Pterional variable topography and morphology. An anatomical study and its clinical significance

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Pterional variable topography and morphology. An anatomical study and its clinical significance

Running head: Pterion anatomical study

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Abstract

Background: Pterion is the junction of the frontal, parietal, greater wing of the sphenoid and the squamous part of the temporal bone. The sphenoparietal, frontotemporal, stellate and epipteric pteria were described. The current study determines pterion topography, morphology (variant types’ frequency) and morphometry, as well as epipteric bones presence in dried skulls. Gender impact is underlined as well.

Materials and methods: Ninety Greek adult dried skulls were observed. The distances in between pterion and the zygomatic arch midpoint and in between pterion and the frontozygomatic suture were measured.
Results: The sphenoparietal pterion was the commonest (58.3%), following by the stellate (25%), epiperic (15.5%) and by the frontotemporal pterion (1.1%). Twenty-eight skulls (15.5%) had epiperic bones, further categorized as quadrissutural (35.7%), trisutural (57.1%), bisutural and multiple (3.57%). The mean distances between pterion and the midpoint of zygomatic arch were $4.13 \pm 0.45$ cm on the right and $4.09 \pm 0.47$ cm on the left side and between pterion and the frontozygomatic suture were $3.47 \pm 0.61$ cm on the right and $3.52 \pm 0.65$ cm on the left. Both distances were symmetrical. Male skulls showed slightly higher values on the left side for the distance pterion and midpoint of zygomatic arch.

Conclusions: Pterion is a commonly used neurosurgical landmark and thus in depth knowledge of the pteric area and its variants could be valuable. Recognition of the possible variability in pterion location, morphology and morphometry, as well as possible occurrence of epiperic bones may render pterional craniotomy safer among different population groups.

Key words: pterion, skull, zygomatic arch, frontozygomatic suture, epiperic bone, variation, anatomy

INTRODUCTION

Pterion, an H-shaped small circular area, is a point of convergence of the frontal (F), sphenoid (S), parietal (P), and squamous part of the temporal bone (T) (articulation of the coronal, sphenoparietal, squamosal, sphenofrontal, and sphenosquamosal sutures) [36]. It corresponds to the site of the anterolateral (sphenoidal) fontanelle which disappears approximately 3 months after birth [50]. Although the sutures contributing to pterion, exhibit a wide variability, their relationships are not yet elucidated. Variant sutural patterns in pterional area are the outcome of combination of various environmental and epigenetic factors [7, 55].

From the morphometric point of view, as the classical anatomical textbooks refer, the pterion is located approximately 3.0-3.5 cm behind the frontozygomatic suture (FZMS) and 4.0 cm above the midpoint of the zygomatic arch (MPZ) forming the temporal fossa floor [36, 50].
Pterion is a reference cranial landmark for the anterior branch of the middle meningeal artery, the Broca’s motor speech area, the insula, the stem of lateral sulcus and the anterior cisterns of the encephalon base [14, 16, 40]. In addition, age and gender determination in forensic and archeological cases could be based on pterion [29].

Although suboptimal pterion localization may compromise surgical access and therefore treatment outcome, studies focusing on pterion morphology and surgical anatomy are scarce. Knowledge of pterion location, presence and distribution of sutural bones convergence, the so-called epipteric bones (EBs), as well as different types of classified pteria are important to prevent complications when drilling burr pterional holes [46]. In such cases, (i.e. in a penetrating orbital injury) surgery should be minimally invasive, while gaining access to the sphenoid ridge and optic canal [59].

The current study underlines morphological variability of the bones forming pterional area, taking into consideration variant distribution of EBs, their frequency and relationship with pterion sutures. A terminology of the EBs is proposed. Exact pterion location in relation to FZMS and MPZ was also recorded. Both morphological and morphometric observations were analyzed taking into account laterality, gender and age as well.

