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Original Article

A study on the pterion position variation and its neurosurgical implications

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ABSTRACT

Introduction: The pterion is a neurosurgical landmark on the lateral aspect of the skull providing access to vital structures such as sylvian fissure, circle of Willis, optic nerve, para-sellar regions, middle meningeal vessels and cavernous sinus. The bilateral and gender variation in the pterion position was analyzed.
Methods: The linear distance of the centre of the pterion from midpoint of zygoma and frontozygomatic suture was measured bilaterally in both sexes in adult dry skulls of Indian ethnic group. This was analyzed statistically using histogram, Student's *t*-test, binary logistic regression and receiver operating characteristic curve.
Results: The mean distance of the centre of the pterion from midpoint of zygoma was 36.85 ± 4.12 mm and 34.35 ± 3.18 mm and its distance from frontozygomatic suture was 31.90 ± 4.14 mm and 29.72 ± 3.75 mm in males and females respectively. The position of the pterion exhibited statistically significant sexual dimorphism, with distance of the pterion from midpoint of zygoma having a p value <0.001 and a sex predictability of 67% and its distance from frontozygomatic suture a p value of 0.001 and sex predictability of 65.3%.
Discussion: The pterion position is higher in males than females and literature review also reveals significant ethnic variation. This knowledge of gender and ethnic variation is essential for a neurosurgeon while drilling a burr hole at the pterion to prevent orbital penetration due to an anterior drilling and an ineffective access for instrumentation due to a posterior drilling.

1. Introduction

The pterion is a neurosurgical landmark on the lateral aspect of the skull that marks the confluence of the frontal, parietal, greater wing of sphenoid and squamous part of temporal bone converging into an H-shaped suture. This landmark corresponds to the anterolateral fontanelle of the neonatal skull and overlies vital structures of profound clinical significance.[1] The pterion provides access to middle meningeal and middle cerebral vessels, sylvian fissure, circle of Willis, anterior pole of insula and Broca's area in surgeries such as trephination for extradural haematoma, repair of aneurysms and in surgeries involving these areas.[2] Deeper structures such as the optic nerve and the orbit can also be accessed through the pterion.[3] The pterion was first classified by Murphy into sphenoparietal, frontotemporal, stellate and epipteric types with sphenoparietal involving fusion of greater wing of sphenoid and parietal bone, frontotemporal involving frontal and temporal bones, stellate where all the four bones articulate and epipteric where a sutural bone is present in the pterion.[4] The surface projection of the pterion is approximately 4 cm above the midpoint of zygomatic arch and 3.5 cm behind frontozygomatic suture.[5] The studies by Apinhasmit et al. in Thai ethnic group,[6] Ukoha et al. in Nigerian ethnic group,[7] Ilknur et al. in Anatolian skulls of thirteenth and twentieth century,[8] Mwachaka et al. in Kenyan ethnic group[9] and Oguz et al. in Turkish ethnic group[10] are a few studies on the pterion involving diverse ethnic groups. The pterion position exhibits moderate variation in different ethnic groups and also exhibits sexual dimorphism. Therefore, a study on its location in different ethnic groups is important considering its clinical implications. The anterolateral fontanelle closes 3 months after birth. The pterion position also exhibits sexual dimorphism. This knowledge is often used for age estimation and

Abbreviations: ZAP, the linear distance from the midpoint of the zygomatic arch (ZA) to the centre of the pterion (P); FZSP, the linear distance from the midpoint of the frontozygomatic suture (FZS) to the centre of the pterion (P); ROC, receiver operating characteristic curve; BLR, binary logistic regression.

