A Cephalometric Statistical Appraisal Of Dentofacial Growth

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Introduction

Successful diagnosis and treatment of malocclusion depend on a knowledge of the growth and proportion of the human face. Man has long studied the form and development of the human head. These early studies provide us with evidence that the face and teeth are an integrated growth complex. Later studies have indicated that, while an individual growth pattern is established, there are changes in proportion within this pattern.

At birth, the head is closer to its adult size than the trunk and limbs, and the cranium is much larger proportionally than the face. By the end of puberty the face achieves most of its adult size and form, and the trunk and limbs have increased their relative size. When we consider the complex arrangement of the bones of the cranium and face and the multitudinous compensations that must be made to transform the infant to the adult, we can understand why this subject has been in the scientific spotlight for many years.

Angle[1] found it useful for the orthodontist to study facial art. He stated that, in normal relations, the entire denture and correlated parts are in harmonious relation to the general architectural plan of the individual. This statement encompasses more than mere art form and proportion. It involves a complex pattern of growth of many parts which, during maturation from infant to adult, must be balanced in such a fashion as to provide efficient function, continued growth, and pleasing esthetics. The orthodontist must be aware of the interplay of these factors as they affect not only the denture but the entire face as well.

The present study was undertaken to determine statistically what changes, if any, occur with age in certain dentofacial proportions in both horizontal and vertical directions. A statistical analysis was made on measurements taken from tracings of lateral cephalometric roentgenograms. This analysis made possible certain observations concerning proportional changes within the denture and between the denture and the face.

Review of Literature

The introduction of the Broadbent-Bolton cephalometer provided a new technique for growth studies using x-rays.[2] In 1937 Broadbent[3] reported on a growth study of the face using this new technique. His illustration of the mean composite pattern of facial development may be found in most orthodontic texts. He placed the establishment of this pattern at the completion of the deciduous dentition and stated that it remained stable thereafter.

In 1941 Brodie[4] reported on a serial cephalometric study of the growth pattern of the human head from three months to eight years. He found a constancy of facial pattern and placed the establishment of this pattern by three months of age. In their reports both Broadbent and Brodie stressed stability

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of pattern in facial growth while recognizing variations of components within the pattern.

The face may develop along a predestined pattern but, at the same time, one must recognize that certain proportions must change during the transition from infant to adult profile. In order to achieve these variations certain skeletal elements must grow at different rates and at different times.

Recognition of these factors brought a concept of variation. In 1946 Brodie[5] deplored the attempts to fit the individual face into prescribed "norms" or averages. Then followed Downs'[9] analysis in which he demonstrated a method of appraising profile harmony on an individual basis. At the same time Wylie[15] presented his "assessment of anteroposterior dysplasia." He found that variations of individual parts could be cumulative to produce disharmony, or "cancel out" to result in balanced harmony.

It long was believed that the development of the teeth was instrumental in guiding facial development. More recent studies indicate that this is not necessarily true. In 1942 Markus[12] reported on a survey of individuals in which their individual measurements were plotted against Hellman's norms for their particular stage of development. He found that facial growth tended to follow a persistent pattern but, at the same time, there was variation in the relative stage of development of the denture and the face. In some instances they coincided, while in others either the denture or the face lagged behind. In each case where a discrepancy existed there was malocclusion.

Wylie,[15] in a study relating the upper first permanent molar to the maxilla and to the cranium, found that the position of this tooth in the maxilla was not the same in different individuals. It also was not uniformly related to the cranium.

Brodie[5] was of the opinion that the teeth do not play an active part in determining the final form of the face; instead, they are more or less passive and at the mercy of the behavior of the parts around them.

A study of all this background and thinking led us to these questions: If there is a developmental pattern of growth change on the denture, is it integrated with the growth of the facial areas around it? Is there any change in the proportional growth of the denture when related to supporting skeletal structures? Does the stability or change of the denture occur with sufficient frequency to warrant orthodontic concern?

