Differential growth of the female face in the anteroposterior dimension

By Surender K. Nanda, DMD, MS

The concept of differential growth is based upon the observation that various structures of the body normally grow at different rates from birth to maturity. As a result, each part of the body may contribute unequally to total size attainment at different points in time. Moreover, since disproportionate growth is inherent to many structures, disharmonious relationships during development should not necessarily be considered abnormal. For example, the head of the infant accounts for 25% of the adult stature. The legs increase in relative length from 35% to 50% of total body height between infancy and adulthood. Therefore, the rates of increase in size between two structures are not equal; they may express a disharmonious or harmonious skeletal relationship during the transition of development. Furthermore, analysis of specific disharmonious relationships during growth of individuals must be considered carefully with regard to the anticipated changes with age in order to determine whether or not the average pattern of growth is appropriate for a particular stage of individual development. This study will provide a framework for interpreting the concept of differential growth in the sagittal plane of the craniofacial complex.

In the face of the newborn, the largest to smallest dimensions are width, height, and

Abstract

This study contrasts the growth rates of the craniomaxillary and mandibular dimensions.

Longitudinal data from lateral head cephalograms of 18 female subjects, between 3 and 18 years old, were used. All of the subjects had yearly cephalograms available and none had received orthodontic treatment. Four linear distances included anterior cranial base, maxillary length and mandibular length and four angular measurements included ANS-S-N, ANS-N-S, Gn-S-N and Gn-N-S.

The mandible lagged in size by 4 years relative to anterior cranial base length and by 2 years relative to maxillary length at 5 years of age. There was an incremental gradient of growth from S-N downward to Ar-Pog such that dimensions successively showed a greater relative amount of growth during the entire period of development. The proportional displacement of nasion and anterior nasal spine maintained a constant S-N-ANS angle. The increase in angle S-N-Gn was due to proportionally greater increase in mandibular length relative to anterior displacement of nasion. The different rates of dimensional increments from anterior cranial base to mandible result in differential growth affecting the spatial relationship of maxilla and mandible in the sagittal plane. Skeletal discrepancies in maxillomandibular relationships between 4 and 10 years of age is a normal transient developmental characteristic.

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Key Words

Differential growth • Longitudinal growth • Anterior cranial base • Maxillary length • Mandibular length

depth respectively. Postnatally, the face grows most rapidly in depth, followed by height, and with the slowest rate of growth being found in width.[1-3] Disproportionate increases in these three dimensions demonstrate a gradient which brings about a change in form. Thus, the proportions change and affect the form of the face.[4] Even within the same anatomical structure, such as the mandible, ramus and corpus increase in size at different rates postnatally.[5] Furthermore, Nanda[6] demonstrated that the upper and lower components of the total face height grow differently.

Of particular significance to the orthodontist is the interrelationship of growth between upper and lower jaws. In its present context, skeletal malocclusion can be defined as failure of the normal differential growth of maxilla and mandible, resulting in a spatial or dimensional relationship of the dental arches.[7] Changes in proportion result from differences in magnitude and timing of growth, while changes in the position of the maxilla and mandible may be considered proportionate or disproportionate growth. The final displacement (position) of the maxilla and mandible is a function of the interaction between the horizontal and vertical vectors of growth. It is not unusual for one vector to predominate, resulting in an unfavorable growth pattern.

Standards in orthodontic diagnosis and treatment planning have tended to obscure the true nature of skeletal dysplasia and its correction. The assessment of skeletal dysplasia is determined by a composite of standards of normality, which in reality may not be appropriate for a particular individual. Contemporary analyses do not include multinormative values for age, sex, race, constitution, facial type, development status, or any other characteristic. Nor do these analyses account for compensations which may occur to attenuate, maintain, or even exaggerate the skeletal dysplasia. Such standards arbitrarily divide normal from abnormal based upon average values for anatomic parts.

In a study of Class II cases,[8] functional orthopedic mechanics were advocated to address "arrested development of the mandible." Sample selection in this study was biased by selection of cases in which an end to end first molar relationship between 8 and 10 years of age (mixed dentition) was was assumed to be a precursor of an adult Class II molar relationship, although this frequently does not occur.[7,9] Another assumption was made that the proportionality between the different anatomic parts of the dentofacial complex is maintained constantly until adulthood. Fundamental aspects of growth and patterns of occlusal relationships were not accounted for in this study. Assumptions which are insensitive to the role of differential growth may lead to unwarranted conclusions.

The notion of relative growth in this context is particularly significant. It is important to note that during development a particular ratio in relative growth of the dentoskeletal structures exists at each age, yet there may exist skeletal dysplasia. To this end, the analysis of the relative growth of the maxilla and mandible is the logical basis for differentiating the nature of dental or skeletal aberrations encountered during the developmental process. The analytical revelation of such abnormal differential morphology would prevent conceptual misconceptions regarding maxillo-mandibular relationships.

A number of cephalometric studies specifically examined individual patterns of development of the craniofacial complex and mandible.[4,5,10-18] All of these studies tend to focus primarily on dimensional increase and positional change.

Mitani[19] concluded that synchronization of growth spurts in both rate and timing produce the proper occlusal relationships. However, the applicability of his criteria is not supported by previous studies. Brash,[20] Scott,[21,22] Coben,[23] and Björk and Skieller[24] examined the growth of the cranial base and midface, but did not extend their work to include a consideration of the relative growth of the anterior cranial base and mandible to that of the maxilla. Agronin and Kokich[25] examined the role of displacement of the glenoid fossa on the position of the mandible and demonstrated a correlation. On the other hand, Kantomaa[26] concluded that the mandibular condyle is adaptive to the sagittal change in glenoid fossa location.