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sex determination of forensic and archaeological specimens.[11] There are also studies that describe the pterional or lateral approach accessed by neurosurgeons in several neurosurgical procedures. "Removal of a cranio-orbital foreign body by a supraorbital-pterion approach",[12] "Surgical management of meningiomas involving the optic nerve sheath",[13] "The lateral pterional approach used in surgeries on olfactory meningiomas",[14] "A pterion keyhole approach for the treatment of anterior circulation aneurysms"[15] and "Side selection of the pterional approach for superiorly projecting anterior communicating artery aneurysms"[16] are a few clinical studies on the pterion which suggest that the precise location of the pterion is of profound significance for a neurosurgeon. The significance of the pterion in neurosurgery is its location, as it overlies vital structures such as the frontal lobe with Broca's area, the temporal lobe, amygdala, hippocampus, insula, sylvian fissure that provides access to the circle of Willis, optic nerve and chiasm, orbit, superior orbital fissure, supra-sellar and para-sellar regions and pituitary, middle meningeal and middle cerebral vessels, cavernous sinus and the midbrain.[2,3,17] The pterional approach is hence, preferred by neurosurgeons in treating vascular aneurysms of circle of Willis and ophthalmic arteries,[15] optic and olfactory meningiomas,[13,14] cavernous sinus haemangioma,[18] selective amygdalohippocampectomy[19] and large tumours in supra-sellar and para-sellar regions.[20] The present study analyzes the variation in the position of the pterion in Indian ethnic group. The study clearly shows that the pterion location is higher in males than females. A review of literature also reveals significant ethnic variation in pterion position. This knowledge of gender and ethnic variation is essential for a neurosurgeon while drilling a burr hole at the pterion to prevent orbital penetration due to an anterior drilling and an ineffective access for instrumentation due to a posterior drilling.

2. Materials and methods

The study involved 41 male skulls and 31 female skulls aged between 25 and 65 years. The sex confirmation was done previously from departmental records. The sex was further ascertained by defining the skeletal morphology. The measurements were made by a single observer to avoid inter-observer errors. The measurements were done using a sliding digital caliper (Lianying 0005) graduated to the last 0.01 mm. The linear distance from the midpoint of the zygomatic arch to the centre of the pterion (ZAP) was measured. The linear distance from the midpoint of the frontozygomatic suture to the centre of the pterion (FZSP) was also measured. The distances measured are shown in Fig. 1. The distance was measured bilaterally in males and females. The technique involved repetition of the measurements twice. If there was a difference of more than 0.1 mm, then a third measurement was taken in accordance to the technique recommended by Krag et al., 1988 for spinal morphometry.[21] The data were analyzed using SPSS (Statistical Package for Social Sciences, version 20.0, SPSS Inc, Chicago, IL, USA) software. A two-tailed Student's t-test ($p < 0.05$), binary logistic regression and receiver operating characteristic curve were used to analyze the data. The sex predictability of the position of the pterion was determined using binary logistic regression and receiver operating characteristic curve.

3. Results

The mean distance of the centre of the pterion from midpoint of zygomatic arch was 36.85 ± 4.12 mm and 34.35 ± 3.18 mm in males and females respectively and its distance from the midpoint of the frontozygomatic suture was 31.90 ± 4.14 mm and 29.72 ± 3.75 mm in males and females respectively. As observed, there is a significant difference in its position between the sexes. This variation is depicted using a histogram in Figs. 2 and 3 and it is evident from the histogram that the position of centre of the pterion is significantly higher in males than in females. Fig. 2 depicts the variation in the distance of the centre of the pterion from midpoint of zygomatic arch and Fig. 3 depicts the variation in its distance from the centre of the frontozygomatic suture. The inter sex variation observed was further confirmed statistically using two tailed Student's t-test. The pterion position exhibited statistically significant sexual dimorphism, with the distance of the centre of the pterion from the midpoint of the zygomatic arch being significant with a p value less than 0.001 and its distance from the midpoint of frontozygomatic suture also being significant with a p value of 0.001. The data was then analyzed using binary logistic regression and its predicted probabilities were analyzed by receiver operating characteristic curve. The area under the curve was obtained and this area is a measure of the sex predictability of the dimension. The area under the curve was 0.670 for the distance of the centre of the pterion from the midpoint of zygomatic arch and 0.653 for distance of the centre of the pterion from the midpoint of the frontozygomatic suture. This suggests that the sex predictability percentage of distance of the centre of pterion from midpoint of zygomatic arch is 67% and the sex predictability percentage of distance of the centre of pterion from the midpoint of frontozygomatic suture is 65.3%. The study therefore confirms the sexual dimorphic trait exhibited by the pterion. The receiver operating characteristic curves for the above mentioned variables are shown in Figs. 4 and 5, where Fig. 4 represents the receiver operating characteristic curve for the distance of the centre of pterion from midpoint of zygomatic arch and Fig. 5 represents the receiver operating characteristic curve for the distance of the centre of pterion from the midpoint of the frontozygomatic suture.