MATERIALS AND METHODS

Ninety (49 male and 41 female) Greek adult dried skulls from the osseous collections of the Department of Anatomy and Surgical Anatomy of the Aristotle University and the Department of Anatomy of the National and Kapodistrian University were investigated on the right and left sides (R and L) (180 sides). Exclusion criteria included children skulls, unknown gender and age skulls, damaged and deformed skulls and skulls with pathology and trauma affecting measurement landmarks. Thus, 180 (98 male and 82 female) pteria were subdivided in 3 age groups: 20–39 years (46 pteria), 40–59 years (40 pteria), over 60 years of age (94 pteria) to examine age effect in pterion topography, morphology and morphometry. All skulls were derived from body donation, before death, after written informed consent.

Pterion morphology: Various pteria frequencies were recorded and all pteria were classified into 4 types, based on Murphy’s classification [37]. Sphenoparietal (SP), frontotemporal (FT), stellate (St) and epipteric (E) pteria appear in Figure 1A, B, C and D, respectively. A circle was drawn to locate the adjacent bones forming pterion area.
**Epipletic bones number and distribution:** Skulls with E pterion (EBs) were further classified having as a guide the number of sutures converging to the EB. A novel epipletic terminology, based on the number and name (frontal-F, parietal-P, temporal-T, and sphenoidal-S) of sutures articulating with EB, is proposed:

1. A single EB articulating with 4 sutures (FPTS) (a typical quadrisutural EB) *(Fig. 2A)*
2. A single EB articulating with 3 sutures (trisutural EB) was further subclassified as superior (FPT) *(Fig. 3A)*, inferior (FTS) *(Fig. 3B)*, anterior (FPS) *(Fig. 3C)*, and posterior (PTS) *(Fig. 3D)*.
3. An EB articulating with two sutures (PS or ST) (bisutural EB) *(Fig. 2B)* and
4. Several EBs or multiple (in the form of multiple fragments) *(Fig. 2C)*.

**Pterion morphometry:** Two distances, in between pterion center and MPZ and pterion center and FZMS were bilaterally measured using a digital caliper *(Mitutoyo, ABSOLUTE 500-196-20 Digital Caliper, 0.001 mm accuracy)* *(Fig. 4)*. The study was conducted in accordance to the Ethical Committee standards and with the 1964 Helsinki declaration and its later amendments. Measurements’ reliability was assessed by examining the interobserver and intraobserver reliabilities using interclass and intraclass correlation coefficient. The *intraclass correlation coefficient* was interpreted as poor if it was less than 0.4; as marginal when it was between 0.4 and 0.75; and as good when it was greater than 0.75. Descriptive statistics were evaluated for pterion morphometric measurements and their statistical distribution was analyzed. Data normality was evaluated with Kolmogorov–Smirnov test. Wilcoxon signed ranks test was applied to investigate side asymmetry, Mann–Whitney *U* test and *t* test for gender dimorphism, and Kruskal–Wallis and one-way ANOVA tests to evaluate correlation with age. For all analyses, *p* value < 0.05 was considered statistically significant. Statistical analysis was carried out using IBM SPSS Statistics for Windows, version 21.0.

**RESULTS**

**Pterion morphology:** All pteria types (SP, FT, St and E) were identified *(Fig. 5)*. SP pterion was the predominant type (58.3%, 105 skulls), St the second most common (25%, 45 skulls) following by the E (15.5%, 28 skulls) and the FT type (1.1%, 2 skulls on the R). Pterional symmetry was detected (57 skulls, 63.3%) (SP in 43, St in 10 and E in 4 skulls). In asymmetrically pairing skulls, the commonest pterion types were the SP-St (16.7%, 15 skulls) and the SP-E (12 skulls). Age and gender had no significant impact on pterion type *(Table 1)*.
**Epipetric bone morphology:** Twenty-eight skulls (15.5%) with EBs were further classified as quadrilsutural (FPTS) (Fig. 6A) (35.7%, 10 skulls, 1 skull bilaterally and 9 skulls unilaterally- 5L and 4R), trisutural (Fig. 6B) (57.1%, 16 skulls unilaterally-11L and 5R), bisutural (3.57%, 1 skull on the L) (Fig.6C) and multiple EBs (3.57%, 1 skull on the L) (Fig. 6D).

