Anatomical Location of Cephalometric Landmarks on the Sphenoid and Temporal Bones

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Quantitative data for studying the morphology and growth of the head and face and for diagnosis and appraisal of orthodontic and surgical treatment can be obtained by measuring distances between specific landmarks on cephalograms. Accuracy in landmarking and measuring, although extremely difficult, is imperative because imprecision increases cumulative error.

Errors in locating landmarks

Errors may be caused by variation of tissue images on consecutive cephalograms resulting from changes in relative positions of bony landmarks during child growth, unclear definition of anatomical landmarks, and insufficient training of landmark iocators. When more than one locator designates landmarks on the same cephalograms, a lack of training or understanding of anatomical landmarks can result in interlocator discrepancies. Therefore, training must be well-coordinated and complete and each locator must be thoroughly familiar with the anatomy of the bones and soft tissues with an identical understanding of the process. Tracings should be cross-checked carefully at regular intervals during the progress of the work to further insure the minimization of intra- and interlocator discrepancies.

Errors in obtaining measurement

The degree of measurement error produced is directly related to the accuracy of the measuring instrument and the measuring technician. Instrument error has been reduced through the development of precision mechanical equipment and a well-trained technician can take measurements with only a negligible degree of error. Thus measurement variability can be reduced until the error is less than that resulting from the locating of the landmarks themselves.[1,2]

The purpose of this paper is to present the variation in landmarks in the sphenoid and the temporal bones during growth and to define the criteria for locating these landmarks on postero-anterior and lateral cephalograms.

REVIEW OF THE LITERATURE

Problems of cephalographic studies pertain principally to the validity, reliability, and variability of landmarks and measurements. Validity is determined by comparison of measurements from a cephalogram of a skull with actual skull measurements; reliability, by repeating measurements on the same cephalogram;[3] and variability is attributed to the pinpointing of landmarks and to measurement techniques. Thus, variability may be considered an antonym to reliability in one sense, but in another as variation among individuals or within one individual at different ages.

Landmarks are defined on the sphenoid for the study of the cranial base: spheno-occipital synchondrosis, anterior contour of sella turcica, spheno-ethmoidal suture;[4] and for the longitudinal study of growth in the sphenoid as a unit; superior orbital fissure, infratemporal crest, and pterygoid process.[5] Reliability of landmarks and measurements on the cranial base have been

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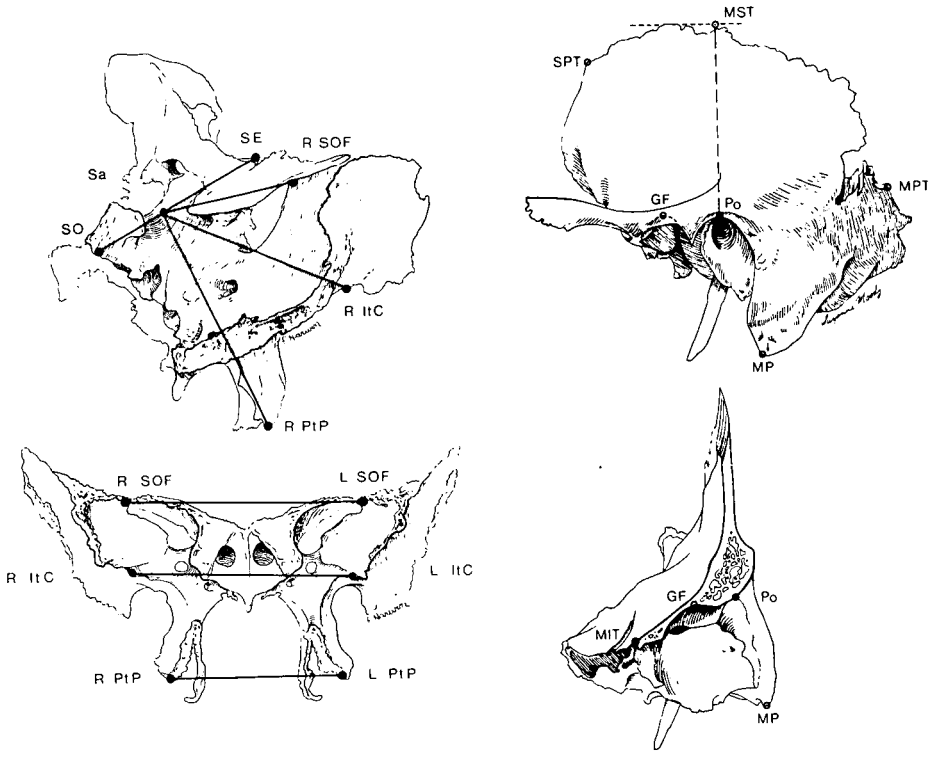

Fig. 1 Illustration of landmarks on sphenoid and temporal bones.

analyzed.[6-12] However, to the best of our knowledge no previous cephalographic study has been undertaken on the temporal bone as a unit. Therefore, we have defined some original landmarks on the temporal bone for the first time.

