A COMPUTER-AIDED STUDY OF CRANIOFACIAL ASYMMETRY UTILIZING THE POSTEROANTERIOR RADIOGRAPHIC PROJECTION

THE RADIOGRAPHIC WIDTH OF THE SELLA TURCICA IN A SAMPLE OF CHILDREN AGED 12 TO 16 YEARS

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INTRODUCTION

Man is all symmetrie,
Full of proportions, one limbe to another,
And all to all the world besides.
Each part may call the furthest, brother:
For head with foot hath private amitie,
And both with moons and tides.

-George Herbert, "Man"

No cephalometric study would be complete without reference to the classic work of B. Holly Broadbent.[1] (Yet there is a certain irony in the observation that Broadbent, himself, distinguished his own technique as applied to the living as "craniometrics," as opposed to the "cephalometric methods" of measuring through soft tissue.) The introduction of the Broadbent Head Holder in 1931 fostered a whole new era of growth studies, based primarily on the lateral headplate, and introduced what has become the "foster child" of orthodontics, the frontal headplate.

Broadbent's purpose was to find "a means of recording craniometric (hard tissue) landmarks on the living child as accurately as it is done with a craniostat in measuring the dead skull."[1] Following the precedent of measuring the head in the dimensions of length, width, and height, Broadbent surveyed his subjects by using the reasonable derivatives, the lateral and frontal projections. Volumes have been devoted to the information amassed from the lateral projection. But in the half century of the existence of the standardized frontal projection, its diagnostic usefulness still remains in question. The various orthodontic uses to which it has been put include: ascertaining the position and angulation of erupted and certain unerupted teeth;[2,3] craniofacial width dimensions;[4] comparison of pre- and postpalatal expansion;[5,6] nasal cavity width;[5,6,7] skeletal anomalies, pathology and variations of normal;[8] and probably most extensively the study of skeletal asymmetry.[3,9,10,11,12,13,14,15] The second-class status of the frontal film becomes quite striking when one compares this meager list to the contributions made by the lateral headplate. Personification might allow one to ascribe to the frontal headplate a feeling of chagrin at the suggestion that its best use may be to elucidate vagueness of landmarks existing in the lateral projection by means of geometry.[18]

Perhaps Lavelle is correct when he states that "growth studies have centered on the sagittal plane, partly due to lateral cephalometric dimensions being less subject to distortion than those of the frontal plane, but also because craniofacial growth changes are more striking in the sagittal than the frontal plane."[16] If one accepts this premise, judgement dictates that he look elsewhere for utility with regard to the frontal projection. It is in this vein that the perusal for anomalies gained consideration: that a film is obtained to provide information for a known condition does not absolve the orthodontist from responsibility for recognizing other, unsuspected conditions that present on that same film. Of course the responsibility for treating medical conditions rests with the physician, but knowledge of the abnormal allows the appropriate referral to be made. A case in point would be the existence of an abnormally large or eroded sella turcica, which may represent an enlarged pituitary gland or increased intracranial pressure.[17] A knowledge of normal length and width of sella would allow a prudent assessment as to whether or not a referral were indicated.

To state that the frontal film has been vilified would be too strong an accusation. It seems, rather, that it has slipped into obscurity, its usefulness limited or unknown, a foster child that may yet be welcomed back.

The purpose of this study is threefold. Leonardo observed that "It is impossible to love or hate anything without first having cognizance of it." Therefore, (1) an atlas of certain landmarks will be prepared from frontal projections of dried skulls. An attempt will be made to determine (2) the normal variation in the width of the sella turcica from a sample of children aged 12-16 years. And (3) a study of facial symmetry will be conducted from the frontal headplates of a similar sample of children, aged 12 to 16 years.

REVIEW OF THE LITERATURE

Part I

The Sella Turcica

Detailed attention has been lavished on the study of the sella turcica in terms of its diagnostic significance. In 1898 Hrdlicka[48] referred to the importance of its normal dimensions and range of variation in his anatomical study of normal human skulls. But the first to observe a defect in the sella in a radiograph of the skull in which a pituitary tumor was implicated was Oppenheim. Reading before the Society of Psychiatric and Nervous Diseases in Berlin on November 13, 1899, he stated:

> Moreover I have found during my experiment an interesting discovery namely, an abnormal deepening and indentation of the sella turcica in a roentgenogram of a patient having signs and symptoms of a swelling in the pituitary gland.

Since that time the radiographic and anatomic study of the relationship of the hypophysis to its bony crypt, the sella, has continued unabated. Researchers have attempted to quantify both what constitutes a normal pituitary gland and a normal sella, in size and configuration. Data have been accumulated that transcend the relationship between changes in the pituitary and their resultant changes in the sella, to include the effects of other intracranial pathologies on the configuration of the sella. These include: studies of cadaver material, radiographic material, and combinations of both in which that which is observed radiographically can be correlated to that which is observed in the dissecting hall. The voluminous literature available testifies to the fact that the sella turcica is much more than a convenient landmark for cephalometric studies.

A multitude of conditions can produce changes in the sella. The vast majority of changes result from intracranial tumors, however, which many authors have attempted to classify. Classification derived its importance from the standpoint of diagnostic inference based on pathognomonic changes in the sella associated with a particular tumor type. The simplest classification was that proposed by Erdheim in 1909, which differentiated only intrasellar and extrasellar tumors.[49] Others, including Kornblum, believe further elaboration was necessary, adopting the classification of intrasellar, extrasellar, and sphenoid bone lesions, further classifying the extrasellar tumors into suprasellar, parasellar and metasellar.[32] A more complex system yet, was proposed by Mahmoud[34] in his prodigious monograph of 1958, as follows:

I. Tumors of the sellar walls

   These include primary or secondary malignant tumors and malignant tumors of the sphenoid sinus and nasopharynx extending upwards into the sella turcica.

II. Perisellar tumors

   These include four subgroups:

   A. Presellar tumors

      1. Olfactory groove meningiomata

      2. Meningiomata of optic nerve sheath

      3. Gliomata of optic nerve

B. Suprasellar tumors

1. Craniopharyngiomata
2. Epidermoids
3. Teratomata
4. Cholesteatomata
5. Suprasellar meningiomata
6. Gliomata of optic chiasma
7. Rarely a pure suprasellar hypophyseal adenoma

C. Parasellar tumors

1. Meningiomata of lesser wing of sphenoid
2. Meningiomata of 5th nerve
3. Neurofibromata of 5th nerve
4. Aneurysms of the Circle of Willis

D. Retrosellar tumors

1. Chordomata
2. Glomus tumor of petrous bone
3. Meningiomata of cerebello-pontine angle or clivus

IV. Metasellar tumors

This group embraces any more remote intracranial tumor.

Since Mahmoud's extensive treatise there have undoubtedly been further classifications. To trace them would be to only belabor the point that there are many tumors that can affect the size and shape of the sella turcica, and that these are by no means limited to tumors of the pituitary, itself. The metasellar tumors produce changes by raising intracranial pressure.[17,32,34] In a like manner hydrocephalus, particularly of slow onset beginning in infancy, will result in enlargement of the sella.[7] Small sellas are frequently observed in cases of idiopathic hypopituitary dwarfism, and occasionally in mongolism, congenital dwarfism and dwarfism secondary to chronic illness, but in no other conditions.[28]

The changes produced in the sella by these various conditions are many and varied. Kornblum stated that:

> the character of the changes produced is to some extent influenced by the location of the lesion . . . . the changes produced by intrasellar lesions depend upon the nature of the tumor, the rapidity of its growth and the direction of its extension. The vast majority of such tumors are adenomata . . . . Of the various types of deformation of the sella turcica produced by neoplasms within the cranial cavity that resulting from an intrasellar tumor is the only one which is in any way pathognomonic. In the majority of instances, this alteration is sufficiently characteristic to establish the diagnosis of a pituitary tumor.[32]

Other authors,[17,34] however, have maintained that the value in differentiating the type of sellar deformity lies in the ability to localize the site of the tumor. Mahmoud states that "if this could be achieved from plain radiography . . . more tumors could be diagnosed earlier since plain radiography of the skull is often a routine examination in the early investigation of disease."[34]

Many investigators have, for the above reasons, minimized the benefits to be gained by measuring the sella turcica. Kornblum states, "The Roentgen diagnosis of intrasellar tumors seldom, if ever, depends solely upon a simple enlargement of the pituitary fossa, and . . . alterations in size may be absent or extremely slight."[32] Camp argues that ". . . the normal sella turcica varies widely in size and shape. So great is this variation that recognition of disease based on alteration of size alone is frequently difficult and even misleading."[23] DuBoulay agrees, citing that "in doubtful cases it is the presence or absence of erosion which is the critical observation in deciding whether or not the sella is abnormal."[17] Rasmussen had previously said that "There are still those, however, who are prone to stress too much the importance of the size of the sella."[40] And Mahmoud makes perhaps the strongest statement that "The measurement of the sella turcica is more of academic than clinical significance."[34] Camp summarizes his feelings with the following:

> My own experience, over a period of many years, indicates that in the past the average roentgenologist has paid too much attention to variations in the dimensions of the sella turcica and has underestimated the significance of certain basic changes in structure WHICH WILL INDICATE THE PRESENCE OF DISEASE LONG BEFORE MEASUREMENTS ALONE HAVE ANY VALUE[23] (emphasis added).

Why, then, is there the amount of literature available that deals with the measurement of the sella turcica? Kornblum partially answers that question when he elaborates on his previous statement with the addendum, "The size of the fossa is of such importance, however, as to make it necessary to be familiar with the measurements of the normal pituitary fossa."[32] Further opinions on this question will be explored following a discussion of the changes that are known to occur in the sella turcica as a result of the various pathologies already mentioned.

Regardless of the location of the tumor, the following cardinal changes occur in deformations of the sella:[32]

(1) atrophy of the dorsum sellae

(2) erosion of the floor of the pituitary fossa

(3) increase in the size of the fossa.

Erosion of the floor may not be recognized if the sphenoid below the floor of the sella is not pneumatized, as is frequently the case in children before the age of 12 years.[23]

The cardinal changes in the sella turcica in cases of intrasellar tumors are:[34]

(1) enlargement of the sella turcica with expansion of its floor, which is often irregular

(2) retention of the posterior clinoid processes

(3) destruction of the dorsum sellae, which is more advanced at its base.

Mahmoud[34] feels that the retention of the posterior clinoid processes and the severity of destruction of the dorsum sellae at its base are more important diagnostically than the enlargement of the sella, since they are not observed in any other intracranial tumor. In tumors other than intrasellar tumors the posterior clinoid processes are usually involved early in the progress of change, and the base of the dorsum sellae is not so radically involved. The floor is also more regular and not as deep, giving the appearance of a shallow sella.

These are the commonest findings, but do not preclude the existence of destruction of the posterior clinoid processes in advanced intrasellar tumors, for example. These are all changes that can be observed in lateral and/or frontal orthodontic headplates.