In reference to the change in relationship of maxillary anterior position (Point A) relative to cranial base, several investigators[27-32] observed virtually no change for the SNA angle in growing subjects. The Bolton standards[33] for dentofacial development, however, exhibit an increase in the SNA angle.

The linear dimension of sella-gnathion (S-Gn) and its angle formed with the nasion-sella line (N-S-Gn) expresses the sum of growth of the face in both the horizontal and the vertical dimensions.[4,18,34-36] The position of gnathion is an expression of the interaction of mandibular dimensional increase and the changes between sella and gnathion.

In spite of several studies reporting the growth of various dimensions of the face which tend to focus primarily on dimensional increase and the positional change of structures, there is a scarcity of relative growth studies of two or more dimensions, specifically anterior cranial base, maxilla and mandible. The rate of increase in size of one measurement relative to another measurement is needed to assess the differential growth ratio. Data describing development and variance in size attainment for each of the three basic dimensions of the face has not been compared within the same individual.

Specifically this study presents a longitudinal analysis of growth in the anterior cranial base, maxilla, and mandible during this developmental period.

Two fundamental aspects of growth analysis will be examined:

1. The contrast in rates of growth of craniomaxillary and mandibular dimensions.
2. The contrast in the differential size increase of maxillary length and mandibular length relative to the anterior cranial base length.

Material and methods

Longitudinal data from annual lateral head cephalograms of 18 female subjects, ranging in age from 3 to 26 years, were selected from the records of the Child Research Council, Denver, Colorado. A minimum of 11 to a maximum of 18 radiographs were available for each subject. All of the subjects were Caucasian with North European ancestry. The selection of these subjects was on the basis of lower face height (ANS-Me) as a percentage of morphologic face height (N-Me) at approximately 13 years 6 months of age. The persons exhibiting the most extreme values at both ends of the distribution were eliminated. The range of percentage of lower face height of the selected sample was 52% to 56%. No subjects received orthodontic treatment. The distribution of selected sample represents true population parameters in occlusal relationship.

Relevant portions of selected lateral cephalometric radiographs of each series were traced. The midpoints of the right and left shadows of bilateral structures were traced. Four linear distances and four angular measurements were made between the following landmarks (Figure 1).

Linear distances included:

1. Sella-nasion (S-N)
2. Anterior nasal spine-posterior nasal spine (ANS-PNS)

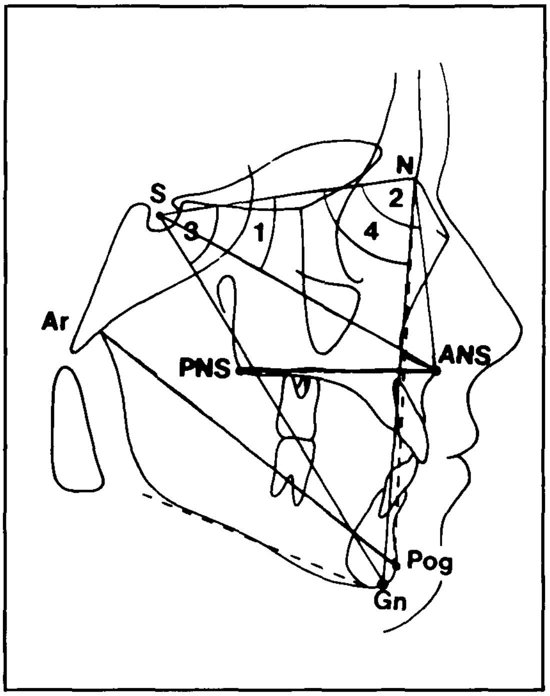

Figure 1

Figure 1
Cephalometric landmarks used to measure four linear distances and four angular measurements.

3. Articulare-Pogonion (Ar-Pog)
4. Sella-Anterior nasal spine (S-ANS)

The angular measurements included:

1. Anterior nasal spine-Sella-Nasion (ANS-S-N)
2. Anterior nasal spine-Nasion-Sella (ANS-N-S)
3. Gnathion-Sella-Nasion (Gn-S-N)
4. Gnathion-Nasion-Sella (Gn-N-S)

The posterior nasal spine (PNS) on the cephalometric tracing was established by the intersection of the nasal floor with the anterior contour of the pterygomaxillary fissure. Gnathion was determined by bisecting the angle formed by the facial (N-Pog) and mandibular planes. The remaining landmarks and planes were identified following the description by Krogman and Sassouni.[37] The magnification of the lateral cephalogram was 0.04 cm for every cm of length in all directions.[4] Since this enlargement was uniformly present in all radiographs, no attempt was made to correct the size of the image.

The data were analyzed by plotting absolute cumulative relative rates of growth curves. Since lateral cephalometric radiographs were not available at the same ages for all of the subjects, a polynomial regression was calculated for each of the four measurements in order to obtain an interpolated value.