Anatomical studies have been done identifying cephalographic landmarks.[4,13-16] However, though landmark identification is of prime importance in the use of cephalograms, the observer's uncertainty makes point location difficult[10] causing variability in landmark location which is often five times that in obtaining measurements.[1,2]

Since some error in measurement may be unavoidable, it is important to consider not only actual measurement differences, but also their relationships to yearly growth increments.[17,18]

Variations exist among individuals, within individuals at different age levels, and among images of landmarks on cephalograms. Additional factors are cephalographic technique, anatomical complexity of the region, and landmark location.[14] Therefore, both a general knowledge of anatomy, including the peripheral structures, and clarity of landmark definition are required to minimize variability in tracing landmarks (Fig. 1).

Material

Sets of lateral and frontal cephalograms were selected from the longitudinal sample of the Child Study Clinic. One child's cephalograms were selected at ages 5, 10 and 15 to illustrate intra-individual variation in images at different ages.

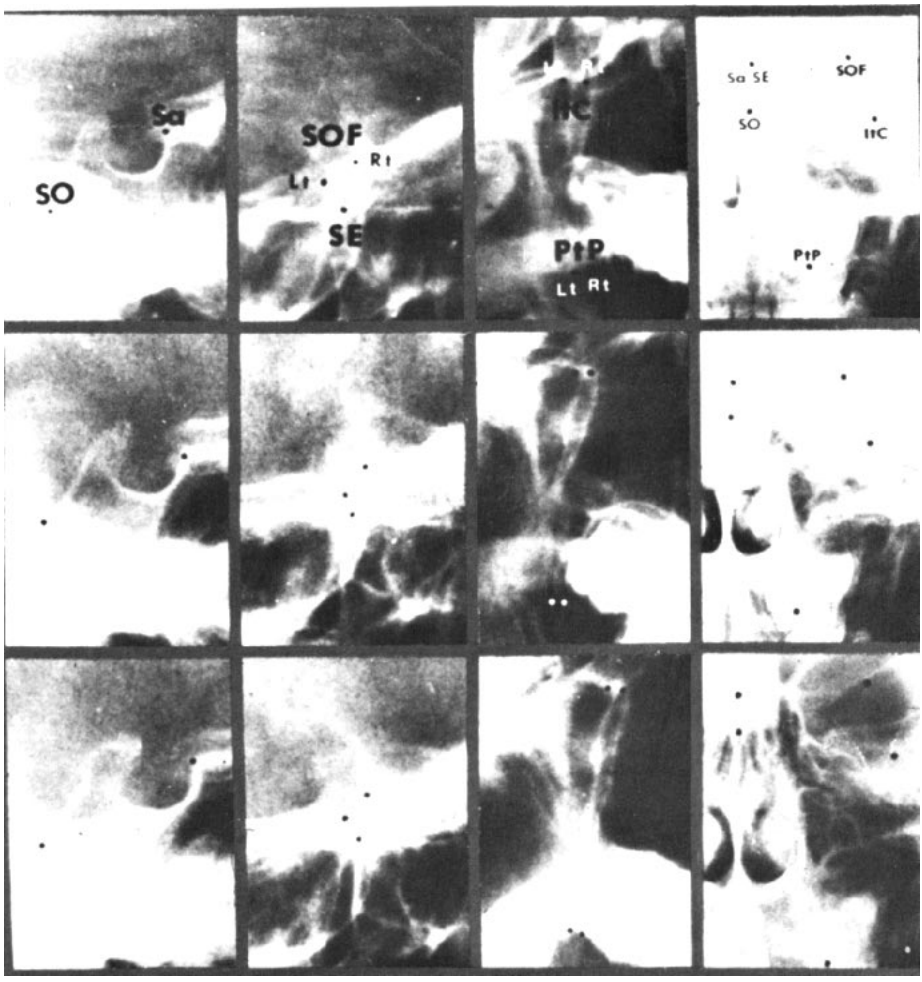

Fig. 2 Location of spheno-occipital synchondrosis and sella anterior, far left; sphenoethmoidal suture and superior orbital fissure, left center; infratemporal crest and pterygoid process, right center; and, far right, landmarks of sphenoid bone on three frontal cephalograms.

