Technique for the Determination of the Size of the Mandibular Apical Base; Its Application to Growth Studies

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INTRODUCTION

Ever since Lundstrom's publication[15] of his article *"Malocclusion of the teeth regarded as a problem in connection with the apical base"* there have been sporadic references to the apical base in the dental literature. At the time of its introduction it constituted a sharp disagreement to the generally accepted concept of functional development which held that if teeth were moved into new positions by artificial forces, bone would grow to support them in their new positions.

Lundstrom maintained that there was a zone at the root ends of the teeth that could not be influenced by artificial forces and that unless the apical base was harmonious in size with the size of the tooth arch there was bound to be malocclusion of the teeth and that orthodontic manipulation of the teeth would fail.

The junction between the alveolar process and the bone of the jaws has been the subject of speculation for 200 years and, as a result, the question arises as to whether the apical base belongs to one or the other. It is known that alveolar bone fails to form in the absence of the teeth and disappears when they are lost.

The form and size of the dental arches have been measured from every aspect because they are readily accessible; but every attempt to establish correlations between such determinations and measurement of adjacent anatomical structures has failed.

With the advent of roentgenographic cephalometrics the way was opened to the longitudinal growth studies of the living child. This supplied a great impetus for researches on the human head but this method was found to be easily applicable to only height and depth determinations, both of which are derived from the lateral film. Widths, with few exceptions, could not be determined from the frontal film because such measurements lie in horizontal planes of which no view is available.

Methods developed recently have made certain width and area determinations in the third plane susceptible to accurate measurement by the use of the plaster models as a control for the frontal and lateral head films. The method employed for the maxillary apical base and dental arch has already been developed. The present work sets forth a technique for the derivation of the same information for the mandibular apical base and dental arch.

REVIEW OF THE LITERATURE

"Roentgen ray anthropometry of the skull," by Pacini[16] set forth the fundamental principles that must be followed in any attempt to derive absolute measurements from the x-ray film. These are: 1) there must be sufficient anode-film distance to avoid undue image enlargement, 2) the object to be x-rayed must be positioned as close as possible

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to the film to assure sharpness of images, 3) the axis ray should be directed at a certain point on the object and should be perpendicular to the film surface, 4) an object of known size should be included in the field to be covered, and 5) the distance of this object to the film surface must be known.

After extensive investigations on skulls, Broadbent,[3] although unaware of Pacini's work, applied the same principles to the x-ray examination of the living and made several noteworthy improvements. These were: 1) provision of calibrated ear posts to insure centering of the head, 2) an orbital pointer to permit orientation of the head in the Frankfort plane and a rest at the bridge of the nose to secure it there, 3) provision for a posteroanterior film without repositioning the head between the two exposures, 4) millimeter scales indicating distance (a) above or below the Frankfort plane, (b) between the midline and the lateral film, and (c) that between the porionic axis and the frontal film.

Since the introduction of the technique of roentgenographic cephalometry, numerous workers have reported the results of longitudinal and cross-sectional growth studies. The first of these was that by Broadbent,[4] *The Face of the Normal Child.* Brodie[8] reported *On the Growth Pattern of the Human Head From the Third Month to the Eighth Year of Life,* and Björk[2] *The Face in Profile.* In all of these studies only the lateral film was utilized and only one, that of Brodie, was quantitative. Brodie used correctional scales (Adams[1]) to reduce the dimensions taken from the films to their absolute values.

As the possibilities of the technique became more widely realized, it was used for other types of investigations. The clinical results of orthodontic treatment were appraised by Brodie et al.[7] and the technique is now generally employed by practitioners for this purpose as well as for the prognosis of treatment. It has likewise been used for the design of various analyses of the head skeleton in relation to malocclusion (Downs,[13] Steiner,[19] Wylie,[21] Coben[11]). All of these have been based on data derived from the lateral film alone and are therefore restricted to height and depth determinations.

The lack of a method to utilize the frontal film to obtain data in the third plane has concerned investigators ever since the introduction of cephalometric roentgenology. That Broadbent anticipated this need is apparent from his insistence on taking the frontal film and his attention to every detail of design to make the two views of the head strictly comparable.