It was the purpose of this investigation to: (1) ascertain from a limited sample the amount of proportional growth of the various points in the facial profile, both in height and depth: (2) determine the proportional changes within the denture and relate these to the facial changes; and (3) subject any findings to a statistical analysis to determine if they are significant.

Method and Material

The material used in this investigation was obtained through the courtesy of Dr. B. H. Williams, Chairman of the Department of Orthodontics, The Ohio State University.

Twenty-five cases were chosen which had not received orthodontic treatment and were in normal or ideal occlusion. Because the growth change during the pubertal "growth spurt" was the principal interest, two films were used, one before and one after the probable onset of puberty. The mean prepubertal age was 7.95 years, and the mean postpubertal age was 15.15 years.

The measurements were made directly from tracings of oriented headplates.

In instances where bilateral structures were not superposed, the mid-point between the structures was used with the exception of the maxillary left first molar. This procedure tends to eliminate errors caused by slightly inaccurate orientation of the patient in the cephalometric head holder.

The usual anatomical points were employed, and further description of them should not be necessary.

It is necessary in any serial roentgenographic growth study to employ a base plane on which to orient succeeding tracings in the series. In previous studies several planes have been used. The use of the Bolton triangle by Broadbent[2] and the Frankfort plane by Downs[9] and Wylie[15] have been described. In other studies, Brodie,[4] Lande,[11] and Williams[14] used the anterior cranial base represented by the sella-nasion plane. Coben used a mean Frankfort plane but maintained it at a constant relation to the sella-nasion plane. While the S-N plane is well situated as a reference, it represents only the anterior cranial base. Further, nasion, as a registration point, is part cranial and part facial. An effort was made in this study to incorporate the Frankfort plane with the entire cranial base represented by the Bolton triangle. The Bolton triangle was drawn and registration point "R" located. It was felt that the "R" point was located in the area of least growth and therefore was ideal as a base-point for measurements.

A pilot study demonstrated the variability of the location of porion making it necessary to determine a mean location of porion for each series. This variance was noted when the tracings of a series were superposed with the Bolton planes parallel. In most cases there was considerable variation in the location of porion. In some instances, the postpubertal porion was above the prepubertal location. Superposing Frankfort planes in these cases gave the appearance of great horizontal growth with little vertical growth. The growth pattern appeared mainly vertical in those cases where postpubertal porion was located below the prepubertal site. A mean location was established by superposing the tracings of each series with Bolton planes parallel and halving the vertical distance between the two points. This mean porion was then transposed to each tracing in the series. It was necessary to establish a mean porion in twenty-one of the twenty-five series measured.

The measurements were made using a sheet of millimeter graph paper which had been divided into four quadrants by two coordinates: one horizontal which was called X, and one vertical which was called Y. The tracings were then laid on the graph paper as follows: the registration point "R" at the intersection of the two coordinates with the Frankfort plane parallel to the X coordinate (Figure 1). Each anatomical point was then established in relation to the X and Y axes for both the prepubertal and postpubertal age groups and recorded as horizontal and vertical distances in millimeters from the respective axes. A profile diagram illustrating the mean growth change of each of these points is shown in Figure 2. The mean measurements were reduced to percentage or proportions of a base line. In this study the distance along the X axis from "R" to N was used as the 100% base for the calculation of the horizontal proportions, and the vertical distance of Gn from the X axis was used as the 100% base for the vertical proportions (Figure1). Thus, by dividing the distance to each point into the length of the relating base line, the proportion that each point contributed in height and depth could be calculated. This was expressed as a percentage of the base line. By comparing