Camp[23] further points out that when the sella has been exposed to destruction and enlargement by pressure from a lesion, and that pressure is subsequently removed, the fossa will retain its abnormal size and shape. A radiograph will, therefore, always reveal antecedent disease, but does not necessarily indicate an ongoing disease process. The character and radiographic density of the bony margins, rather than the variation in size, are the primary indicators of disease. Radiographs taken at different time points, therefore, provide the opportunity for comparison as evidence of an active process.

As alluded to previously in reference to Kornblum's early work, a knowledge of that which is normal is necessary in order to recognize that which is abnormal. Thus, a study of the anatomy and radiographic appearance of the sella turcica and its contents has been the object of a great deal of research. Since the earliest observed association between disease state and sellar distortion involving the pituitary early attention focused on obtaining standards for the size of the pituitary, itself. Rasmussen determined that the average adult hypophysis weighed approximately 0.6 grams (range 0.350-0.900 grams),[50] and was noticeably heavier in the female than the male, differences being slight if there had not been a pregnancy.[40] Other workers have confirmed that a significant difference in gland weight, volume, and linear dimensions exists between the sexes.[20,24,35,36,46] However, again, the inference is that the increased size is due to past pregnancies. The weight and volume of the pituitary markedly increase during pregnancy (may even double),[20,25] reaching a maximum at the end of pregnancy, and then rapidly decline.[24] McLachlan, et al[35] conclude that, though the decline is rapid, it is incomplete. This supposition is challenged by Muhr and co-workers,[36] however, who found no correlation between parity in women and volume of the pituitary, concluding that pregnancy leaves no significant residual enlargement and, therefore, a significant sex difference exists apart from parity. This trend begins to develop during the teens when the growth rate of the anterior lobe accelerates in girls.[41] On the other hand, when sellar volumes between the sexes were compared, it was found that there was no significant difference.[35,36]

The shape of the pituitary gland varies greatly. In general it may be said that the width is equal to or greater than its length or height.[20,33,40,42] The anterior, inferior, and posterior contours correlate fairly well with the corresponding portions of the sella.[20,35] However, the lateral margins are bounded by soft tissues of the cavernous sinus, which may affect the shape of the gland.[27] The advent of computerized tomography has given new insight into the normal shape of the upper margin, as well as providing dimensions derived from the living.[30,33,46] A convex upper margin is considered to be abnormal.[46] Rasmussen[40] gave the gland average dimensions of 13 mm in width, 10 mm in length, and 6 mm in height. Syvertsen and co-workers[46] found the average height to be greater in cadaver glands than in living subjects when evaluated by computerized tomography. They determined that a height greater than 7 mm in females and 5 mm in males is abnormal. A gland that is greater than 9 mm in height and convex upward is thought to be strongly suggestive of microadenoma of the pituitary. McLachlan et al[35] reported normal glands exceeding 7 mm in height in cadavers, however.

An important finding in Rasmussen's early work[40] was that there may be a wide variation between the size of the sella and the weight of the enclosed hypophysis. He demonstrated two sellas of nearly identical size, the hypophysis contained in one being 50 percent larger than that contained in the other. He observed that the amount of the surrounding connective tissue and the capacity of the intercavernous sinus vary greatly, accounting for the difference in size between the sella turcica and the pituitary. Di Chiro[24] states that the dura surrounding the pituitary may represent as much as 25 percent of the contents of the sella. Pockets of subarachnoid space may also be contained within the cavity of the sella. Furthermore, a somewhat rare phenomenon known as "empty sella," in which a relatively small pituitary is found around the periphery of the sella turcica, which contains a large subarachnoid space, has been described.[25,46,35] This condition is found predominantly in women (9 to 1), creating speculation that the pituitary may have enlarged enough during pregnancy to enlarge the sella, and then resumed a normal or smaller size.[45] This condition is usually associated with a larger than average sella turcica.[25,45,36]

These observations were certainly influential in molding the opinions of many authors[17,23,32,34,35,40] to discredit the importance of measuring the sella turcica. Di Chiro,[24] who is one of the greatest advocates of the mensuration of the sella, himself observed the limitations to be considered when appraising the pituitary gland volume from the volume of the sella: (1) the intrasellar contents include not only the pituitary, itself, but its coverings; (2) part of the pituitary gland is extrasellar (the stalk, which is located above the diaphragma sellae, may account for 5 percent of the weight of the pituitary); (3) the sella may enlarge without enlargement of the pituitary for various pathologic reasons; (4) the pituitary may enlarge without causing the sella to enlarge. In some instances the volume of the pituitary may actually exceed the volume of the sella.[25] However, Di Chiro emphasizes, "these instances of marked disparity between the pituitary and the sella are the exception rather than the rule."[25] This will be further explored later as a part of the discussion of sellar volume.

The normal anatomy and normal variants of the sella turcica have been explored on autopsy specimens, radiographs, and tomograms. The shape is quite variable in lateral view, and may be circular, oval or flat. The shape, however, is of no apparent significance.[34] The anterior floor is generally one millimeter or less in thickness, with thicker spongiosum bone more commonly seen toward the posterior sellar floor, and the clivus nearly always comprised of spongiosum.[20] The floor is usually uniformly thick in children (up to 20 mm) but becomes thinner with age as the sphenoid sinus enlarges.[20] Its cortical bony layer should be dense and clearly outlined to be considered normal.[34] The cortical layer of the dorsum sellae should also be distinct and clearly outlined, and in the absence of cortical changes the thickness, height, and direction of the dorsum sellae have no significance.[34] The chief factor insofar as abnormality of the posterior clinoid processes is concerned is also that their cortical margins be intact and of the same density as that of the dorsum sellae.[34] The diaphragma sellae is presumed to extend from the superior aspect of the posterior clinoid processes to the superior margin of the tuberculum sellae, but may be found several millimeters below these points.[20] (This is an important observation, since the diaphragma provides the superior limit of the hypophysis.) The contours of the tuberculum sellae usually form an obtuse or right angle, very rarely being acute.[22,36] The middle clinoid processes are small elevations on the anterolateral part of the sellar floor, but more frequently than not are not visible radiographically.[22] The sphenoid sinus more frequently than not (60 percent of cases) presents with one or more septa, and is usually pneumatized with extension to the clinoid processes occurring 14 percent of the time.[22,26] The floor of the sella in frontal view is with about equal frequency flat or concave and far less frequently convex.[22,26,36] The depth of the central depression when the floor is concave is rarely greater than 3.5 mm, and when the floor is convex presents an elevation of less than 1 mm.[26] The lateral angles of the floor are generally smoothly rounded and obtuse, occasionally sharp and obtuse, but never acute.[22,26] The floor is symmetrical more than twice as frequently as it is not.[22,36] A slope to the floor is a frequent finding in normal subjects.[22,26,36] Asymmetry or concavity of the floor and its frequent slope relative to the base of the skull singularly or in combination explain the double contour often seen on the lateral headplate. If the double contours in lateral projection are separated by an elevation of more than 2 mm, it is considered to be pathologic.[22] The image of an S-shaped groove on the wall of the sphenoid sinus in lateral projection may be due to the carotid sulcus or an extra-sellar septum of the sinus, sometimes referred to as a "false carotid sulcus."[22] Enlargement of the sella increases the width of the floor as well as the other dimensions[24,25] and produces sharp and angled lateral margins to the floor.[45]

Perhaps to the radiologist there are changes in the sella that are more diagnostic than the changes in size. Yet the sella does enlarge in response to sufficient enlargement of the pituitary as well as to the other intracranial tumors, as already discussed. Because of this a number of studies have endeavored to establish what relationship exists between the size of the pituitary and the cavity that encloses it, and to determine the dimensions of the sella that would be considered abnormal. The initial dimensions considered were the length and height as visualized on the lateral headplate. The recognition of the extreme variability in shape of the sella caused investigators to realize that a combination of these two dimensions may be more appropriate, and in 1922 Haas proposed a method to measure the area of the lateral projection of the sella, later refining the method and establishing standards according to age and sex.[29] Haas chose to superimpose the outline of the sella onto millimeter graph paper and "count squares" to determine the area, rather than make computations from linear measurements. Choosing the mean plus or minus two standard deviations as the normal limits of the values, he determined that for males age 21-50, 55.9-117.2 square millimeters, and for females age 21-50, 57.2-118.9 square millimeters represented the normal range of variation. For practical purposes he concluded that 58-120 square millimeters could be regarded as the limits of normal sellar area in adults.

In 1956 Acheson[19] created his own standards based on the length and depth of the fossa. For the measurement of length he took the distance between the tuberculum sellae and dorsum sellae. Depth was taken as the measure from a line joining these points to the lowest part of the sella. Acheson's study is one of the few to study the error involved in the technique. He determined that his standard deviation of the difference between two determinations was 0.929 mm, which he included in his assessment of normal range of variation. Taking his mean plus two standard deviations he concluded that for the sexes combined, ages 18 to 80, the upper limit of normal for length of the sella is 16.8 mm and for depth 9.4 mm. He also estimated, based on data obtained from the study of subjects from the Oxford Child Health Survey during the first five years of life and from his data on adults, that between the ages of six and 18 years the upper limit of normal increase in length is 2.6 mm and in depth 1.3 mm, for the sexes combined. Further increase in adulthood was concluded to be abnormal if greater than 1.8 mm in length and 0.6 mm in depth, both sexes combined.

Silverman in 1957[44] studied a sample of children aged one month through 18 years from the Fels Research Institute. He believed that the area of the sella provided a closer relationship to pituitary gland size than did linear dimensions, due to the variability in shape between individuals and in the same individual from time to time as a result of growth and development. Using a compensating polar planimeter he traced the contour of the sella from the tip of the dorsum sellae clockwise to the tuberculum sellae, and then following a straight line back to the point of origin. To be acceptable paired readings had to agree within .01 square inch. Recognizing the fact that the average radiologist would not have a planimeter available, Silverman also measured the length and depth of the fossa and created tables for the mean area observed for each particular combination of length and depth. Length was defined as the distance from the tuberculum sellae to the dorsum sellae (which corresponds generally to the position of the diaphragma sellae). Depth was taken as the length of a perpendicular from this line to the deepest portion of the pituitary fossa. The results of this study indicated that there was a rapid increase in area during the first year of life followed by a gradual deceleration in growth rate. The male pituitary fossa tends to be larger than that of females between the ages of one and 13 years, at which time the size of the female fossa reaches that of the male and subsequently exceeds that of the male. This correlates well with Rasmussen's[41] observations concerning the growth of the hypophysis during childhood. Silverman also demonstrated with growth curves the acceleration which occurs in the size of the female sella between the ages of 11 and 15 years. In males the acceleration occurs about two to three years later than in females, is less pronounced, but may last longer. Equalization is not quite reached even in late adolescence. This growth pattern bears striking resemblance to that of general somatic growth, which is not surprising considering the role of the anterior lobe of the pituitary. However, Savara and co-workers[37] determined that the dorsal surface of the sphenoid bone, forming the floor of the cranium, follows the growth pattern of the brain and cranium, while the ventral surface, which forms the posterior boundary of the facial skeleton is analogous in growth to the facial bones. Specifically the dorsal surface exhibits most of its growth before age 10 years with little or no discernible adolescent growth spurt, while the ventral surface has a distinct adolescent growth phase. The exception would be the sella turcica, only. For purposes of comparison with other authors, Silverman's data for 18-year-old subjects indicated a mean area plus two standard deviations of 132.9 square millimeters for males and 110.5 square millimeters for females. (The means were 86.7 square millimeters and 88.3 square millimeters, respectively, with far greater variation demonstrated in the male sample.)