Descriptive statistics at each age were calculated from yearly absolute values for each of the parameters between 4 and 18 years of age. The

Table 1
Descriptive statistics on the absolute interpolated values for the four facial dimensions from 3 to 18 years of age

Age Yr.	S-N Attained Size Mean	S-N SD	S-ANS Attained Size Mean	S-ANS SD	ANS-PNS Attained Size Mean	ANS-PNS SD	Ar-Pog Attained Size Mean	Ar-Pog SD
3	57.74	1.50	67.26	2.29	41.96	1.77	77.68	2.65
4	59.11	1.66	69.23	2.64	43.64	2.03	80.78	3.02
5	60.16	1.76	70.87	2.77	44.85	1.67	83.50	2.96
6	61.29	1.98	72.52	3.28	46.04	1.74	86.51	3.39
7	62.11	1.93	74.13	3.27	46.91	1.69	88.58	3.21
8	63.11	2.19	75.13	3.40	47.75	1.88	90.29	3.14
9	63.83	2.31	76.31	3.47	48.52	2.32	92.51	3.47
10	64.31	2.30	77.59	3.70	49.23	2.40	94.39	3.57
11	65.22	2.34	79.16	3.62	49.86	2.46	96.61	3.64
12	65.87	2.27	80.12	3.45	50.41	2.55	98.43	3.50
13	66.54	2.42	81.11	3.77	50.70	2.65	100.61	3.74
14	66.87	2.47	81.78	3.86	51.12	2.83	101.92	4.17
15	67.10	2.55	82.23	3.98	51.48	2.88	102.95	4.31
16	67.20	2.77	82.47	4.30	51.72	3.30	103.71	4.58
17	67.17	2.95	82.27	4.57	51.97	3.62	103.61	4.56
18	67.06	3.51	81.92	5.22	52.13	4.25	103.13	5.47

Hotelling T^2 test for repeated measures analysis was used to test whether the age-associated differences in various parameters were significantly different.

Results

The results of this study will be presented in the following sections:

I. Individual representations of absolute size changes in facial dimensions.
II. Percentage attainments of linear dimensions.
III. Proportional changes in the depth of the face relative to anterior cranial base.
IV. Changes in angular position of maxilla and mandible.

I. Individual representations of absolute size changes in facial dimensions

Descriptive statistics on the absolute values and yearly increments of four facial dimensions are reported in Table 1. In Figure 2A-D, absolute growth curves of S-N, S-ANS, ANS-PNS and Ar-Pog are plotted as an example. They exhibit the general somatic configuration common to many parts of the body. Significant differences occur from one age to the next without any consistency of growth pattern between individuals in gross size. The tendency to show overlapping of curves in the preadolescent period is apparent and later at the initiation of adolescence differentiation occurs in the slopes of the curves. Note that there was a wide variation in absolute size for each dimension. There were five extreme subjects in the growth curves of Ar-Pog, two early-maturing, generally larger in

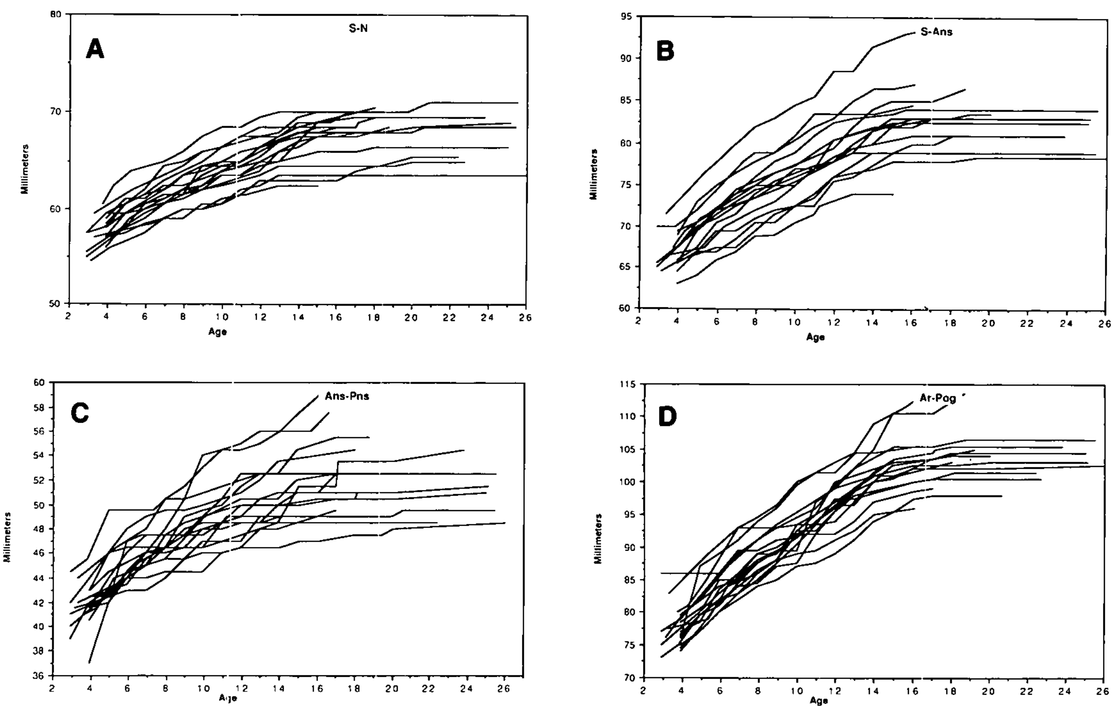

Figure 2A-D
A: Individual growth curves for S-N plotted for the 18 girls.
B: Absolute curves of growth for S-ANS dimension plotted for the 18 girls.
C: Absolute curves of growth for ANS-PNS plotted for each subject.
D: Absolute curves of growth for Ar-Pog plotted for each subject, compare with average gross size curve in Figure 3.

size, and three late-maturing girls represented by their different slopes and smaller magnitude of growth increments. These contrasting slopes of the growth curves for each individual are a direct function of rate and magnitude of increments.

II. Percentage attainments of linear dimensions

The values for S-N, S-ANS, ANS-PNS and Ar-Pog were expressed in terms of percentage of attainment at each chronologic age; the absolute size at 18 years of age was treated as 100% attainment (Table 2, Figure 3). This procedure was done to contrast the relative rates of growth between each of the parameters.