The mean distance of the centre of the pterion from midpoint of zygomatic arch was 36.09 ± 4.0 mm and 35.45 ± 3.77 mm on right and left sides respectively and its distance from the centre of the frontozygomatic suture was 31.00 ± 4.10 mm and 30.92 ± 4.13 mm on right and left sides respectively. As observed, there is no significant variation in its position bilaterally and this was confirmed statistically by applying Student's t-test which revealed that the difference was statistically insignificant with a p value of 0.334 for the distance of the

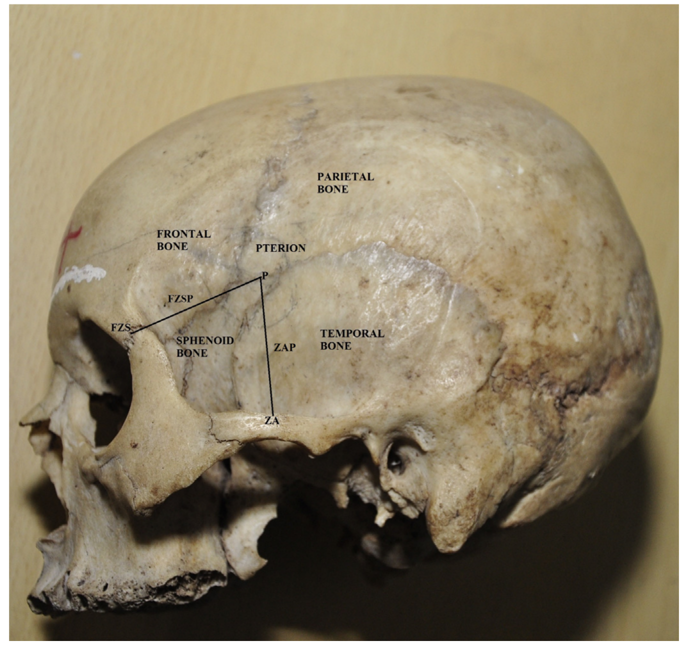

Fig. 1. The measurements of centre of the pterion as linear distances from centre of the frontozygomatic suture and midpoint of zygomatic arch.