Wylie and Elsasser[22] introduced the use of a compensating device that made possible the determination of width between structures discernible in the frontal film. Although extremely accurate, this had limited advantages because such widths could not be located anteroposteriorly. This required references to the lateral film in the use of which the differences between bilateral structures was halved and the point of bisection treated as a midsagittal point. This obscured all differences of the two sides that were due to asymmetry.

Vogel[20] modified the Wylie-Elsasser compensator in such a way that the x-ray distortion in the lateral film could be corrected with the same degree of accuracy as that in the frontal. By projections of the same point from the two films, this made possible the accurate location of any point in the third plane. Plotting of bilateral points in this manner quickly revealed asymmetry. In all work involving the techniques of projection from one plane to another it is essential that the two views from which such projections are to be made must

be positioned to each other accurately. Broadbent[6] had assured this by the development of the orientator for the correct placement of the frontal and lateral films on the tracing surface.

A completely different approach to the derivation of determinations in the horizontal plane was that instituted by Downs.[12] He x-rayed models of the dental arches by placing them, teeth down, on films and directing the beam at the center of their bases. This yielded a good image of the details of the dental arches and, in the upper model, an outline of the maxilla. This outline he assumed to be the apical base.

When Richardson and Brodie[17] undertook to study the apical base, they employed Downs' method at first but after checking models and occlusal x-rays of the same individuals they found it necessary to establish the level of the apical base from the lateral head film. Brodie[10] demonstrated that by utilizing a 1 x 1 pantograph (Stanton[18]) the occlusal x-ray could be eliminated and the form and area of the apical base determined directly from the plaster model.

Lagerstrom and Brodie[14] combined the above mentioned technique with the lateral head film tracing and demonstrated how this made possible: 1) the location of any point discernible on the film to its position in the horizontal plane, or vice versa, 2) reduction of x-ray enlarged dimensions to absolute values, 3) detection of asymmetries, and 4) delineation of all individual tooth changes in relation to other teeth, to the apical base, and to cranial landmarks. All such determinations were found to be accurate to within fractions of a millimeter.

The study reported in the following pages describes the development of a technique that makes it possible to derive similar information from mandibular records.

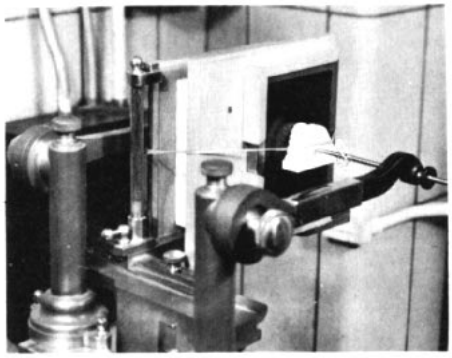

Fig. 1 Positioning of plaster model in midsagittal plane of cephalometer for x-ray exposure.

Materials and Method

The method proposed for the study was first tested on two dried skulls from a battery of records that could be readily obtained on the living subject. These were: 1) plaster models derived from accurate impressions of the teeth and alveolar processes of both upper and lower jaws, 2) x-rays of the occlusal aspect of the lower dental arch obtained by placing the lower model, teeth down, in contact with the surface of a film cassette, care being taken that only cusp tips touched the cassette. The axis ray was directed at the center of the base of the model from a distance of five feet. This yielded, essentially, a contact print of the dental arch (Fig. 1), 3) posteroanterior and lateral cephalometric roentgenograms taken in the Broadbent-Bolton cephalometer after placing lead solder dots on all landmarks that could ordinarily be located on the frontal and lateral head films of the living. The points so marked were: 1) midline point of base of crista galli, 2) root of nasal septum, 3) intermaxillary suture, 4) incisal edges of maxillary and mandibular incisors, 5) most buccal point of the crowns of the lower first molars, 6) right and left orbital points, 7) lowest points of both right and left mastoid processes, 8) the highest right and left molar cusp tips, i.e.,