Differences in the rate and amount of growth and pattern of deceleration are revealed in a comparison of the four curves. The pattern of the growth curves were established at an early age and maintained during the progression of growth. These growth curves are continuous and the intensity of growth varies in the entire period of study. All curves have the same forms, but the pattern of growth of the mandibular length is different from the other three dimensions, since it decelerates more slowly, until 13 years of age.

The percentage growth curve for anterior cranial base (S-N) emphasized the characteristics of a neural curve as it is initially closer to its ultimate size in contrast to the other three curves. The maxillary length (ANS-PNS) and the length of maxillary vector (S-ANS) growth curves were positioned halfway between the anterior cranial base and the mandibular length (Ar-Pog) curves. The rate and pattern of dimensional increase is similar between S-ANS and ANS-PNS curves until 9.9 years of age, at which time the S-ANS continued to accelerate in close proximity to S-N curve. The relatively more slowly growing mandibular length, as demonstrated by the position and slope of the curve compared to the other dimensions during the same period, shows a parabolic character of the curve indicating pronounced deceleration at 12.9 years of age. The slow deceleration of mandibular length results in its greater dimensional increase.

Comparisons of the rates of increase in size of maxillary and mandibular length at 10 years revealed that during the decelerating phase, the pattern of growth in maxillary length is linear and is significantly different ($P < .01$) than mandibular length. The maxillary length curve after 10 years of age decelerates more slowly and maintains its advanced position compared to mandibular length until approximately 13

Table 2
Percentile attainments for each facial dimension relative to absolute size at age 18

Age Yr.	S-N Percentage Attainment Mean	SD	S-ANS Percentage Attainment Mean	SD	ANS-PNS Percentage Attainment Mean	SD	Ar-Pog Percentage Attainment Mean	SD
3	86.25	3.34	82.31	3.77	80.77	4.55	75.43	2.60
4	88.29	3.36	84.70	3.64	83.79	4.72	78.46	3.63
5	89.85	3.40	86.71	4.03	86.35	4.71	81.10	3.65
6	91.53	3.33	88.70	3.87	88.67	5.40	84.01	3.59
7	92.74	3.13	90.67	3.99	90.33	5.07	86.02	3.42
8	94.23	3.39	91.88	3.83	91.91	4.80	87.68	3.50
9	95.30	3.11	91.33	3.94	93.33	4.14	89.83	3.55
10	96.02	3.16	94.89	4.12	94.69	4.15	91.67	3.96
11	97.37	3.29	96.81	3.91	95.91	4.44	93.80	3.59
12	98.34	3.16	97.99	4.08	96.96	4.14	95.57	3.43
13	99.33	2.80	99.18	3.88	97.48	4.00	97.66	2.79
14	99.82	2.73	99.99	3.78	98.27	3.93	98.90	2.49
15	100.16	2.59	100.54	3.54	98.96	3.50	99.90	2.46
16	100.29	2.13	100.79	2.98	99.36	3.03	100.63	2.09
17	100.21	1.44	100.51	1.98	99.78	2.18	100.52	1.70
18	100.00	—	100.00	—	100.00	—	100.00	—

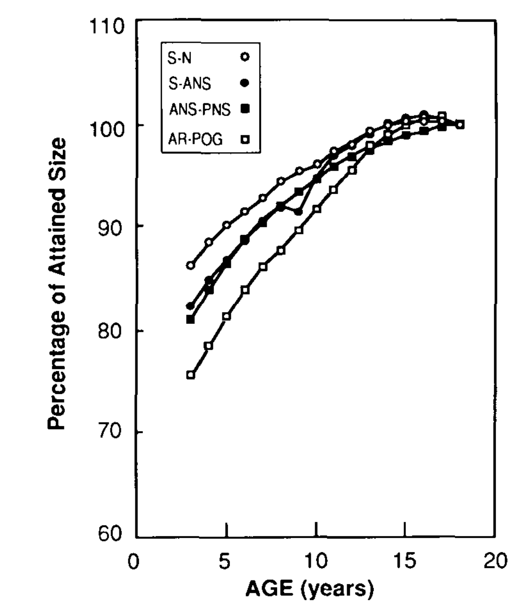

Figure 3

Figure 3
Percentile growth curves for S-N, S-ANS, ANS-PNS and Ar-Pog using terminal value at 18 years of age as 100%.

Table 3
Comparison of absolute incremental growth of the four dimensions of the face from 4 to 15 years.

	S-N	S-ANS	ANS-PNS	Ar-Pog
Absolute size at 4 years (mm)	59.11	69.23	43.64	80.78
Increments				
4-7 yrs	3.97	5.87	4.10	9.51
8-11 yrs	2.74	4.98	2.64	8.12
12-15 yrs	1.52	2.33	1.29	5.26
Total increments 4-15 yrs	8.23	13.18	8.03	22.89
Absolute size at 15 yrs	67.10	82.23	51.48	102.95
Percentage of total increment over absolute size at 4 yrs	13.92	19.03	18.40	28.33
Ratio	1	1.36	1.32	2.03

years of age. Of particular interest is the difference in the rate of growth at 5 years, 90% of adult absolute size of the S-N dimension is complete; 90% completion of S-ANS and ANS-PNS is at 7 years, and Ar-Pog at 9 years.