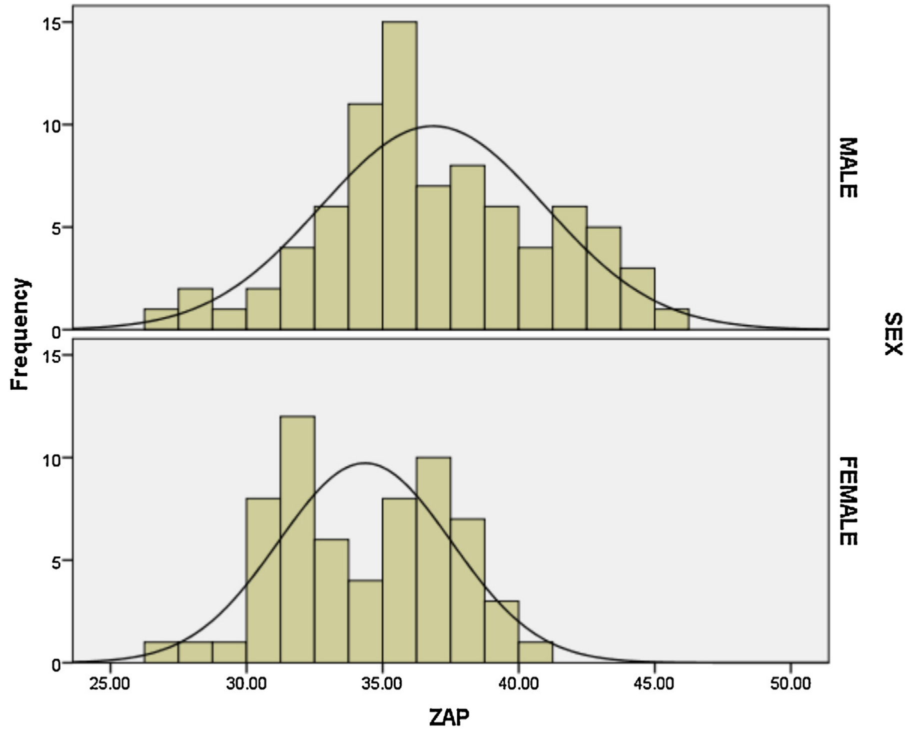

Fig. 2. The variation in the distance of centre of the pterion from midpoint of zygoma (ZAP).

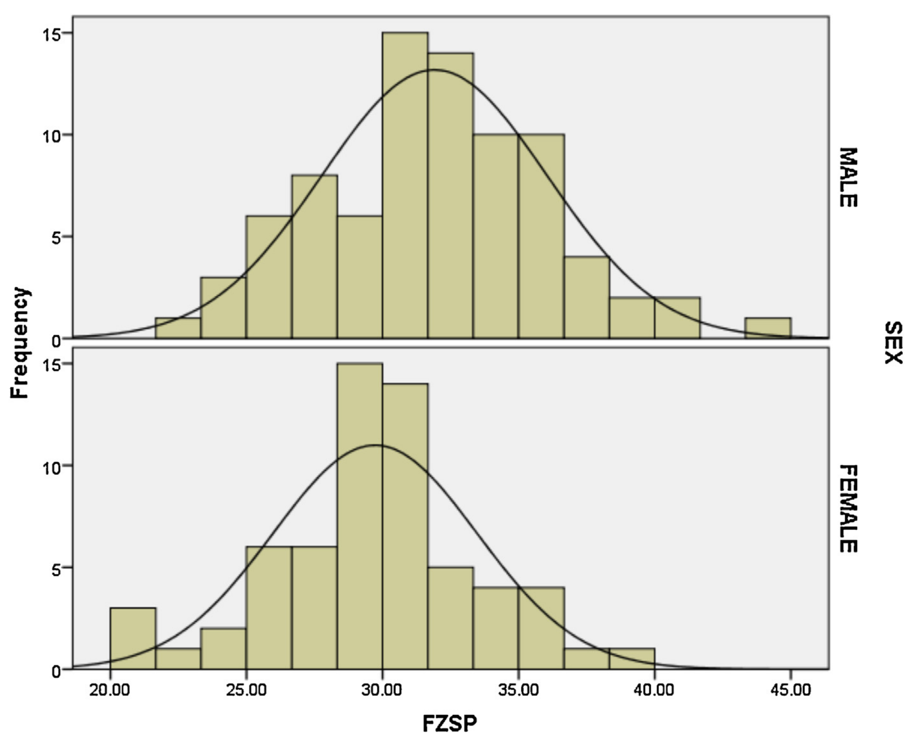

Fig. 3. Variation in the distance of centre of the pterion from the centre of the frontozygomatic suture (FZSP).

centre of the pterion from midpoint of zygomatic arch and a p value of 0.904 for its distance from frontozygomatic suture.

The sutural morphology of the pterion was observed and it was found that sphenoparietal was the commonest (79.25%) followed by frontotemporal (10.25%), stellate (6.3%) and epipteric (4.2%) varieties.

The descriptive statistics of the position of pterion bilaterally and in both sexes and their statistical significance is shown in Table 1.

The binary logistic regression equations for linear distance of centre of the pterion from the midpoint of zygomatic arch and the midpoint of the frontozygomatic suture and their significance are shown in Table 2.

