ORIGINAL RESEARCH

Morphological and Morphometric Study of the Pterion – A Cadaveric Study in Sri Lanka

S C Samarasinghe[1], T H Gangodawila[1], S Dissanayake[1]

[1]*Department of Anatomy, Faculty of Medical Sciences, University of Sri Jayewardenepura*

Abstract

Introduction: Pterion is an important landmark as its relation to the anterior branch of middle meningeal artery, Broca's motor speech area on the left side, and surgical interventions relating to pathologies of the sphenoid ridge and optic canal as it provides access to vital structures such as sylvian fissure, circle of Willis, optic nerve, para-sellar regions, middle meningeal vessels and cavernous sinus. Approach through pterion is mostly used to treat lesions of anterior and middle cranial fossa. Pterion ossicle or Epipteric bone are sometimes mistaken as a fracture at this point.

Objective: The aim is to study the types of pterions and measure the distance from various bony landmarks on skull to the midpoint of pterion.

Methods: Specific measurements were taken, and type of the pterion recorded by two independent investigators in the Frankfurt plane on both sides of 37 adult dry skulls of unknown age, gender and race, without calvaria which were prepared for academic purposes, none of which showed any obvious pathology or trauma. The skulls with broken lateral walls were excluded. The linear distance from the center of the pterion to four anatomical landmarks were measured using a Vernier caliper with an accuracy of 0.1 mm.

Results: The sphenoparietal type of pterion was the most common (83.8% left, 81.1% right), followed by the frontotemporal (8.1% left, 13.5% right), and epipteric (8.1% left, 2.7% right) types and the stellate type was the least commonly observed (2.7% left side only). The distances on the left and right sides respectively from the center of the pterion to the frontozygomatic suture were 3.60 ± 0.57 cm and 3.68 ± 0.50 cm, to the zygomatic arch 3.76 ± 0.39 cm and 4.03 ± 0.40 cm, to the tip of the mastoid process 7.96 ± 0.58 cm and 8.16 ± 0.61 cm, and to the topmost part of the external auditory meatus 5.42 ± 0.34 cm and 5.53 ± 0.35 cm.

Conclusions: This knowledge is essential in surgical approaches and interventions via the pterion, especially for neurosurgeons 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. It will also be helpful for surgeons, radiologists, anthropologists, forensic pathologists in their diagnosis and treatment.

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Corresponding author

S Dissanayake
E-mail: sdissanayake@sjp.ac.lk

Introduction

Pterion receives its name from the Greek word pteron, meaning “wing”. It is generally an H-shaped sutural confluence on the norma lateralis of the bony skull, which is formed by the conjunction of four (4) bones: frontal bone and parietal bone superiorly, and greater wing of sphenoid bone and squamous part of temporal bone inferiorly. These 4 bones together form the floor of the temporal fossa. Also, this site corresponds to the sphenoidal fontanelle (anterolateral fontanelle) of the infant’s skull which closes nearly at 3 months of age (1).

It is situated within a 1 cm diameter circle centred approximately 2.5 cm posterior and 1.5 cm superior to the posterolateral margin of the zygomaticofrontal suture. Alternatively, the pterion is located approximately 4 cm above the midpoint of the zygomatic arch (1). With respect to surface marking, pterion is located two (2) finger breadths superior to the zygomatic arch and a thumb’s breadth posterior to the frontal process of the zygomatic bone (2).

Pterion is an important craniometric point, as it overlies both the anterior division of the middle meningeal vessels and the stem of the lateral cerebral sulcus (Sylvian fissure). Additionally, structures such as: middle cerebral vessels, anterior pole of the insula, Broca’s motor speech area in the dominant hemisphere, circle of Willis, optic nerve and chiasm, supra-sellar and para-sellar regions and pituitary, and the cavernous sinus are related to it internally (1).

Pterion is regarded as the weakest part of the human calvarium, due to being the point of union between 4 bones. Therefore, it is more susceptible to traumatic fracture with consequent rupture of the middle meningeal artery and then extradural haemorrhage (3). Extradural haemorrhage is usually evacuated by creating burr holes on the pterional site for decompressing brain tissue (1). Furthermore, the pterional approach is used in treating vascular aneurysms of the middle cerebral artery, as well as those of the upper basilar complex (4), optic and olfactory meningiomas (5,6), cavernous sinus haemangioma (7), lipomas of Sylvian fissure (8), tumours in supra-sellar and para-sellar regions (9), and in surgical procedures involving Broca’s motor speech area (10). Thus, pterion is an anatomical landmark for neurosurgical approaches to anterior and middle cranial fossa. In addition, it is an important guide for age and sex determination as well as archaeological and forensic estimation (11).

