A Quantitative Method for Measuring Changes in the Maxilla Due to Growth and Orthodontic Procedures

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INTRODUCTION

Since 1931 when Broadbent and Hofrath separately described x-ray techniques for measuring the living head, this method has been widely used in growth studies as well as in those of a clinical nature in which changes might be expected over intervals of time.

The preponderance of findings derived from those studies has been obtained from the lateral head x-ray alone, although the Broadbent technique calls for a posteroanterior view as well. The neglect of the frontal image has been due to the difficulty of controlling the variables encountered in this view.

It was the purpose of the present work to attempt to solve these difficulties, in order that changes in the third plane of space (horizontal) would be as susceptible to measurements as those in the vertical and anteroposterior (height and depth) planes.

METHOD

The technique of cephalometric roentgenology has been adequately described by Broadbent[2] and Brodie[3] and will not be repeated here.

All linear measurements were read to the nearest 0.5 mm with correctional scales. Angular measurements were read to the nearest 0.5 degrees with a standard protractor.

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Anteroposterior (depth) measurements and vertical (height) were taken from the lateral head film by establishing a skeletal coordinate system. The two tracings of each case were superimposed on the anterior cranial fossa and registered on sella (S). Measurements of depth were taken parallel to the Frankfort horizontal plane. Vertical measurements were taken parallel to the perpendicular line from S.

All landmarks, planes and angles were marked on the tracings as shown in Figure 1. Two of the reference

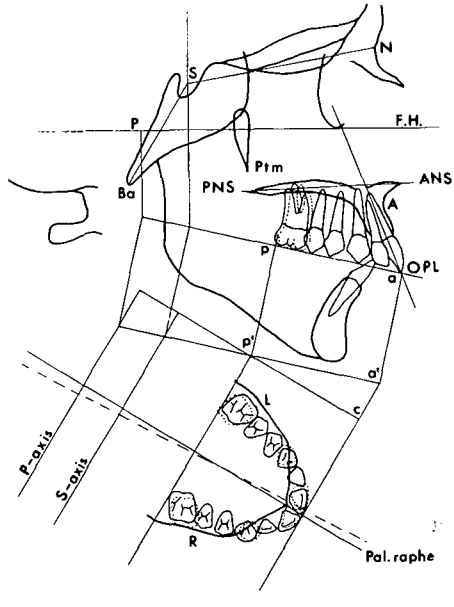

Fig. 1 Method of registering coordinate systems derived from lateral head film (above) and that derived from tracing of plaster model (below).

planes, viz., Frankfort horizontal and the perpendicular plane through S, have already been described. The third plane of reference, for determination of horizontal measurements, is the occlusal plane.

For determination of the occlusal plane in relation to the Frankfort horizontal, the maxillary model was placed, teeth down, on a horizontal table with the cusp tips touching the table. The contacting cusp tips on the left side of the dental arch were marked on the lateral headplate tracing. A straight line connecting these points was taken to represent the occlusal plane in the lateral view.

In order to construct a coordinate system of the dental arch, it was necessary to obtain an accurate tracing of it. To accomplish this, the upper model was fastened with its teeth in contact with an x-ray cassette positioned at the midsagittal plane of the cephalometer (Fig. 2). The central ray was focused at the center of the base of the model and an exposure was made. Measurements obtained from the plaster model when compared with those from the occlusal film were identical.

Two small lead dots previously fastened to the model in the median raphe line were also registered and connected by a straight line to indicate the midline (Fig. 3). This was taken as the base line of the rectangular coordinate system for the occlusal view. The next step was to bring the two coordinate systems into correct registration with each other (Fig. 1).

On the lateral film tracing, perpendiculars to the line representing the occlusal plane were drawn from the two ends of the arch, i.e., tangential to the most labial surface of the incisors in front, and a point posteriorly representing the distal surfaces of the first permanent molars.