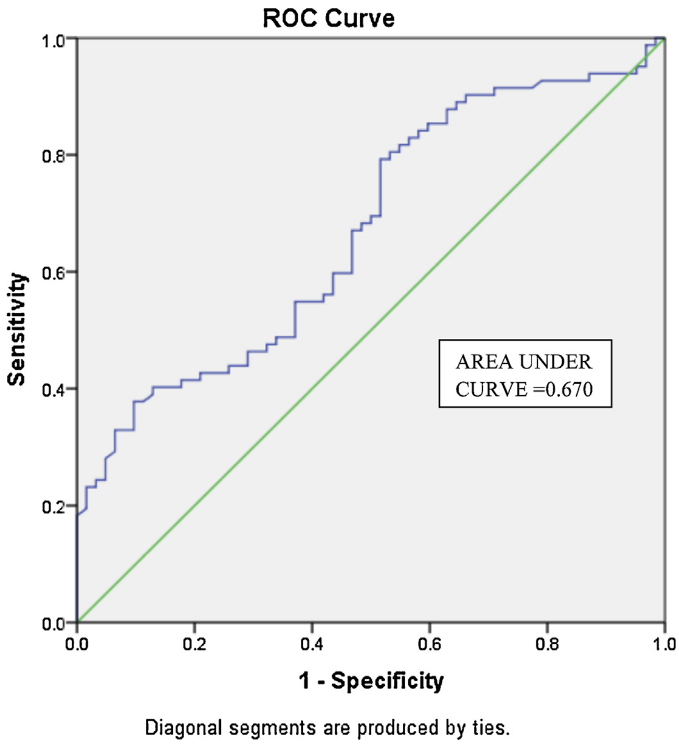

Fig. 4. The ROC curve for the distance of centre of the pterion from the midpoint of zygomatic arch.

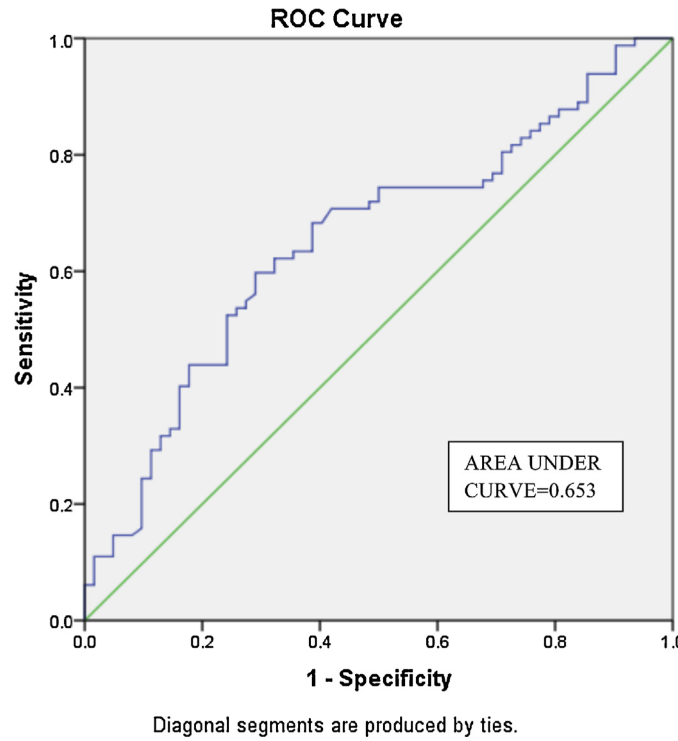

Fig. 5. The ROC curve for the distance of centre of the pterion from the centre of frontozygomatic suture.

Table 1
The descriptive statistics of position of the pterion bilaterally and in both sexes. (All distances are in millimetre.)

Dimension measured	Side	Mean ± SD	*p* value	Sex	Mean ± SD	*p* value
ZAP	Right	36.09 ± 4.08	0.334	Male	36.85 ± 4.11	<0.001
	Left	35.45 ± 3.77		Female	34.34 ± 3.17	
FZSP	Right	31.00 ± 4.10	0.904	Male	31.90 ± 4.13	0.001
	Left	30.92 ± 4.13		Female	29.72 ± 3.75	

ZAP implies distance in millimeter from centre of the pterion (P) to the midpoint of zygomatic arch (ZA), FZSP implies distance in millimeter from centre of the pterion (P) to the midpoint of frontozygomatic suture (FZS), SD implies standard deviation, *p* value<0.05 is considered statistically significant.

