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MORPHOLOGICAL VARIATIONS OF THE PTERION AMONG SKULLS AT THE GALLOWAY OSTEOLOGICAL COLLECTION IN THE DEPARTMENT OF HUMAN ANATOMY MAKERERE UNIVERSITY.

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ABSTRACT

Background: The pterion is an important anatomical landmark in anatomy, neurosurgery, radiology, and forensic examinations. The region is prone to damage following blunt trauma of the head. Although the structure varies with age, sex and ethnicity, this has not been documented in the Ugandan setting. The study set out to describe the morphological variations of the pterion among skulls in the Galloway Osteological Collection at the Department of Anatomy, Makerere University. **Methods:** This was a descriptive cross-sectional study that examined human skulls for the type of pterion, the distance between the center of the pterion and mid zygomatic arch, and the distance between the center of the pterion and the frontozygomatic suture. The measurements were conducted using a digital Vernier caliper. Data was analyzed using the Welch t-test and student t-test. **Results:** A total of 65 skulls were studied, the sphenoparietal type of pterion was the commonest 65.4%. The pterion in females was located more posteriorly from the frontozygomatic suture compared to that of males, however the p-value was 0.10. The distance from pterion to zygomatic arch and frontozygomatic suture showed variations with age and nationality. **Conclusion:** The Pterion exhibited variations which need to be considered during examinations and operations of the region.

Keywords: Pterion types, Galloway Osteological Collection, Makerere University

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INTRODUCTION

The pterion is a visible craniometric point that is located bilaterally on the skull and represents the sutural confluence of four cranial bones: frontal, parietal, sphenoid and temporal (Avalos et al., 2011). In humans, there are four types of pterions and these include sphenoparietal, stellate, frontotemporal and epipteric pterion (Wang et al., 2006). The sphenoparietal pterion type is one in which the sphenoid and parietal bones are in direct contact, preventing the frontal and temporal bones from contacting one another. In contrast to the frontotemporal type, the frontal and temporal bones are in direct contact, preventing contact between the sphenoid and parietal bones. In the Stellate type, the four bones meet at a point, and in the epipteric type, a suture bone also referred to as the wormian bone is found between the parietal bone and the greater wing of the sphenoid bone (Murphy, 1956, Wang et al., 2006).

The pterion is at the confluence of these bones and is known to be the weakest part of the skull. The pterion also overlies the middle meningeal artery and for this reason, it is susceptible to rupture in the event of blunt head trauma (Ma et al., 2012, Walulkar et al., 2016). Aside from the middle meningeal artery, the pterion also overlies the deeper structures of the anterior and middle cranial fossa, and Broca's area, making it an important neuro-surgical landmark (Rodriguez Rubio R, 2019). In neurosurgery, success of keyhole surgeries is dependent on pre-operative planning and placement of the craniotomy tailored to the individual. The pterional approach is the most common approach in these surgeries as it minimizes brain retraction and increases the exposure of the neurovascular structures within the anterior basal cistern (Hopf and Perneczky, 1998).

In addition to neurosurgery, the pterion is important to forensic scientists due to existence of morphological variations in different populations. Age can be estimated from a skull depending on the degree of pterion obliteration (Apinhasmit, 2011), while sex can be determined by measuring the Krotaphion-sphenion distance of the pterion (Jellinghaus et al., 2020).

Currently there is little, or no study done about the pterion in Uganda. The current study aimed at describing the morphological variations of the pterion of the skulls at the Galloway Osteology Collection in the Department of Human Anatomy, Makerere University.

MATERIALS AND METHODS

Study design and setting

This was a descriptive cross-sectional study that was conducted in the Department of Anatomy at Makerere University College of Health sciences. The Department of Anatomy houses the Galloway Osteological Collection whose collection of bones was initiated in 1947 by Sir Alexander Galloway, the first Dean of the then Makerere University Medical School. The collection currently has 121 human skulls that were collected aged 18 to 60 years. This was to reduce the variation explained by developmental constraints caused by advanced age which may influence the results of any statistical examinations (Parsons and Box, 1905).

Sample size estimation

One hundred twenty-one skulls were available and evaluated for possible inclusion in the study. However, only 65 skulls were complete, and all were included in the study. According to Gay and Airasian , if the known population is 100 or less, then all the available specimens should be included in the study (Gay and Airasian, 2003).