On the occlusal tracing of the dental

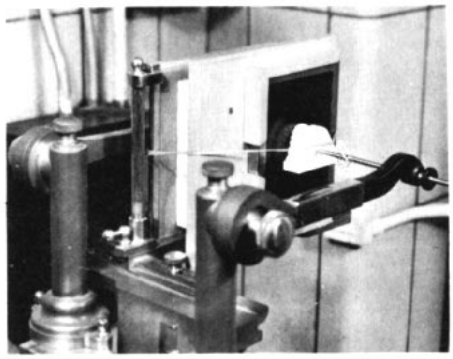

Fig. 2 Positioning of plaster model in midsagittal plane of cephalometer for x-ray exposure.

arch, perpendiculars to the midline were drawn tangential to the same points. The two tracings were then shifted until the two perpendiculars from the molars intersected each other, and those from the incisors did likewise. This established points a′ and p′. A line was drawn through p′ parallel to the occlusal plane p,a. This represents the coordinate system of the lateral view. Another line was drawn through p′ parallel to the midline of the occlusal tracing representing the coordinate system of this view. This resulted in the creation of the angle a′p′c. This will be referred to as the correctional angle.

By means of a correctional angle it is possible to reduce the enlarged measurements obtained from the lateral

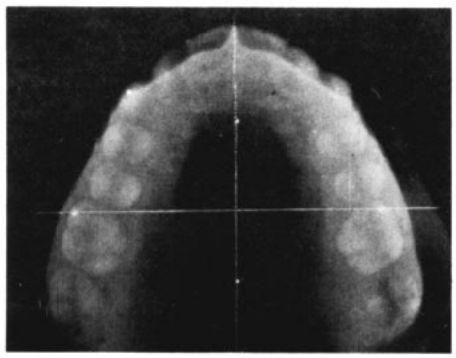

Fig. 3 Occlusal x-ray of the plaster model.

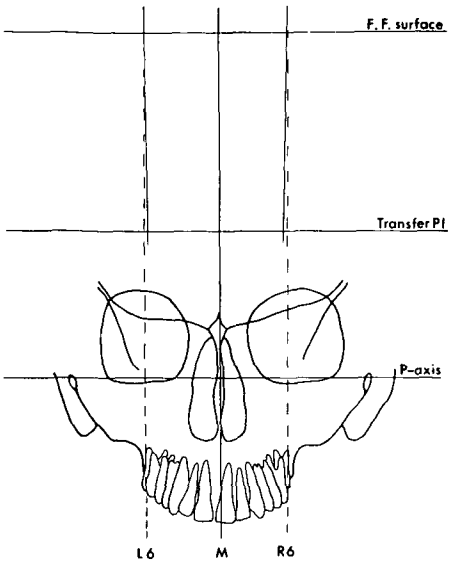

Fig. 4 Tracing of frontal film indicating method used to derive absolute measurements from enlarged images.

cephalometric headplate to their exact size and anteroposterior location on, or posterior to, the model; or in reverse, to project any dimension on the model to its enlarged value and corresponding anteroposterior location on the lateral cephalometric headplate. In this method of analyzing the maxillary dental arch in its relation to the lateral cephalometric headplate, the plane of reference is the midsagittal plane, and the means between bilateral points are taken as midsagittal points. The superimposing of the midpalatine raphe line on the midsagittal axis in the dental coordinate system is based on the assumption that the midsagittal plane and the dental midline coincide.

However, deviation from symmetry in the dental arch, in the maxilla, in the cranium, or in the positioning of the head in the head-holder will cause errors in measurements when only midsagittal points are used. To correct these errors it was found necessary to have recourse to the frontal cephalometric headplate.

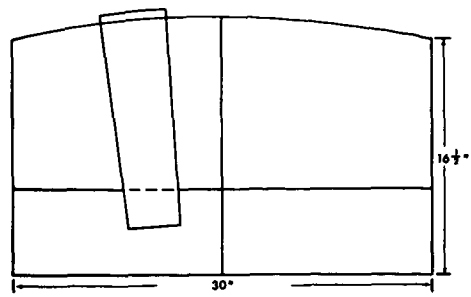

Fig. 5 The Wylie-Elsasser compensator.

To correct readings from the frontal cephalometric headplate, e.g., widths and asymmetries, it is necessary to determine the location in space of the points in question. The location of points in the horizontal or occlusal plane must be determined by intersections of projections from both the lateral and frontal films. This was accomplished as follows (Fig. 4).