Studies have demonstrated that the type and location of the pterion exhibit a significant population-based variations with regard to age, sex, and race. Initially, the pterion was classified into three (3) types by Broca in 1875: sphenoparietal, frontotemporal, and stellate (12). In 1956, Murphy described four (4) types of pterions: sphenoparietal, frontotemporal, stellate, and epipteric (13). Lastly, Wang et al. proposed six (6) types of pterions: sphenoparietal, frontotemporal, stellate, epipteric zygomatico-parietal, and zygomatico-temporal (14). Therefore, pterion being an extensively used versatile neurosurgical technique with numerous indications, it is of utmost importance to be knowledgeable about various types of pterions and its precise anatomical location.

After thorough literature review, very few studies were found in Sri Lanka about the pterional morphology and morphometry. The objective of the present study is to determine the various morphological types of pterion and to measure the distance from certain distinct anatomical landmarks on the skull to the mid-point of pterion.

Methods

A descriptive cross-sectional study was performed on 37 adult dry skulls which were prepared for academic purposes. Age, sex, and race of the skulls were not known. The skulls were obtained from the Department of Anatomy of Medical Faculties of University of Sri Jayewardenepura and University of Colombo, Sri Lanka. Adult skulls were identified by the eruption of the third molars. Skulls without calvaria, with no apparent pathology, deformity, or traumatic lesions were included in the study. Skulls in which the pterion was unclear or the landmarks for measurement were affected due to damage or abnormal synostosis were excluded.

The sutural patterns and the location of pterion were assessed on both sides of each skull. Classification and morphometric measurements were taken independently by two investigators in the Frankfurt plane and any discrepancy of data was resolved by consensus. All the Measurements were taken thrice at different sittings and then averaged to minimize bias errors.

The pattern of bone articulation at the pterion was recorded by direct visual inspection. Four types of pteria were identified which resembled the previously established Murphy's classification: sphenoparietal type, frontotemporal type, stellate type, and epipteric type (13). In sphenoparietal type greater wing of sphenoid bone articulates with parietal bone giving the resemblance of suture to the letter "H" (Figure 1-A). In frontotemporal type squamous part of the temporal bone articulates with the frontal bone giving the resemblance of suture to the letter "H" rotated by 90 degrees (Figure 1-B). In stellate type all four bones articulate at a single point in the form of letter "K" (Figure 1-C) (12). In epipteric type irregularly shaped small bone or bones (sutural bone or bones) lodged in between the four bones (Figure 1-D) (13). The presence of epipteric (sutural) bone in the area, can possibly lead to wrong radiological diagnosis and clinical management of fracture in the pterion. Also, the epipteric type may cause inadvertent penetration into the orbit in pterional craniotomy (15). Hydrocephalic skulls show numerous sutural bones, indicating a link to rapid cranial expansion (1).

Morphometric measurements to assess exact location of pterion, were taken using stainless-steel sliding vernier caliper with an accuracy of 0.1 mm. Linear distance from the centre of the pterion to four (4) specific identifiable bony landmarks in the skull were measured: distance from centre of pterion to the anterior aspect of frontozygomatic suture (P-FZS) (Figure 2-A),

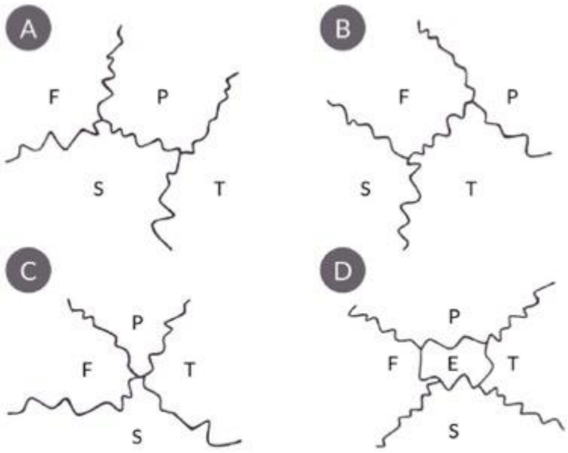

Figure 1: (A) Sphenoparietal Type; (B) Frontotemporal Type; (C) Stellate Type; (D) Epipteric Type