Data collection

Data was collected using a data tool adopted from Nongnut Uabundi for social demographic information from the catalogue of bones in the laboratory and distances were recorded in millimeters (Uabundit et al., 2021). The skulls were obtained and assessed for eligibility by the investigator assisted by an expert anatomist and a technician. The skulls that met the inclusion criteria were examined to determine the type of pterion on either side of the skull. Photographs were taken using a Canon IXUS digital camera with a resolution of 20.0-megapixel IXUS for representative samples. The distance between the centre of the pterion and the zygomatic arch, and the frontozygomatic suture were measured. The centre of the pterion was identified using the perpendicular bisectors theorem using the help of compass and lead pencil by drawing a small circle with the smallest diameter including the 4 bones at the pterion, there after the radius was determined as shown in figure 1.

Figure 1: Illustration of how measurements were obtained.

In the sphenoparietal type of pterion, the suture between the sphenoid and parietal bones was used as a segment to determine the centre of pterion. One end of this sphenoparietal suture was taken as centre, a compass was placed here and arcs having more than half the length of the suture were drawn above and below it. Then another end of this sphenoparietal suture was taken as center and arcs were drawn above and below it. The point where both arcs intersected was joined by a thread. The obtained line was again intersected using perpendicular bisectors; the point where both these lines intersected was taken as center of pterion. (see figure 2 and 3)

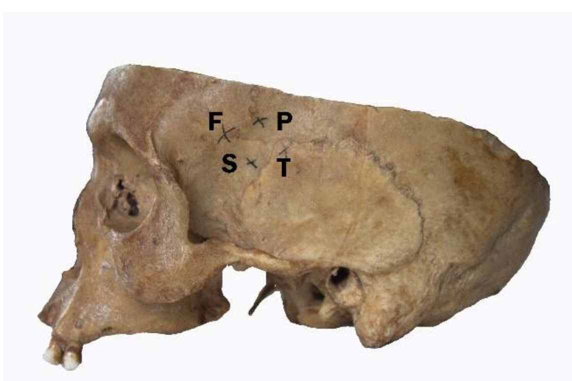

Figure 2: Illustration of how arcs were drawn for the sphenoparietal pterion.

In the frontotemporal type, the suture between the frontal and temporal bones was used as a segment. The segment was intersected using perpendicular bisectors theorem (Oguz et al., 2004). In the epipteric type, the point where the fronto-sphenoidal and parietotemporal sutures meet the Wormian/ suture bone was taken as the center. Taking radius more than half of the length of the Wormian bone at each of the two sutural ends arcs were drawn above and below it. The point where both arcs intersected was joined by a thread. The obtained line was again intersected using perpendicular bisectors, the point where both these lines intersected was taken as the center of pterion. In the stellate type, the point where all the four bones meet was considered the midpoint of pterion. The measurements for the linear distance from the midpoint of the zygomatic arch to the center of the pterion (ZAP) and the linear distance from the midpoint of the frontozygomatic suture to the center of the pterion (FZSP) was measured three times using Draper Expert 52427 digital Vernier caliper (Draper Tools LTD, Hampshire, UK: accuracy +/- 0.01mm); Coolpix S2900 digital camera (Nikon Corporation, Tokyo, Japan.)

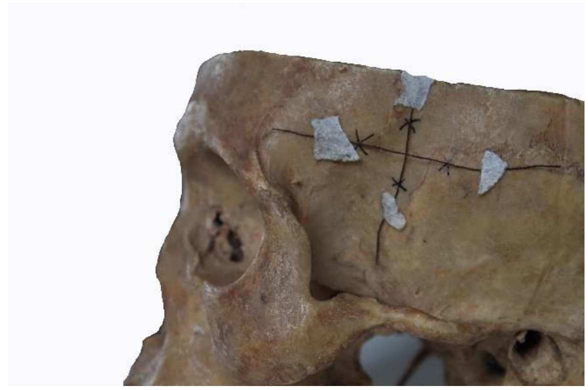

Figure 3: Illustration of the center of pterion in the sphenoparietal type.

Data management and analysis.

The data collection forms were given numbers for identification before data collection. After data collection the forms were checked for completeness and correctness. Data was entered into R version

4.1.1; correctness of the data was ascertained by double data entry.

