be the adolescent increase. Ages of greatest variability for boys and girls are very different and occur in boys from 14 to 15 years and in girls from 3 to 4 years. Greatest relative increment occurs from 3 to 6 years in both boys and girls. In addition, boys show a pronounced increase from 13 to 15 years.

Adolescent Period

Mean age of maximum circumpuberal increment occurs earlier in girls than boys for all dimensions. In girls, the dimension representing maxillary height displays an earlier maximum increment than dimensions representing length and width. The reverse is true for boys; dimensions representing height, except for that of ANS-PRO, occur later than those representing length and width. In both boys and girls, the dimension ANS-PRO shows the earliest mean age of maximum circumpuberal increment. In girls a dimension of width (L-R PTM) has the latest mean age of maximum increment.

For both boys and girls the dimensions utilizing prosthion as a landmark (NMS-PRO and ANS-PRO) show the largest and smallest maximum circumpuberal increments, respectively. In both cases NMS-PRO shows the greatest variability of any dimension. This

increased variability, two years for boys and three years for girls, is prior to the age of maximum circumpuberal increment.

Interrelations of Maxillary Height, Length and Width

Interrelations of growth among the seven dimensions selected as representing the maxilla can be interpreted from the findings. Dimensions of height (NMS-PRO, NMS-ANS, DAM-IOM) have a faster growth rate than those of length (ANS-PTM) and width (L-R PTM, L-R ZMS). The dimensions having prosthion as a landmark (NMS-PRO and ANS-PRO) have the largest and smallest total increments, respectively (NMS-PRO, 1.98 cms; ANS-PRO, 0.36 cms). Upper maxillary height (NMS-ANS) has the fastest growth rate of any dimension until 8 years, after which total maxillary height (NMS-PRO) has the greatest acceleration. Length (ANS-PTM) has a slower growth rate than width (L-R PTM) until 8 years and then shows a faster rate; compared with width (L-R ZMS), however, length has a faster growth rate until 8 years and is slower later. Of the two measures of width, L-R PTM has a faster rate of growth until 11 years of age, after which L-R ZMS rapidly accelerates.

Variability of increments is greatest for all ages for the dimensions utilizing prosthion as a landmark (NMS-PRO, 0.29 cms; ANS-PRO, 0.28 cms), the maximum occurring from 6 to 7 years. Length (ANS-PTM) has the least variability of increment for the total age span.

Discussion

Studies which have utilized linear dimensions to assess facial growth have used landmarks in different morphogenetic areas. Investigations using cephalograms which superpose head tracings on one of the anthropometric planes are inaccurate as no landmark in the head has been shown to be stationary, so that any observed growth changes are relative to the plane chosen.

Enlow (1966) demonstrates that the pattern of development of the entire face obscures actual growth patterns in individual anatomical units. Thus, growth patterns of individual bones must be examined separately if the total facial growth is to be made meaningful. The present study evaluates growth changes in one anatomical component of the face, the maxillae; the dimensions selected represent the measures of height, length, and width.

Comparison of our findings with those of other investigators follows (Table 5). Differences in the methods and samples used for each study do not permit direct comparisons. Hellman (1927) utilized skeletal material from the American Museum of Natural History. The sample was American Indian and dated back more than two thousand years, apparently from a homogeneous group. Brodie (1940) utilized cephalograms from the longitudinal records of the Bolton Foundation and the University of Illinois orthodontic department. He presented findings for two series based on starting age of subjects. Björk (1947) made the first statistical study of the associations between x-ray cephalometric measurements and found a relationship between prognathism and flexion of the cranial base. Jones and Meredith (1966) utilized longitudinal data from the University of Iowa program; serial *norma lateralis* roentgenograms were made for age intervals from 4½ to 16 years. Enlow and Hunter (1966) utilized serial cephalograms of ten normal white children, both sexes equally represented at 6, 9, and 15 years of age, who were enrolled in the Elementary School Growth Study at Ann Arbor.

TABLE 5

REVIEW OF LITERATURE FOR SIZE OF THE MAXILLA

REFERENCE	Sample Description	Age in years	Findings (in cms.) Size	S.D.
Measurements of Maxillary Height				
Enlow and Hunter (1966)	10 children (5 boys, 5 girls)	F-M Suture to Alveolar Margin		
	Technique: cephalometric; corrected for cephalometric enlargement	6	4.86	
		9	5.19	
		15	6.07	
		F-M Suture perpendicular to Palatal Plane		
		6	3.46	
		9	3.79	
		15	4.38	
		Palatal Plane to Alveolar Margin		
		6	1.40	
		9	1.39	
		15	1.69	
Jones and Meredith (1966)	20 boys; longitudinal records, collected every two years.	5	1.50	0.14
		7	1.11	
		9	1.29	0.15
	Technique: cephalometric; corrections made for magnification.	11	1.38	0.15
		13	1.44	0.16
		15	1.53	0.17
	Landmarks: TANS-UAJ, tip of anterior nasal spine to upper alveolar junction.			