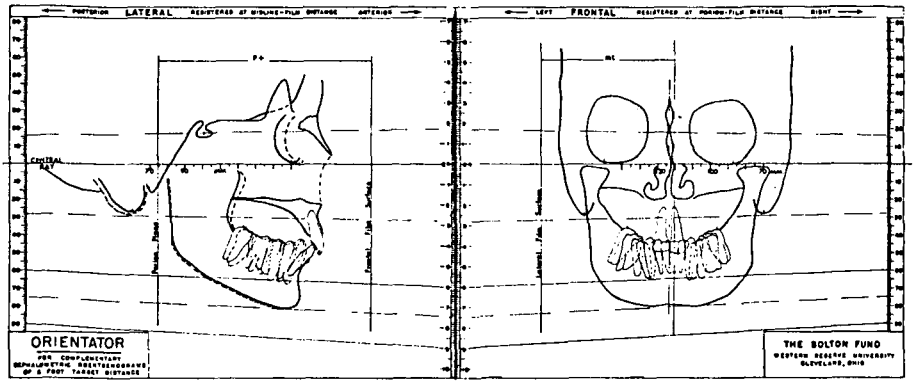

Fig. 2 The orientator with tracings of lateral and posteroanterior head films correctly positioned. (Courtesy of Dr. B. Holly Broadbent)

those which contacted the film cassette of the x-ray of the model. These points would determine the posterior ends of the occlusal plane lines.

Additional points used only on skulls to determine the relations of the mandibular body to the lower dental arch were: 1) right and left points midway between the occlusal plane and the mandibular border on the buccal surface of the mandible in the first permanent molar area, 2) right and left points on the lower border of the mandible in first permanent molar area, 3) pogonion, the most anterior point of the mandible with the skull oriented in the Frankfort plane.

There are two details that should be emphasized if accurate quantitative determinations are to be made from frontal and lateral films. These are: 1) the centering of the head in the holder, as shown by the calibrations on the ear rods. This places the head in the midsagittal plane of the machine although this plane will not necessarily coincide with the anatomical midline. 2) The recording of the distance from the porionic axis to the frontal film surface (P.+) and that from the midsagittal plane of the headholder to the lateral film surface (M.L.). These measurements are derived from vernier scales in the bedplate of the cephalometer immediately after the exposures are made.

Frontal and lateral x-rays are oriented to each other on the Bolton orientator (Fig. 2). This is a sheet of acetate that is fastened to the illuminated tracing surface and is marked with a series of fine divergent lines. Running horizontally across its center is a prominent line marked "Central Ray," which represents the path followed by the axis ray for both films. Along the central axis are certain figures which permit the placement of the lateral film at its P.+ distance and the frontal film at its proper M.L. distance. Additional fine lines above and below the central axis line indicate the paths followed by rays emanating from an anode at a five foot distance. Any of these lines passing through a point on one film, if followed, will be found to pass through the same point on the other film.

The frontal film is placed in such a way that a line running through the middle of the left and right ear posts superposes the central ray line on the orientator. The film is then shifted along this line until the midpoint of the film superposes the same M.L. distance on the scale of the central ray axis as

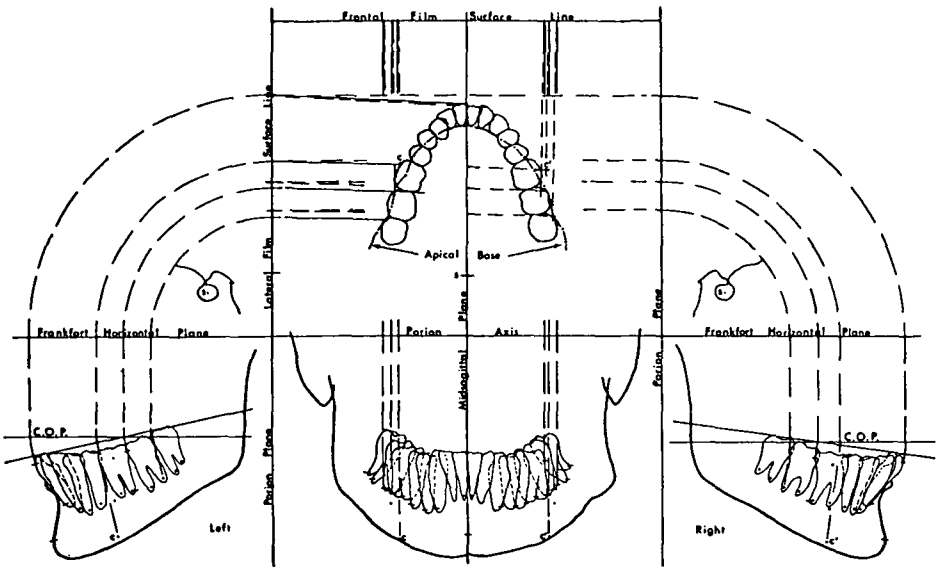

Fig. 3 Master tracing showing reference plane lines and construction of the corrected occlusal plane (C.O.P.).

recorded on the film. The midpoint is determined by bisecting the distance between the shadows of the right and left ear posts.