The pterion type percentage was determined as the proportion of skulls with a given type of pterion to the total number of skulls studied multiplied by 100%. The pterion to anatomical landmark distances were recorded as the average of 3recordings. Pterion types were assessed using the Pearson chi square test while the pterion to anatomical landmark distance was assessed using the Welch t-test. A p-value of < 0.05 was considered significant. The student's t-test was also used to assess for difference between the left and right sides of the skull.

Ethical considerations

Permission to conduct the study was obtained from the Department of Human Anatomy, College of Health Sciences, Makerere University. Ethical approval was obtained from the School of Biomedical Sciences Research Ethics Committee (REC. Number SBS-2021-71) and skulls were assigned code numbers.

RESULTS

A total of 65 adult human skulls were used in this study, majority of which were female (73.8%). The mean age of the individuals from whom the skulls were collected was 35 years (SD 12.1, range 18- 60). Of the 65 specimens, 35 (53.8%) were Ugandans and the rest were non-Ugandan as shown in Table 1. The sphenoparietal type was the most common (65.4%) as shown in Table 2.

Table 1 Demographic characteristics of the skulls

Characteristics	Frequency	Percent
Age group (years)		
<21	8	12.3
21-30	19	29.2
31-40	21	32.3
41-50	9	13.8
51-60	8	12.3
Sex		
Male	48	73.8
Female	17	26.2
Total	65	100.0
Nationality		
Ugandan	35	53.8
Non-Ugandan	30	46.2

Table 2. Type of pterion

Pterion type	Right side: n=65	Left side: n=65	Both side n=130
Stellate	3 (4.6%)	5 (7.7%)	8 (6.2%)
Sphenoparietal	43 (66.2%)	42 (64.6%)	85 (65.4%)
Epipteric	10 (15.4%)	11 (16.9%)	21 (16.2%)
Frontotemporal	9 (13.8%)	7 (10.8%)	16 (12.3%)
Total	65 (100%)	65 (100%)	130 (100%)

Table 3. Mean distances from midpoint of pterion to various bony landmarks

Distances from midpoint of pterion To	Right Side (Mean ±SD) mm	Left Side (Mean ±SD) mm
Midpoint of zygomatic arch	34.17 ±3.89	33.21 ±4.5
Frontozygomatic suture	24.54 ± 4.79	25.36 ±4.5

Table 4. Relationship between age and distance from midpoint of pterion to Midpoint zygomatic arch and Frontozygomatic suture

	Midpoint zygomatic arch				**Frontozygomatic suture**			
Age group	Left pterion		Right pterion		Left pterion		Right pterion	
	Mean ± SD	p-value	Mean ± SD	p-value	Mean ± SD	p-value	Mean ± SD	p-value
<21	32.9 ± 3.01	0.27	34.0 ± 3.43	0.29	25.0 ± 3.61	0.78	23.0 ± 4.42	0.43
21-30	31.7 ± 3.95		33.0 ± 3.58		26.0 ± 5.13		25.6 ± 4.06	
31-40	33.9 ± 4.33		34.6 ± 3.77		25.7 ± 4.73		24.4 ±5.22	
41-50	35.6 ± 2.99		36.4 ± 4.24		23.7 ± 2.93		22.7 ± 3.59	
51-60	32.7 ± 7.65		33.5 ± 4.57		25.1 ± 5.33		26.0 ± 6.54	

DISCUSSION

This study set out to investigate the morphological variations of the pterion in the Galloway Osteology Collection. The most common type of pterion was the sphenoparietal (65%), followed by Epipteric (16.2%), frontotemporal (12.3%) and the least being Stellate (6.2%) as shown in table 2. These observations can be explained according to the hereditability of the genes that determine sutural patterns (Wang et al., 2006). Genes linked to sutural fusion, such as MXS2, play a role in determining sutural configuration patterns. The MSX2 gene encodes a homeodomain transcription factor that is known to have a role in craniofacial morphogenesis. Mutations in the homeobox genes for MSX2 and fibroblast growth factor FGF receptors cause premature fusion of cranial sutures, known as craniosynostosis, in humans (Liu et al., 1999, Opperman, 2000). Also, the high occurrence of the sphenoparietal pterion type has an evolutionary basis as it's the commonest type in humans and primates such as Orangutans and bonobos (Ashley-Montagu, 1933, Liu et al., 1999). In the case of epipteric type, Ranke noted that this pterion appears when there is fusion failure of the postero-superior border of the greater sphenoidal wing (via its separate ossification center) with the rest of the greater wing, during the fourth month of intrauterine life (Ranke, 1898, Bellary et al., 2013). Our findings are consistent with those from the Tamil Nadu population that reported the sphenoparietal and epipteric types as the most common pteria (Praba and Venkatramaniah, 2012, Sarvaiya et al., 2019). Our findings are also consistent with a Kenyan study that reported the sphenoparietal type in 66% of 90 skulls (Mwachaka, 2017). Studies that had a similar sample size to the current study reflected similar findings; however, those with either so high or so low showed varying percentages in pterion types (Ukoha et al., 2013).