The relative proportions of facial dimensions at 4 years of age tends to emphasize a size gradient, the S-N dimension reveals 88.29%, followed by S-ANS 84.7%, ANS-PNS 83.79% and Ar-Pog 78.46%. The incremental gradient of growth from 4 to 15 years is reversed showing differential size increases (percentage of total increment over absolute size at 4 years) greatest in mandibular length (28.33%), successively less for the maxillary length (18.4%), sella-anterior nasal spine (19.03%) and anterior cranial base (13.92%) (Table 3). Attained individual dimensions indicate the different patterns of dimensional increase from S-N downward to Ar-Pog that determine proportional changes in the depth of the face during the course of development. Accordingly, if cranial base increment between 4 to 15 years is used as standard of comparison, the ratios obtained for mandibular length are 2.03, maxillary length 1.32, sella-anterior nasal spine 1.36.

III. Proportional changes in the depth of the face relative to the anterior cranial base

The sequential change in pattern of craniofacial proportions is demonstrated by growth of one measurement (S-N) relative to the dimensions of the face (S-ANS, ANS-PNS, Ar-Pog). The S-N dimension was used as a baseline for comparison to reveal different patterns of dimensional increase which determine proportional changes in the depth of the face (Table 4, Figure 4).

The relative curves of growth for S-ANS, ANS-PNS and Ar-Pog are very similar at 4 years of age; they then progressively diverge throughout the entire period of development. The wide spread of the curves results from differences in growth increments and in the rate of growth. The progressively small relative increases of maxillary growth relative to mandibular growth throughout the entire period of development result in differential growth. Thus, mandibular growth makes the greatest contribution to the increase in depth of the face, followed by the maxilla, with the cranial base contributing least.

IV. Changes in angular position of maxilla and mandible

The change in position of ANS and Gn is effected by the relative change in dimension, which is due to the difference in magnitude of growth (size) and the displacement caused by the adjacent bones (Tables 5 and 6, Figure 5). The three major dimensions of the face in depth, S-N, ANS-PNS and Ar-Pog contribute to the reciprocal position of maxilla and mandible in the anteroposterior dimension. The anterior position of maxilla (ANS) and mandible (Gn) is measured by the angle Gn-S-N, S-N-Gn, ANS-S-N and S-N-ANS.

Mandible. Figure 5, Table 5. The relative growth direction of gnathion expressed by the angles Gn-S-N (Y-axis) shows slight decrease of 0.56 degrees from 4 to 18 years of age. In contrast, larger increase in the S-N-Gn angle after 10 years is related to proportionally greater forward displacement of gnathion than at nasion. The changes in angles across age are significantly different at ages 5 to 6, 10 to 11 and 13 to 14 years of age.

The angle S-N-Gn generally shows increase of 4.05 degrees in the entire period of study.

The major intensity of increase in the angle was at 10 years (Figure 5) and continued to increase until 14 years of age. Prior to 10 years there was no appreciable increase in this angle indicating that the relative displacements of nasion and gnathion are equal. The tendency of displacement after 10 years was horizontally oriented relative to nasion. The angle S-N-Gn is significantly different at 10 to 11, 12 to 13, 13 to 14 and 14 to 15 years of age.

The comparative increments of Gn-S-N and S-N-Gn are shown in Figure 6 at successive ages. The increment curves of Gn-S-N and N-S-Gn are divergent and are mirror images to each other after 10 years of age, though different in magnitude. These corresponding divergent fluctuations of both angles are attributed to the relative horizontal displacements. Prior to 10 years, the angle Gn-S-N opens and expresses displacement in a vertical direction, while S-N-Gn closes very slightly, thus maintaining the relative position of gnathion and nasion.

Correlation coefficients (r^S) between Gn-S-N and S-N-Gn at ages 4 through 16 years range from -.93 (4 years) to -.88 (16 years); the relationship tends to be relatively constant at each successive age; they are all significant.

Maxilla. Figure 5, Table 6. Age changes in the growth direction of ANS expressed by the angles ANS-S-N exhibited an increase of 2.63 degrees (4 to 18 years), but was significantly different between 4 to 8 years, 10 to 11, 11 to 12 and 14 to 15 years of age. At age 5 through 18 years the angle opens displacing the ANS vertically. At 14 years, the angle continues to close displacing ANS in the horizontal direction. The S-N-ANS angle shows slight fluctuations in the entire period of study with a small net increase of 0.79 degrees. The slight increase in this angle occurs after 10 years of age, reflecting horizontal displacement of ANS. The annual change in the S-N-ANS angle is significantly different at 7 to 8, 9 to 10 and 14 to 15 years of age.

Analyzing the directional change at ANS at successive ages (Figure 7), the fluctuations of ANS-S-N angle are predominately in the vertical direction, while S-N-ANS fluctuations tend to be in a horizontal direction. Correlation coefficients between ANS-S-N and S-N-ANS at ages 4 through 16 years range from -.71 to -.59. The highest "r" value (-.75) was at 11 years of age.

Discussion

The data reported in this study are discussed here with respect to:

1. The significance of patterns of dimensional

Table 4
Relative facial dimensions as percentage of S-N dimension from 4 to 18 years of age.