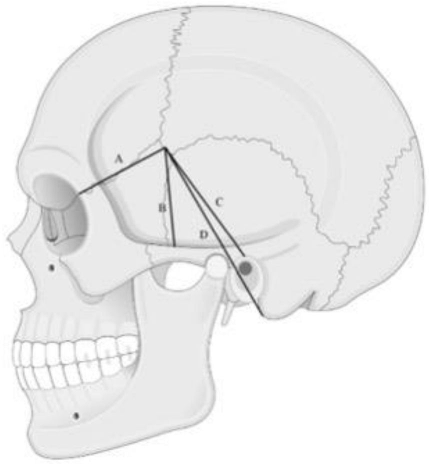

Figure 1: (A) P-FZS; (B) P-ZA; (C) P-EAM; (D) P-MP

Table 1: Frequencies of the types of pterions on left and right sides of the skulls

Type of pterion	Left side	Right side	Total
Sphenoparietal	83.8%	81.1%	82.5%
Frontotemporal	8.1%	13.5%	10.8%
Epipteric	8.1%	2.7%	5.4%
Stellate	2.7%	0	1.4%

to the midpoint of the zygomatic arch (P-ZA) (Figure 2-B), to the upper edge of the external auditory meatus (P-EAM) (Figure 2-C), and to the tip of the mastoid process (P-MP) (Figure 2-D).

Data analysis was done using the Statistical Package for Social Sciences (SPSS) version 26.0. In this research, descriptive statistics; frequency, mean, and standard deviation were used to analyse the data. Differences in the distance between the pterion and selected anatomical landmarks between the two sides were analyzed using the Student's t-test and a $p < 0.05$ was considered as statistically significant.

Results

Classification and prevalence of pterion types. The frequencies of the different types of pterions on each side of the skulls are shown in Table 1. Four types of pteria were identified which were similar to the classification described by Murphy in 1956. Out of the 37 skulls, the sphenoparietal type of pterion was observed in a majority (left 83.8%, right 81.1%). On both sides collectively it was 82.5%.

This was followed by the frontotemporal type (left 8.1%, right 13.5%) which accounted for 10.8% together on both sides, the epipteric type (left 8.1%, right 2.7%) with a total of 5.4%, and the stellate type (only on left 2.7%) representing 1.4% bilaterally. In all four identified types of pteria, the distribution was asymmetrical.

<u>Morphometric analysis of pterion landmarks</u>
The means and standard deviations of the linear measurements obtained from the centre of the pterion to various anatomical landmarks are presented in Table 2. The mean distances with standard deviations on left and right sides respectively from the centre of the pterion; to the anterior aspect of the frontozygomatic suture (P-FZS) were 3.60 ± 0.57 cm and 3.69 ± 0.50 cm, to the midpoint of the zygomatic arch (P-ZA) were 3.76 ± 0.39 cm and 4.03 ± 0.40 cm, to the upper edge of the external auditory meatus (P-EAM) were 5.42 ± 0.34 cm and 5.53 ± 0.35 cm, and to the tip of the mastoid process (P-MP) were 7.96 ± 0.58 cm and 8.16 ± 0.61 cm. The left side distances were relatively shorter than on the right side. But the difference was statistically significant only for P-ZA ($p = 0.007$).

Discussion

The pterional approach is originally described and popularised by the renowned Turkish neurosurgeon Gazi Yasargil in the 1970s (16). After more than 50 years it is still one of the most common procedures in neurosurgery which is routinely employed in treatment of various anterior and middle cranial fossae pathologies. This approach has better advantages over traditional surgical approach with minor tissue damage, lesser brain retraction, a superior cosmetic result, and a shorter duration of surgery (17). Therefore, a comprehensive knowledge of the morphological types of pterions and its location in relation to different bony landmarks of the skull is crucial in neurosurgical practice.

This allows neurosurgeons to perform successful surgery avoiding its potential complications. In addition to its clinical significance, the knowledge of pterion variations is essential in human identification, legal medicine, and anthropology.

In the standard textbooks of anatomy, the pterion was defined as an H-shaped formation of sutures representing the junction of four skull bones: frontal bone, the greater wing of sphenoid bone, the squamous part of the temporal bone, and parietal bone (1). In spite of the fact that the H-shaped pattern is observed in the majority of skulls, there is abundant evidence from literature describing other types of pteria among different populations.