4. Discussion

The pterion is an H-shaped suture on the lateral aspect of the skull with profound neurosurgical implications. It marks the point of surgical entry in pterional surgeries as it provides direct access to the stem of sylvian fissure which constitutes the anatomical pathway to access the circle of Willis aneurysms.[15] From the perspective of a neurosurgeon, it is essential to be familiar with the precise position of the pterion prior to surgery.[22] The location of the pterion is usually described externally as a linear distance of its centre from the midpoint of zygoma and the midpoint of the frontozygomatic suture. However, it can also be described internally as a linear distance from the optic canal and sphenoid ridge. Apinhasmit et al. in their study in Thai ethnic group observed that externally, the pterion was located 38.48 ± 4.38 mm superior to the zygomatic arch and 31.12 ± 4.89 mm posterior to the frontozygomatic suture and internally, it was located 38.94 ± 3.76 mm lateral to the optic canal and 11.70 ± 4.83 mm from the sphenoid ridge.[6] This position varies moderately in diverse ethnic groups.

Table 2
The binary logistic regression equation obtained and its significance.

Dimension measured	Binary logistic regression equation	*p* value
ZAP	6.219–0.183 × ZAP	<0.001
FZSP	4.080–0.142 × FZSP	0.002

ZAP implies distance in millimeter from centre of the pterion (P) to the midpoint of zygomatic arch (ZA), FZSP implies distance in millimeter from centre of the pterion (P) to the midpoint of frontozygomatic suture (FZS), *p* value <0.05 is considered statistically significant.

4.1. Ethnic studies on pterion position in adults

Urzi et al. conducted a study involving 506 adult human skulls of Italian ethnic group where the pterion was accurately reconstructed on polyethylene sheets and analyzed morphologically into various types. The study also involved evaluation of length of the sphenoparietal suture, the minimum gap between the frontal and the temporal bones, the influence of sutural bones on the pterion variability and correlations between measurements and cranial indexes.[23] The variability in the position of the pterion in diverse ethnic groups is summarized in Table 3. It is evident from the table that the distance of the centre of the pterion from the midpoint of zygoma is approximately 40 mm in the Turkish and Nigerian ethnic groups, 38 mm in Thai, Anatolian and Kenyan ethnic groups and 36 mm in Indian ethnic group. The distance of the centre of the pterion from the centre of the frontozygomatic suture is about 35 mm in Anatolian skulls, 33 mm in Turkish skulls and on an average 30 mm in other ethnic groups mentioned above. This suggests that, comparatively the location of the pterion is

Table 3
The ethnic variation in the position of the pterion with distance in millimeter.

Authors	Ethnicity	Mean distance ± SD of the centre of the pterion from			
		ZA	FZS	OC	R
Oguz et al. (2004)[10]	Turkish	(R)40.5 ± 3.9 (L)38.5 ± 2.5	(R)33.0 ± 4 (L)34.4 ± 3.9	(R)43.9 ± 4 (L)43.6 ± 4	(R)14 ± 3.3 (L)14.8 ± 3.2
Mwachaka et al. (2008)[9]	Kenyan	(R)38.88 + 3.49 (L)38.24 + 3.47	(R)30.34 ± 4.30 (L)30.35 ± 3.40		
Ilknur et al. (2009)[8]	Anatolia	(R)38 ± 4 (L)39 ± 4	(R)35 ± 5 (L)35 ± 5		
Apinhasmit et al. (2011)[6]	Thailand	38.48 ± 4.38	31.12 ± 4.89	38.94 ± 3.76	11.70 ± 4.83
Ukoha et al. (2013)[7]	Nigerian	(R)40.2 ± 0.5 (L)40.1 ± 0.3	(R)27.4 ± 0.7 (L)27.4 ± 0.6		
Adejuwon et al. (2013)[2]	Nigerian	(R)39.1 ± 0.58 (L)38.77 ± 0.63 (M)39.74 ± 0.50 (F)37.95 ± 0.65	(R)31.52 ± 0.67 (L)30.82 ± 0.80 (M)31.87 ± 0.64 (F)30.35 ± 0.83		
[a]Kamath et al. (2016) (present)	Indian	(R)36.09 ± 4.0 (L)35.45 ± 3.77 (M)36.85 ± 4.12 (F)34.35 ± 3.18	(R)31.00 ± 4.10 (L)30.92 ± 4.13 (M)31.90 ± 4.14 (F)29.72 ± 3.75		

ZA implies zygomatic arch, FZS implies frontozygomatic suture, OC implies optic canal, SR implies sphenoid ridge, SD implies standard deviation.
[a] Present study.

highest in Turkish and Nigerian ethnic groups. Moreover, the pterion in Anatolian and Turkish skulls is located more posteriorly compared to the other ethnic groups studied.