According to Keith, the pterion is reported to be 40mm above the zygomatic arch and 30-35 mm behind the frontozygomatic suture (Keith et al., 2006). In this study as shown in table 3, the mean distances from mid-point of pterion to mid zygomatic arch and frontozygomatic suture on either side of the skull was 34.17mm +-3.89 on the right, 33.21mm +-4.5 on the left and 24.54mm +-4.79 on the right, 25.36mm +-4.5 on the left respectively. Literature suggests that the adult skull shows variations in craniofacial size and shape. This is due to multiple, intricate developmental processes that are affected by both genetic and epigenetic stimuli (Hallgrímsson et al., 2004, Hallgrímsson et al., 2002). Though there is evidence supporting genetic determinism on craniofacial form, there is a general appreciation that epigenetic stimuli plays a major role in influencing overall skull shape both from interactions within the organism (e.g., patterning of migrating neural crests cells as they come into contact with mesoderm) as well as from environmental stimuli (Hallgrímsson et al., 2007). Among the many environmental factors that may have influenced the evolution of the highly derived human face, masticatory loading in response to variations in hardness, toughness, and particle size in diet is thought to be important (González-José et al., 2005, Lieberman, 2008). Previous studies agree that hard, tough and unprocessed diets generally lead to an increase in the overall robusticity, size of the skull, or an increase in facial size.(Sardi et al., 2006) Mastication generates a gradient of strains in the face with highest strains in the regions of muscle attachment and insertion such as the zygomatic arch and the coronoid process. These forces stimulate bone growth resulting in some degree of change in terms of the vertical orientation of the zygomatic bone and other related skull bones (Lieberman et al., 2004, Paschetta et al., 2010). Since most of our study specimens were obtained from individuals who died more than 70 years ago and Uganda being a developing country, studies should be carried out on the current population to document its pterion morphometry. Growing industrialization in food processing has increased peoples' access to processed foods hence relative reduction of the temporal fossa and in the displacement of the attachment of the temporal muscle.

In the current study, a gradual increase in the distance between the pterion and zygomatic arch on both sides of the skull with increasing age was observed. But there was no clear pattern observed for the distance between the pterion and frontozygomatic suture on both sides of the skull. To better understand the effect of age on the skull bones it's important to know that bone is a dynamic, sensitive, ever-changing tissue. Bone growth takes place from birth until the hormonal stimulus ceases, with long bone epiphysis consolidation usually around 15–18 years of age. On the other hand, bone remodeling continues throughout life, determined not by intrinsic factors, but mainly by regional changes in the soft tissues related to each bone, such as muscles, tongue, lips, skin, and brain, among others (Coleman and Grover, 2006, Enlow et al., 1998). Bone remodeling serves to adjust bone architecture to meet changing mechanical needs, repair micro damages, and guarantee calcium homeostasis. Therefore, it is transitory and does not involve the totality of the bone. The process of bone remodeling involves the removal of mineralized bone by osteoclasts and formation of bone matrix through the osteoblasts. Both processes of bone remodeling occur throughout life, although the balance between them changes according to the period of life (Rucci, 2008).