In primate evolution, the anterosuperior segment of squamous part of temporal bone of lower primates became detached from its parent and incorporated into the posterosuperior angle of greater wing of the sphenoid bone of humans. This has initiated an adaptation of frontotemporal morphology to sphenoparietal type in higher primates like humans to create space that will accommodate increasing brain size (18). It has been shown that increased activity of the MSX2 gene plays a direct role in morphogenesis of skull bones (19). Wang stated that the etiology of pterion variations was multifactorial including genetic and environmental factors (14). Therefore, it can be considered that the pterion type is subject to evolutionary and racial variations, which was evidenced across studies.

Table 2: Linear distances from the centre of the pterion to the specific bony landmarks (Data are expressed in cm as mean ± standard deviation)

Distance	Left side (cm)	Right side (cm)	Significance (p)
P-FZS	3.60 ± 0.57	3.68 ± 0.50	0.529
P-ZA	3.76 ± 0.39	4.03 ± 0.40	0.007
P-EAM	5.42 ± 0.34	5.53 ± 0.35	0.193
P-MP	7.96 ± 0.58	8.16 ± 0.61	0.169

Table 3: Comparison of the incidence of pterion types in different populations as reported in previous studies

Author	Population	Pterion types				
		Sphenoparietal type	Frontotemporal type	Epipteric type	Stellate type	Atypical type
Murphy T (1956) (13)	Australian Aboriginal	73.2%	7.7%	18.3%	0.7%	0
Mwachaka et al. (2009) (29)	Kenyans	66.7%	15.5%	6.7%	11.1%	0
Adejuwon et al. (2013) (28)	Nigerian	86.1%	8.3%	0	5.6%	0
Sindel et al. (2016) (27)	Turkish	63%	2%	16%	19%	0
Gindha et al. (2017) (20)	North Indian	72.31%	4.61%	23.0%	0	0
Cimen et al. (2019) (21)	Turkish	82%	4.66%	10.66%	2.66%	0
Knezi et al. (2020) (24)	Serbian	87%	0	13%	0	0
Disanayake et al. (2020) (22)	Sri Lankan	82.5%	5.3%	3.5%	8.7%	0
Ananya et al. (2020) (25)	Indian	62.85%	0	12.85%	1.42%	22.85%
Marandi et al. (2021) (30)	Iranian	84.2%	8.1%	2.4%	3.5%	0
Uabundit et al. (2021) (23)	Thai	62.1%	5.2%	11.7%	1.2%	0

Table 4: Comparison of the location of pterion in different populations as reported in previous studies

Author	Population	P-FZS	P-ZA	P-EAM	P-MP
Adejuwon et al. (2013) (28)	Nigerians	30.82 ± 0.809 mm (L) 31.52 ± 0.677 mm (R) 31.87±0.642 mm (M) 30.35±0.8358 mm (F)	38.77 ± 0.631 mm (L) 39.1 ± 0.583 mm (R) 39.74 ± 0.505 mm (M) 37.95 ± 0.657 mm (F)	- - -	- - -
Gindha et al. (2017) (20)	North Indian	36.29 ± 3.7307 mm (L) 38.71 ± 3.1037 mm (R)	37.00 ± 3.3481 mm (L) 39.00 ± 2.5635 mm (R)	- -	- -
Cimen K et al. (2019) (21)	Middle and South Anatolians (Turks)	- -	36.5 ± 6.6 mm (M) 35.5 ± 5.9 mm (F)	57.1 ± 7.7 mm (M) 53.4 ± 3.6 mm (F)	82.6 ± 5.1 mm (M) 76.2 ± 6.0 mm (F)
Knezi N, et al. (2020) (24)	Serbian	39.67 ± 4.61 mm (M-L) 39.98 ± 3.85 mm (M-R) 35.94 ± 6.46 mm (F-L) 37.38 ± 6.38 mm (F-R)	39.23 ± 1.98 mm (M-L) 42.48 ± 4.18 mm (M-R) 37.57 ± 5.35 mm (F-L) 38.61 ± 5.43 mm (F-R)	- - - -	74.83 ± 5.60 mm (M-L) 78.47 ± 4.12 mm (M-R) 67.43 ± 7.02 mm (F-L) 70.23 ± 6.84 mm (F-R)
Disanayake et al. (2020) (22)	Sri Lankan	- - -	38.54 ± 3.10 mm (L) 37.20 ± 4.52 mm (R) 38.92 ± 3.55 mm (M) 36.16 ± 3.83 mm (F)	52.87 ± 2.83 mm (L) 52.90 ± 2.95 mm (R) 53.62 ± 2.58 mm (M) 51.91 ± 2.98 mm (F)	79.36 ± 4.35 mm (L) 80.61 ± 5.05 mm (R) 81.54 ± 4.62 mm (M) 77.79 ± 3.88 mm (F)
Ananya et al. (2020) (25)	Indian	-	37.84 ± 3.99 mm (L) 38.86 ± 3.63 mm (R)	51.37 ± 3.39 mm (L) 51.70 ± 3.20 mm (R)	79.59 ± 5.70 mm (L) 80.77 ± 6.10 mm (R)
Uabundit et al. (2021) (23)	Thai	34.5 ± 4.8 mm (L) 35.8 ± 5.0 mm (R) 35.7 ± 4.5 mm (M) 35.0 ± 5.1 mm (F)	38.0 ± 3.8 mm (L) 39.7 ± 4.3 mm (R) 38.9 ± 3.4 mm (M) 38.9 ± 4.3 mm (F)	- - -	84.2 ± 4.5 mm (L) 85.4 ± 5.1 mm (R) 86.4 ± 3.5 mm (M) 84.3 ± 5.1 mm (F)