Sphenoid Bone

Spheno-occipital synchondrosis (SO) (Fig. 2, far left) has been defined as the "uppermost point of the suture in the midsagittal plane."[4] The SO has an important role in cranial base growth.[19,20,21] Its time of fusion is still in controversy, but growth at this point continues until at least age 13 or 14. On lateral cephalograms during the first 8 years, a clear, radiolucent line shows between the sphenoid and occipital bones. As the radiolucent line becomes increasingly obscure following ossification of the SO, the landmarks become difficult for even highly trained investigators to verify,[9] and the greatest variability in angles occurs in measurements which utilize this point.[8]

When the outline from the posterior clinoid process to the occipital bone is carefully drawn, a "bend" along the clivus is the landmark SO. On frontal cephalograms this landmark is identical

to the point of intersection between an extended line of the superior surface on the radiopaque image of the petrous ridge and a line drawn from crista galli to basion.

Anterior contour of sella turcica (Sa) (Fig. 2, far left) is defined as the "most anterior point of the anterior contour of sella turcica."[4] On lateral cephalograms a clear, radiopaque line usually marks the Sa. However, if this point overlaps and is obscured by the anterior clinoid processes, the point of intersection of the anterior contour of sella turcica and the superior surface of the planum of the sphenoid bone may be used. On frontal cephalograms Sa is identical to the point of intersection of the radiopaque line of the limbus sphenoidalis and a line drawn from crista galli to basion.

Sphenoethmoidal suture (SE) (Fig. 2, left center) has been defined as the "most superior point of the suture in the midsagittal plane."[4] The closure time of the SE is not definitely known[4] but, because it begins at an early age, the SE may not be visible on the cephalograms. On lateral cephalograms the location of SE is determined by the midpoint of the radiopaque lines of the greater wings of the sphenoid bone on the radiopaque line of the superior surfaces of the planum of the sphenoid and ethmoid bones. Therefore, strictly speaking, this landmark is a "derived" point as well as a bony point. On frontal cephalograms it is identical to the point of intersection of the radiopaque line of the limbus sphenoidalis and a line drawn from crista galli to basion. Thus, SE and Sa on frontal cephalograms are the same point in a three-dimensional method.[23]

Superior orbital fissure (SOF) (Fig. 2, left center) is defined as the "most lateral point of the superior orbital fissure where the lesser and greater wings of the sphenoid bone meet."[5] From observations of the lateral cephalograms of dry skulls marked with minute steel balls, SOF can be identified as the point of intersection of the radiopaque line of the greater wing of the sphenoid bone and the line of the roof of the orbit. Therefore, the relationship between the position of right and left SOF is determined by the discrepancy of the right and left lines of the greater wing of the sphenoid bone and of the roof of the orbit. The image of the superior orbital fissure on frontal cephalograms is usually shaped like a wishbone of which the inner and outer outlines represent the lesser wing and the greater wing of the sphenoid bone, respectively, and SOF is the point where the two outlines meet.

Infratemporal crest (ItC) (Fig. 2, right center), which is defined as the "most superior ventral point of the pterygomaxillary fissure,"[5] may be unfamiliar to some readers. In *Oral Anatomy*, Sicher[2] states that the ItC "is located laterally from the zygomatic crest, on the surface of the greater wing of the sphenoid facing laterally. It is slightly concave in an anteroposterior direction and is part of the temporal groove. Its lower end is marked by a sharp but irregular bony crest which projects at its anterior end as a bony spine, infratemporal crest and infratemporal spine."

On lateral cephalograms the ItC is identical with the most anterosuperior point on the image of the pterygomaxillary fissure and the positional relationships of the right and left ItC can be identified easily because the outline of the image of the pterygomaxillary fissure is somewhat radiopaque. However, on frontal cephalograms the ItC is sometimes difficult to locate because it is neither on the suture nor on the clearly distinguishable contour of the bone, and the images of the petrous

portion of the temporal bone and the orbital floor often overlap ItC. A useful means of locating this landmark is given by the oblique orbital line and the image of the inferior orbital fissure. The outer surface of the oblique line is traced, then the lower outline of the inferior orbital fissure is drawn with ItC approximately identical to the point of intersection of these lines.