The lateral film is placed on the orientator in such a position that the porion point lies on the central ray line and at its correct P.+ position. This film can now be rotated around the porion point until corresponding anatomical points of the frontal and lateral films fall on the same lines of the orientator. A sheet of matte acetate is stretched over both films and securely fastened. This will become the master tracing.

The first plane of reference is the central ray or porionic axis (Fig. 3). This is drawn through the centers of the ear rods shown on the frontal film. Since the porionic points determine this line and are common to both frontal and lateral views, the line is extended both to the right and left sides. In the lateral view it becomes the Frankfort horizontal.

To establish a midsagittal plane, the distance between the ends of the shadows of the ear rods is bisected and a perpendicular to the porionic axis is drawn through the point of bisection. This line represents the midsagittal plane of the cephalometer, not the anatomical midsagittal plane. To the left and right of the midline, perpendiculars to the central axis line are drawn at the M.L. distance. That on the left represents the lateral film surface line and the porionic plane for the left side. On the right it represents only the porion plane.

The frontal film-surface line is drawn above and parallel to the central ray axis line at the P.+ distance from it.

The details traced will depend upon the particular interest of the investigator. In the present study, interest was centered upon the determination of the area of the apical base of the mandible. This is defined as the area enclosed by a line around the roots of the teeth, two mm from their apices and extending from the distal root of one first molar to that of the other. For the

orientation of the reader as well as to demonstrate the possibilities of other investigators, additional material was included.

Nearly all details that could be derived from the frontal film of the mandible were traced. These included the crowns and roots of all teeth as well as the outline of the mandibular body and ramus. All points indicating the location of the solder dots, e.g., those at the highest tips of the second molars as well as on the buccal surfaces and lower border of the mandible, were transferred to the tracing. Finally, the anatomical midline was drawn through the midline point of the base of crista galli, the root of the nasal septum, and the intermaxillary suture. This line was extended below to indicate the anatomical midline of the lower dental arch.

The lateral film presents the superposed images of the right and left sides. These must be traced separately, the right side first. A straight line is drawn between the highest tooth points in the front and back of the dental arch to represent the occlusal plane for this tracing. If a study is to include references to the sella point, a perpendicular to the central ray axis through point S. is also drawn.

To trace the left side of the mandible another piece of matte acetate is fastened over the tracing of the right side. This should be of a size just sufficient to cover all details including the reference lines, i.e., the porionic and Frankfort planes. After drawing all details of the left side and constructing its occlusal plane, the tracing of the left side is laid aside for subsequent use.

All x-ray images are enlarged, the degree depending on the distances between the source of the ray, the object x-rayed, and the film surface. Even films taken at a five foot target distance are enlarged sufficiently to negate their use for strict quantitative determinations. Heights and depths can be derived from the lateral film by means of correctional scales, but even with these it is necessary to halve all differences between bilateral structures and treat them as though they lay in the midsagittal plane. Structures lying on either side of the midline cannot be measured separately nor positioned correctly in space.

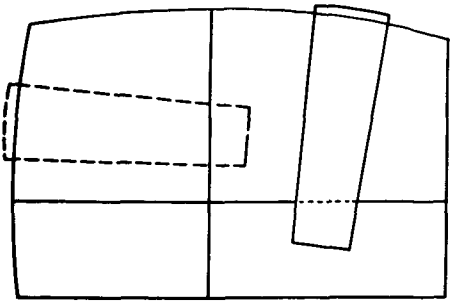

Fig. 4 Wylie-Elsasser compensator as modified by Vogel. Top and left side are arcs of a five foot radius.