**Pterion morphometry:** The mean distances (pterion-MPZ) and (pterion-FZMS) were symmetrical (R 4.13±0.45cm, L 4.09±0.47cm) and (R 3.47±0.61cm, L 3.52±0.65cm). No gender dimorphism was detected for all measured distances, except for the mean distance (pterion –FZMS) on the L (males 3.65±0.72 versus females 3.37±0.51cm, p=0.039) (Table 2). No statistically significant difference was detected for both measurements among different age groups (Table 3). Intraclass correlation coefficient (ICC) for the interobserver and intraobserver reliabilities was 0.892 and 0.901 for pterion-MPZR, 0.879 and 0.845 for pterion-MPZL, 0.908 and 0.897 for pterion-FZMSR and 0.867 and 0.856 for pterion-FZMSL, respectively.

**DISCUSSION**

**Pterion morphology:** Pterion variable morphology is classified into SP, FT, St and E types and has been extensively studied among different populations (Table 4). In depth knowledge of pterion type and location could be an extremely useful tool in neurosurgerical procedures, skull identification and forensics. Yasargil (1975) first introduced the pterional approach and its extension [58]. Pterional approach achieves more accurate and safer outcomes for sellar or suprasellar lesions, brain arterial circulation and lateral sulcus, as well as for aneurysms of the distal internal carotid artery, as the conventional craniotomy was replaced from mini-craniotomy and to contemporary keyhole surgery [12]. Although classical anatomical textbooks describe St pterion as the typical pattern, this pterion was found with a frequency of 25% in the current study, while the predominant pterion was the SP (58.3%), similarly to all the other studies summarized in Table 4. In Asians, the SP pterion frequency ranged between 71.7% and 93.55% and among them Indians have the highest frequencies (69.25%-93.5%) [Southern (80-93.55%) and Western Indians (91.7%) showed higher frequencies compared to Northern (71.7-89.2%)], while Koreans have the lowest (76.5%) [26]. Kenyans had the lowest reported frequency (66%) [38]. The high frequency of SP pterion could be a result of evolution [28], given that it is the commonest type in primates [8, 47].
The second commonest pterion type is the FT [54], with a varying incidence among different populations: Nigerians (10.1% and 23.6%) [46], Northern Indians (10%) [62], Turkish (10%) [40] and Kenyans 15% [38]. In the current study, the frequency of FT pterion was significantly lower (2.2% on the R), whereas no skull was found with a FT pterion on the L. However, the frequency is similar to those of Indian (Western [31] and Southern [36]) populations. In the present study, St pterion was the second most common type on the R (30%) and L (20%). The frequency of the E type of Pt is similar to that reported in Indians (11.8%) [8] and Kenyans (12%) [38].

**Epipteric bone morphology:** Ranke (1898) proposed the most suitable hypothesis concerning the EBs occurrence. He supported that an EB appears in case of fusion failure of the postero-superior border of the greater sphenoidal wing (via its separate ossification center) with the rest part of the greater wing, during the 4th month of the intrauterine life. The EBs occurrence and laterality is variable among different populations, as the result of genetic and epigenetic factors combination [45, 9]. In the current study, among the 28 skulls with EBs (31.1%), trisutural EBs were found in 16 skulls, (17.7%), quadrissutural in 10 skulls (11.1%), bisutural and multiple EBs in a single skull (1.11%) per each, on the L. Among Indian populations, a wide range of EBs frequency was reported ranging between 2.5% to 24% in Northern [42] and Karnataka Indians [5]. Saxena et al. (2003) found the lowest frequency of EBs in Nigerians (3.79%), contrariwise to the present study reporting the highest frequency of 31.1% [46]. Neurosurgeons should be aware of EBs occurrence and variant distribution, since their presence when making burr holes over the pterional area may lead to complications.

In such cases caution must be made, as the most anterior point of junction of four bones may be mistaken to be the pterion center resulting in orbital penetration. High index of suspicion is required from both radiologists and neurosurgeons, since in pterional trauma the EBs may be mistaken as skull fracture in x-rays [9, 62].