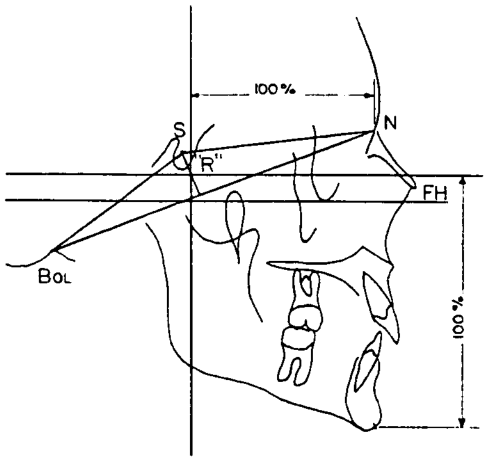

Fig. 1 Method of orienting tracings to plane of reference and axes.

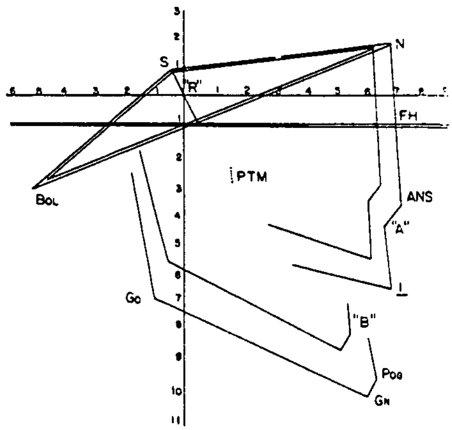

Fig. 2 Profile diagram illustrating mean position of each point in prepubertal and postpubertal age groups.

the percentages of prepubertal and postpubertal proportions, any change in the proportion of a given area could be ascertained. The mean prepubertal and postpubertal dimensions and the proportions they represent are recorded

TABLE I

Table showing facial proportions horizontally and vertically from mean measurements, and the changes in proportion.
Horizontal Proportions. X-N = 100%

Points Measured	Dimensions Pre-	Dimensions Post-	Percentages Pre-	Percentages Post-	Diff.
X-N	64.8	70.6	100.0	100.0	0.0
X-ANS	66.7	73.6	102.9	104.2	1.3
X-A	61.8	67.8	95.3	96.0	0.7
X-1	62.9	70.2	97.1	99.4	2.3
X-B	54.7	61.8	84.4	87.5	3.1
X-Pog	55.1	64.2	84.8	91.7	6.9
X-Gn	52.1	61.1	80.4	86.5	6.1
X-6	27.3	35.2	42.1	49.8	7.7
X-PTM	15.8	16.0	24.3	22.6	1.7

Vertical Proportions. Y-Gn = 100%

Points Measured	Dimensions Pre-	Dimensions Post-	Percentages Pre-	Percentages Post-	Diff.
Y-Gn	85.4	100.5	100.0	100.0	0.0
Y-ANS	29.5	36.5	34.5	36.3	1.8
Y-A	35.2	43.1	41.2	42.8	1.6
Y-1	54.8	65.1	64.2	64.7	0.5
Y-B	69.0	80.3	80.8	79.9	-0.9
Y-Pog	79.8	94.6	93.4	94.1	0.7
Y-6	43.5	56.5	50.9	56.1	5.2
Y-PTM	23.4	28.0	27.4	27.8	0-3

in Table I. Table I also shows the change in proportion that occurs during this age range. This is merely the percentage difference recorded as a positive or negative value indicating increase or decrease in proportional growth of each point.

In this study the actual distance to each point will be called the absolute distance, and the mean growth change the absolute change. The proportions will be referred to as relative distances and change in proportion will be called the relative change.