The position of pterion varies significantly in both sexes. It is evident from this study that the position of the pterion is much higher in males than in the females. This observation is supported by several authors such as Apinhasmit et al. in their study involving 268 Thai dry skulls,[6] Mwachaka et al. in their study involving 90 skulls of Kenyan ethnic group[9] and Adejuwon et al. in their study in Nigerian ethnic group.[2]

The bilateral variation in the position of the pterion was statistically insignificant in this study. A similar observation was made by Adejuwon et al. in their study in Nigerian ethnic group[2] and Ilknur et al. in Anatolian skulls.[8] However, in a study by Apinhasmit et al. involving 268 Thai dry skulls statistically significant bilateral variation in the position of the pterion was observed.[6]

This knowledge of gender and ethnic variation in the position of the pterion is important while performing a pterional keyhole surgery as the burr hole position must be precise as an anterior drilling can involve the orbit while a posterior drilling can move away from the operating field resulting in inadequate space for instrumentation.

There are also studies that define the precise position of the pterion in neonates. Aydin et al. conducted a study on 35 term neonatal cadaveric skulls. This study was unique as at this age the pterion exists as a membranous anterolateral fontanelle. The study concluded that in order to locate the pterion in a neonate, a vertical line must be drawn first passing 1.5 cm posterior to orbital rim and then a horizontal line must be drawn passing 1 cm superior to the zygomatic arch. A square with an area of 1 square cm located in the posterosuperior region of these of two lines marks the position of the pterion in a neonate.[24]

4.2. Sutural morphology of the pterion

Majority of the studies on the pterion have also analyzed the types of the pterion and classified the types. From the perspective of a neurosurgeon, it is essential to be familiar with the sutural morphology of the pterion as well prior to surgery. As already described, the pterion was first classified into four basic types by Murphy based on the articulating bones with sphenoparietal involving fusion of greater wing of sphenoid and parietal bone, frontotemporal involving fusion of frontal and temporal bones, stellate involving all four bones meeting at a point and the epipteric variety involving a sutural bone found within the pterion.[4] Ersoy et al. have stated that in cases where there exists an epipteric bone, the location of the pterion may be mistaken to be at the anterior most point of junction of the four bones. Consequently, the burr hole may be placed anteriorly by the surgeon resulting in orbital penetration.[25] The sutural morphology has been studied by several authors in different ethnic groups. Matsumura et al. studied the formation and variations of the pterion in 614 Japanese skulls (258 skulls of Japanese foetuses, 20 skulls of Japanese juveniles and 336 skulls of Japanese adults). The incidence of epipteric bones was observed to be more than 10% in juveniles and adults. The most common variety was sphenoparietal which was further classified into usual (306), high (119), low (21) and narrow (32) types. This was followed by frontotemporal and stellate types and the epipteric variety was the least common. The results of their study suggested that the pterion formation occurs in two phases, with the first phase occurring before the occlusion of sphenoidal fontanelle and the second phase starting after 40 years of age.[26] The sutural morphology of the pterion in diverse ethnic groups is summarized in Table 4. It is evident from the table that in all the studies on sutural morphology, the sphenoparietal variety was the commonest type, followed by frontotemporal, stellate and the epipteric varieties.

4.3. Defining the surface anatomy of the pterion in radiographs

It is observed that the surface anatomy of the pterion is described inconsistently by diverse authors. Ma et al., in 2012, analyzed the position of the pterion in 50 adult cone beam CT scans of crania and 76 adult dry skulls with the skulls positioned in Frankfurt plane. This study is significant clinically, as the relationship of the anterior division of middle meningeal artery to the centre of the pterion was observed. The pterion centre was found to be a mean of 26 ± 4 mm behind and 11 ± 4 mm above the posterolateral margin of the frontozygomatic suture in adult dry

Table 4
The sutural morphology of the pterion in diverse ethnic groups.