**Pterion morphometry:** The mean distances (pterion-MPZ) and (pterion-FZMS) in different populations are summarized in Table 5. In the present study, the mean (pterion-MPZ) distance was 4.13 ± 0.45 cm on the R and 4.09 ± 0.49 cm on the L, similarly to Nigerian (4.02±0.05cm on the R and 4.01±0.03cm on the L) [53] and Turkish population (4.05±0.39cm on the R and 3.85±0.25 cm on the L) [40] (4.0±0.40cm on the R and 3.98±0.40 cm on the L) [3]. A lower mean distance has been reported in Australian (3.4 ± 4.0cm) [30] and Anatolian (3.8 ± 0.4 cm) populations [22]. However, a higher mean
distance has been reported in Indians (4.52±0.32cm on the R and 4.45±0.35cm on the L) [10].

In the present study, the pterion was detected behind FZMS up to 3.51cm in males and up to 3.39cm in females. This slight difference may be explained by the larger male skulls. The mean distance (pterion-FZMS) was 3.47 ± 0.61 cm on the R and 3.52 ± 0.65 cm on the L. The highest mean values were reported in Indians [10] (3.93 ± 0.37cm on the R and 3.80 ± 0.40cm on the L) and the lowest in Australians (2.6 ± 4.0cm on the R and 2.5 ± 4.0 cm on the L) [30] and Nigerians (2.74 ± 0.07cm on the R and 2.74 ± 0.06 cm on the L) [53]. Since significant differences were observed for pterion-MPZ and pterion-FZMS distances among various studies’ populations, the pterion topography may vary due to epigenetic, environmental factors and evolution [10, 21].

Pterion could be safely used as a surface landmark in neurosurgical approaches and interventions [40], even in neonates [14]. Its clinical importance derives from the fact that it overlies the anterior (frontal) branch of the middle meningeal artery, which is the most frequent source of acute traumatic epidural hematoma [30]. The knowledge of pterional typical anatomy, as well as its variants is important to neurosurgeons during pterional craniotomy, especially during extradural haematoma evacuation [49]. If the ophthalmic artery originates from the frontal branch of the middle meningeal artery [27, 48], pterional craniotomy could cause ophthalmic artery occlusion, which may end up in blindness [48]. Pterion is also used in various neurosurgical approaches treating anterior and middle skull base lesions [33], such as anterior and posterior cerebral circulation lesions, middle cerebral artery or upper basilar complex aneurysms, optic nerve and sellar and parasellar area lesions, sphenoidal wing, cavernous sinus, orbit, anterior and medial temporal lobe, midbrain, and posterior-inferior frontal lobe tumors, as well as cerebral tumors [4, 12, 15, 17, 57-61].

Information obtained from the current study may be of significant value in preoperative planning and perioperative navigation. Furthermore, recognition of the possible variants in location, morphology and morphometry of the pterion, as well as EBs occurrence may render pterional craniotomy safer among different population groups.

CONCLUSIONS

All pteria types were found in the current study and SP pterion was the predominant one, while FT was the less frequently observed. Pterional symmetry existed in the majority of cases, while gender and age had no significant impact on pterion type. EBs
were observed in 15.5% of the skulls, and in the majority of the cases were tri- and quatrisutural. The distances of the pterion from MPZ and FZMS were symmetrical and gender dimorphism was found only in pterion-FZMS distance on the L. Information obtained from the current study may be of significant value in preoperative planning and perioperative navigation. Such data are especially mandatory to achieve the optimum craniotomy when neuronavigation is not available. Based on osseous landmarks, the neurosurgeon should be familiar with the sutural junctions, as well as with EBs variants which may be complicate the orientation. Furthermore, recognition of possible variants in pterion location, morphology and morphometry, as well as possible EBs occurrence may render pterional craniotomy safer among different population groups.