The frontal cephalometric headplate was traced and a horizontal line drawn through the earpost shadows to represent the porionic axis. A perpendicular representing the midsagittal plane was dropped through crista galli and the nasal septum. The most buccal points on the first maxillary molars, L6 and R6, and a point C representing the contact point between the upper central incisors were marked on the tracings. Since all of these landmarks are distorted by enlargement, they required correction with the Wylie-Elsasser compensator (Fig. 5).

The tracing of the frontal film is oriented on the compensator with the lines representing the porionic and midsagittal planes superimposed on the engraved horizontal and vertical lines of the compensator. Another line representing the film surface is drawn parallel to the porionic axis. The distance between the film surface and the porionic axis is derived from a vernier mm scale in the base plate of the Broadbent-Bolton cephalometer, which is read at the time of exposure and imprinted on the film.

In the present study, perpendiculars were drawn to the film surface line tangential to the buccal surfaces of L6 and R6. The distance between their points of intersection with the frontal film (FF) surface represented their enlarged distance from each other on the film. To reduce this distance to its absolute size, a third line (transfer plane) parallel to the porionic axis and film surface lines was drawn at the corrected distance from the porionic line to the midline point of the line connecting L6 and R6. This distance was derived from the lateral film. Using the sliding T-square, lines were drawn through the points L6 and R6 on the frontal film line to intersect this third line. The intersection of these lines represents the corrected relation of these points to the midsagittal plane. The occlusal tracing could now be oriented to the dental coordinate system using the points L6, R6 and C.

Thus it is possible to place the tracing of the dental arch in the dental coordinate system according (Fig. 1) to midline structures as first described (solid lines), or according to corrected width measurements obtained from both the lateral and the frontal headplates using the Wylie-Elsasser compensator (dotted lines).

The techniques described for the correct positioning and measurement of the dental arch can also be employed for similar studies of the maxillary apical base. The technique for measuring that zone was described by Brodie[4] and will not be repeated in detail here. Suffice it to say that the findings are derived directly from the maxillary plaster model and result in an outline of the maxillae at the level of the root apices including all teeth anterior to the first permanent molars. The outline is closed in back by a transverse line connecting the contact points between the first permanent molars. The area enclosed by this perimeter can be measured with a compensated polar planimeter, and the results stated in square millimeters.

Table I.

		Mean	Range
D	Ba-N	1.77	0.0 to 5.0
E	Ba-S	0.65	-1.0 to 2.5
P	S-Ptm	-0.35	-2.0 to 1.5
T	Ptm-A	-1.05	-3.5 to 0.5
H	N-A	2.18	0.5 to 4.5
	P-Ba	-1.55	-5.5 to 1.5
H	N-⊥	3.68	-1.0 to 6.5
E	N-ANS	2.33	-0.5 to 6.5
I	ANS-⊥	1.35	-1.0 to 5.5
G	S-⊥	2.63	-1.0 to 4.5
H	S-PNS	1.23	-1.0 to 3.0
T	PNS-⊥	1.40	-2.0 to 3.0
	⊥-A	-0.68	-3.0 to 2.0
A	Ba-S-N	-0.25	-2.5 to 1.0
N	S-N to FH	-0.05	-1.0 to 0.5
G	Ba-S to FH	-0.20	-2.0 to 1.5
L	⊥ to FH (Cl. II div. 1)	-10.20	
E	⊥ to FH (Cl. II div. 2)	21.30	
S	ANS-PNS to FH	2.23	-1.5 to 4.0

Table I Differences between measurements obtained from pretreatment and posttreatment lateral cephalometric headplates.

The method here described was applied to a sample of twenty Class II malocclusions. The anteroposterior molar relationship was corrected with cervical traction and the tooth movement was measured according to the methods described.

Observations

The observations are divided into three major parts.

1. *Data derived from the skeletal coordinate system*

The means and ranges of pre and posttreatment differences as derived from skeletal coordinate system are presented in Table I. The upper section of Table I includes the corrected depth measurements. These reveal that the total depth Ba-N exhibited a mean increase of 1.77 mm with a range of 0.0

to 5.0 mm. However, of the five components contributing to total depth, S-Ptm and Ptm-A revealed decreases, but the range indicates that there were increases as well. Ba-S increased slightly, while N-A showed the largest increase.