Authors	Ethnicity	Spheno parietal (%)	Fronto temporal (%)	Stellate (%)	Epipteric (%)
Murphy (1956)[4]	Australian	73.2	7.7	0.7	18.3
Oguz et al. (2004)[10]	Turkish	88	10	0	2
Ilknur et al. (2009)[8]	Anatolian	89.2	3.6	3.6	3.6
Apinhasmit et al. (2011)[6]	Thailand	81.2	1.1	0.4	17.4
Ukoha et al. (2013)[7]	Nigerian	75.5	19.6	1.8	3.6
Adejuwon et al. (2013)[2]	Nigerian	86.1	8.3	5.6	0
Present study (2016)	Indian	79.25	10.25	6.3	4.2

skulls. In the cranial CT scans, the distances from the frontozygomatic sutures were marginally greater being 29 and 16 mm respectively. The reproducibility of these measurements was assessed bilaterally and in both sexes and was found to be consistently accurate. The study concluded that in most adults the pterion is located within a circle of 1 cm diameter 2.6 cm behind and 1.3 cm above the posterolateral margin of the frontozygomatic suture. The circle overlaps the anterior branch of the middle meningeal artery in 68% of cases and in 32% cases the artery was located a few millimetres posterior. The mean thickness of the skull at the centre of the pterion was 4.4 mm.[27]

4.4. Defining the clinical landmarks of the pterion

It is evident that researchers have described diverse methods to locate the position of the pterion. Moreover, the pterion is always described as an area rather than a point or a suture line. The first step to define the pterion location is that the skull must be in Frankfurt plane.[6,27] Most authors state that the centre of the pterion is measured as a linear distance above the midpoint of zygomatic arch and behind the posterolateral margin of the frontozygomatic suture.[5–10] In the present study, we have also followed the same method to define the centre of the pterion. However, researchers like Ma et al. prefer to consider only frontozygomatic suture for locating the pterion and conclude that pterion is located within a circle of 1 cm diameter 2.6 cm behind and 1.3 cm above the posterolateral margin of the frontozygomatic suture.[27] Apinhasmit et al., in 2011, have described another method of defining the pterion. The authors describe an external and an internal location. Here, a circle is drawn with the smallest radius connecting all the four bones involved in the formation of the pterion and the centre of this circle is marked as the centre of the pterion. This marks the external location. The internal location was then marked by placing the skull in the Frankfurt plane and marking the corresponding point of the centre of the pterion on the internal aspect. The distance of the internal location from the lateral end of the crest of the ridge of the lesser wing of sphenoid and the lateral end of the optic canal was recorded. The internal location is clinically significant as it provides information to the neurosurgeon regarding the depth of optic nerve and sphenoid ridge while operating on meningiomas involving the structures.[6,28] Aksu et al., in 2014, described the pterion location as mean distances of the centre of the pterion from the zygomatic arch, frontozygomatic suture, zygomatic angle, mastoid process and external acoustic meatus. The study involved 128 adult dry skulls of West Anatolian population. The mean distance between the anterior edge of lateral wall of orbit and the foremost point of the pterion was also analyzed in the study.[29]

5. Conclusions

As observed, the area of surgical entry has reduced over the years with the surgical technique evolving from craniotomy to keyhole surgery. This implies that the neurosurgeon must precisely locate the pterion as it marks the point of entry of the burr hole in pterional keyhole surgeries. It is observed that the position of the pterion exhibits significant gender and ethnic variation as described in the study. The knowledge of such a variation is important for a neurosurgeon, especially when the size of surgical entry is reduced from craniotomy to a keyhole. The entry must be precisely over the pterion and the sylvian fissure as any anterior shift will involve orbital penetration and a posterior shift will move away from the surgical field and will reduce space for instrumentation and increase surgical complications.

Conflicts of interest

The authors have none to declare.

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