**Conflict of interest:** All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest (personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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**Abbreviations:** sphenoparietal (SP), frontotemporal (FT), stellate (St), epipteric (E), epipteric bones (EBs), right side (R), left side (L), zygomatic arch midpoint (MPZ), frontozygomatic suture (FZMS)

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Table 1. Pterion type frequency observed on the right (R) and left (L) sides of the skulls, combination types on asymmetrical skulls, gender (M-males, F-females) and age impact

| Independent variables | Pterion Types |  |  |  |  |
|-----------------------|---------------|---|---|---|---|
| Laterality            | Sphenoparietal type (SP) | Frontotemporal type (FT) | Epipteric type (E) | Stellate type (S) |
| Right side (R)        | 50 (55.5%)    | 2 (2.2%)    | 11 (12.2%) | 27 (30%) |
| Left side (L)         | 55 (61.1%)    | -           | 17 (18.9%) | 18 (20%) |
| Total                 | 105 (58.3%)   | 2 (1.1%)    | 28 (15.5%) | 45 (25%) |

| Combination types of pterion |  |  |  |  |  |
|-------------------------------|---|---|---|---|
| SP-SP                         | 43 (47.8%) | 15 (16.7%) | 12 (13.3%) | 10 (11.1%) | 4 (4.44%) | 2 (2.22%) |
| SP-S                          | 15 (16.7%) | 12 (13.3%) | -           | 10 (11.1%) | 4 (4.44%) | - |
| SP-E                          | 12 (13.3%) | -           | 10 (11.1%) | -           | -           | - |
| S-S                           | -           | -           | 10 (11.1%) | -           | -           | - |
| E-E, SP-FT                    | 4 (4.44%)  | -           | -           | -           | -           | - |
| E-S                           | -           | -           | -           | -           | -           | - |

| Gender | Type SP | Type FT | Type E | Type S |  |
|--------|---------|---------|--------|--------|---|
|        | R       | L       | R       | L       | R   | L   | p value |
| Males  | 30 (61.2%) | 31 (63.26%) | 1 (2.04%) | - | 2 (4.08%) | 10 (20.4%) | 16 (32.65%) | 8 (16.32%) | 0.187, 0.829 |
| Females | 20 (48.78%) | 24 (58.53%) | 1 (2.43%) | - | 9 (21.95%) | 7 (17.07%) | 11 (26.82%) | 10 (24.39%) | - |
| Total  | 61 sides in M, 44 sides in F | 1 side in M, 1 side in F | 12 sides in M, 16 sides in F | 24 sides in M, 21 sides in F | - | - | - | - | - |
Table 2. Mean ± SD, minimum and maximum distances of pterion (Pt) to the midpoint of zygoma (MPZ) and to the frontozygomatic suture (FZMS) (cm) on the right (R) and left (L) sides of the skulls, male and female incidence

| Value                  | Distances according to side | Distances according to gender |
|------------------------|----------------------------|-----------------------------|
|                        | Pt-            | Pt-MPZ         | Pt-        | Pt-MPZ     | Pt-MPZ          | Pt-MPZ          | Pt-FZS       | Pt-FZS       | Pt-FZS          |
|                        | MPZ L          | R              | FZMS R     | FZMS L     | R            | FZMS L          | R            | FZMS L       | R              |
| Mean ± SD              | 4.13±0.45      | 4.1±0.4        | 3.47±0.61  | 3.52±0.65  | 4.19±0.44    | 4.12±0.55      | 4.04±0.46    | 4.07±0.42    | 3.51±0.62      | 3.65±0.73      | 3.43±0.59      | 3.37±0.51      |
| Minimum                | 2.87           | 3.11           | 2.0        | 1.73       | 3.29         | 3.11           | 2.87         | 3.16         | 2.09           | 1.73           | 2.0            | 2.48           |
| Maximum                | 5.32           | 5.7            | 4.81       | 5.2        | 5.32         | 5.7            | 5.2          | 5.1          | 4.63           | 5.2            | 4.81           | 4.78           |

p=0.608 (symmetry) p=0.471 (symmetry) p=0.133 right ANOVA, p=0.619 left ANOVA p=0.517 right ANOVA, p=0.039 left (gender dimorphism)