Observations

A comparison of the mean relative change of each point in the profile along both axes makes possible some general observations. PTM, although it falls behind proportionally, seems to be quite stable along the X axis. The amount of proportional change of Point A along the X axis was the smallest of any of the changes of the profile points in the horizontal direction. This would seem to indicate that it is proportionally stable in horizontal growth. As we progress from nasion down the profile to gnathion, there is progressive increase in relative horizontal growth of each point with pogonion showing the greatest relative change. The upper face tends to maintain proportion in forward growth, while the lower face shows a marked relative increase. This is illustrated graphically in Figure 3 and agrees with the results of Williams.[14]

The impression gained by comparing the relative vertical changes is one of more uniformity than was observed along the horizontal axis (Figure 4). The range of percentage change among the several points vertically was from —0.9%to 1.8%, while it was from 0.7% to 6.9% horizontally. These figures were taken from Table I. The upper first molar is not included in

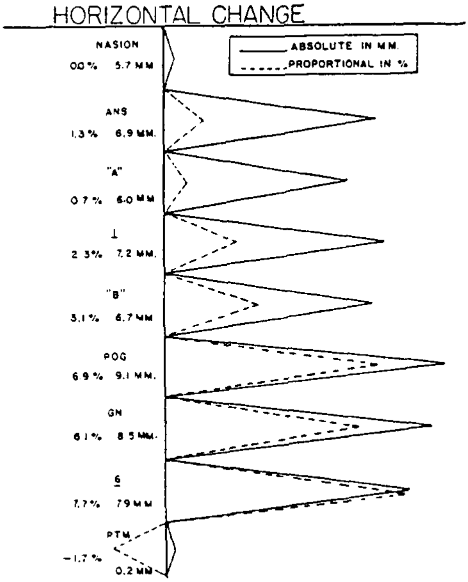

Fig. 3 Diagram illustrating absolute and relative horizontal change of the facial points.

these ranges because only the facial profile is being considered at the moment. This difference in range does

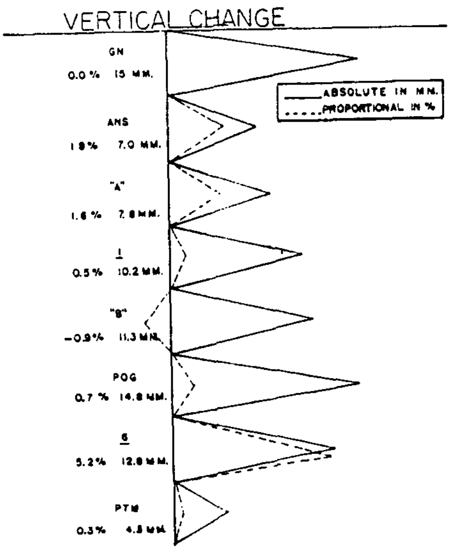

Fig. 4 Diagram illustrating absolute and relative vertical change of the facial points.

	Y-N	X-ANS	Y-ANS	X-A	Y-A	X-B	Y-B	X-On	Y-On	X-Pog	Y-Pog	X-Go	Y-Go	X-PTM	Y-PTM	X-6	Y-6	X-1	Y-1
X-N	.56	.51	.24	.55	.04	.27	.28	.38	.53	.46	.44	.13	.40	.37	.24	.31	.51	.57	.45
Y-N		.35	.07	.43	.22	.34	.02	.30	.09	.32	.08	.07	.21	.34	.03	.24	.12	.36	.02
X-ANS			.05	.73	.03	.30	.24	.08	.35	.25	.36	.30	.22	.46	.15	.35	.29	.38	.21
Y-ANS				.05	.79	.11	.42	.10	.47	.08	.47	.08	.15	.02	.39	.13	.64	.11	.51
X-A					.09	.46	.19	.32	.21	.48	.27	.12	.35	.54	.24	.56	.24	.42	.13
Y-A						.26	.54	.37	.51	.25	.51	.46	.07	.20	.24	.02	.59	.45	.47
X-B							.20	.68	.00	.80	.00	.19	.22	.55	.43	.65	.29	.45	.08
Y-B								.30	.79	.09	.78	.17	.46	.14	.18	.01	.63	.03	.60
X-On									.01	.85	.27	.35	.05	.59	.18	.54	.12	.48	.24
Y-On										.12	.02	.94	.16	.03	.44	.04	.80	.15	.73
X-Pog											.12	.35	.48	.61	.42	.64	.30	.56	.07
Y-Pog												.01	.54	.13	.43	.15	.77	.12	.73
X-Go													.22	.44	.16	.36	.13	.37	.17
Y-Go														.29	.48	.43	.53	.33	.46
X-PTM															.31	.67	.16	.36	.01
Y-PTM																.46	.68	.32	.50
X-6																	.36	.40	.02
Y-6																		.25	.76
X-1																			.29