P-FZS - Distance from the centre of the pterion to the anterior aspect of the frontozygomatic suture.
P-ZA – Distance from the centre of the pterion to the midpoint of the zygomatic arch
P-EAM – Distance from the centre of the pterion to the upper edge of the external auditory meatus (P-EAM)
P-MP – Distance from the centre of the pterion to the tip of the mastoid process

Sutural morphology of the pterion

In the present study, we observed all four types of pteria as described by Murphy (13). A comparison of the incidence of pterion types in different populations as reported in previous studies is summarized in Table 3.

The predominant type of pterion in our study was the sphenoparietal type (82.5%) which was comparable with the previous studies. The incidence of other three types of pterions vary across different studies and different populations. The frontotemporal type (10.8%) was the second common type of pterion we found. But in most studies, it was reported to be the third common type: Australian Aboriginals (7.7%) (13), North Indians (4.61%) (20), Turks (4.66%) (21), Sri Lankans (5.3%) (22), and Thai (5.2%) (23). The third common type we observed in our study is the epipteric type (5.4%). This type was much less common compared to most of the studies where it was second in frequency among Australian Aboriginals (18.3%) (13), North Indians (23.0%) (20), Turks (10.66%) (21), Serbians (13%) (24), and Thai (11.7%) (23). The incidence of the stellate type was reported to be the lowest (1.4%) in current study. Our results were compatible with four studies: Australian Aboriginals (0.7%) (13), Turks (2.66%) (21), Indians (1.42%) (25), and Thai (1.2%) (23). An atypical pterion type was observed in a study performed in India (25), which was not seen in any other past studies except by Satpute et al. who observed 1.76% atypical type in his study (26).

The above findings indicate that the pterion types exhibit variability across different populations. When compared between Indian and Turkish population, they reveal regional differences in the incidence of pterion types (20,21,25,27). Furthermore, these morphological types of pterions demonstrate an asymmetrical distribution between the left and right sides of the skulls. This asymmetry has also been observed in previous studies (21-25,28).

Location of the pterion

To assess the precise location of the pterion, various anatomical landmarks such as: frontozygomatic suture, zygomatic arch, external auditory meatus, mastoid process, glabella, asterion, optic canal, sphenoid ridge, external occipital protuberance have been used in previous studies. Frontozygomatic suture and zygomatic arch being the most frequently used anatomical landmark in past literature, and external auditory meatus and mastoid process being easily identifiable and clinically palpable on a patient, we utilised these four landmarks in our study to localise the pterion. A comparison of the location of pterion in different populations as reported in previous studies is summarised in Table 4.

