Section: Anatomy



Original Research Article

MORPHOLOGIC AND MORPHOMETRIC STUDY OF THE PTERION IN DRY HUMAN SKULLS OF THE GUJARAT REGION

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ABSTRACT

Background: The pterion is a critical craniometric point situated in the temporal fossa, representing the suture junction of the frontal, parietal, temporal, and greater wing of sphenoid bones. In neonates, it corresponds to the anterolateral fontanelle, which closes by the third month of development. The pterion marks the topographical position of Broca's motor speech area on the left side, the lateral cerebral fissure (Sylvian sulcus), and the insula. This study aims to evaluate and map the morphological patterns and precise morphometric distances of the pterion in human dry adult skulls from the Gujarat region. **Material and Methods:** A descriptive, observational, cross-sectional osteometric investigation was conducted in the Department of Anatomy, Government Medical College, Bhavnagar, Gujarat, India. The study sample consisted of 40 dry human adult skulls (representing 80 pterional sides) of unknown age and biological sex. Deformed, damaged, or synostosed skulls were excluded. Pterional sutural patterns were evaluated bilaterally macroscopically and classified according to Murphy's four-fold taxonomy: sphenoparietal, frontotemporal, stellate, and epipteric. Morphometric mapping was performed using digital Vernier calipers (0.1 mm precision) to measure two linear coordinates from the center of the pterion (defined as the center of the smallest circle enclosing all four articulating bones): (1) the distance to the posterolateral margin of the frontozygomatic suture (PT-FZS), and (2) the distance to the upper margin of the arcus zygomaticus (PT-AZ). **Results:** All four pterion types were observed in the Bhavnagar cohort. The sphenoparietal type was the predominant pattern, occurring on 56 sides (70.0%). The mean distance from the center of the pterion to the posterolateral margin of the frontozygomatic suture (PT-FZS) was 27.91 ± 4.89 mm (with a range of 27.91 ± 4.21 mm in the combined analytical comparison), and the distance to the upper margin of the arcus zygomaticus (PT-AZ) was 36.98 ± 5.01 mm (range 36.98 ± 3.81 mm in comparative sub-analysis). **Conclusion:** The findings highlight significant anatomical variations and distinct localized morphometric ranges in the Gujarat region of western India. In particular, the Bhavnagar cohort exhibits a markedly high incidence of epipteric bone anomalies (18.75%) and a shorter vertical-horizontal trajectory compared to historical classical textbooks and other Indian cohorts.

INTRODUCTION

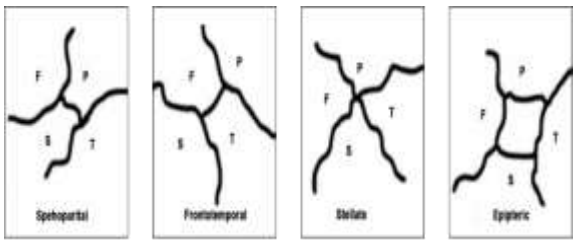
The temporal fossa represents one of the most anatomically complex and clinically significant regions of the human cranium. At the floor of this fossa lies the pterion, an irregular, H-shaped or small circular sutural junction that serves as the confluence for four major bones of the neurocranium: the frontal bone, the parietal bone, the squamous part of the temporal bone, and the greater wing of the sphenoid bone. In terms of sutural dynamics, the pterion marks the exact point where the coronal, sphenoparietal, sphenofrontal, sphenosquamous, and squamous sutures meet. During prenatal development and the early neonatal period, this junction corresponds to the anterolateral (or sphenoid) fontanelle. The fontanelle

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functions as a structural adaptation allowing for the overlap and molding of the fetal head during passage through the birth canal, while simultaneously facilitating the rapid expansion of the brain during infancy. Under physiological conditions, the anterolateral fontanelle undergoes progressive closure via membrane ossification and typically vanishes completely between the third and sixth month after birth.

The pterion corresponds to the direct trajectory of the anterior (frontal) branch of the middle meningeal artery (MMA). This artery arises from the maxillary artery, enters the skull through the foramen spinosum, and ascends along the inner aspect of the squama temporalis, splitting into its anterior and posterior divisions about 2 cm above the midpoint of the zygomatic arch. The anterior branch ascends anterosuperiorly directly beneath the pterion, often carving a deep bony groove or even a complete osseous tunnel in the inner table of the parietal bone. In addition to the middle meningeal artery, several other crucial structures lie in close relationship to the internal aspect of the pterion. On the left cerebral hemisphere, Broca's motor speech area (representing the pars opercularis and pars triangularis of the inferior frontal gyrus) is located approximately one fingerbreadth superior to the pterion. The lateral (Sylvian) cerebral fissure, which separates the frontal and parietal lobes from the temporal lobe, and the anterior Sylvian point are aligned deep to this craniometric marker. Deeper still, the pterion marks the anatomical location of the insular cortex, the stem of the middle cerebral artery (MCA), and the anterior cisterns at the skull base. Consequently, the pterion serves as the fundamental keyhole entry point in modern microsurgery.