Levels of Significance:
.01 - .35
.05 - .40
.10 - .51

Table II

not imply presence or lack of stability of growth along either axis. Rather, it merely indicates that the vertical proportions in growth during this age range do not vary as much as the horizontal proportional changes. It was noted that the upper face tended to increase slightly in relative distance, while the lower face remained in proportion. Point B shows a decrease in relative change vertically. These comparisons are illustrated graphically in Figures 3 and 4.

An examination of relative changes in the maxillary denture revealed indications that the denture did not completely follow the same pattern as the face. The upper central incisor showed over three times more relative change than did Point A (Figure 3). The relative change of the upper first molar was greater along both axes than any other point measured.

These computations were made from mean figures and therefore represent only a mean growth pattern. A statistical analysis was made to determine whether or not any of these findings were significant. The mean prepubertal position and mean change of each point were correlated with each other and with those of each of the other points, both horizontally and vertically. This made it possible to ascertain the degree of dependence of each variable on every other variable along either axis. Since it was the purpose of this study to relate the denture to the profile, only those correlations which are pertinent are shown in Table II. For example, to find the correlation between the horizontal change in Point A and the vertical change in Point A, follow the X-A line horizontally on the chart to its intersection with the vertical column Y-A. The coefficient of correlation in this instance is .09. This low figure indicates that these two variables are not mutually dependent.

The correlation values were of some assistance in determining which relations were significant. For example, the relative change of Point A, when related to ANS, shows a high coefficient of correlation along both axes. This would be expected, since Point A and ANS are anatomically closely related. When Point A is related to Point B in either plane the correlation is not as high but still significant.

The relative change of the upper first molar showed significant coefficients of correlation when related to the change of all other profile points along the horizontal axis except nasion. The upper first molar showed even higher correlation values when related to the other points in the vertical direction, again with the exception of nasion. The same general relations existed between the upper central incisor and other profile points along both axes. In this instance, the horizontal correlation with nasion is significant, but the vertical is not. The relative change of the molar with that of the incisor was significant along the X axis and was highly significant along the Y axis. The molar was well correlated when related to PTM.

With some exceptions already noted, the coefficients of correlation of the relative distances of all points are significant in the same plane but not to the opposite plane. Does this mean that horizontal and vertical growth are independent of each other?

Nasion, along the Y axis, showed no significant level of correlation with relative vertical change of any other profile point. This could be due to the method of orienting and measuring the tracings. Nasion lies above the X axis while the other points in question lie below it. Thus, in growth, nasion moves away from the orienting axis in one direction while the other profile points move away from it in the opposite direction. Further, since nasion is an anterior cranial base point, it would tend to follow a cranial growth gradient while the other points follow a facial growth gradient.

Discussion

This attempt to relate the denture to the facial profile in growth makes one factor stand out uppermost: variability. One is impressed with the complexity of growth of the skull. No single factor or variable can of itself be significant unless it is integrated into the total complex arrangement.

From the data presented, certain areas seem to maintain proportion in growth. Certain other areas exhibit a change in proportion. Point A maintained proportional stability in horizontal growth and verified the findings of Williams[14] and of Coben.[8] However, it was less stable in its proportional vertical growth and in this respect did not agree with Williams'[14] results. Possibly this could be because of the different method of orienting the tracings.