Bone formation is more prominent in childhood; the processes are balanced in adults, although bone resorption is more prominent in the elderly (Enlow et al., 1998). Uabundit stated that age-related bone change could lead to longer pterion-frontozygomatic suture (PFZS), and pterion-zygomatic angle (PZAN) distances. In his findings the PFZS and PZAN distances were positively correlated with age (Uabundit et al., 2021). His findings were in line with the zygomatic bone change that happens with age. It was previously found that the inferolateral aspect of the orbit, which is part of the zygomatic bone, has a tendency to resorb as individuals age, resulting in the lengthening of the lid–cheek junction (Mendelson and Wong, 2020). Our results for the pterion-frontozygomatic suture differed from Uabundit who reported an increase in this distance with age. This could have been due to the small number of skulls studied that could not give us a definitive pattern. Natsis reported that specimens between 20-39 years had a high distance from pterion to zygoma and pterion to frontozygomatic suture, then a decrease in this distance between 40-59 years and for those specimens above 60 years showed an increase in the stated distance (Natsis et al., 2021)

STUDY LIMITATION

The sample size was small; therefore, our findings may not be generalizable to the Ugandan population. Also, the skulls used in this study were collected from different ethnic groups in the 1940s hence may not represent the current trends due to transformation in diet and feeding habits.

CONCLUSION

Morphological variations of the pterion were observed among the adult skulls at the Galloway osteology collection. All four pterion types were observed in the 65 skulls studied with sphenoparietal type being the most frequent variety of pterion.

Variations in pterion morphometrics occur among different nationalities, age and sex with female skulls having a pterion that was more posteriorly located. The measured distances varied with varying age groups since our specimens were not obtained from individuals of the same nationality.

RECOMMENDATION

A radiological study with a large sample size should be carried out using specimens from living persons to accurately study pterion morphometrics and distribution of the different pterion types in the Ugandan population.

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REFERENCES

1. APINHASMIT, W. C., SUPIN CHAISUKSUNT, VIPAVADEE, THIRAPHATTHANAVONG,PAPHAPHAT PHASUKDEE, NOPPADOL 2011. Anatomical consideration of pterion and its related references in Thai dry skulls for pterional surgical approach. *Journal of the Medical Association of Thailand= Chotmaihet thangphaet,* 94**,** 205-214.
2. ASHLEY-MONTAGU, M. 1933. The anthropological significance of the pterion in the primates. *American Journal of Physical Anthropology,* 18**,** 159-336.
3. AVALOS, R. M., ALVARADO, M. V. A., OMAÑA, R. E. E. & LÓPEZ, S. G. 2011. Estudio morfológico del pterion y asterion en cráneos adultos mexicanos. *Rev Arg de AnatClín,* 3**,** 77-83.
4. BELLARY, S. S., STEINBERG, A., MIRZAYAN, N., SHIRAK, M., TUBBS, R. S., COHEN-GADOL, A. A. & LOUKAS, M. 2013. Wormian bones: a review. *Clinical Anatomy,* 26**,** 922-927.
5. COLEMAN, S. R. & GROVER, R. 2006. The anatomy of the aging face: volume loss and changes in 3-dimensional topography. *Aesthetic surgery journal,* 26**,** S4-S9.
6. ENLOW, D. H., HANS, M. G. & OPPIDO, T. 1998. *Noções básicas sobre crescimento facial*, Santos.
7. GAY, L. R. & AIRASIAN, P. 2003. Educational research: Consequences for analysis and applications. Upper Saddle River, NJ: Pearson.
8. GONZÁLEZ-JOSÉ, R., RAMÍREZ-ROZZI, F., SARDI, M., MARTÍNEZ-ABADÍAS, N., HERNÁNDEZ, M. & PUCCIARELLI, H. M. 2005. Functional-cranial approach to the influence of economic strategy on skull morphology. *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists,* 128**,** 757-771.