P-Ba was measured in order to relate the porionic axis to the skeletal coordinate system at the two measurements. Mean reading was —1.55 mm.

The middle section of Table I includes the height measurements. N-ANS yielded the larger increase as would be expected. S-$\underline{6}$ is the total posterior height and its mean increase was only about 1 mm less than the total anterior height increase. Of its two components, the PNS-$\underline{6}$ increase slightly exceeded that of S-PNS indicating greater dental than nasal growth.

$\underline{6}$-A dimension was measured parallel to the occlusal plane from the midsagittal mesial contact point of the maxillary first molars to point A, and cannot be correlated with data derived from the skeletal coordinate system because it is not parallel to the horizontal plane. This measurement showed a mean decrease of —0.68 mm.

The cranial base angle, Ba-S-N, revealed a mean decrease of —0.25 degrees. It was further divided into two angles, viz., S-N to FH (anterior cranial base angle) and Ba-S to FH (posterior cranial base angle). It was found that the posterior cranial base angle was responsible for the greater part of the decrease in the cranial base angle, the anterior part showing only a very slight mean decrease.

In the measurement of the angle formed by the axis of the central incisor with the FH, the striking difference between the individuals with Class II, Div. 1 and those with Class II, Div. 2 malocclusions dictated their separate analyses.

The palatal plane angle, ANS-PNS to FH, yielded a mean increase of 2.23 degrees. Only two cases in the sample showed a decrease.

2. *Determination of amount and direction of tooth movements derived (a) from coordinate systems alone and (b) from combination with frontal projections.*

To arrive at these determinations it is necessary to make separate analyses of each case before and after treatment in order to determine the difference between them. Table II sets forth data on each case in the sample analysed by both methods.

In the first column the numerals 1 and 11 indicate pretreatment and posttreatment respectively, and "dif." signifies the difference between them.

In the second column the median raphe to transporionic axis angle is marked; positive if the deviation is to the left, and negative if the deviation is to the right. In thirteen of the cases the pre and posttreatment angular differences varied from 0 to 1 degree, in four cases the difference was 1.5 to 2.5 degrees; only three cases exceeded 2.5 degrees. Four cases in the sample had a pre and posttreatment reading of 90 degrees; in those cases the median raphe line coincides with the midsagittal plane, or was a parallel to it. In ten cases one of the readings was 90 degrees, while in another ten cases none of the readings was 90 degrees.

In the third column the S-Ptm measurement from the skeletal coordinate system is given. This is for the purpose of allowing comparison with any change in the posterior movement of the first maxillary molars. In the fourth column the distance $\underline{6}$ to sella is shown for right and left sides. These measurements are derived from the midsagittal registration in the dental coordinate system.

In the fifth column the same measurements derived from the frontal

Table II.