The addition of an object of known dimensions and form, such as a model of the dental arch lying in the third (horizontal) plane, makes it possible to reduce measurements derived from the x-ray films to their absolute positions and dimensions. To accomplish this it is necessary to place the object in its correct relation to the x-ray tracings.

The object in the present case was an accurate tracing of the details of the dental arch as seen on the occlusal x-ray of the dental arch. This tracing must be available for subsequent steps if accuracy is to be checked.

At this juncture the master tracing is removed from the orientator and transferred to the Wylie-Elsasser compensator (Fig. 4). This is a ¼ inch thick sheet of clear lucite with intersecting vertical and horizontal lines in the middle. The top edge is cut in an arc of a circle with a five foot radius. The compensator used in this study was the

modified form developed by Vogel, i.e., the left edge was also an arc with a five foot radius. The bottom and right side edges were straight and at right angles to each other. A special T-square, with its bearing edge an arc with a five foot radius, applied to the top or left edges of the compensator permits the drawing of lines which represent the course of x-rays traveling through points from a source at a five foot distance. The tracing is placed on the compensator so that the cephalometric midline and the central axis lines are superposed on the vertical and horizontal lines of the compensator, respectively. It is then fastened to the tracing surface.

Using a standard T-square against the bottom edge of the compensator, points are located on the frontal film surface line to denote the points at which tangents to the buccal surfaces of the first molars of the frontal tracing would intersect it (Fig. 3). The midpoint of the dental arch in the incisor region is similarly projected. These points represent the mediolateral locations of their corresponding structures on the frontal x-ray films, i.e., they are enlarged by the divergence of the rays.

To correct for this divergence the Wylie-Elsasser T-square is applied to the top edge of the compensator to project lines downward through the points on the frontal film surface line. This orients the occlusal tracing mediolaterally.

Before entering into a description of the techniques employed in this orientation it is necessary to point out that it involves a problem not encountered previously. Until now all determinations have been related to three rectilinear or coordinate systems at right angles to each other. In the management of the occlusal plane as viewed from the lateral aspect, allowance must be made for the fact that it is neither perpendicular nor parallel to any of the three coordinate systems. Thus allowance must be made for foreshortening before it can be brought into correct relation with other dimensions. This is accomplished as follows:

On the right lateral film tracing, perpendiculars are drawn from the occlusal plane line to the most distal point on the first molar and the most prominent incisor point. Through the point of intersection of the perpendicular from the molar with the occlusal plane line, a horizontal is drawn parallel to Frankfort. The junction of the two lines is called the correction angle because it is used to bring the canted occlusal plane into registration with the coordinate systems previously utilized. An arc is drawn from the incisal point on the lateral film, with its center at the apex of the correction angle, to the constructed horizontal which is now the corrected occlusal plane.

The molar and incisor points on the corrected occlusal plane line are transferred to the Frankfort horizontal by projections, using a standard T-square against the bottom edge of the compensator. From here they are transferred to the right porionic plane by means of arcs, drawn with their centers at porion. They are transferred from here across the tracing to the lateral film surface line with a standard T-square applied to the right side of the compensator.

To reduce these points derived from the lateral film to their correct positions relative to the undistorted occlusal tracing, they are projected back across the tracing using the Wylie-Elsasser T-square against the left edge of the compensator. Since they were derived from the right mandibular tracing, they are carried to their intersections with the corrected projections from the right side of the frontal film surface line.

To relate the previously made tracing of the left side of the mandible to the

occlusal, it is placed, *face down,* to the left of the frontal view with its reference lines superposed on those of the master tracing.

The procedure followed from here is the same as that for the right side until the projected points are registered on the lateral film surface line. They are projected from here, again with the Wylie-Elsasser T-square applied to the left side of the compensator, but the projections are now carried only far enough to intersect the lines from the left side of the frontal film surface line.

The occlusal tracing can now be positioned by superposing the anatomical midlines of the dental incisor region over that derived from the frontal tracing and the vertical and horizontal projections will form tangents to the buccal and distal surfaces of the first molars.