Mahmoud in 1958[34] also assessed the area of the sella in lateral view by means of the compensating polar planimeter. He took the average of five replicate readings on each of 100 adult subjects, following the same landmarks as Silverman,[44] and determined the upper limit of normal for adults to be 130 square millimeters, both sexes combined.

In 1970 Israel[31] following the technique of Silverman[44] evaluated a cross-sectional sample and a longitudinal sample of adults. The longitudinal group consisted of 19 females and 22 males drawn from the cross-sectional sample. A radiograph taken at an earlier age of at least 25 years was compared with one taken at least 14 years later. A statistically significant increase in the area of the sella with increasing age was observed. The cross-sectional sample showed no statistically significant difference to exist between the sexes. Israel concluded that the gain in sella size with age is not in response to gland increase but rather is a part of the process of skeletal remodeling and redistribution with age. If this is true the disparity between the size of the sella and the size of the hypophysis increases with age. It has been stated[45] that conceivably the pituitary gland enlarges during the period of active growth, causing the sella to enlarge with it, and that later the gland may decrease in size with the sella remaining unchanged. In children, unlike adults, the pituitary fossa may become smaller if the gland decreases in size.

In 1979 Preston,[39] following the method of Silverman, evaluated pituitary fossa size and facial type. He could find no relationship between the size of the sella and vertical development of the face or facial convexity. He concluded that except for age, there is no relationship between the size of the sella and other parameters.

Other investigators have felt, like Rasumssen, that "it is the bulk of the tissue that we are interested in and not its exact shape."[40] The area of the fossa as viewed on the lateral headplate gives a two-dimensional perspective of a three-dimensional object that is very much a function of its shape. The first to suggest the measurement of the width of the fossa to obtain an idea about the third dimension of the sella was Fariñas in 1939.[51] He attempted to produce the measurement of width from the Towne's view, however, which proved impracticable due to the obliqueness of the rays, which produces a distorted image.[34]

In 1959 Bloch and Joplin[21] introduced radiopaque markers into various landmarks in and around the pituitary fossae of cadavers to demonstrate the radiological relationships that exist. They demonstrated in the lateral projection that the diaphragma sellae was found to lie on a line drawn from the tuberculum sellae to the most anterior convexity of the posterior clinoid process. They were also able to demonstrate in the fronto-occipital projection that the transverse diameter of the pituitary gland approximated the width of the "waist" of the dorsum sellae just below the posterior clinoid processes.

The following year Di Chiro[24] published what has become a landmark article in the measurement of the sella. Di Chiro felt that the dorsum sellae, as described by Bloch and Joplin, was not really suitable for assessing the width of the sella for many reasons. He pointed out that it varies in its transverse dimension from being broad in its upper extremity and slightly constricted inferiorly to just the opposite and that a "waist" as such may not actually be discernible. Furthermore, when the sella enlarges the dorsum frequently is eroded but does not grow wider. It is therefore not reliable in providing information regarding sellar width in cases of pathology. Instead, he suggested that the floor of the sella be measured from the posteroanterior radiographic projection, pointing out that it can be recognized in over 90 percent of the cases. He described the floor as a plateau, frequently connected to the lateral walls of the sphenoid sinus by two short sloping edges, the carotid sulcuses, on which lie the carotid syphons. The lateral edges of the plateau are usually well demonstrated, and the width of the sella was taken as the distance between their highest points. (A convex sellar floor makes this determination difficult, and in this case he alternatively measured the distance "between two ideal lines continuing cranially from the lateral walls of the sphenoid sinus.")

This publication and the oft-quoted "Di Chiro and Nelson" article of 1962[25] deserve considerable attention, as they delineated the advantages to be gained by a three-dimensional study of the sella. Among these are: (1) the fact that though there is generally correspondence between the increase in length and height and the increase in width of of the sella, in some instances only one dimension may enlarge while the others remain within normal limits; (2) sellas thought to be enlarged in the lateral projection may actually be long and narrow, but normal; (3) sellas thought to be normal in lateral projection may be wide and therefore pathologic; (4) sellas described as small may, by possessing a greater width, actually be normal or even enlarged. Haas[29] had recognized the limitation that measurement of the sella in two dimensions had posed, but without a reliable means of quantitating the third dimension, had felt the correlation with pituitary size to be adequately expressed as surface area. Di Chiro felt that he had discovered the means to provide that third dimension and set out to establish a reliable method of estimating pituitary volume from the three linear dimensions of the sella. These dimensions were defined as follows:

1. The length of the sella was taken as the greatest antero-posterior diameter in a horizontal plane. If the dorsum sellae presented a double or triple contour, the length was measured to the most posterior contour observed.
2. The depth was taken as the length of a perpendicular from the line connecting the tip of the tuberculum sellae and the top of the dorsum sellae to the deepest point in the floor of the sella. If there were two contours of the floor, the point was taken as the midpoint between them; if there were three contours the middle one was used.

The above dimensions were obtained from the lateral projection. The width was derived from the frontal headplate and defined as:

3. The distance between the two highest points located on the lateral edges of the plateau that forms the floor of the sella.

Making the assumption that the shape of the pituitary gland is an ellipsoid, Di Chiro used a modified formula for determining the volume of an ellipsoid to estimate the volume of the pituitary. That formula is VOLUME = $\frac{1}{2}$(LENGTH x HEIGHT x WIDTH).

The volumes of the pituitaries of 60 cadavers were determined after dissection by their displacement of distilled water. The actual volumes of the sellas were determined by filling them with "dentist's wax." And the radiographic estimate of volume was determined for each. The correlation between the volume of the wax cast of the sella and the radiologic estimate of sellar volume was 0.846. The correlation between the pituitary and the sella was 0.854, with the pituitary found to occupy an average of 79 percent of its sella. The radiographic volume of the sella was also generally larger than the pituitary volume, the correlation being 0.862 between pituitary and radiographic volume. The three linear dimensions of the sella will permit an estimate of the pituitary size which will deviate from the directly measured volume of the pituitary by an average of 16 percent of the volume of the pituitary. An estimate of sellar volume will deviate from the observed volume by an average of 19 percent. Thus the formula is more accurate for predicting the pituitary volume than the sellar volume, possibly because the pituitary is more regularly ellipsoidal than the sella, which may sometimes be rectangular.

The mean normal volume of the sella turcica in this study[25] was 594 cubic millimeters with a range of 233 to 1092 cubic millimeters, based on the radiographic evaluation of 173 normal adults. The width of the sella ranged from eight to 20 millimeters, with a mean value of 12.9 millimeters observed in 270 normal adults.

Oon[38] soon after the publication of the work by Di Chiro and Nelson attempted to estimate the sellar volume by taking the product of the lateral area of the fossa and the fossa width. The lateral area was measured according to the generally adopted definition of the area as it exists below the diaphragma sellae,[21,34,44] plotted on millimeter graph paper. The width was determined after the fashion of Di Chiro.[25] Oon analyzed 250 normal adults from the heterogeneous ethnic mix of Singapore. Their ages ranged from 20 to 74 years. The mean values obtained in the various dimensions plus or minus two standard deviations were:

length	8.5 -	14.1	millimeters (mean, 11.3 mm)
depth	6.5 -	11.3	millimeters (mean, 8.9 mm)
width	9.6 -	18.0	millimeters (mean, 13.8 mm)
area	52 -	116	square millimeters (mean, 84 mm^2)
volume	741 -	1842	cubic millimeters (mean, 1291 mm^3)

Oon estimated that these figures should be reduced by 15 percent to allow for radiographic enlargement. Doing so reduced his mean sellar volume to a figure of 860 cubic millimeters, which differs substantially from the mean value of 594 cubic millimeters proposed by Di Chiro and Nelson. It was Oon's contention that 700 to 2000 cubic millimeters should be regarded as the limits of normal sellar volume in adults.

In 1968 McLachlan and co-workers[35] attempted to resolve the issue as to whether the best estimate of sellar volume was derived according to the method of Di Chiro or Oon. They examined 27 women aged 22 to 84 years and 23 men aged 36 to 75 years who had died from causes that would preclude changes to the pituitary or sella turcica. They determined that the dimension of the fossa that correlated best with that of the gland was that of length; that which correlated most poorly was that of height; and that width was of intermediate correlation. The determination of volume of the pituitary from the radiographic image of the sella was no better in males when derived from the cross product of surface area and width than when taken from the three linear dimensions of length, width and height. For females the method of Oon showed a better correlation. For males the best estimate of gland volume was derived from the regression equation:

$$\text{VOLUME OF GLAND} = 0.30(L \times H \times W) + 131\ \text{mm.}^3 \quad (r = 0.68)$$

For females the best estimate followed from the equation:

$$\text{VOLUME OF GLAND} = 0.39(A \times W) + 226\ \text{mm}^3 \quad (r = 0.65)$$

The correlations reported in this study were considerably lower than those reported by Di Chiro and Nelson.[25]

Though the McLachlan study did not provide a clearcut answer in favor of the reliability of the Di Chiro method, it is the one that nevertheless has been chosen by several investigators.[36,42,43,45,47] It would seem likely that this is due to the facility of its use: the calculation of the lateral surface area is a much more laborious process and apparently little, if any, superior.

Fisher and Di Chiro[28] and Underwood et al[47] are two groups of investigators who assessed the implications of abnormally small sellar size, based on calculated volume. Underwood's group utilized Fisher and Di Chiro's mean values for various age groups of children and estimated from their own data the scatter of a normal population about these means. Thereby they created standards by which to assess the sella turcica volume in children. The conclusions of these investigators are that the small sella turcica is an extremely rare entity, suggestive of hypopituitarism, and is of value in the differential diagnosis of hypopituitary dwarfism in children. It is a condition that doesn't exist in the adult population except in dwarfs.

Therefore, the enlarged sella turcica is the more important entity. Measurements have been shown to be estimates, only, of pituitary size, and variable estimates at best. Yet enlargement of the sella is associated with a number of pathologic processes, as previously enumerated, and because of this it has been felt important to establish criteria to determine the possible presence of enlargement. As Taveras and Wood[45] point out, one method "is used daily by practically everyone and consists in the use of linear measurements for the length and depth of the sella turcica." They describe a length of greater than 17 millimeters as practically always abnormal. The finding of a depth greater than 13 millimeters they also consider abnormal. The width of a normal sella varies from 10 to 15 millimeters, and the upper limit of 1100 cubic millimeters is accepted by these authors as "normal." As reported earlier Di Chiro reported normal sellar widths as being from eight to 20 millimeters. Renn and Rhoton[42] found a range of 10 to 16 millimeters.