Table 3. Mean distances (cm) from the pterion to the midpoint of zygoma (MPZ) and to the frontozygomatic suture (FZMS) on the right (R) and left (L) sides of the skulls among the three age groups

| N         | Age groups | MPZ R | MPZ L | FZS R | FZS L | MPZ R | MPZ L | FZS R | FZS L |
|-----------|------------|-------|-------|-------|-------|-------|-------|-------|-------|
| 20-39     |            | 4.15±0.43 | 4.12±0.44 | 3.40±0.7 | 3.37±0.75 | 4.1±0.4 | 4.1±0.5 | 3.38±0.6 | 3.46±0.71 |
| 40-59     |            | 4.1±0.45 | 4.1±0.5 | 3.38±0.66 | 3.46±0.7 | 4.13±0.48 | 4.1±0.4 | 3.54±0.53 | 3.62±0.56 |
| Over 60   |            | 4.13±0.48 | 4.1±0.4 | 3.54±0.53 | 3.62±0.56 | 3.54±0.53 | 3.62±0.56 | 3.54±0.53 | 3.62±0.56 |
| Mean ± SD |            | 4.1±0.4   | 4.1±0.5 | 3.54±0.53 | 3.62±0.56 | 4.1±0.4 | 3.54±0.53 | 3.62±0.56 | 3.54±0.53 |
| Minimum   |            | 3.51      | 3.44   | 2.0     | 2.25   | 3.29      | 3.11   | 2.09     | 1.73   |
| Maximum   |            | 5.2       | 5.1    | 4.81    | 4.69   | 4.73      | 4.93   | 4.32     | 4.90   |

p=0.916 right MPZ, p=0.522 right FZS, p=0.962 left MPZ and p=0.319 left FZS
**Table 4.** Comparative review of pterion types in different populations among several studies, arranged in order by year of publication

| Author(s) | Year  | Population  | Sample N = skulls (sides) | Type of pterion | Sphenoparietal (%) | Frontotemporal (%) | Stellate (%) | Epipteric (%) |
|-----------|-------|-------------|---------------------------|-----------------|---------------------|--------------------|--------------|--------------|
| Murphy    | 1956  | Australian  | 368                       |                 | 73.2                | 7.7                | 0.7          | 18.4         |
| Agarwal et al. | 1980  | North Indian | 450 (900 sides) |                 | 71.7                | 3.3                | 1.7          | 23.3         |
| Saxena et al. | 1988  | Indian      | 72 (144)                 |                 | 82.6                | 2.8                | 1.4          | 13.2         |
| Saxena et al. | 1988  | Nigerian    | 40 (80)                  |                 | 81.2                | 11.3               | 5.0          | 2.5          |
| Manjunath et al. | 1988  | South Indian| 172                      |                 | 93.5                | 3.5                | 2.9          | 17.3         |
| Matsumura et al. | 1991  | Japanese    | 614                      |                 | 82.4                | 2.9                | 0.7          | 14.0         |
| Asala and Mbaioju | 1996  | Nigerian    | 212                      |                 | 82.1                | 23.6               | -            | 5.7          |
| Lee et al.      | 2001  | Korean      | 149                      |                 | 76.5                | -                  | -            | 40.3         |
| Saxena et al.   | 2003  | North Indian| 203                      |                 | 87.7                | 10.0               | 5.17         | -            |
| Ersoy et al.    | 2003  | Turkish     | 300 (490 sides)         |                 | 96.0                | 3.8                | 0.2          | 9.0          |
| Oguz et al.     | 2004  | Turkish     | 26 (52)                 |                 | 88.0                | 10.0               | -            | 2.0          |
| Mwachaka et al. | 2009  | Kenyan      | 50                       |                 | 66.0                | 15.0               | 7.0          | 12.0         |
| Ilknur et al.   | 2009  | Anatolian   | 28                       |                 | 89.2                | 3.6                | 3.6          | 3.6          |
| Zalawadia et al.| 2009  | West. Indian| 42                       |                 | 91.7                | 2.4                | 1.2          | 4.7          |
| Hussain Saheb et al. | 2010  | Indian     | 125                      |                 | 69.25               | 17.35              | 9.7          | 3.7          |
| Apinhasmit et al.| 2011  | Thais       | 268 (536)               |                 | 81.2                | 1.1                | 0.4          | 17.3         |
| Natekar et al.  | 2011  | Indian      | 150 bones               |                 | 85.3                | 8.0                | 10.6         | 51.4         |
| Ma et al.       | 2012  | Australian  | 76                       |                 | 78.4                | 5.2                | -            | 16.4         |
| Praba and Venkatramaniah | 2012  | Indian     | 50                       |                 | 74.0                | 3                   | 9.0          | 14.0         |
| Ukoha et al.    | 2012  | Nigerian    | 56                       |                 | 75.3                | 19.5               | 1.7          | 3.6          |
| Adejuwon et al. | 2013  | Nigerian    | 62                       |                 | 86.1                | 8.3                | 5.6          | -            |
| Kumar et al.    | 2013  | Indian      | 40                       |                 | 86.25               | 11.25              | 2.5          | -            |
| Sudha et al.    | 2013  | South Indian| 150                      |                 | 80.0                | 3.0                | 5.3          | 11.3         |
Table 5. Comparative review of pterion (Pt) distances from the frontozygomatic suture (FZMS) and the midpoint of zygoma (MPZ) among different populations in several studies, in order by year of publication (in cm)