Measurements of Maxillary Length				
Björk (1947)	322 boys, aged 12.	12	5.17	0.28
	Technique: cephalometric; distortion and magnification corrections not shown.			
	Landmarks: ANS-PTM			
Enlow and Hunter (1966)	10 children (5 boys, 5 girls)	6	4.13	
		9	4.35	
	Landmarks: PTM-Point A parallel to palatal bone.	15	4.73	
Brodie (1941)	31 boys; longitudinal study.	Group I		
	Two series based on age first studied.	1	3.98	
		2	4.14	
		3	4.25	
	Technique: cephalometric; corrected for magnification.	4	4.35	
		5	4.62	
		6	4.67	
		7	4.75	
	Landmarks: PTM-ANS	Group II		
		1	3.88	
		2	4.15	
		3	4.20	
		4	4.33	
		5	4.53	
		6	4.65	
		7	4.70	
		8	4.83	
Measurements of Maxillary Width				
Hellman (1927)	108 American Indian Specimens, including 78 complete skulls.	I	6.60	0.28
		II	7.27	0.41
		III	8.25	0.46
	Technique: anthropometric; Ages based on stage of dental development.	IV	9.32	0.69
		V	9.86	0.55
		VI	10.22	0.59
		VII	10.12	0.66
	Landmarks: Right and Left maxillomalar sutures at lowest point.			

Height:

Studies of facial height have generally utilized nasion as the superior landmark, as evidenced by the work of Hellman (1927, 1935), Brodie (1941), Björk (1947), Krogman (1951), Meredith (1958), Jones and Meredith (1966), and Carroll et al, (1966). Nasion reflects the union of frontal and nasal bones and manifests a compounding of facial and neural growth (Nanda, 1955) and, therefore, is not used as a landmark in this study.

Hellman (1935) and Krogman (1951) observed the face to change most markedly in length followed by height and width, respectively. When considering the maxilla, however, dimensions of height, except for ANS-PRO, have the fastest growth rates, followed respectively by length and width. This observation substantiates the findings of Goldstein (1936) and Enlow (1966) who observed a predominant downward movement of the entire maxilla. Measurements which utilize prosthion as a landmark (NMS-PRO, ANS-PRO) decrease in size at 7 years reflecting loss of deciduous incisors and accompanying resorption of alveolar bone with resultant negative increments. However, these dimensions increase and "catch up" with the expected size as if no loss had occurred at 6 and 7 years. ANS-PRO, the smaller measurement, exhibits a greater decrease and also takes about two years (from 7 to 9) to rebuild to original size. Gains in the upper portion of the maxilla compensate for, and largely obscure, the simultaneous loss in the alveolus from 6 to 7 years; thus, NMS-PRO demonstrates a continuous increase in size during the entire age period.

Enlow and Hunter (1966) reported on three measures of height only one of which, the frontomaxillary suture to alveolar margin, is comparable to NMS-PRO. For the three ages listed by Enlow and Hunter, we found NMS-PRO to be considerably larger for both boys and girls.

Jones and Meredith (1966) report the distance from the tip of anterior nasal spine to the upper alveolar junction for twenty boys. This measurement is comparable to ANS-PRO used in this study. A comparison shows that Oregon boys are not only larger at each age, but also that the difference increases with age; the difference of 0.01 cms at age five increases to 0.22 cms at age fifteen. The distances which Jones and Meredith present are closer to those reported for girls by Singh and Savara (1966).

Length:

Investigators studying facial depth or length have located landmarks variously on the transmeatal axis (Hellman, 1927; Smythe and Young, 1932; and Keith and Campion, 1922), or on a point on the occipital condyle (Meredith, 1959).

Brodie (1941) used the same landmarks as employed in this study for maxillary length measurements; his measurements are smaller at all ages and the differences in mean size increase with age. Comparison with Björk's (1947) data shows his twelve year old boys to be 0.63 cms smaller in maxillary length than Oregon boys which may be attributed in part to uncorrected distortion error. Enlow and Hunter (1966) presented length measurement based on landmarks PTM and point A. Landmark point A is not used in this study, but is valid for measurement of the maxilla.

Width:

Upper face width has been measured as bizygomatic width by Woods (1950), Hellman (1935), Goldstein (1936), O'Reilly (1951), and Meredith (1954). Bizygomatic width is not used in this study since it is a measurement

between the zygoma at their widest spread. Hellman (1927) presented means of bimalar width for the various dental ages. This distance is comparable with left to right ZMS, as Hellman used the lowest point of the maxillomalar suture as his landmark. His findings are presented as stages of dental ages. Stage II occurs at about six years, Stage III at about ten years and Stage IV at about fifteen years. Comparison with the Oregon children shows that the differences decrease with age from 0.81 cms at six years to 0.07 cms at fifteen years.

An adolescent spurt in maxillary dimensions was expected (Goldstein, 1936; Nanda, 1955) and is substantiated by the present study.

Summary

This is a mixed longitudinal study of maxillary growth in fifty-two boys from three to sixteen years of age. Seven dimensions representing the maxillae (four for height, one for length, and two for width) were measured from posteroanterior and lateral cephalograms. Norms of size and increments, corrected for roentgenographic magnification and distortion, are provided for clinical use and research. Growth changes in maxillae are most marked in height, less so in length, and least in width. The pattern of growth changes is similar to that observed in girls. An adolescent spurt in maxillary growth occurs from one to three years later in boys than in girls.

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