Age Yr.	S-ANS Percent S-N		ANS-PNS Percent S-N		Ar-Pog Percent S-N	
	Mean	SD	Mean	SD	Mean	SD
4	117.13	3.53	73.85	3.59	136.70	5.20
5	117.82	3.75	74.57	2.56	138.85	5.03
6	118.33	4.00	75.15	2.77	141.18	4.73
7	119.35	3.66	75.56	2.40	142.67	4.58
8	119.06	3.80	75.71	3.17	143.17	5.33
9	119.57	4.04	76.05	3.56	145.03	5.99
10	120.66	4.30	76.58	3.41	146.90	6.70
11	121.40	4.22	76.48	3.61	148.28	7.27
12	121.67	4.19	76.57	3.69	149.59	7.03
13	121.93	4.49	76.22	3.69	151.37	7.59
14	122.32	4.77	76.46	3.69	152.57	8.05
15	122.58	4.68	76.74	3.65	153.60	8.15
16	122.74	4.67	76.98	4.03	154.52	8.47
17	122.49	4.47	77.38	4.25	154.49	8.90
18	122.16	4.89	77.75	4.82	154.07	9.79

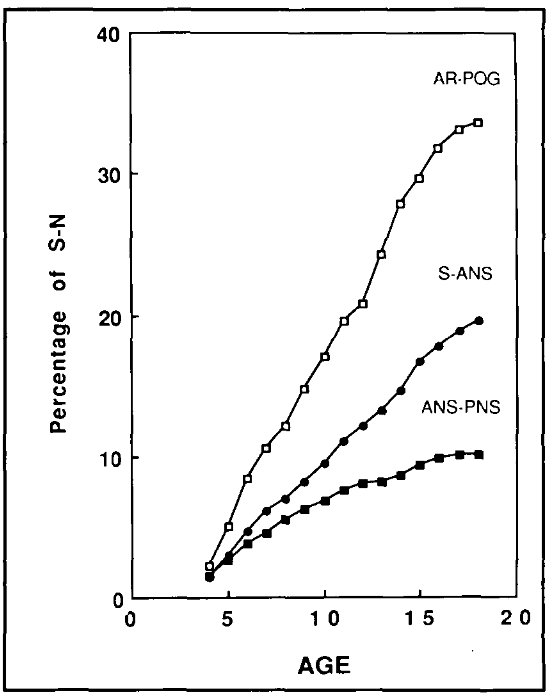

Figure 4
Relative average growth curves for S-ANS, ANS-PNS and Ar-Pog as percentage of anterior cranial base length.

Figure 4

Table 5
Mean absolute and annual changes in the angles for assessing the position of chin

Age Yr.	Gn-S-N Attained Angle Mean	SD	Gn-S-N Annual Change Mean	SD	S-N-Gn Attained Size Mean	SD	S-N-Gn Annual Change Mean	SD
4	66.23	3.07	.55	1.24	76.00	3.51	.50	1.16
5	66.93	3.40	.70	1.22	75.90	3.55	-.10	1.16
6	67.06	3.12	.12	1.78	76.34	3.28	.44	1.84
7	67.19	3.03	.13	1.39	76.54	3.25	.19	1.38
8	67.29	3.03	.93	.952	76.65	3.33	.10	.93
9	67.62	2.89	.33	1.00	76.80	3.15	.15	.82
10	68.00	3.08	.37	.841	76.74	3.27	-.61	.80
11	67.34	3.15	-.66	.647	77.74	3.46	.99	.63
12	67.40	3.25	.64	1.06	78.15	3.43	.41	1.02
13	67.18	3.17	-.22	.901	78.59	3.27	.43	.80
14	66.79	3.27	-.38	.708	79.28	3.44	.69	.77
15	66.55	3.34	-.24	.560	79.70	3.68	.41	.56
16	66.45	3.13	-.98	.917	79.87	3.63	.17	.82
17	66.11	3.50	-.34	1.43	80.08	4.07	.20	1.24
18	65.67	4.68	-.43	2.22	80.05	5.05	-.24	2.04

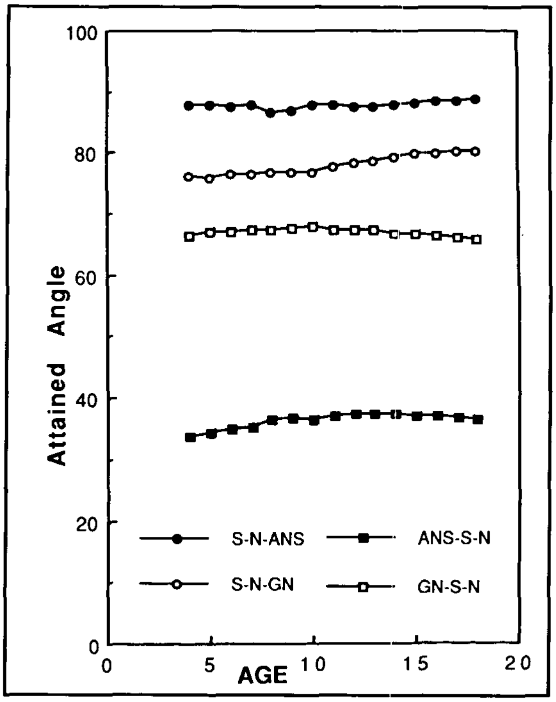

Figure 5

Figure 5
Attained angles for the position of ANS and Gn from 4 to 18 years in reference to the S-N plane. These angles are shown with and without the effect of nasion. The relative decrease or increase in angles reflect their size and the interaction of the vertical and horizontal displacements.

increase and their influence on proportional changes of the face.

2. Differences in the direction of growth affecting change in proportion.
3. Clinical implications.

The findings of this study are not directly comparable to previous studies, since most previous studies are limited to the use of longitudinal cephalometric data during adolescence. Many investigators have examined individual dimensions, and no effort has previously been made to compare relative rates of growth.