Conspicuous in the studies of Di Chiro and the authors since is a lack of regard for potential error in their technique. The formula proposed by Di Chiro for computing the volume of the sella includes a factor for "magnification error and the empirical error found in a small series of 15 cases."[25] The calculations subscribed to by Oon[38] included a magnification correction estimated at 15 percent. No further assessment of error has been offered, including the reliability of locating the landmarks utilized for the measurements. Dimensions for the widths of the sellae of children were apparently procured but never published as such; information on lateral area and volume only are available. The desirability of having available such information, from the standpoint of screening for pathology in a typical orthodontic treatment age group, would seem apparent.

It is one of the objectives of the present study to provide information on the feasibility of assessing the width of the sella turcica from the standard orthodontic frontal headplate.

REVIEW OF THE LITERATURE

Part II

Craniofacial Asymmetry

The study of facial symmetry far antedates the preoccupation with form that has occurred in this century within the orthodontic concept of desirability. Drawings by the neoclassicists depicting facial and bodily symmetry about certain delineated axes underscore the value these artists placed on its contemplation. Yet, Hasse's[60] study of classic Greek sculpture revealed the existence of slight asymmetries, leading him to conjecture that the artists were attempting to duplicate that which they observed in nature. Thompson[13] has stated that "In the study of facial asymmetry, it must be recognized that there is no truly symmetrical face regardless of the race, age or period of the individual." Cook[56] promulgates the view that "primary morphological symmetry in man is genetically determined but it is also recognized that true symmetry is very rarely found in nature--possibly only in molecular structure. Symmetry is a biological principle that applies to the species as a whole but is subject to considerable individual modification as a result of environmental factors." It has been suggested that the asymmetry that occurs in the normal face characterizes rather than disfigures it;[67] and in fact that a perfectly symmetrical face is not only unobtainable but would appear insipid[54] and monotonous.[13] Thus, in evaluating facial asymmetries the salient point must be whether or not the asymmetry is of sufficient degree to be displeasing to the observer and therefore abnormal.[54] Because the subjective evaluation determines whether or not a problem exists, it has been the objective of most studies to diagnose which structures are involved in creating the asymmetry and whether the basis is skeletal in origin, related purely to the soft tissues, or involves both.

In 1931 Woo[71] presented findings based on the direct measurement of a large number of skulls from the 26th to the 30th Egyptian dynasties. It was observed that the cranial bones exhibited an overall asymmetry, the right side being larger than the left, which was thought to be associated with right hemisphere dominance of the brain. However, these skulls also demonstrated a tendency toward a facial asymmetry in favor of a larger left zygoma and maxilla relative to those of the right side. This study excluded the lower third of the facial skeleton from consideration.

Thompson[13] had observed combat injuries to the craniofacial complex and was concerned about the treatment and prevention of resulting deformities. In 1943 he published in response a study of asymmetry dealing with both derangements in growth pattern as well as those arising from bone loss due to injury. He studied 25 individuals using clinical findings, cephalometric radiographs, temporomandibular radiographs, photographs and models. Thompson demonstrated the effects of asymmetries on the overall appearance of an individual by pairing the right and left sides of the face with their respective mirror images. The result gives the appearance of totally different individuals. He demonstrated asymmetries radiographically with reference to a vertical midline that bisected the distance between the medial aspects of the orbits and passed through the nasal septum. He categorized the etiologic factors in cases of abnormal facial asymmetry and concluded that there was a direct correlation between the severity of the asymmetry and the age at which the etiologic condition develops. It was Thompson's view that normal asymmetry is not very evident but that abnormal asymmetry is quite obvious.

Campbell[54] on the other hand felt that it is difficult to determine at just what point an asymmetry is no longer normal. He felt that the condition may not only be muscular or skeletal but also functional, to be discerned only during movement such as mastication or smiling. As such, he felt that recognition required any or all of the following means of appraisal: (1) the eye of the observer; (2) radiographs; (3) mechanical methods, from a straightedge across the mandibular plane to the most complicated appliance. Campbell adopted the method of Nove,[65,66] which compares the parallelism of the line connecting the mylohyoid ridges with that connecting the lowest parts of the orbits, on the frontal projection. In a perfectly symmetrical skull these lines were said to be parallel. Based on this assumption it was advocated that models be trimmed with their bases parallel to the mylohyoid line. To enhance the ability to locate the mylohyoid line radiographically, a baseplate with amalgam inserts was worn by the patient during the exposure of the film.

Fischer[57] approached the subject of asymmetry from the standpoint of the limitations that may be imposed on orthodontic treatment. He pointed out that asymmetries may be unilateral or bilateral and may occur antero-posteriorly, supero-inferiorly, or medio-laterally. The fact that facial asymmetries are often associated with dental asymmetries was described as the basis for clinical relevance. Yet he pointed out some reservations that must be considered when evaluating asymmetries from a diagnostic standpoint:

(1) Facial asymmetry is a natural phenomenon and there is nothing abnormal about it.

(2) Most of the structural facial asymmetries can be detected only by comparing homologous parts of the same face.

(3) Natural asymmetry of the face does not necessarily interfere with the attainment of a correct occlusion.

(4) The only clinical significance of structural facial asymmetries is in fact that they are not amenable to change by orthodontic means, and therefore they place certain limitations on orthodontic tooth movement in treatment.

Fischer described the permutations of positional patterns of the teeth as being innumerable, yet many patterns occurring with sufficient regularity for the orthodontist to become familiar with them. This is labelled the "trait concept" of malocclusion, which he feels facilitates the ability to attain treatment goals through familiarity arising from past experience.

In 1954 Harvold[12] endeavored to study asymmetries in children with cleft lip and palate by evaluation of posteroanterior radiographs. He first established a means of constructing a midsagittal axis, his "x-line," from the films of noncleft children. The construction of the x-line consisted of a horizontal line connecting the lateral parts of the zygomatico-frontal sutures to which a perpendicular line through the root of the crista galli was drawn. In more than 90 percent of the cases reviewed the anterior nasal spine was found to be less than 1.5 millimeters from the x-line. Harvold found that the deformity associated with clefting is localized mainly to the alveolar and palatal processes of the lateral parts of the maxilla and in the nasal septum and premaxilla. He did not find the growth potential to be reduced.

Sassouni[3,64] included the frontal projection in creating a three-dimensional cephalometric analysis. Special landmarks from the frontal view included:

(1) Lo - latero-orbitale, or the intersection of the oblique orbital line with the lateral contour of the orbit.

(2) Nc - the neck of crista galli.

(3) Mx - maxillare, the maximum concavity of the contour of the lateral maxilla between the coronoid process and the maxillary first molar.

Sassouni's midsagittal line was a perpendicular to the line Lo-Lo, through the neck of crista galli. Bilateral asymmetries were evaluated according to this line. Vertical asymmetries were referenced to the Lo-Lo line. The length of the line connecting dorsum sellae and nasion (Na) and that of the line connecting gonion (Go) and pogonion (Pog) were projected to the frontal view and the line Lo to maxillare (Mx) drawn on both sides. According to his norms the buccal contours of the maxillary first molars should be tangent to the line Lo-Mx. Lo-Sp-Lo should equal Go-Pog-Go, which should also equal Go-Sp-Go. Lo-Lo should also equal Go-Go.

Sassouni[64] felt that cephalometric analyses should not be based on a single plane of reference, since any reference plane is variable due to error of location. He demonstrated the variability of diagnoses according to which reference plane was chosen. Thus both his frontal and lateral analyses were based on a plurality of planes.

Cheney[55] described four types of dentofacial asymmetry which he felt required special consideration in the treatment of malocclusions. These types were categorized as: (1) unilateral anteroposterior displacements, (2) vertical displacements, (3) lateral displacements, and (4) rotary displacements. Unilateral anteroposterior displacements were described as the result of horizontal anteroposterior differences in the size, shape, and/or position of parts on the two sides of the face. Vertical displacements were said to result from height differences in size, shape, and/or form between dentofacial parts on the two sides of the face. Lateral displacements were considered as asymmetries resulting from horizontal lateral differences in size, shape, and/or position of dentofacial parts on one side of the face as compared to those of the opposite side. And rotary displacements were defined as asymmetrical variations resulting from a displacement of the whole maxilla or the whole body of the mandible which may or may not involve unilateral size variations. The following were observed from the front of the face: upward displacement of orbital point, malar process height, lateral displacement of the malar process, mandibular ramus height, lateral displacement of the mandibular angle, lateral displacement of the chin, dental height in the maxilla, and dental height in the mandible. Cheney's analysis was made three-dimensional by utilizing observations of the following from the inferior view of the face: mandibular body length, rotary displacement of the mandibular body, rotary displacement of the palate, and posterior displacement of the malar process. It is the direct observational procedure from an inferior view that made Cheney's analysis unique. His reference planes for analysis from the frontal perspective were the midsagittal, passing through points nasion and anterior nasal spine (both of which can be palpated and identified on the external surface of the face), and the orbital plane, which was defined as perpendicular to the midsagittal plane and passing through right orbitale.

Cheney observed that profile differences, i.e. differences when viewing the same patient from the right and left lateral aspects, are characteristic of asymmetries. Another common observation was asymmetry of ear position on one side of the head as compared to the opposite side. Such an asymmetry may or may not be associated with dentofacial asymmetry; but because of the relevance to oriented frontal headfilms, he argues for including this assessment as a part of every orthodontic evaluation.

Björk and Björk[53] studied a series of skulls from early Indian cultures of Peru where the practice of artificial deformation of the head had been exercised as a cultural norm. Of 149 crania studied, 44 had no evident deformation and were used to comprise the control group. It was found that where asymmetric occipital deformation occurred, the cranial base on the more deformed side was shortened with resultant ventral displacement of the mandibular fossa on that side. A compensatory asymmetry of the maxilla and mandible resulted due to decreased growth of the jaws on the affected side. As such the midline of the face did not show asymmetry comparable to that observed in the cranial base.

Kulaga[62] investigated to what extent three points, nasion, sella turcica and basion, are true midsagittal points by examining antero-posterior radiographs of 50 Asiatic skulls. Seven hundred fifteen angular and linear measurements were collected and analyzed, the conclusion derived being that basion and sella turcica are probably midsagittal points, whereas nasion is not.