| Author(s)          | Year | Population   | Sample N = skulls (sides) | Distances       |
|--------------------|------|--------------|----------------------------|-----------------|
| Oguz et al. [8]    | 2004 | Turkish male | 26 (52)                    | 3.3±0.39        |
| Ilknur et al. [31] | 2009 | Anatolian    | 28                         | 3.5±0.5         |
| Mwachaka et al. [30]| 2009 | Kenyan      | 50                         | 3.03±0.34*      |
| Bhargavi et al. [52]| 2011 | Indian      | 70                         | 3.93±0.37       |
| Ma et al. [36]     | 2012 | Australian  | 76                         | 2.6±4.0         |
| Ukoha et al. [38]  | 2012 | Nigerian    | 56                         | 2.74±0.07       |
| Adejuwon et al. [39]| 2013 | Nigerian    | 62                         | 3.15±0.67*      |
| Aksu et al. [42]   | 2014 | Anatolian    | 128                        | 3.18±0.45*      |
| Eboh and Obavoefe  | 2014 | Nigerian    | 50                         | 3.21±0.26*      |
| Present study      | 2019 | Greek       | 90                         | 3.47±0.61*      |

*studies with modified measurements into cm from mm
Figure 1. The frequency of various types of pterion based on Murphy’s classification as modified accordingly, sphenoparietal (A), frontotemporal (B), stellate (C), and epipteric (D)

Figure 2. Classification of epipteric bones as quadrisutural (A), bisutural (B) and multiple (C)

Figure 3. Classification of the trisutural epipteric bones observed according to their location as superior (A), inferior (B), anterior (C) and posterior (D)

Figure 4. Distances from the pterion (Pt) center to the midpoint of zygoma (MPZ) and from the Pt center to the frontozygomatic suture (FZMS)

Figure 5. Depiction of various pterion types in Greek skulls, sphenoparietal (A), frontotemporal (B), stellate (C), and epipteric (D).

Figure 6A. Quadrisutural epipteric bones (red arrow), F-frontal bone, P-parietal bone, S-sphenoid bone and T-temporal bone.

Figure 6B. Trisutural epipteric bones according to their location [superior 1, posterior 2, inferior 3 (not found) and anterior 4]

Figure 6C. Bisutural epipteric bones in between patietal and sphenoid bones (PS) as well as in between sphenoid and temporal bones (ST)

Figure 6D. Multiple epipteric bones depicted with red arrows
3. INFERIOR WAS NOT FOUND

4. ANTERIOR (FPS)

1. SUPERIOR (FPT)

2. POSTERIOR (PTS)