Case no.	P. raphe to P-axis.	S-Ptm	S-$\frac{6}{}$ mid. seg. reg. R.	S-$\frac{6}{}$ mid. seg. reg. L.	S-$\frac{6}{}$ front. reg. R.	S-$\frac{6}{}$ front. reg. L.
1. B.P. I.	90.0	22.0	39.5	41.0	39.5	41.0
II.	-88.0	21.5	40.0	40.0	41.0	39.0
dif.	2.0	0.5	0.5	-1.0	1.5	-2.0
2. B.K. I.	90.0	19.0	36.5	34.5	36.5	34.5
II.	87.0	19.0	35.0	35.5	36.0	34.5
dif.	3.0	0.0	-1.5	1.0	-0.5	0.0
3. C.P. I.	90.0	15.0	34.0	33.0	34.0	33.0
II.	90.0	15.0	33.5	34.0	33.5	34.0
dif.	0.0	0.0	-0.5	1.0	-0.5	1.0
4. C.D. I.	90.0	20.0	41.0	38.0	41.0	38.0
II.	-89.0	19.5	37.0	36.0	36.5	36.5
dif.	1.0	-0.5	-4.0	-2.0	-4.5	-1.5
5. E.R. I.	88.5	19.0	36.0	36.0	36.5	35.5
II.	87.5	19.0	33.0	33.0	34.0	31.0
dif.	1.0	0.0	-3.0	-4.0	-2.5	-4.5
6. F.J. I.	90.0	18.5	34.0	31.0	34.0	31.0
II.	88.0	18.5	28.5	27.5	29.0	27.0
dif.	2.0	0.0	-5.5	-3.5	-5.0	-4.0
7. F.A. I.	87.0	13.0	28.5	29.0	30.0	27.5
II.	87.5	13.0	31.0	30.5	32.5	29.0
dif.	0.5	0.0	2.5	1.5	2.5	1.5
8. H.B. I.	87.5	16.0	33.0	34.0	34.0	33.0
II.	-87.5	16.5	29.5	30.0	28.5	31.0
dif.	5.0	0.5	-3.5	-4.0	-5.5	-2.0
9. K.B. I.	89.0	19.0	37.0	37.5	37.5	37.0
II.	88.0	18.0	35.0	36.0	36.0	35.0
dif.	1.0	1.0	-2.0	-1.5	-1.5	-2.0
10. M.D. I.	88.0	20.5	40.0	40.0	41.0	39.0
II.	-89.0	20.5	36.0	35.5	35.5	36.0
dif.	3.0	0.0	-4.0	-4.5	-5.5	-3.0
11. O.M. I.	90.0	18.0	34.5	34.0	34.5	34.0
II.	90.0	18.0	33.5	34.0	33.5	34.0
dif.	0.0	0.0	-1.0	0.0	-1.0	0.0
12. P.V. I.	86.5	18.0	37.5	39.0	39.5	37.0
II.	87.0	17.5	34.5	34.0	36.0	32.5
dif.	0.5	-0.5	-3.0	-5.0	-3.5	-4.5
13. P.M. I.	87.0	21.5	39.5	39.5	41.0	38.0
II.	88.0	21.5	39.0	40.0	40.0	39.0
dif.	1.0	0.0	-0.5	0.5	-1.0	1.0
14. R.K. I.	86.5	16.5	33.0	32.0	34.5	30.0
II.	87.0	15.0	32.0	31.0	33.0	29.5
dif.	0.5	-1.5	-1.0	-1.0	-1.5	-0.5

Table II. (Continued)

Case no.	P. raphe to P-axis.	S-Ptm	S-$\frac{6}{}$ mid. seg. reg. R.	S-$\frac{6}{}$ mid. seg. reg. L.	S-$\frac{6}{}$ front. reg. R.	S-$\frac{6}{}$ front. reg. L.
15. R.B. I.	90.0	15.5	33.5	33.5	33.5	33.5
II.	90.0	17.0	35.5	34.5	35.5	34.5
dif.	0.0	1.5	2.0	1.0	2.0	1.0
16. S.R. I.	90.0	19.5	41.0	38.5	41.0	38.5
II.	90.0	17.5	38.0	37.0	38.0	37.0
dif.	0.0	2.0	-3.0	-1.5	-3.0	-1.5
17. S.L. I.	88.0	18.5	37.0	35.0	38.0	34.0
II.	90.0	18.0	35.0	35.0	35.0	35.0
dif.	2.0	-0.5	-2.0	0.0	-3.0	1.0
18. S.D. I.	88.5	17.5	35.0	37.0	36.0	36.0
II.	88.5	16.5	37.5	37.0	38.5	36.0
dif.	0.0	-1.0	2.5	0.0	2.5	0.0
19. T.L. I.	87.5	18.5	38.0	38.0	39.0	37.0
II.	90.0	17.5	32.5	32.5	32.5	32.5
dif.	2.5	-1.0	-5.5	-5.5	-6.5	-4.5
20. T.S. I.	87.0	17.0	38.0	38.0	39.0	37.0
II.	87.0	16.5	35.5	34.0	36.5	33.0
dif.	0.0	-0.5	-2.5	-4.0	-2.5	-4.0
Total Sample Mean:			-1.75	-1.62	-1.95	-1.43

Table II Anteroposterior movement of the maxillary first molar with treatment according to the two methods employed.

registration are found. Both methods of registration reveal a greater difference for the right side than for the left; the upper first molar on the right side moved more posteriorly than did that on the left side during the treatment period.