To delineate the apical base and relate it to the dental arch in the horizontal view the same procedures are carried out from the points located on the roots of the teeth in both lateral and frontal views. It must be remembered that all those derived from the lateral film must be brought to their positions on the corrected occlusal plane lines of their respective sides. The resulting points on the occlusal view may be connected by straight lines or drawn with a French curve. The area enclosed by such a perimeter can then be determined by a planimeter.

To determine the degree of error in measurements taken according to the technique that has been described here, they were checked against those taken from a Western Reserve craniostat. This instrument was loaned to us by Dr. B. Holly Broadbent.

This craniostat permits the placing of a skull firmly in the Frankfort horizontal position for measurement. A sharp anthropometric needle is placed in a frontal carrier which is equipped

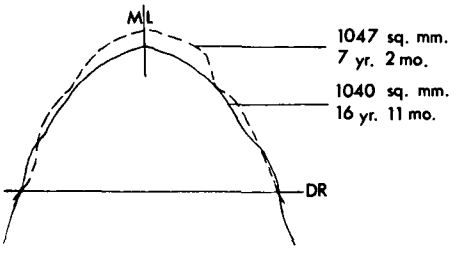

Fig. 5 Mandibular apical base changes in a female between ages seven and seventeen years. (ML) anatomical midline, (DR) most distal root surfaces of the first permanent molars.

with vernier scales in the horizontal and vertical planes with zero points coinciding at the midsagittal and frontal planes. Placing the needle on a point makes possible the exact determination of its distance from the midsagittal plane as well as its position anterior to porion. The readings are accurate to within 1/10 mm. Table 1 sets forth the measurements derived from the x-ray films and from the craniostat on skull #109026.

To test the usefulness of the technique for longitudinal studies it was applied to a series of records of a female from seven years two months to sixteen

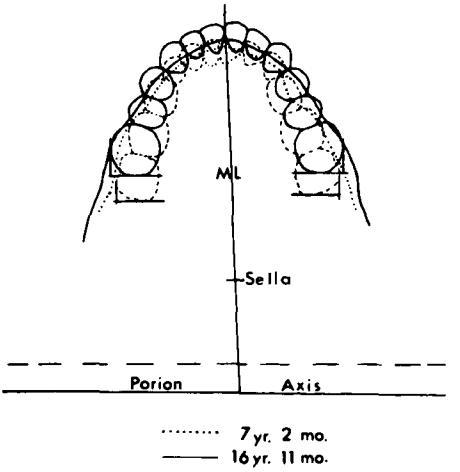

Fig. 6 Superposed tracing of dental arch and apical base of a female at seventeen years on that of seven years. (ML) midline superposed with sella registered to show forward movement.

years eleven months (Fig. 5). The apical base as defined previously was measured by planimeter as described by Brodie.[10] To determine the change in the spatial position of the arch and apical base the first and last tracings were superposed on the anatomical midline and the sella points registered (Fig. 6).

Findings

Measurements derived from the frontal and lateral x-rays of two dried skulls were checked for accuracy by comparing them with identical dimensions taken with the skulls mounted in the Western Reserve craniostat. Two determinations for each skull were made one month apart. Bilateral measurements were made between each pair of tooth crowns of the buccal segments as well as between the solder points on the mandible. These were further checked by measuring right and left points independently, from the cephalometric midline (M.L.) (Fig. 7).

The following anteroposterior measurements were made parallel to the occlusal plane: each right and left denture point to the central incisor, i.e., the most anterior point of the denture; each solder point on the right and left body and border of the mandible to pogonion. The right and left porionic points (P′ and P) to pogonion were

DIMENSIONS DERIVED FROM FILM AND CRANIOSTAT (SKULL 109026)

WIDTHS

	Bilateral					Right to Midline (M. L.)					Left to Midline (M. L.)			
	April 2, 1966		May 1, 1966			April 2, 1966		May 1, 1966			April 2, 1966		May 1, 1966	
	Cran	Film	Cran	Film		Cran	Film	Cran	Film		Cran	Film	Cran	Film
A-A′	54.4	54.4	54.1	54.5	A′	28.0	27.9	26.6	28.0	A	26.5	26.5	27.5	26.5
B-B′	59.0	58.8	58.4	59.0	B′	31.2	31.5	29.6	31.3	B	27.8	27.3	28.8	27.8
C-C′	54.8	54.7	54.8	54.5	C′	29.8	30.7	28.4	29.5	C	25.0	24.0	26.4	25.0
D-D′	44.2	43.5	43.2	43.6	D′	22.3	22.4	21.2	22.2	D	21.9	21.1	22.0	21.4
E-E′	37.7	37.6	37.0	37.2	E′	18.7	19.1	18.1	19.0	E	19.0	18.5	18.9	18.2
F-F′	29.6	29.4	28.9	29.1	F′	15.0	15.7	14.5	15.1	F	14.6	13.7	14.4	14.0