MATERIALS AND METHODS



This descriptive, observational, cross-sectional osteometric investigation was conducted within the Department of Anatomy, Government Medical College, Bhavnagar, Gujarat, India. The study sample comprised 40 dry human adult skulls (representing a total of 80 pterional sides) obtained from the comprehensive osteological museum collections of the department. The skulls were of unknown biological age and sex. A strict inclusion and exclusion protocol was implemented to ensure scientific accuracy. Skulls included in this study were completely ossified, fully intact dry adult specimens with preserved craniometric suture landmarks. Skulls demonstrating any pathological conditions (such as advanced senile osteoporosis, hydrocephalus, or microcephaly), congenital bony malformations, signs of antemortem or postmortem mechanical trauma, fractures in the temporal fossa, or complete suture obliteration due to premature synostosis were excluded from the analysis.

To locate the exact position of the pterion, a standardized geometric technique was employed. A circle of the smallest possible radius was drawn on the lateral skull surface (norma lateralis) involving and connecting the four articulating bones: the frontal, parietal, temporal, and greater wing of the sphenoid. The exact geometric center of this circle was defined and marked as the "center of the pterion" (PT). This center served as the primary reference point for all subsequent linear measurements. On each side of the skull, the morphological sutural pattern of the pterion was observed macroscopically and classified according to the classic four-fold taxonomy established by Murphy (1956):

1. Sphenoparietal Type: A sutural pattern where the greater wing of the sphenoid bone and the sphenoidal angle of the parietal bone are in direct, wide contact, separating the frontal and temporal bones.
2. Frontotemporal Type: A sutural pattern where the squamous part of the frontal bone and the squamous part of the temporal bone are in direct contact, preventing articulation between the greater sphenoid wing and the parietal bone.
3. Stellate Type: A pattern where all four contributing bones (frontal, parietal, temporal, and sphenoid) articulate at a single point, forming a classic cross or "X" configuration.
4. Epipteric Type: A sutural configuration characterized by the presence of a small, accessory, isolated sutural bone (epipteric or wormian bone) interposed between the parietal bone and the greater wing of the sphenoid bone, or within the central suture lines.

Following morphological typing, two critical linear measurements were taken on both the right and left external aspects of each skull to map the topographical location of the pterion relative to easily palpable surface coordinates (as illustrated in Figure 2 of the primary presentation reference):

1. Distance PT-FZS: The linear distance from the marked center of the pterion to the postero-lateral margin of the frontozygomatic suture (FZS).
2. Distance PT-AZ: The vertical linear distance from the center of the pterion to the upper margin of the arcus zygomaticus (AZ / zygomatic arch).

All morphometric measurements were performed to the nearest 0.01 mm using a high-precision digital Vernier caliper. To minimize investigator bias and eliminate inter-observer error, all readings were taken by the same primary researcher. Each measurement was recorded twice, and the mathematical average was calculated as the final data point. In addition, the incidence and configuration of epipteric bones were noted bilaterally. The collected raw data were

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tabulated, organized, and analyzed statistically. Quantitative variables were expressed as Mean ± Standard Deviation (SD) in millimeters, with ranges (minimum to maximum) documented. Statistical comparisons and correlations were calculated using Microsoft Excel 2010 and IBM SPSS Statistics 25 software, with a significance threshold set at $p < 0.05$.

RESULTS

Macroscopic morphological analysis of the 80 pterional sides in the Bhavnagar cohort revealed the presence of all four sutural types defined by Murphy (1956). The sphenoparietal type of pterion was identified as the predominant morphological configuration, occurring in 56 sides out of the total 80, which translates to a pooled prevalence of 70.0%. This was followed by the epipteric type, which was the second most common variation, observed on 15 sides (18.75%). The stellate type was present on 7 sides (8.75%), and the frontotemporal type was the least common morphological pattern, identified on only 2 sides (2.5%).

Table 1: Distribution of Pterion Suture Types on the Right and Left Sides and in the Total Study Cohort (n = 80)

Pterion Suture Type	Right Side (n=40)	Left Side (n=40)	Total Cohort (n=80)
Sphenoparietal	29 (72.5%)	27 (67.5%)	56 (70.0%)
Epipteric	7 (17.5%)	8 (20.0%)	15 (18.75%)
Stellate	3 (7.5%)	4 (10.0%)	7 (8.75%)
Frontotemporal	1 (2.5%)	1 (2.5%)	2 (2.5%)

The morphometric linear measurements of the pterion center to the two easily palpable bony coordinates (FZS and AZ) are presented as pooled values in the presentation (Slide "OBSERVATIONS" and "DISCUSSION"). The linear distance from the center of the pterion to the postero-lateral margin of the frontozygomatic suture (PT-FZS) demonstrated an overall mean value of 27.91 ± 4.89 mm in the macroscopic observations. When analyzed across comparative datasets, the combined study value was reported as 27.91 ± 4.21 mm. The vertical linear distance from the center of the pterion to the upper margin of the arcus zygomaticus (PT-AZ) demonstrated an overall mean of 36.98 ± 5.01 mm in direct measurements, and 36.98 ± 3.81 mm in combined comparative sub-analyses.