Pterygoid process (PtP) (Fig. 2, right center), defined as the "most infraventral point of the pterygoid process which is approximately identical to the most infraposterior point on the contour of the tuberosity of the maxilla,"[5] is taken as the lowest point on the junction between the pyramidal process of the palatine bone and the posterior surface of the maxillary tuberosity, but is approximately identical with the pterygoid process. On lateral cephalograms PtP is often obscured by the growing tooth germ farthest posterior in the maxilla. In finding PtP the point of intersection of the posterior surface of the maxillary tuberosity and an extended line of the alveolar crest of the posterior teeth may be used. The positional relationship of the right and left PtP may be very close to the relationship of the right and left discrepancy of the distal outline of the maxillary unerupted or erupted terminal molars. On frontal cephalograms (Fig. 2, far right) preliminary study using minute steel balls to help identify PtP shows it to be identical to the cervical line of the most posterior erupted tooth on the palatal surface.

Temporal Bone

The landmarks which we have defined and use herein are located only on the left temporal bone.

Most posterior point of the temporal bone (MPT) (Fig. 3, far left) is defined as the junction of the parietomastoid, the lambdoid, and the mastoid-occipital sutures. Although this landmark has been called asterion,[25] it is preferable to use the term MPT when studying the temporal bone as a unit because it clearly shows its relationship to other landmarks. Anatomically, the lambdoid and the mastoid-occipital sutures have a serrated suture structure, while the parietomastoid suture overlaps less than the squamoparietal suture. On lateral cephalograms the radiolucent lines of these sutures are clear enough to locate MPT precisely at their junction. On frontal cephalograms the radiolucent line of these sutures can be seen if MPT is above the petrous ridge but, if MPT is within the image of the petrous portion, it is more difficult to pinpoint. Therefore, designation of MPT is accomplished only through careful observation of the suture lines.

Spheno-parieto-temporal junction (SPT) (Fig. 3, left center), defined as the junction of the sphenotemporal, the sphenoparietal, and the squamoparietal sutures, is one of the most difficult landmarks to determine on cephalograms. One bone overlaps the other in a zone of variable width along the sphenotemporal and the sphenoparietal sutures[24] and, in addition, the bone in this region is very thin and its image on the cephalogram obscure since X-ray factors are adjusted for the thicker and more complicated structures of the middle face. This landmark is approximately identical to the point on the radiopaque line of the greater wing of the sphenoid bone extending supraposteriorly on the lateral film at the height of SPT determined on the frontal cephalogram, where SPT is identical to the junction of two radiolucent lines of the sphenotemporal and squamoparietal sutures. Since variable vascular grooves in the squamous portion of the temporal bone extend into the parietal bone, it is possible to mistake one of these grooves for the sphenotemporal or squamoparietal suture.

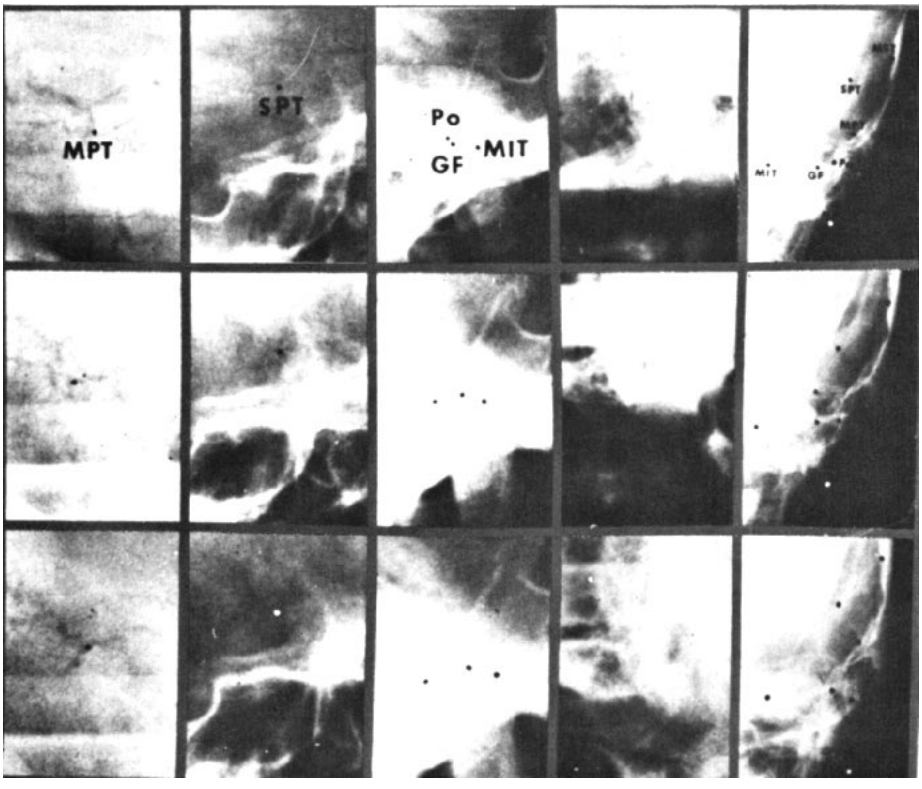

Fig. 3 Location of most posterior point of temporal bone, far left; spheno-parieto-temporal junction, left center; porion, glenoid fossa, and most inner point of temporal bone, center; mastoid process, right center; and location of landmarks of temporal bone on three frontal cephalograms, far right.