A study of craniofacial asymmetry in twins was undertaken in 1965 by Mulick.[63] By different pairings of six same-sex sets of Caucasian triplets, aged nine to 15 years, he obtained six same-sex sets of identical twins and 12 same-sex sets of fraternal twins. Oriented lateral and frontal headplates utilizing the Broadbent-Bolton cephalometer were obtained initially on each subject and again after three years, and a three-dimensional analysis performed orthogonally along perpendiculars to three reference planes. The midpoint of the cranial reference system was the ethmoid triad point, that of the maxillary reference system was anterior nasal spine, and that of the mandibular reference system was menton. Absolute differences between right and left sides were converted to relative differences for comparisons between subjects, since not all subjects were the same size. Mulick could not demonstrate significant differences between identical and fraternal twin groups, leading him to conclude that except for hereditary syndromes, heredity is not the controlling factor in the production of craniofacial asymmetry. Cross-sectional analysis revealed that differences in the amounts of asymmetry of the various regions existed, but none could be demonstrated in serial analysis. From this he concluded that the initial differences that may have existed were not intensified as the parts enlarged with age, and there is no effect on the individual's mean asymmetry with advancing age. Thus, existing patterns of asymmetry were not intensified with dimensional changes. Therefore, asymmetries existing on an individual bone level are reduced in relation to the craniofacial complex as a whole by the interaction of the components of the craniofacial complex. It was proposed by Mulick that, based on his findings, "any modification of environment by treatment procedures could feasibly modify or eradicate craniofacial asymmetry."

Letzer and Kronman[9] compared a sample of 50 children aged nine years zero months to 11 years 11 months possessing "excellent occlusion" with a like sample of 50 children possessing malocclusion for trends in asymmetries. To minimize factors related to the circumstance that the frontal headplates were obtained with a Broadbent-Bolton cephalometer for the excellent occlusion group and with a Margolis cephalostat for the malocclusion group, they utilized an entirely angular analysis, eschewing linear measurements after the fashion of Gresham's lateral projection study.[59] The relationship between symmetry of the anterior cranial base and that of the mandible was assessed by geometrically including the point crista galli as common to the analysis of both. They concluded that the anterior cranial base demonstrated a higher degree of symmetry in the group possessing excellent occlusion, but that harmony between the anterior cranial base and the mandible was not significantly greater for this group. Neither the mandible nor occlusion were determined to be valid means of differentiation between the two groups. There was no correlation between occlusion of the teeth and symmetry or lack of it. Individuals in both groups demonstrated asymmetries, suggesting that facial asymmetry is a normal finding.

Sutton[14] felt that asymmetries should be assessed not by measurements of lateral structures relative to a constructed median plane, but rather by bisecting the actual facial width and evaluating midline structures relative to the perpendicular through this bisection. His was a technique of direct observation, utilizing the zygions as the lateral extremities of the face. Subnasale and pogonion were considered to represent the position of the nose and the chin, respectively, which were assigned an arbitrary value relative to the median line as follows: 0 when no asymmetry was detected, 1 when the asymmetry was considered to be slight, 2 when moderate, and 3 when it was marked. He noted an increase in the degree of lateral asymmetry of the nose with age, a condition which he found to be uncommon in children. The degree of asymmetry of the chin, on the other hand, fluctuated with age, when evaluated according to his technique in a cross-sectional sample of 1,029 subjects.

Plint and co-workers[68] distinguished between true asymmetries and apparent facial asymmetries. True asymmetries included malformations, which generally result in asymmetries that become more pronounced with growth and development, and nonpathological true asymmetries, which may range from the obvious to minor variations of normal. Apparent facial asymmetries were considered to be due to an eccentric position of the mandible which had been displaced by occlusal anomalies; the hard and soft tissues of the facial components were normal. Mandibular displacements were described as occurring in any of the facial asymmetry groups but could only produce asymmetry when the teeth were in occlusion. (Patients with true asymmetries maintain an asymmetrical appearance in the rest position as well.) A high proportion of Class III cases were observed to have mandibular displacements. This study found the frontal radiographic view to be of value in differentiating between true and apparent asymmetries by comparing films taken at rest with those taken in occlusion. The authors felt that the orthodontist should make every effort to distinguish between the two types of asymmetry, a task which may be quite difficult at times since the same objectives of treatment may often not be equally attainable.

Vig and Hewitt[70] in 1975 published a posteroanterior cephalometric study of 63 children, aged nine to 18 years, representing 20 males and 43 females. The authors marked the midpoints of lines connecting bilateral landmarks and by drawing a line of best fit through the appropriate points, created an axis "X" representing the middle third of the face and an axis "N" representing the lower third of the face. By bisecting the angle between the two axes an arbitrary anatomical axis of the face was obtained. A method of triangulation was used to evaluate the relative asymmetries of the component areas of the facial complex. Using 11 anatomic points (sella, medial extent of each orbit, inferior extent of each orbit, right and left condylar point, right and left mastoidale, anterior nasal spine, right and left zygomatic point, right and left upper molar point, incisor point, right and left gonion, and menton), seven bilateral triangles were constructed representing the following regions: 1) cranial base region, 2) lateral maxillary region, 3) upper maxillary region, 4) middle maxillary region, 5) lower maxillary region, 6) dental region, 7) mandibular region. The results of this study indicated that in two-thirds of the subjects, the axis representing the middle third of the face deviated to the left of the axis representing the lower third of the face. The cranial base and two maxillary regions showed an overall asymmetry, with the left side being significantly larger than the right. The mandibular, dental, lower and middle maxillary regions demonstrated no significant overall asymmetries. These findings were interpreted to suggest that compensatory changes occur in the dentoalveolar regions to minimize the underlying asymmetries that occur during growth and development in the spatial arrangement and size of the jaws.

Three years later Shah and Joshi[11] utilized the method of triangulation proposed by Vig and Hewitt to evaluate 29 male and 14 female Indian adults, aged 18 to 25 years, who possessed apparently symmetrical faces and normal occlusions. Their findings were in contradistinction to those of Vig and Hewitt in that the total facial structure was found to be larger on the right than on the left side. The total maxillary area was also found to be significantly larger on the right side than on the left, but individually only the lateral maxillary area was significantly larger on the right than on the left. The fact that the subjects in this study were chosen on the basis of symmetrical appearance led the authors to suggest that the soft tissue tends to minimize the underlying skeletal asymmetry. Furthermore, asymmetry of the face occurs even when the teeth are in excellent occlusion with coincident upper and lower midlines. Since the dentoalveolar region and the mandibular region were found to be symmetrical, it was proposed that the moulding influence of the musculature was responsible.

Svanholt and Solow[69] proposed a method for analyzing the amount of dentoalveolar compensation occurring in maxillo-mandibular midline discrepancies. Their premise was that in cases where the dentobasal midline relation is normal, a deviation in the midlines between the maxilla and mandible will result in a midline discrepancy between the dental arches. Dentoalveolar compensation occurs when a deviation exists in the dentobasal relations, which reduces the dental midline discrepancy. Compensations may be complete or incomplete; bypass complete compensation to be classed as overcompensation; or displace the dental arch midpoints in a direction opposite to the maxillo-mandibular deviation, to be termed dysplastic. The facial midline in this study was constructed as follows: A line was drawn connecting the bilateral points, latero-orbitale (Lo), defined as the intersection of the lateral orbital contour with the innominate line. The perpendicular to line Lo-Lo through the top of the nasal septum at the base of the crista galli was taken to represent the midfacial plane. The maxillary midpoint was represented by the anterior nasal spine and the mandibular midpoint by the projection of the mental spine onto the lower mandibular border, perpendicular to a line connecting the right and left antegonial notches. The transverse jaw relationship was based on the angular derivative of the line connecting the mandibular and maxillary midpoints and that representing the midfacial plane. Transverse maxillary and mandibular relationships were independently assessed by their respective angular incidences to the midfacial plane. Upper and lower incisal compensation were evaluated according to their respective angular relationships to the line through the maxillary and mandibular midpoints, the midline point of each dental arch being projected to that line through its respective basal midpoint. The authors found a small variability for the measures of transverse jaw position, indicating that the face is generally symmetrical. They felt that this tendency toward symmetry is responsible for the fact that the evaluation of the posteroanterior radiograph has found only limited use as a standard procedure in orthodontic case analysis. The value of their analysis was purported to be in localizing and quantifying the dental response to an underlying asymmetry.

Marmary and co-workers[15] argued against using structures that can be altered when an asymmetry is being developed to establish a midline for assessment of the asymmetry. They believed that the location of neurovascular bundles must remain invariably constant during growth and that a midline drawn between the basal foramina should therefore be reliable. A basilar radiographic view of each of 86 adult skulls from India was obtained, and on an acetate tracing of each, the centers of the foramina spinosa were connected. The perpendicular bisector of this line was designated as the midline of the base of the skull, and measurements to this line of paired and unpaired landmarks were analyzed. It was concluded on the basis of this analysis that the centerline, as constructed, does fall in the midsagittal plane.

Cook[56] described three types of craniofacial asymmetry: 1) gross pathological conditions with asymmetry as a side effect, 2) biological variation where minor lack of symmetry of the component parts of the facial complex result in an asymmetry of no clinical significance, and 3) those patients whose asymmetry lies between these two extremes and presents a clinical sign with occlusal implications. Cook evaluated 50 cases which best belonged to the third category by means of three radiographic projections, the lateral skull, the posteroanterior (P-A), and the submento-vertex (SMV). The lateral view was found to be of little value in the assessment of asymmetry without information from other projections. The posteroanterior view was evaluated for reliability of locating landmarks and for the effects of rotational positioning errors by means of exposures taken on dried skulls. A comparison of two films which differed in object position by only five degrees resulted in a complete reversal of the apparent asymmetry, the dominant side being dependent on the orientation of the transmeatal (interporionic) axis. Indeed, a study by Julius[64] in 1975 indicated that rotation of the head in the cephalostat by as much as three degrees was not uncommon. The author therefore felt that interpretation of asymmetries from the P-A view must be regarded with care. The SMV view was found to be the most subject to distortion, but altering the tilt of the object to the film plane, while showing variation in the relative position of landmarks, showed no change in the side of asymmetry. Though demonstrable, the asymmetries could not be quantified from this view.

Ricketts[10] studied symmetry by relating point A and pogonion to the midsagittal plane. He felt the best representation of the midsagittal plane was by a line through the top of the nasal septum or crista galli perpendicular to the line through the centers of the zygomatic arches. Denture symmetry was assessed from points between the upper and lower central incisor roots and compared to the midsagittal plane.

Grayson and co-workers[58] presented a three-dimensional cephalometric analysis of craniofacial asymmetry utilizing the posteroanterior and basilar projections. Midlines at selected depths of the craniofacial complex could be determined and associated anatomic structures compared sequentially to produce an image of a warped midsagittal plane for localization of the asymmetry. The radiographic landmarks used to define the midsagittal plane thus varied according to the depth of the plane under consideration.