The distance between the pterion and the anterior aspect of the frontozygomatic suture in our study was 3.60 ± 0.57 cm on the left and 3.69 ± 0.50 cm on the right side. This is comparable with the results of a study on North Indian skulls where this distance was 36.29 ± 3.7307 mm on the left and 38.71 ± 3.1037 mm on the right side (20), and a study on Thai skulls where this was reported to be 34.5 ± 4.8 mm and 35.8 ± 5.0 mm on the left and right side respectively (23). A study done on Serbian skulls demonstrated that the pterion was located 39.67 ± 4.61 mm on the left and 39.98 ± 3.85 mm on the right side in male skulls, and 35.94 ± 6.46 mm on the left and 37.38 ± 6.38 mm on the right side in female skulls (24). In the current study, the pterion was located 3.76 ± 0.39 cm and 4.03 ± 0.40 cm above the midpoint of the zygomatic arch on the left and right side respectively. Our results were relatively similar with the results of three studies (20,22,28). Pterion has been reported to lie 37.00 ± 3.3481 mm on the left and 39.00 ± 2.5635 mm on the right side above the zygomatic arch in a North Indian study (20). In a study done on Nigerian skulls the pterion was positioned above the midpoint of the zygoma 38.77 ± 0.631 mm on the left and 39.1 ± 0.583 mm on the right side (28). Disanayake et al. observed that in Sri Lankan skulls this distance was 38.54 ± 3.10 mm and 37.20 ± 4.52 mm on the left and right side respectively. In the same study this distance was 38.92 ± 3.55 mm in males and 36.16 ± 3.83 mm in females (22).

Our study found the distance between the pterion and the upper edge of the external auditory meatus as, 5.42 ± 0.34 cm and 5.53 ± 0.35cm on the left and right side respectively. Despite the fact that being easily identifiable and palpable, this landmark has rarely been used across studies to locate the pterion. Among those few studies, this distance was reported to be 51.37 ± 3.39 mm and 51.70 ± 3.20 mm on Indian skulls (25) and 52.87 ± 2.83 mm and 52.90 ± 2.95 mm on Sri Lankan skulls (22) on the left and right sides respectively. In contrast to our findings, the two studies cited above demonstrated lower values. In Turkish population this was measured as 57.1 ± 7.7 mm in males and 53.4 ± 3.6 mm in females (21).

The distance between the pterion and the tip of the mastoid process in our study was 7.96 ± 0.58 cm and 8.16 ± 0.61 cm on the left and right side respectively. The population with findings nearer those of the present study is the Indians, where this distance was 79.59 ± 5.70 mm on the left and 80.77 ± 6.10 mm on the right side (25). Uabundit et al. observed that the pterion was located from the mastoid process at a distance of 84.2 ± 4.5 mm on the left and 85.4 ± 5.1 mm on the right side which were relatively higher than the present study results (23). The same study demonstrated a measurement of 86.4 ± 3.5 mm in male skulls and 84.3 ± 5.1 mm in female skulls, while this was reported to be 82.6 ± 5.1 mm and 76.2 ± 6.0 mm respectively in a Turkish study (21).

The mean distances from the centre of the pterion to the four anatomical landmarks were lower on the left side compared to the right side. However, this difference was significant only for the P-ZA measurement. Similarly, all the studies we have referenced in Table 4 reported lower left side values compared to the right, except for the Sri Lankan study where the P-ZA distance was greater on left side (22). A significant difference between the two sides was observed on Serbian male skulls for P-MP (24), and on Thai skulls for P-FZS, P-ZA, and P-MP (23). In other studies, this difference was either not significant or not mentioned.

Although the sex of the skulls in our study is unknown, some studies have considered this factor (21-24,29). Those studies reported relatively higher morphometric measurements in males compared to females, attributed to the generally larger size of male skulls than of females. This sex-based difference was significant in the Nigerian population for P-FZS (28), in Turks for all the measurements except P-FZS and P-ZA (21), in Sri Lankans for all the measurements except P-ZA (22), and in Thai for P-MP (23).

Conclusion

The pterional approach is a cornerstone of cranial surgery, facilitating entry to both the anterior and middle cranial fossae. Nevertheless, this approach requires significant mobilsation of overlying soft tissues, resulting in temporalis muscle atrophy and temporomandibular joint dysfunction. Newer keyhole approaches such as the micropterional or pterional keyhole craniotomy (PKC) can offer similar exposure for many pathologies while reducing surgical morbidity with shorter hospital stay, reduced operative time, and superior cosmetic outcomes. This necessitates the neurosurgeons to accurately locate the pterion as it serves as the initial site for the creation of burr hole in pterional keyhole surgeries. In summary the sphenoparietal type is the prevailing pterion type in our study and it is observed that the mean distances from the pterion to the surrounding bony landmarks significantly vary among different populations. Therefore, a detailed knowledge of the morphology and morphometric measurements of the pterion would greatly aid surgeons to perform pterional approach successfully.

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