There appeared to be a progressive increase in amount of horizontal proportional change along the facial profile from nasion to gnathion. The lower face tended to become more prognathic during the age span studied, indicating that the chin point swings out from under the cranium. This agrees with the findings of other investigators. The mean changes in these areas were quite close to those reported by Coben[8] in 1955.

Point B increased in relative horizontal distance while Point A remained in proportion. This verifies earlier findings regarding the reduction in angle of convexity during this age range.

Pogonion and gnathion advance horizontally at a more rapid rate than Point B. This could be due in part to appositional growth in these areas.

The maxillary denture base, as represented by Point A, remains proportionally stable along the X axis while the denture moves forward. This is probably due to the growth necessary to accommodate the molar teeth. This forward movement of the denture is interesting when applied to the question of distal movement of teeth in orthodontic treatment. A portion of the apparent distal movement may be an actual shift of the tooth over the base, while the remainder may be due to holding the tooth while the base grows forward. If the denture continues to move forward on the base, as Sved[13] discusses, the orthodontic implications continue. This may influence decision concerning extraction of teeth as well as establishing the best method of treatment.

The profile points seemed to have a fairly equal amount of relative change vertically with the exception of Point B which showed a decrease in relative change. This would suggest that vertical growth within the denture is lagging proportionally to total vertical facial growth. It was noted that high correlation coefficients resulted when the vertical changes of the denture points were related to the vertical change of Point B. This implies that the orthodontist should not routinely expect vertical growth in the alveolar region and in the mandibular condyle to maintain proportion in the lower face during this age range. The high standard deviations of the vertical changes of these points suggest that lack of vertical development of the lower face could cause lack of intermaxillary space. In these cases, development in this direction would have to be encouraged mechanically.

On the other hand it is possible that Point B is not a stable point. It has been pointed out that, when serial tracings of the mandible are related, only the mental area and the lingual outline of the symphysis remain fairly constant. Brodie[7] has shown that the occlusal plane descends during growth. As the lower incisor erupts toward a descending occlusal plane, Point B is also moving occlusally and this may explain the apparent decrease in relative vertical proportion.

While the upper incisor demonstrated a significant increase in horizontal relative change, the upper first molar showed even more pronounced differences. The proportional change of 6 is over three times that of 1 horizontally, and four times vertically. The vertical change of 6 indicates a continuing change in the occlusal plane angle, and verifies Brodie's[6] findings. The horizontal relative change of 6 compared with that of 1 would indicate a decrease in arch depth. However, Table I shows a mean change between the two points of only 0.6 mm, and both means showed high standard deviations. The coefficient of correlation is only moderately significant. This tends to agree with Wylie's[15] statement that the position of the upper first molar is not the same in different individuals.

Vertically, there is high correlation between 6 and 1, and between 6 and Go and Gn. It is also high between 1 and Gn. Apparently the relative change of the occlusal plane is related to change in the mandibular plane. This verifies Goldsman's[10] conclusion that the occlusal plane is more closely correlated with skeletal pattern measurements than with those of the denture pattern.

It must be stressed that statistical evaluation of this sort is limited by the size and choice of the sample. Further studies of larger samples including the classes of malocclusions must be made before data of this type can be applied to appraisal of an individual case.

Summary

The horizontal and vertical dentofacial proportions of twenty-five individuals were compared before and after the onset of puberty. It was found X-A and Y-1 maintained proportional growth. The remainder of the points measured showed proportional change in growth. The horizontal proportion of the upper face tended to remain stable while the lower face demonstrated an increase. The upper face increased in relative vertical distance while the alveolar region decreased. The lower face showed less increase in vertical proportion.

The maxillary denture moved forward on its base. The denture appeared to be more closely correlated with the vertical facial growth pattern than with the horizontal pattern. There is a tendency toward decreased arch depth during this age range. Changes within the denture, and between the denture

and base are apparent. All of these changes are very variable and require further study.

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