MATERIALS AND METHODS

The sample for the study of facial asymmetry consisted of patients from the OHSU Orthodontic Department, who had been diagnosed as possessing Angle Class I molar relationships and who are primarily of Northern European ancestry. The male sample contained 32 subjects, aged 12 years two months to 15 years 10 months (mean age 13 years nine months). The female sample also consisted of 32 subjects, ranging in age from 12 years zero months to 16 years zero months (mean age 14 years zero months). The frontal headplate for each subject was obtained from his/her initial diagnostic records, an 8" x 10" sheet of acetate tracing paper was affixed to the radiograph, and the following landmarks were identified on the film and recorded on the overlying acetate by means of a small pin hole:

A. Midline landmarks
   1. Root of crista galli (CG)
   2. Anterior nasal spine (ANS)

B. Bilateral landmarks
   1. Condylar point (C) - the most superior and lateral point on the curvature of the condyle
   2. Molar alveolar point (MA) - the level of the alveolar crest on the most lateral aspect of the image of the crown of the maxillary second molar

3. Antegonial notch (AG) - the point of greatest concavity of the antegonial notch

A constructed point, menton (M), was also recorded by projecting the line connecting crista galli and anterior nasal spine to the inferior border of the mandible.

The nine points thus obtained were sequentially digitized on an Apple graphics tablet and entered into an Apple IIE computer. (See Figure 1 for the sequence of entering the points.) The areas of the following triangles were thereby computed for the right and left sides of the face of each subject (refer to Figure 1):

Triangle A (representing the left body of the mandible) - CG-AG-M, left

Triangle B (representing the right body of the mandible) - CG-AG-M, right

Triangle C (representing the left upper maxillary region*) - CG-MA-ANS, left

Triangle D (representing the right upper maxillary region*) - CG-MA-ANS, right

Triangle E (representing the left ramus of the mandible) - CG-C-AG, left

Triangle F (representing the right ramus of the mandible) - CG-C-AG, right

*According to the method of Vig and Hewitt

The areas obtained were statistically analyzed through calculation of the respective means, standard deviations, and standard errors of the means. The standard error of the measure was also calculated for each area by repeating the procedure on a mixed random sample of 16 subjects. Student's t-test was used to compare right side with left according to sex and the male to the female sample.

The sample for the study of the width of the sella turcica was also drawn from the treatment group of patients from the OHSU Orthodontic Department and also consisted of patients who are primarily of Northern European ancestry. However, no attempt was made to limit the sample to any particular form of malocclusion. Therefore, a broader spectrum of orthodontic problems was represented. The male portion of the sample was comprised of 32 subjects, aged 12 years zero months to 15 years 10 months (mean age 13 years nine months). The female portion consisted of 32 subjects, aged 12 years zero months to 16 years zero months (mean age 13 years five months).

The frontal headplate for each subject was obtained from his/her initial diagnostic records, an 8" x 10" sheet of acetate tracing paper was superimposed on the radiograph, and a small pin hole was placed in the acetate at the right and left extremities of the image of the sellar floor, as defined by Di Chiro and Nelson.[25]

The distance between the two points was then measured to the nearest 0.1 mm using a vernier caliper.

The statistical analysis of the data included computation of the mean and standard deviation for males and females. The standard error of the measure was calculated by repeating the marking and measurement procedure on a mixed random sample of 16 subjects. The means for the male and female samples were compared through Student's t-test to determine if a difference in sellar width exists with regard to sex.

FINDINGS

Six tables were compiled from the data obtained in this study.

Table I provides the mean, standard deviation, and standard error of the mean for each of the six triangular areas of the face under consideration for the male portion of the sample. It also contains a like appraisal, by hemispheres, of the total mandibular area and total facial area, obtained by summation of the appropriate component triangular regions. Table II provides this information for the female portion of the sample.

Table III compares the means of the areas for the right and left sides of the face, according to sex, by means of Student's t-test.

Table IV provides a comparison of the male sample with the female sample, region-by-region, by means of Student's t-test.

Table V indicates the means obtained for the male and female samples with respect to the width of the floor of the sella turcica. It also shows the corresponding standard deviation and range, as well as a comparison of the two groups by means of Student's t-test.

Table VI documents the error involved in the method.

Examination of Table III reveals that no difference in size could be demonstrated between the right and left sides of the face for either males or females in any of the regions or their combinations.

Table IV, however, indicates that without exception each region and each combination of regions was statistically significantly larger for the male sample than for the female sample.

Table V discloses the finding of a mean sellar width of 11.8 mm for males and 11.5 mm for females. The difference was found not to be significant.

DISCUSSION

A difficulty immediately encountered in any study utilizing frontal cephalograms is that of landmark location. The superimposition of structures makes this a much more arduous task than that encountered when analyzing lateral headplates. In 1948 Brader[72] proposed that the technique of laminagraphy be utilized to reduce the problem and make the posteroanterior projection a viable one for use in growth studies. The technique was never well-accepted, however. Adams[73] described the technique referred to as the depressed posteroanterior projection in a publication of 1963. Again, the objective was to make the location of landmarks more facile by reducing the amount of superimpositioning. The main drawback to the technique was that distortion was increased as well, and therefore it has drawn little favor in orthodontic applications. Ultimately the difficulty in landmark location has been overcome with the advent of computed tomography. Unfortunately, this is not a technique amenable to common use in orthodontics. Thus, any study using the true posteroanterior projection must accept the fact that there are a fairly limited number of usable landmarks available for consideration.

A second factor that must be considered is that of enlargement. The area of interest is generally that of the face, which is presented in relation to the transporionic axis. Linear dimensions are therefore subject to considerable variation depending on the anteroposterior dimensions of the face of the subject. Correction of frontal dimensions was accomplished to some degree by Wylie and Elsasser[74] but required perfect positioning of the head and a rather laborious drafting procedure. Impracticality was also a major deficiency in the approach proposed by Vogel in 1967.[75]

Frontal analysis therefore suffers from the same types of errors as other analyses, yet probably to a greater degree. If validity is the extent to which the value obtained represents the object of interest and reliability is an expression of the precision of measurement reproducibility, the limited number of viable landmarks and the vagueness of even those, at times, pose significant problems in terms of experiment design. Furthermore, there are no error studies available for guidance, such as the ones by Bjork[76] and Baumrind[77] concerning landmarks in the lateral projection.

The landmarks chosen for use in the current study of facial asymmetry were selected on the basis of their estimated validity, but with as much regard as possible to how easily they could be located by the average orthodontic practitioner. The points CG and ANS have been used together or in combination with other landmarks by several authors as midsagittal points. Their ease of location is relatively great. The point AG was chosen in preferance to gonion because it may be relatively more stable[10] in the event that the method were to be used in a longitudinal fashion. The point MA was chosen rather than maxillare, as used by Vig and Hewitt[70] and Shah and Joshi,[11] because it is visible on a greater number of radiographs. The difficulty in visualizing the condyles makes the location of point C the most uncertain. Yet it was thought to best represent the upper limit of a very pertinent contributor to asymmetry, the ramus.

In this study the mandible was evaluated relative to a midsagittal line derived from points outside the mandible. This provides a means of referencing the mandible to the maxilla. Thus, in the individual mandibular compensation for maxillary or craniofacial asymmetry should be detectable.

The use of triangles follows the reasoning of Vig and Hewitt[70] that the face is composed of numerous constituent parts, and therefore the degree of harmony between the parts determines the symmetry of the whole. Angular relations coupled with linear dimensions to provide calculated areas were also used as a means to minimize differences due to the difficulties encountered in landmark location. Table VI indicates the relatively small amount of error involved deduced by replicate landmark location and calculation of the areas. The amount of error contained in the process of digitizing the data has been evaluated by Johnson[78] and represents a very small portion of the overall error.

The findings of this study are in contradistinction to those of Vig and Hewitt, who determined an overall facial asymmetry to exist in favor of a larger left side, and to those of Shah and Joshi, who found the right side to be larger than the left. The two studies cited differed from each other both in the ages and the ethnic populations under consideration. (The second point is conjecture since Vig and Hewitt did not specify the ethnic distribution of their sample. However, the children were selected from the orthodontic clinic at London Hospital. By contrast Shah and Joshi studied an adult sample of students from Ahmedabad, India.) The studies by these authors made no distinction in their findings between males and females. They did, however, employ the identical methodology. If their results are to be accepted, it would seem apparent that one of two conclusions must be drawn: either (1) the face of the child shows an asymmetry favoring the left side, which at some point converts to an asymmetry favoring the right side in adulthood; or (2) ethnogeny has generated groups demonstrating asymmetries with a basis in opposite facial hemispheres. The current study differed from the other two in methodology to a substantial degree. Whether it is less sensitive and therefore unable to detect an existing trend in asymmetry is purely speculative. The fact that none was discovered, however, removes the burden of attempting to explain a finding that has no plausible explanation.

The finding of significantly larger dimensions for the male sample than for the female sample is in agreement with the lateral projection study by Fry[79] on essentially the same subjects. The conclusion drawn is that boys of this age group have facial dimensions generally larger than girls of this age.

The program produced by Dr. Fred Sorenson for this study was designed primarily to evaluate individuals for the presence of facial asymmetries. In a manner similar to that applied to the group data comparable right and left areas are compared for relative size. By dividing the value obtained for a particular region of the left side by that obtained for the like region of the right side, a ratio is generated. In the instance of perfect symmetry the ratio should be 1.0. In practice this rarely occurs, however, since many variables affect the actual recorded values for the two sides. By extrapolating from the data obtained for the sample in this study, it should be possible to determine the minimum or maximum ratio below which or above which an individual must fall to have a significant asymmetry for the region in question. For example, when evaluating the body of the mandible for the female group, on the basis of the values generated for area A, area B would have had to have a mean less than 2344.28 square millimeters or greater than 2527.52 square millimeters (and the same variation demonstrated) to have been statistically different than the mean for area A (at the .05 level of probability). That would translate into a ratio of A to B of greater than 1.04 or less than 0.96. These guidelines would not present a particularly stringent test of asymmetry, however, as only 50% of the female sample had A/B ratios between 0.96 and 1.04.

A second approach would be to employ the convention of accepting the mean plus or minus two standard deviations as the range of "normal." In this case the "normal" left side of the body of the female mandible (represented by area A) would fall between 2048.4 and 2823.4 square millimeters, and the "normal" right side of the female mandible (represented by area B) would fall between 2080.7 and 2746 square millimeters. A mean-sized area A coupled with an area B outside the range of "normal" would produce a ratio less than 0.89 or greater than 1.17. In similar fashion a mean-sized area B coupled with an area A outside the range of "normal" would result in a ratio less than 0.85 or greater than 1.17.

Therefore, if one were analyzing a particular female subject and calculated a ratio of A/B for that subject lying beyond the range of 0.85 and 1.17, a significant asymmetry in the body of the mandible might be suspected. Similarly, if one encountered a ratio of C/D less than 0.84 and a ratio of E/F less than 0.89 in a female subject, it might be concluded that a maxillary asymmetry had been followed by compensatory growth in the right ramus of the mandible.

Table VII lists the ratios for males and females based on the relevancy of $\pm$ 2 standard deviations from the mean. Any ratio that varies from 1.0 may be suggestive of a regional asymmetry, however. The figures in Table VII provide a reference system for interpreting the ratios calculated for an individual. Certainly the greater any ratio varies from 1.0, the greater the asymmetry may be assumed to be. By the same token the nearer a calculated ratio approaches the limits detailed in Table VII, the greater the chances of clinical significance become.