3. *Data of pre and posttreatment maxillary apical base*

Table III lists the sample in order of assigned case numbers. Pre and posttreatment readings and differences are shown. The mean increase for the whole sample is 106 sq mm with a range of 20 to 200 sq mm. This table shows that there is no correlation between treatment time and increase in apical base area.

Discussion

The lateral head film reveals a superimposing of the left and right sides of the head. Most bilateral structures cast double images on the film. It has been shown by Adams[1] and others that a bisection of the distances between them

Table III.

Area of Maxillary Apical Base (sq. mm.)

Pre and posttreatment readings and treatment time.

Case no.	Pretreatment	Posttreatment	Difference	Months
1. B.P.	810	830	20	28
2. B.K.	750	810	60	24
3. C.P.	780	870	90	30
4. C.D.	820	920	100	24
5. E.K.	790	860	70	18
6. F.J.	920	980	60	30
7. F.A.	870	940	70	40
8. H.B.	700	900	200	16
9. K.B.	860	940	80	21
10. M.D.	980	1170	190	11
11. O.W.	1060	1160	100	26
12. P.V.	730	870	140	15
13. P.M.	900	980	80	29
14. R.K.	790	870	80	20
15. R.B.	910	1010	100	20
16. S.R.	870	1000	130	19
17. S.L.	930	1060	130	23
18. S.D.	930	1070	140	19
19. T.L.	700	900	200	13
20. T.S.	750	830	80	25
	Mean Difference		Range	
	106		20 to 200	

Table III Area of maxillary apical base (sq mm) pre and posttreatment readings and treatment time.

yields midline dimensions which can be brought to their absolute values by correctional scales. For these reasons the lateral film has been used almost to the exclusion of the posteroanterior or frontal view. However, the lateral view yields only measurements of height and depth.

The frontal view does not lend itself to an uncomplicated method of handling. Numerous dissimilar structures lie in the path of the rays and their images are superimposed. Furthermore, they lie at different distances between the film surface and the porionic axis which is at the only controlled distance from the anode. Correction for these factors has been difficult.

To derive measurements in the third plane, i.e., widths, it is necessary to locate the same point on both the lateral and the frontal films and project it into the third plane. It is further necessary to determine absolute measurements, i.e., to correct for enlargement.

With the introduction of the Wylie-Elsasser compensator[10] and the refinement of its use by Vogel,[9] it is possible to measure accurately between bilateral points and to locate them anteroposteriorly as well, but the details of their form, as these would be seen from above or below, are still inscrutable.

To obtain such details it is necessary to add a tracing derived from an occlusal x-ray of a model. If the form and size of the apical base is to be studied, a 1 to 1 pantograph drawing must be made according to the technique described by Brodie.[4] Both of the latter techniques yield absolute values and serve as checks on all other measurements. In the sample of twenty cases none was found in which the coordinate system constructed from the lateral head tracing could not be made within 0.5 mm of error. The correctional angle here introduced is a simple way of correcting any dimension derived from the lateral tracing.

In order to measure accurately the amount and direction of tooth movement induced by treatment, it is necessary to have tracings of the frontal and lateral head films taken before and after treatment as well as corresponding models. The two lateral tracings are superimposed on the anterior cranial fossa with *S* registered. Constructed S-N lines were found to be almost identically reliable.

In the depth measurements two small mean decreases were found, S-Ptm, —0.35 mm and Ptm-A, —1.05 mm. According to Coben,[5] S-Ptm is the most stable dimension and small differences noted in this work might disappear with a larger sample.

The Ptm-A reading derived from the lateral coordinate system has a direct correlation with the 6-A measurement similarly derived. This, however, tends

to conceal an obvious decrease in the 6-A because it is taken on a line parallel to the occlusal plane.

In the analysis of the total height measurements the anterior face shows greater increases than the posterior. In front, the bony nose contributes proportionately more of the total than it does in back. This correlates with the increase observed in the palatal plane angle. In the dentoalveolar area the reverse is true; PNS-6 increases proportionately more than ANS-1. However, it is quite possible that this difference would not be found in an untreated sample. Some supraeruption of the molars may result from the Kloehn-type head gear.