The role of differential growth and its implications for maxillo-mandibular relationships in the sagittal dimension of the face has been inferred in numerous previous studies. Within these studies, malocclusions have frequently been characterized as products of "disharmonious growth of the jaws" while normal occlusal relationships are the result of "coordinated growth of the jaws." Moreover, it is typically assumed that orthodontic treatment, if effective, has "normalized" disproportionate growth. The evidence reported in this study indicates that these concepts are not as simple as might be assumed. There is no explicit understanding concerning the dynamics of relative growth of facial dimension that in turn would determine facial form. Further, Coben[38] contended that normal maxillo-mandibular development requires synchronization of the amount, timing and direction of growth of the cranio-maxillary complex and mandible. Neither of these opinions is corroborated by the patterns of growth observed in this study.

The four facial dimensions examined did not grow equally, but did maintain the same general relationship to each other from early childhood to adulthood. About 80% of maximum size was achieved by 4.5 years for S-N, by 6.3 years for ANS-PNS, by 6.5 years for S-ANS, and by 8.5 years for Ar-Pog. This indicates differential growth and by inference there is no close correspondence in size and growth rates between component structures of the face during development. An interesting feature in the growth of these dimensions is observed when expressed in percentages of the adult size.

The different patterns of dimensional increase determine proportional changes in the depth of the face. The early cessation of growth of the anterior cranial base, the following near-completion of growth of the maxilla (9 to 10 years of age), and the continuing growth of the mandible, were directly responsible for the altered

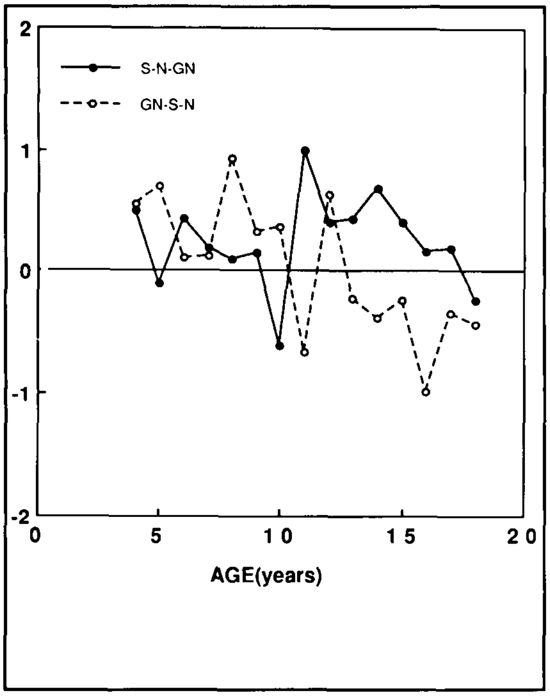

Figure 6

spatial relationship between the maxilla and mandible. The change in relationship was brought about by the disproportionately greater growth of the mandible which assumed a more forward structural position than any other dimension of the face studied.

Of particular interest to the orthodontist is the finding that relative growth rates of the maxilla and mandible were not the same, nor did they attain equal relative size, in reference to adult size, at each age. During development, particularly between 4 and 10 years of age, the skeletal discrepancy found in maxillo-mandibular relationships is a normal, transient developmental characteristic, which in a normal population exhibits a wide range of individual variation.

These findings were further illustrated when the anterior cranial base length was used as a constant to assess different growth rates contributing to incremental growth. In this comparison, maxillary and mandibular length progressively increased with different ratios produced a modification in the configuration of the facial form. This comparison indicates that maxillary growth lagged behind mandibular growth throughout the entire period of development. The greater growth of the mandible contributed to the reduction of convexity of the face during the entire period of development. The comparison with S-N leads to the conclusion that successive reduced growth increments and rate from above downward results in differential growth affecting the spatial rela-

Table 6
Mean absolute and annual change in the angles for assessing the position of maxilla

Age Yr.	ANS-S-N Attained Angle Mean	SD	ANS-S-N Annual Change Mean	SD	S-N-ANS Attained Size Mean	SD	S-N-ANS Annual Change Mean	SD
4	33.61	2.26	.51	.96	87.83	3.71	-.24	1.55
5	34.24	2.35	.63	1.06	87.76	3.88	-.70	1.28
6	34.97	2.06	.72	.83	87.43	3.75	-.33	1.58
7	35.31	2.55	.34	.89	87.85	3.66	.42	1.28
8	36.37	2.06	1.06	1.19	86.63	3.46	-1.22	1.50
9	36.64	1.90	.27	.57	86.70	3.35	.73	1.07
10	36.44	2.17	-.20	.841	87.63	3.67	.92	1.21
11	36.96	2.35	.52	1.05	87.66	3.91	.26	1.52
12	37.26	2.23	.30	.58	87.51	3.56	-.14	.886
13	37.32	2.13	.58	.58	87.61	3.55	.99	1.05
14	37.31	2.37	-.37	.56	87.86	3.87	.25	.966
15	37.14	2.43	-.17	.29	88.20	3.87	.33	.491
16	37.02	2.34	-.11	.87	88.38	3.48	.17	1.03
17	36.81	2.76	-.21	1.39	88.39	3.37	.13	1.38
18	36.24	4.35	-.57	2.36	88.62	4.41	.22	2.72