It has been pointed out earlier that the significance of the finding of a true skeletal asymmetry lies in the fact that it is not amenable to correction by orthodontic means, and therefore places certain limitations on orthodontic tooth movement in treatment.[57] In the case of a unilateral crossbite, it may be better to accept the crossbite if a skeletal asymmetry can be recognized.[68] Surgical correction may be the only viable alternative.

The findings for the portion of the study concerning the width of the sella turcica are consistent with the information available from other workers, though the width was found to be narrower in this study. Di Chiro and Nelson[25] reported a mean sellar width of 12.9 mm with a range of eight to 20 mm. Oon[38] found the mean of his sample to be 13.8 mm with a range of nine to 21 mm and a standard deviation of 2.1 mm. Taveras and Wood[45] simply described the width of the normal sella as varying from 10 to 15 mm, while Renn and Rhoton[42] stated the range of normal to be from 10 to 16 mm. All of these authors dealt with samples drawn from adult populations and none reported the results divided according to sex.

The results of this study indicate that for children aged 12 to 16 years there is no signficant difference in sellar width between boys and girls. Silverman[44] determined that at approximately the age of 13 years the area of the pituitary fossa in lateral projection became equal in males and females. (Between the ages of one and 13 years, that of the male exceeds that of the female and after the age of 13 years, that of the female surpasses that of the male.) Increase in the size of the sella continuing beyond the adolescent years has been confirmed by other authors.[28,29,31,47] Increase in width, per se, of the sellar floor has not been documented but is a reasonable corollary to generalized sellar enlargement.

Another finding of interest is the apparent accuracy with which the sellar floor can be measured. The standard error of the measure (0.3 mm) for this dimension is identical to that reported by Bjork for the nasion-sella dimension.[76] The method of measuring indirectly on tracing paper versus directly on the film was evaluated for landmarks on depressed posteroanterior cephalometric radiographs by Richardson,[80] who found no significant difference in accuracy between the methods.

It was also found that the sphenoid sinus (and therefore the sellar floor) was more frequently discernible and generally much clearer on those radiographs where the portion of the craniostat that supports the bridge of the nose had been removed prior to the exposure.

SUMMARY AND CONCLUSIONS

When one delves into the study of craniofacial asymmetry, the most cogent point to remember is that the subject deals with the degree of occurrence rather than its prevalence. The question is not whether or not an individual exhibits an asymmetry. Rather, it is important to know the anatomical basis for the asymmetry and the clinical implications: Does the asymmetry impose limitations on treatment? Does the asymmetry, itself, require treatment? Does the asymmetry concern the patient? Asymmetry has been shown to be a universal, naturally-occurring phenomenon. If none of the above questions requires an affirmative answer, the occurrence of an asymmetry presents a moot point for discussion.

The current study modified the method of Vig and Hewitt[70] to examine the trends of asymmetries in a population. Past studies have given results contradictory to each other. This investigation offered no support to the tenet that asymmetries occur with any predilection for a particular hemisphere within a population. Other workers have stumbled in their attempts to explain why any such tendency should exist when their data have, in fact, yielded such a conclusion. Beyond that there has been no particular significance attached to such findings. This seems proper in view of the fact that asymmetry is a problem for individuals and not populations.

Among the many considerations inherent in the subject is the role played by the soft tissues in reducing, enhancing, or creating the appearance of asymmetry. The basis of the current investigation is the skeletal aspect of hemispheric proportions. From an orthodontic standpoint this is probably the most pertinent. Yet it leaves much to explore.

A fundamental weakness of any analysis of symmetry based on the posteroanterior cephalometric radiograph is in the fact that orientation of the subject to the radiographic source is by means of the transporionic axis . . . and there is no particular reason to think that the ears present with any greater symmetry to the cranium than other structures. Ideally the design of the experiment would include the establishment of the true midsagittal plane, which ideally would lie perpendicular to the transporionic axis. In practice, however, the midsagittal "plane" is actually a line that gives a best estimate of the midsagittal plane. There is no certainty, therefore, that any of the studies does more than measure the relation of one ear to the other, creating an apparent radiographic asymmetry of the craniofacial complex by deflecting the midsagittal line to one side or the other. Perhaps this diminishes the value of all findings. Yet it must be realized that in research "perfection may be the goal but adequacy is the most useful standard."[81]

The method of the current study seems to have met the standard of adequacy. Sutton[14] felt that it is of fundamental importance to define the median line. In this instance the critical relation is that of the mandible to the rest of the craniofacial complex. The median line has therefore appropriately been chosen independently of the mandible and with meaningful intent regarding the craniofacial complex. The application of data derived from groups to further the understanding of that derived from individuals is the primary value of this investigation. It is of interest, nevertheless, to note that the facial dimensions of a theoretically less mature group of males should still exceed those of a skeletally more mature group of females. The disparity in size would therefore be expected to be greater in an adult sample.

The investigation into the width of the sella turcica demonstrates the greater versatility of the frontal projection than is commonly perceived. Perhaps a brief discussion of cranial tumors and their incidence would make apparent the usefulness of sellar examination:

> As stated earlier any of the cranial tumors can result in changes in the sella. The ones most commonly producing changes, however, are the pituitary tumors which are the adenomas and the craniopharyngiomas. The craniopharyngioma is most commonly encountered in childhood.[45] There are an estimated 88,000 persons with brain tumors living in the United States, with an estimated 22,000 new cases each year.[82] The incidence rate of primary intra-cranial tumors has been estimated at between four and five cases per 100,000 per year.[83] However, a retrospective study of incidental pituitary tumors in 500 consecutive autopsied subjects yielded 42 glands with occult pituitary adenomas.[84]
>
> The pituitary tumors are frequently responsible for endocrinopathies but particularly the craniopharyngioma may also be life-threatening. Total craniopharyngioma removal allows excellent survival rates. If total removal is not possible, further therapy

will be required as more than 90 percent will recur within 10 years.[85] Early diagnosis is, thus, important.

The width of the sella in this study was found to be less than in studies of adult subjects, which is consistent with continued growth through adolescence. The width is of little diagnostic value alone but provides the third dimension for a proper assessment of sellar size when combined with information available from the lateral projection.

In both studies there was a surprising degree of accuracy, considering the difficulty in landmark location on frontal radiographs. A good portion of the reliability in the study of asymmetry is likely due to the use of area triangulation, which helps to minimize the effect of errors made in landmark recognition. The inherent accuracy of the computer methodology also benefitted the study. It can only be assumed that further practice and greater familiarity with frontal radiographs would result in still higher accuracy.

Further study suggested by this investigation would include a soft tissue analysis of asymmetry for correlation with the skeletal analysis. A study of error in landmark location on frontal radiographs similar to that by Baumrind[77] on lateral headplates would benefit any future attempts to gain cephalometric data from the posteroanterior projection.

The current investigation is a departure from the cephalometric studies of the lateral projection. The convention of analysis by use of lines and angles has been replaced by the assessment of the relationships of geometric areas, one to another. Both have been designed to provide clinically relevant data for the evaluation of individual patients. The extent to which any analysis is used depends on the perceived needs of the patient as well as the merit of the technique in the eyes of the individual practitioner. It has been demonstrated that in many instances practitioners who insist that a cephalometric analysis is vital to the diagnosis of every patient would have arrived at the same diagnosis without any cephalometric data at all.[87] Moyers and Bookstein[86] have argued that conventional cephalometrics are actually inappropriate, based on the following observations:

1. Cephalometric conventions today may have little basis in either biology or biometrics.

2. There is no theory of cephalometrics, only conventions which involve landmarks and straight lines only. These fail to capture the curving of form and its changes, exclude proper measures of size for bent structures and misrepresent growth, portraying it as a vector displacement rather than a generalized distortion.

3. Conventional cephalometric procedures misinform by fabrication of misleading geometric quantities, by confusion about what is happening (analysis of rotations, treating shape separately from size, and registering angles on landmarks as vertices), and by subtraction as a representation of growth.

This is a rather severe indictment of a system having roots in a half century of research. If Moyers and Bookstein are correct, then one must assume that it is impossible to germinate the vast storehouse of data so far collected from the galaxy of oriented headplates and meticulous tracings. Rather, one must stand like a character of Voltaire sighing and muttering between his teeth, "_O che sciagura d'essere senza coglioni!_"

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FIGURE 1

Areas of Triangles under Consideration

and the Sequence of Entering Points into the Apple IIE Computer

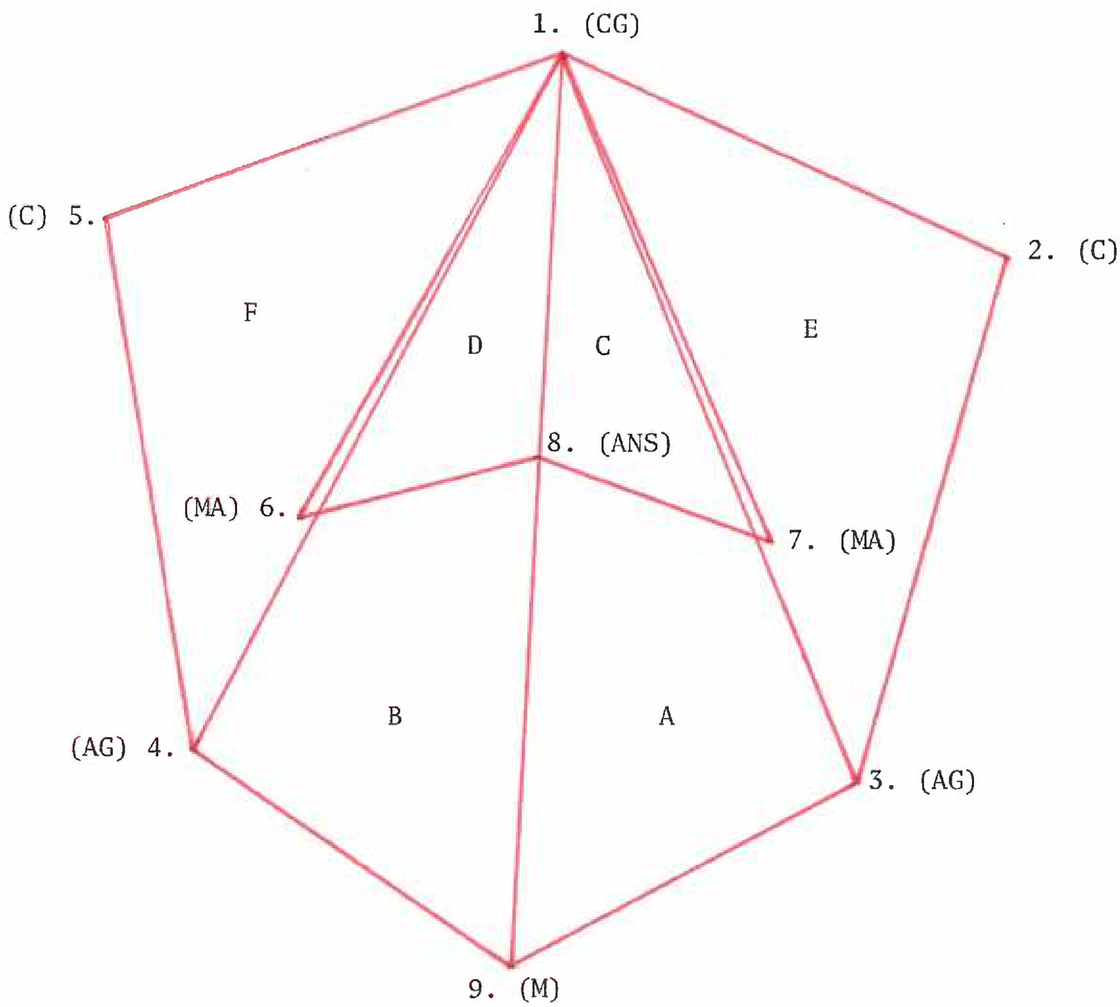


TABLE I

AREAS OF FACIAL TRIANGLES

(Square Millimeters)