DEPTHS

	Right to Central Incisor (Z)					Left to Central Incisor (Z)			
	April 2, 1966		May 1, 1966			April 2, 1966		May 1, 1966	
	Cran	Film	Cran	Film		Cran	Film	Cran	Film
A′	26.0	26.5	25.8	26.0	A	26.9	26.8	26.0	26.7
R_6	31.0	31.7	31.8	32.1	L_6	32.8	32.8	32.3	32.0
R_5	14.6	15.2	14.7	15.2	L_5	15.1	15.2	14.9	15.4
R_4	9.3	9.3	9.0	9.4	L_4	8.4	9.0	9.1	9.2
R_3	3.6	4.0	3.7	4.0	L_3	5.8	5.1	4.7	4.9
To Pogonion (Pog)									
B′	20.9	20.0	23.2	24.0	B	23.5	23.1	22.9	23.1
C′	19.6	19.1	20.9	22.0	C	21.8	21.3	21.1	22.9
To (Pog) parallel to (F H)									
P′	79.8	79.0	78.6	78.9	P	80.0	79.0	78.4	78.9

Table I

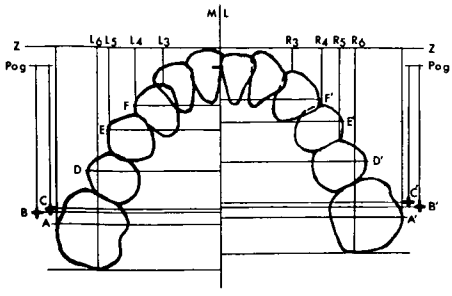

Fig. 7 Tracing indicating dental points measured.

measured parallel to Frankfort horizontal.

Table 1 sets forth the measurements taken of skull #109026. The average difference between all craniostatic measurements and all film measurements was found to be 0.5 mm. If only bilateral and anteroposterior measurements were considered, the average difference was found to be 0.37 mm. The difference between the two averages was a result of failure to locate the same midsagittal plane in the craniostatic analysis as that used in the film analysis.

Similar results were found for skull #109025. The average difference between the measurements of the two analyses was 0.56 mm. Bilateral and anteroposterior measurements revealed an average difference of 0.4 mm.

In the application of the technique to the records of a living subject it was found that the apical base area of the deciduous dentition was slightly larger than that of the permanent dentition. It became shorter anteroposteriorly and narrower across the premolar area but increased in width in the permanent molar area (Figs. 5 and 6).

Discussion

The method that has been described here is applicable to any quantitative study involving time, i.e., longitudinal. However, the procedures followed would be determined by the information sought.

If changes in the dimensions, form or area of the dental arch or apical base were being analyzed, successive tracings would be superposed on the anatomical midline and some transverse line toward the back of the arch, e.g., between the distal root surfaces of any of the completely erupted molars.

If it were desired to measure changes in relation between the maxillary dentition and cranium, the tracings would be superposed on the anatomical midline with the sella point registered.

Areas of the apical base and the dental arch must be read from a compensated polar planimeter. Perimeters should be read with a map reader.

The reliability of reducing bilateral structures to midline values in lateral films was shown by Brodie[8] and Adams.[1] However, in cases of malpositioning or asymmetry further consideration should be given to this problem before attempting to locate any anatomical point in space. Here the degree of x-ray enlargement must be determined for each side by means of the Wylie-Elsasser compensator as modified by Vogel.

Error in tracing the roots of teeth can be minimized in a longitudinal study by preparing templates of teeth that are of critical value. This is done by tracing the clearest image of a tooth that can be found in a series of head plates. This error is further reduced by the use of the Bolton orientator.