To avoid error, serial cephalograms should be compared during landmarking.

Porion (Po) (Fig. 3, center) has been defined differently by several authors. Of two main approaches to its definition, one was anatomical[27,28,29] and the other pragmatic.[6,30,31] Evidently, most authors picked up the apparent confluence of the top of the ear rod and the cartilaginous meatus more or less by inspection.[4] Reliability of Po and measurements involving it have been studied.[6,10,31,32] Björk considered Po an inferior point. Baumrind and Frantz illustrated the distribution of estimating error on Po by means of the "hundred-point scattergram," taking the superior point of the image of the cephalostat ear rod, and demonstrated Po to be a highly reliable landmark. It is unavoidable that this landmark is a "derived" as well as an anatomical point because the image of the external meatus on cephalograms is obscured by the cephalostat and the complicated bony structure at this region. Although we define this landmark as the most superior point on the roof of the external auditory meatus at the border of the external cartilaginous ear canal, it is identical to the most superior point of the cephalostat ear rod. On frontal cephalograms it is very difficult to identify the border of the external cartilaginous ear canal. From observation of frontal cephalo-

grams of dry skulls marked with minute steel balls, Po can be defined as the point of intersection of an extended line along the outer contour of the ramus and the superior line of the image of the cephalostat ear rod.

Glenoid fossa (GF) (Fig. 3, center), defined as the uppermost point on the superior margin of glenoid fossa, can be distinguished as a radiopaque line on frontal cephalograms. It is more difficult to locate on lateral cephalograms because its image is obscured by surrounding structures. However, the outline of the mandibular condyle can be used as a guide with a template made from cephalograms taken of the wide-open mouth and superimposed on tracings of cephalograms with the teeth in occlusion, not always possible because of some additional distortion of the image as a result of spatial change in the mandible.[14] Following the outline of the condylar head, GF can be carefully located on the superior margin of glenoid fossa.

Most inner part of the temporal bone (MIT) (Fig. 3, center), defined as the point on the temporal bone facing the angular spine of the sphenoid bone, is identical to the point of intersection of the radiopaque lines of the greater wing of the sphenoid bone and the middle cranial fossa. However, the former line is sometimes unclear, while the latter is almost always visible necessitating careful scrutiny of serial cephalograms of the same individual to minimize landmark variability. On frontal cephalograms MIT is identical to the point of intersection of the inner surface of the oblique orbital line and the superior surface of the radiopaque line of the middle cranial fossa.

Mastoid process (MP) (Fig. 3, right center) is defined as the lowest point on the contour of the mastoid process, occasionally abbreviated "MS". The MP is lacking in the temporal bone of the newborn infant but grows actively during the postnatal period.[24] It has been located on frontal cephalograms.[26] On lateral cephalograms, especially at earlier ages, the point is usually overlapped by the image of the occipital condyle. MP is usually slightly inside the distal contour of the occipital condyle. In locating it, it is helpful to draw the outlines of the peripheral anatomical structures: the occipital condyle, the styloid process, and the mastoid-occipital suture. It is highly reliable on frontal cephalograms because the lower contour of the mastoid process does not overlap other bony structures in most cases and, while the inside of the mastoid process is often radiolucent, the radiopaque line which indicates the contour of the mastoid process can be seen.

Most superior point of the temporal bone (MST) (Fig. 3, far right), defined as the uppermost point of the squamoparietal suture, is the most difficult landmark to locate on cephalograms since the squamoparietal suture is formed by a beveling of the two joining bones so that one bone overlaps the other in a zone of variable width[24] and X-ray factors are adjusted for the complex bony structures of the middle face, thus exceeding the maximum limit for clarity of the thinner region of the temporal bone. Further, the squamous portion is isolated from other bony structures, therefore lacking the guidelines to some landmarks, as in the outline of the key ridge for orbitale. By nature limited to a three-dimensional method, MST is a truly "derived" landmark shown on frontal cephalograms as the highest point of the squamoparietal suture as indicated by a radiolucent line extending from the sphenotemporal suture and, on the lateral cephalograms, as the perpendicular height at Po. As with SPT, careful observations of serial

cephalograms can help increase reliability in locating MST.

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