Males 12 - 16 Years

	Mean	S.D.	$S.E._{Mean}$
Rt. Upper Maxillary Region (D)	842.7	71.6	12.9
Rt. Body of Mandible (B)	2532.5	253.6	45.5
Rt. Ramus of Mandible (F)	2030.7	227.7	40.9
Rt. Total Mandible (B+F)	4563.1	357.5	64.2
Rt. Total Face (B+D+F)	5405.8	400.2	71.9
L. Upper Maxillary Region (C)	847.9	76.7	13.8
L. Body of Mandible (A)	2648.8	280.4	50.4
L. Ramus of Mandible (E)	2021.0	201.5	36.2
L. Total Mandible (A+E)	4669.8	379.9	68.2
L. Total Face (A+C+E)	5517.7	429.2	77.1

TABLE II

AREAS OF FACIAL TRIANGLES

(Square Millimeters)

Females 12 - 16 Years

	Mean	S.D.	$S.E._{Mean}$
Rt. Upper Maxillary Region (D)	801.6	64.9	11.7
Rt. Body of Mandible (B)	2413.5	166.4	29.9
Rt. Ramus of Mandible (F)	1913.4	174.3	31.3
Rt. Total Mandible (B+F)	4325.6	280.9	50.5
Rt. Total Face (B+D+F)	5127.2	324.5	58.3
L. Upper Maxillary Region (C)	795.3	62.9	11.3
L. Body of Mandible (A)	2435.9	193.7	34.8
L. Ramus of Mandible (E)	1851.2	210.4	37.8
L. Total Mandible (A+E)	4287.1	429.2	56.4
L. Total Face (A+C+E)	5082.4	354.5	63.7

TABLE III

COMPARISON OF RIGHT AND LEFT

FACIAL AREAS BY MEANS

(Student's t-Test)

MALES

	Rt. Mean	L. Mean	"t" Value
Upper Maxillary Region	842.7	847.9	0.28
Body of Mandible	2532.5	2648.8	1.71
Ramus of Mandible	2030.7	2021.0	0.18
Total Mandible	4653.1	4669.8	1.14
Total Face	5405.8	5517.7	1.06

FEMALES

	Rt. Mean	L. Mean	"t" Value
Upper Maxillary Region	801.6	795.3	0.39
Body of Mandible	2413.5	2435.9	0.49
Ramus of Mandible	1913.4	1851.2	1.27
Total Mandible	4325.6	4287.1	0.51
Total Face	5127.2	5082.4	0.52

None significant at $p = .05$ level of probability
$t(.05) = 2.00$ df = 62

TABLE IV

MALE VS. FEMALE COMPARISON

OF FACIAL AREAS BY MEANS

(Student's t-Test)

	Male Mean	Female Mean	"t" Value
Rt. Upper Maxillary Region	842.7	801.6	2.36*
L. Upper Maxillary Region	847.9	795.3	2.95*
Rt. Body of Mandible	2532.5	2413.5	2.18*
L. Body of Mandible	2648.8	2435.9	3.48*
Rt. Ramus of Mandible	2030.7	1913.4	2.28*
L. Ramus of Mandible	2021.0	1851.2	3.25*
Rt. Total Mandible	4563.1	4325.6	2.91*
L. Total Mandible	4669.8	4287.1	4.32*
Rt. Total Face	5405.8	5127.2	3.01*
L. Total Face	5517.7	5082.4	4.35*

*Significant at $p = .05$ level of probability
$t(.05) = 2.00$ df = 62

TABLE V

WIDTH OF THE SELLA TURCICA (MILLIMETERS)

	Males	Females	"t" Value
Mean Width	11.81	11.45	0.82
Standard Deviation	1.67	1.85	
Range	8.5 - 16.8	8.5 - 15.2	

("t" at .05 probability level = 2.00, df = 62)

TABLE VI

STANDARD ERROR OF THE MEASURE FOR THE COMPONENTS OF THIS STUDY (IN SQUARE MILLIMETERS, UNLESS OTHERWISE SPECIFIED)

Rt. Upper Maxillary Region	11.98
L. Upper Maxillary Region	7.36
Rt. Body of Mandible	41.24
L. Body of Mandible	29.71
Rt. Ramus of Mandible	29.36
L. Ramus of Mandible	26.67
Width of the Sella Turcica (Millimeters)	0.3

TABLE VII

RATIO OF AREA MEAN TO AREA OF CONTRALATERAL SIDE

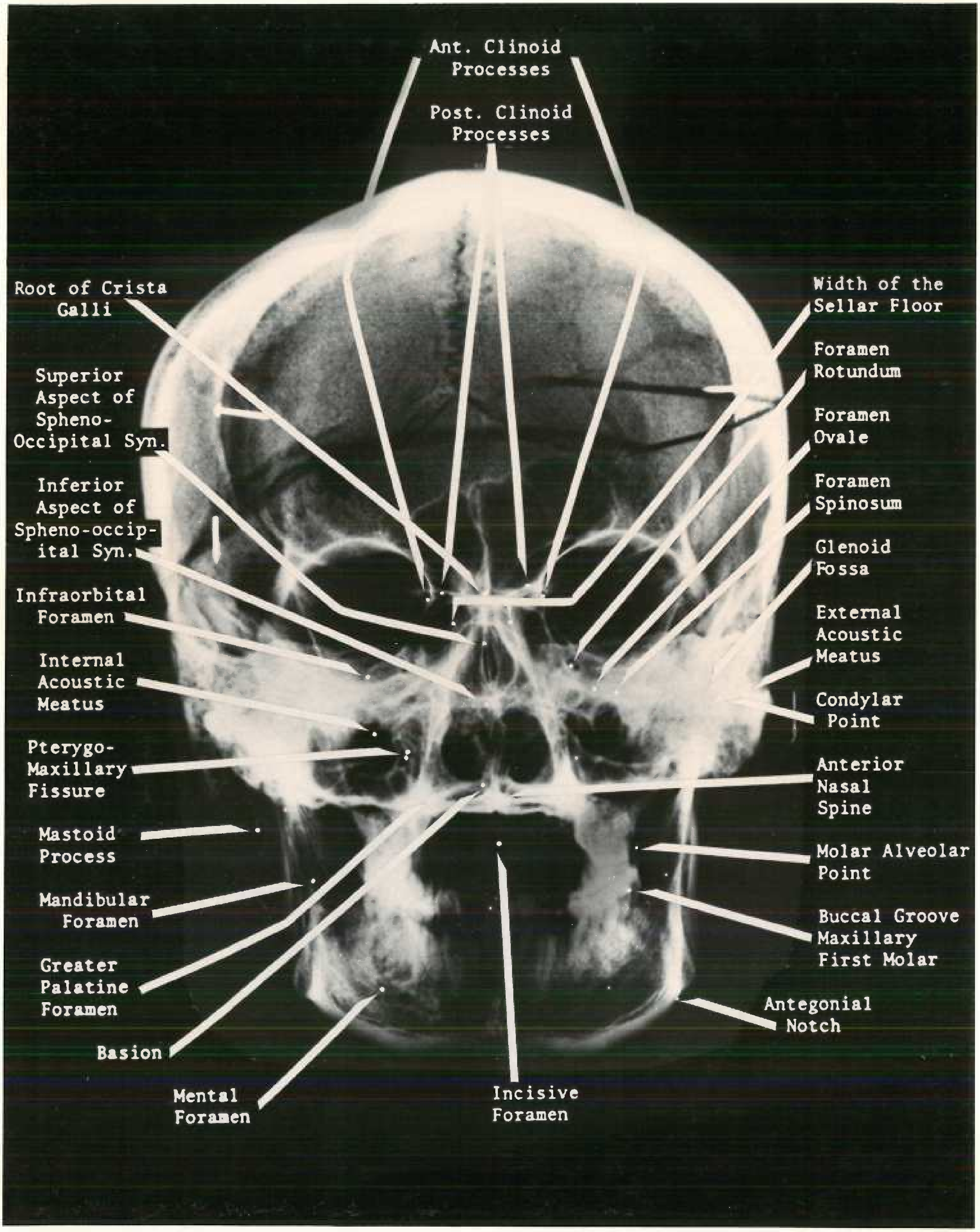
BEYOND THE RANGE OF ±2 STANDARD DEVIATIONS

FEMALES

	Range of "Normal" Ratios
Mean A/Mean B ±2 S.D.	0.89 - 1.17
Mean A ±2 S.D./Mean B	0.85 - 1.17
Mean C/Mean D ±2 S.D.	0.85 - 1.18
Mean C ±2 S.D./Mean D	0.84 - 1.14
Mean E/Mean F ±2 S.D.	0.89 - 1.06
Mean E ±2 S.D./Mean F	0.93 - 1.17

MALES

Mean A/Mean B ±2 S.D.	0.87 - 1.07
Mean A ±2 S.D./Mean B	0.82 - 1.27
Mean C/Mean D ±2 S.D.	0.86 - 1.21
Mean C ±2 S.D./Mean D	0.82 - 1.19
Mean E/Mean F ±2 S.D.	0.81 - 1.28
Mean E ±2 S.D./Mean F	0.80 - 1.19



Ant. Clinoid Processes
Post. Clinoid Processes
Root of Crista Galli
Width of the Sellar Floor
Superior Aspect of Spheno-Occipital Syn.
Foramen Rotundum
Foramen Ovale
Inferior Aspect of Spheno-occip-ital Syn.
Foramen Spinosum
Glenoid Fossa
Infraorbital Foramen
External Acoustic Meatus
Internal Acoustic Meatus
Condylar Point
Pterygo-Maxillary Fissure
Anterior Nasal Spine
Mastoid Process
Molar Alveolar Point
Mandibular Foramen
Buccal Groove Maxillary First Molar
Greater Palatine Foramen
Antegonial Notch
Basion
Mental Foramen
Incisive Foramen