It will be recalled that separate occlusal plane lines were used for each side of the dental arch and that they were not identical. If midline points, e.g., pogonion and roots of the central incisors, are projected from each occlusal plane line, they may be found to fall one behind the other on the mid-

line of the occlusal view of the denture. To establish the true position the difference should be bisected.

But, if one molar point is higher than the other, the occlusal plane is tipped. To correct for this, i.e., to bring the occlusal plane into register with the horizontal coordinate system, it is necessary to have recourse to the same procedure as that applied to the lateral views, viz., establish a corrected occlusal plane for the frontal view. This is accomplished as follows:

A line connecting the occlusal molar points is drawn on the frontal film. Perpendiculars to this line are drawn from the *buccal* points of the molars and from the anatomical midline where it crosses the incisal edge. A line parallel to the porionic axis is drawn through the intersection of the occlusal plane line and the perpendicular from the anatomical denture midline. This line represents the corrected occlusal plane. To bring tooth and apical base points to this corrected plane each is located in a like manner on the original (tipped) occlusal plane line. Such points are carried to the corrected occlusal plane line by arcs drawn with the center at the midline intersection. From here they may be projected to the occlusal view.

When measuring the distances that the apical base and dental arch have moved in space during the period between films, the possibility that the subject is positioning the mandible should be considered. If the exposures have been made with the molars in occlusion, this is unlikely.

If only the denture and its related structures are to be located in space, the occlusal plane of the lateral view is used as the reference line. However, if skeletal structures are to be located in space, the Frankfort horizontal is used as reference in the lateral view.

The decrease in the area of the apical base with age in the living subject can be explained as follows: The *form* of the apical base has changed somewhat over the time interval between records. In the early mixed dentition stage it was of a more rounded form but became more tapering in the stage of the permanent dentition. It has been found that changes in the forms of perimeters of identical lengths alter significantly the size (square millimeters) of the areas they enclose. If an equilateral triangle and a semicircle with identical perimeters are measured by planimeter, the semicircle will be found to enclose twenty per cent more area.

Summary

A technique has been described that makes possible the location of the correct position in space of all points that can be discerned in both the posteroanterior and lateral head films taken with the Broadbent-Bolton cephalometer. The method requires the establishment of three rectangular coordinate systems that are visualized as meeting right angles in the middle of the head. One is representative of the midsagittal plane; the second, a frontal plane running through the right and left porionic points and the third, a horizontal plane running through the two porionic points and the left orbital point. The Broadbent-Bolton cephalometer is designed to facilitate the placing of the living human head in relation to these three planes but it must be realized that these planes are determined by the headholder. Asymmetries of various sorts in any plane of the head will lead to a lack of coincidence of the planes of the head and those of the cephalometer.

Since the records from which data are to be gathered are posteroanterior and lateral x-ray films and since x-ray images are enlarged over the absolute dimensions of the object, it is necessary to make corrections for this. To this

end it is essential that not only the distance from anode to reference planes be known, but also that from reference planes to the films. Both of these are available directly from the cephalometer. These readings, used in conjunction with the orientator developed by Broadbent, assure the correct placement of the films to each other for tracing.

To make the technique applicable to the study of dental arch changes, a tracing was made of the x-ray image of the arch by x-raying the plaster model from a five foot distance. This not only provided a means of determining changes in tooth position within the arch, but as well, changes of the mandibular dentition in relation to points of reference in the skull.

To bring the tracing of the occlusal view into its correct relation with the reference planes of the frontal and lateral tracings, it was necessary to make allowances for the fact that the occlusal plane is neither parallel nor perpendicular to the others, and that only the dimensions of the occlusal view are absolute. These necessitated the introduction of a correction angle to establish a parallel relation between the occlusal plane and the Frankfort horizontal and projection procedures carried out with the Wylie-Elsasser compensator as modified by Vogel.

The technique described in this paper was developed from cephalometric head films of two dried skulls which were previously prepared by placing small round pieces of solder on all points for accurate determination. Measurements between these points, as located on the x-ray films, were checked on a Western Reserve craniostat and yielded findings that were within 1 mm of error.

The method was finally applied to the serial records of a female from seven to seventeen years and changes in the dental arch and apical base, as well as the relation of these to cranial reference points, were noted.

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