The decrease of the P-Ba dimension clearly indicates that *P* moves downward and backward with age making it impossible to use the porionic axis as a basis for determination of tooth movements.

The analysis of tooth movements by the method of determining asymmetry, i.e., by the use of the frontal film, demonstrates the risk of relying exclusively on the coordinate system and the constructed midline. Although the mean differences between the registered tooth movement on right and left sides were 0.13 mm and 0.52 mm, respectively, a case-by-case appraisal revealed differences up to 2 mm. In terms of tooth movement this introduces an error of considerable extent.

Of the findings made in this study those on the apical base are among the most important. Since the beginning of cephalometric roentgenology, attention has been focused almost exclusively on the lateral view and growth changes have been appraised largely from midline profile points, e.g., nasion, anterior nasal spine, point A, upper and lower incisors, gnathion and/or pogonion. From the behavior of these points it has been assumed that like changes were taking place throughout the face, i.e., the subject was growing or was not growing.

As is commonly known, growth is characterized by increases in size in all three planes of space, height, depth and width. The lateral head film permits measurements of only heights and depths. The technique herein described makes possible the measurement of both linear and areal dimensions in the third plane, the horizontal, where areas become of critical importance.

It has been demonstrated[4] that changes in the form of perimeters, e.g., the dental arch and apical base, are accompanied by changes in the areas they enclose. A semicircle encloses twenty per cent more area than an equilateral triangle with a perimeter of identical length. This has profound significance especially for the orthodontist. An example or two will make this clear.

In Class II, Div. 1 treatment with only head cap, the narrow, peaked arch gradually assumes a more rounded form and the apical base does likewise. In such cases the bicanine width frequently increases dramatically, as does the apical base above it. Point A in such cases will frequently be found to remain stationary or even move posteriorly, thus decreasing the midline length of the apical base as it would be measured from the lateral head film alone.

Case #10 illustrates the above situation. The lateral head film revealed little or no increase in either height and depth and would be thought of as not growing. However, measurements of the apical base area revealed one of the largest increases of the entire sample, 190 sq mm (Table IV).

Case #8 similarly shows very small growth increments in depth and height, but 200 sq mm increase in the apical base.

TABLE IV

Complete data for cases ten and eight.

Case No.	10. M.D.			8. H.B.		
	Start 13.1	End 14.0	Dif. 11	Start 12.2	End 13.6	Dif. 16
Ba-N	96.0	96.0	0.0	84.0	85.0	1.0
Ba-S	27.5	26.5	—1.0	21.0	21.0	0.0
S-Ptm	20.5	20.5	0.0	16.0	16.5	0.5
Ptm-A	49.0	47.0	—2.0	43.0	41.5	—1.5
N-A	—1.0	2.0	3.0	4.0	6.0	2.0
P-Ba	4.0	2.5	—1.5	2.5	0.0	—2.5
N-1	80.0	80.0	0.0	72.5	77.0	4.5
N-ANS	49.5	50.5	1.0	48.0	49.5	1.5
ANS-1	30.5	29.5	—1.0	24.5	27.5	3.0
S-6	62.0	64.0	2.0	59.0	62.5	3.5
S-PNS	43.0	43.5	0.5	42.5	43.0	0.5
PNS-6	19.0	20.5	1.5	16.5	19.5	3.0
6-A	23.0	24.0	1.0	20.0	21.0	1.0
Ba-S-N	132.5	130.0	—2.5	125.0	125.0	0.0
S-N/FH	7.0	6.5	—0.5	7.0	7.0	0.0
Ba-S/FH	125.5	123.5	—2.0	118.0	118.0	0.0
ANS-PNS to FH	2.5	1.5	—1.0	—5.0	—1.0	4.0
1 to FH	109.5	102.5	—7.0	125.0	100.5	—24.5
Apical base sq mm	980	1170	190	700	900	200

Conclusions

From the findings of this study these conclusions seem warranted:

1. That it is not safe to measure changes due to growth or to any other cause from the lateral head film alone, no matter how carefully it has been taken. The postero-anterior film is an indispensable adjunct.
2. The accurate plaster model of the dental arch is equally indispensable for the absolute determination of changes in form and area of the apical base and the dental arch, as well as the amount and direction of individual tooth movements.

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