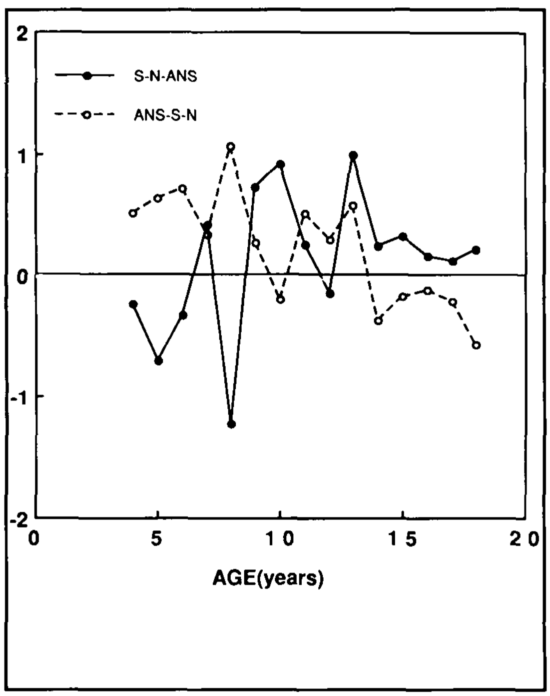

Figure 7

Figure 6
Comparative increments in the S-N-Gn and Gn-S-N angles at successive ages. The increment curves are divergent, the corresponding fluctuations of angles are attributed to the increase in the Ar-Pog dimension and the relative horizontal and vertical displacements.

Figure 7
Graph showing divergences at successive ages of the S-N-ANS and ANS-S-N angles. The fluctuations of the ANS-S-N angle are predominantly in the vertical direction, while those of S-N-ANS tend to be in the horizontal direction. The net effect of ANS is vertical displacement.

tionship of maxilla and mandible in the sagittal plane.

Vectors of growth

The displacement of both N and ANS was proportional, as evidenced by the constancy of the angle S-N-ANS. S-N-Gn increased as a result of a proportionally greater increase in mandibular length over the anterior cranial base length (S-N). It is evident from this study that transient developmental aberrations in maxillo-mandibular relationships occurring prior to the adolescent growth spurt are normal events. The observed differences appear to be due to a higher growth rate of the maxilla by age 10, which subsequently decelerated slowly.

Further, there is a dominant vertical displacement of the maxilla, while the mandible is characterized with horizontal displacement. The reciprocal effect in the positions of ANS and Gn is due to relative greater increase of mandibular length over that of S-N and ANS-PNS and a dominant horizontal vector of growth in angle S-N-Gn contributes to the forward positioning of the chin. The reciprocal behavior between the maxilla and mandible indicates a necessity in distinguishing between those factors responsible for the assessment of size and those that influence position.

The clinician may incorrectly characterize a discrepancy observed in preadolescence as skeletal dysplasia. Such characterization of normal structures at this stage is unwarranted. It is somewhat puzzling that in a developing dentition, the end-to-end first permanent molar relationship, which is an expression of the level of development of the jaws, is considered normal. Even within the same set of dentoskeletal criteria, within the same subject dental relationships are considered normal and skeletal relationships are implicated for malocclusion. The two aspects of dentoskeletal relationships and their criteria for normality are operated from different frames of reference in assessing the mixed dentition. Contrary to the findings of the present study, McNamara[8] characterized normal occlusal relationships in the mixed dentition as Class II malocclusion with retrusive mandible. McNamara's study has been quoted in untold numbers by numerous investigators and clinicians that corrective measures are necessary with functional appliances, when this mythical malocclusion might have been self-corrected.

Clinical implications

The clinical implications of the results reported here are significant. The data suggest that the maxilla is at least 2 years ahead in its relative size in comparison to the mandible, in preadolescent ages. Thus, a discrepancy will always be seen in the growth rate of the maxilla during these ages. Criteria used to identify abnormal skeletal relationships in adults are not appropriate for the evaluation of the preadolescent child. For example, in a Class II malocclusion, where the mandibular ratio relative to the S-N dimension is greater, the potential for remaining growth is relatively less in contrast to those individuals where these ratios are low. Nevertheless, some of these individuals will require treatment.

Based upon potentially normal structures during the mixed dentition, it is conceivable that children receive unnecessary treatment directed to stimulate the growth of the mandible. In the course of time, the greater magnitude of incremental and relative rate of mandibular growth affects the change in form of the face. If an appliance has been recommended, this normal and expected facial change is attributed to the treatment outcome and effect of the appliance.

The anterior cranial case from sella tursica to nasion appears to be extremely variable in size. This suggests that the use of this plane as a reference line, or use of nasion point to assess maxillo-mandibular relationship are not reliable. However, sella-nasion reference line is appropriate to use for the evaluation of treatment and its effect in growth.

Conclusions

The following conclusions can be put forward from this study of patterns of development of the maxilla and mandible in the sagittal plane of the face in females.

1. Each of the four dimensions examined were found to grow differently, but each maintained its relative position to the others. The length of anterior cranial base was found to have a higher rate of growth and earlier completion than the maxillary and mandibular length and further, it decelerates very rapidly.

2. The mandible lagged in sized by 4 years relative to anterior cranial base length and by 2 years relative to maxillary length at 5 years of age.

3. There was an incremental gradient of growth from S-N downward to Ar-Pog such that dimensions successively showed a greater relative amount of growth during the entire period of development.

4. Between 4 and 10 years of age, skeletal dis-

crepancy between the maxilla and mandible is a normal transient developmental characteristic.

5. The proportional displacement of nasion and anterior nasal spine maintained a constant angle S-N-ANS. The increase in angle S-N-Gn was due to proportionally greater increase in mandibular length relative to anterior cranial base length (S-N).

6. The findings presented have practical clinical relevance as they demonstrate that in mixed dentitions, skeletal discrepancy is a normal, transient characteristic.

Author Address

Dr. Surender K. Nanda
Professor of Dentistry
Department of Orthodontics
University of Michigan
Ann Arbor, MI 48109-1078

S.K. Nanda is a professor in the Department of Orthodontics and Pediatric Dentistry at the University of Michigan in Ann Arbor.

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