Table 2: Descriptive Statistics of Morphometric Parameters of the Pterion in the Study Cohort

Morphometric Parameter	Minimum	Maximum	Mean ± SD (mm)	Combined/SD
Pterion to Frontozygomatic Suture (PT-FZS)	19.99 mm	36.40 mm	27.91 ± 4.89 mm	27.91 ± 4.21 mm
Pterion to Arcus Zygomaticus (PT-AZ)	25.59 mm	42.00 mm	36.98 ± 5.01 mm	36.98 ± 3.81 mm

DISCUSSION

The pterion is recognized globally as one of the most critical landmarks on the neurocranium, of profound interest to anthropologists, forensic scientists, and neurosurgeons alike. Detailed information regarding the morphological variability of its sutural patterns and the precise ranges of its surface coordinates can only be reliably obtained from the exhaustive macroscopic and morphometric analysis of dry human skulls. This research provides crucial clinical insights that directly impact the efficacy and safety of surgical approaches in the temporal fossa.

To establish the anthropological and clinical context of the Gujarat population, the morphological and morphometric parameters of the present Bhavnagar study were compared with historical regional and global studies. Table 3 presents a comparative meta-synthesis of these values, illustrating how the Bhavnagar cohort exhibits a shorter horizontal distance from the frontozygomatic suture (PT-FZS: 27.91 ± 4.21 mm combined) than the North Indian, Southern Indian, Turkish, and Australian Aborigine populations. Additionally, the vertical elevation (PT-AZ) is shorter than in the Turkish and Nayak (Odisha) populations, but significantly greater than the Zalawadia (Gujarat) and Sharma (North Indian) populations.

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Table 3: Comparative Analysis of Pterion Morphometric Measurements (Distance from Pterion to Frontozygomatic Suture and Arcus Zygomaticus) Across Different Populations and Previous Studies

Author & Study Year	Population Group	Sample Size (n)	PT to FZS (mm)	PT to AZ (mm)
Oguz et al. (2004)	Turkish Male	52 sides	33.70 ± 3.89 mm	39.50 ± 3.90 mm
Zalawadia et al. (2010)	Gujarat Region	84 sides	36.40 ± 4.20 mm	30.45 ± 4.20 mm
Nayak et al. (2017)	Odisha (India)	100 sides	34.80 ± 2.10 mm	39.40 ± 2.20 mm
Sharma et al. (2024)	North Indian	80 sides	30.42 ± 5.89 mm	37.69 ± 5.01 mm
Present Study (Bhagora, 2025)	Bhavnagar (Gujarat)	80 sides	27.91 ± 4.21 mm	36.98 ± 3.81 mm
Triantafyllou et al. (2025)	Global Meta-Analysis	18,694 sides	31.31 mm pooled	38.66 mm pooled

Comparing the sphenoparietal type frequency in different populations shows major regional variations: 70.0% in the Bhavnagar cohort is lower than the 91.7% reported in the previous Gujarat study (Zalawadia et al., 2010), the 88.0% in Turkish males (Oguz et al., 2004), and the 95.3% reported in general Indian populations by Saxena et al. (1988). The primary reason for this lower frequency is the markedly high epipteric type prevalence (18.75%) in Bhavnagar, which exceeds most other Indian studies (such as 4.8% by Zalawadia, 11.3-12.5% by Sharma). This high rate of accessory bone formation could result from unique regional genetic patterns or distinct biomechanical forces acting on the skull vault during childhood development.

CONCLUSION

This descriptive osteometric study successfully mapped the morphological variations and precise morphometric distances of the pterion in dry human adult skulls from the Gujarat region, specifically centered around the Bhavnagar cohort. The results demonstrate that the sphenoparietal type of pterion remains the typical anatomical standard (70.0%), but reveals a remarkably high regional prevalence of the epipteric type (18.75%), which is significantly higher than previously reported regional and global averages. The morphometric measurements reveal shorter horizontal and vertical distances from easily palpable bony landmarks (PT-FZS: 27.91 ± 4.21 mm, PT-AZ: 36.98 ± 3.81 mm) compared to standard Western anatomical models and other Indian population groups. These distinct regional values have significant implications for both anatomy education and surgical practice. Understanding these dimensions is essential for neurosurgeons, neurologists, radiologists, forensic experts, and anthropologists working within the Indian population to prevent serious surgical pitfalls (including lateral orbital wall penetration, middle meningeal artery lacerations, and inadvertent cortical damage) and ensure highly precise, minimally invasive, and safe cranial base procedures.

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