9. HALLGRÍMSSON, B., LIEBERMAN, D. E., LIU, W., FORD-HUTCHINSON, A. & JIRIK, F. 2007. Epigenetic interactions and the structure of phenotypic variation in the cranium. *Evolution & development,* 9**,** 76-91.
10. HALLGRÍMSSON, B., WILLMORE, K., DORVAL, C. & COOPER, D. M. 2004. Craniofacial variability and modularity in macaques and mice. *Journal of Experimental Zoology Part B: Molecular and Developmental Evolution,* 302**,** 207-225.
11. HALLGRÍMSSON, B., WILLMORE, K. & HALL, B. K. 2002. Canalization, developmental stability, and morphological integration in primate limbs. *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists,* 119**,** 131-158.
12. HOPF, N. J. & PERNECZKY, A. 1998. Endoscopic neurosurgery and endoscope-assisted microneurosurgery for the treatment of intracranial cysts. *Neurosurgery,* 43**,** 1330-1336.
13. JELLINGHAUS, K., MATIN, S., URBAN, P., BOHNERT, M. & JANTZ, R. 2020. Study of the KS distance on skulls from different modern populations for sex and ancestry determination. *Rechtsmedizin,* 30**,** 451-457.
14. KEITH, L., MOORE, A. & AGUR, A. 2006. *Clinically oriented anatomy*, Lippincott Williams & Wilkins.
15. LIEBERMAN, D. E. 2008. Speculations about the selective basis for modern human craniofacial form. *Evolutionary Anthropology: Issues, News, and Reviews: Issues, News, and Reviews,* 17**,** 55-68.
16. LIEBERMAN, D. E., KROVITZ, G. E., YATES, F. W., DEVLIN, M. & CLAIRE, M. S. 2004. Effects of food processing on masticatory strain and craniofacial growth in a retrognathic face. *Journal of human evolution,* 46**,** 655-677.
17. LIU, Y.-H., TANG, Z., KUNDU, R. K., WU, L., LUO, W., ZHU, D., SANGIORGI, F., SNEAD, M. L. & MAXSON JR, R. E. 1999. Msx2Gene dosage influences the number of proliferative osteogenic cells in growth centers of the developing murine skull: A possible mechanism forMSX2-mediated craniosynostosis in humans. *Developmental biology,* 205**,** 260-274.
18. MA, S., BAILLIE, L. J. & STRINGER, M. D. 2012. Reappraising the surface anatomy of the pterion and its relationship to the middle meningeal artery. *Clinical Anatomy,* 25**,** 330-339.
19. MENDELSON, B. & WONG, C.-H. 2020. Changes in the facial skeleton with aging: implications and clinical applications in facial rejuvenation. *Aesthetic Plastic Surgery,* 44**,** 1151-1158.
20. MURPHY, T. 1956. The pterion in the Australian aborigine. *American journal of physical anthropology,* 14**,** 225-244.
21. MWACHAKA, P., HASSANALI, J, ODULA, P 2017. Sutural morphology of the pterion and asterion among adult Kenyans. *Journal of Morphological Sciences,* 26**,** 0-0.
22. NATSIS, K., ANTONOPOULOS, I., POLITIS, C., NIKOLOPOULOU, E., LAZARIDIS, N., SKANDALAKIS, G., CHYTAS, D. & PIAGKOU, M. 2021. Pterional variable topography and morphology. An anatomical study and its clinical significance. *Folia Morphologica,* 80**,** 994-1004.
23. OGUZ, Ö., GÜRARSLAN ŞANLI, S., BOZKIR, M. & SOAMES, R. 2004. The pterion in Turkish male skulls. *Surgical and radiologic anatomy,* 26**,** 220-224.
24. OPPERMAN, L. A. 2000. Cranial sutures as intramembranous bone growth sites. *Developmental dynamics: an official publication of the American Association of Anatomists,* 219**,** 472-485.
25. PARSONS, F. & BOX, C. 1905. The relation of the cranial sutures to age. *The Journal of the Anthropological Institute of Great Britain and Ireland,* 35**,** 30-38.
26. PASCHETTA, C., DE AZEVEDO, S., CASTILLO, L., MARTÍNEZ-ABADÍAS, N., HERNÁNDEZ, M., LIEBERMAN, D. E. & GONZÁLEZ-JOSÉ, R. 2010. The influence of masticatory loading on

craniofacial morphology: A test case across technological transitions in the Ohio valley. *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists,* 141**,** 297-314.
27. PRABA, A. & VENKATRAMANIAH, C. 2012. Morphometric Study of different types of Pterion and it's relation with middle meningeal artery in dry skulls of Tamil Nadu. *J Pharm Biomed Sci,* 21**,** 1-4.
28. RANKE, J. 1898. *Der Stirnfortsatz der Schläfenschuppe bei den Primaten*.
29. RODRIGUEZ RUBIO R, C. R., VIGO V, ET AL. 2019. Immersive Surgical Anatomy of the Pterional Approach. *Cureus,* 11.
30. RUCCI, N. 2008. Molecular biology of bone remodelling. *Clinical cases in mineral and bone metabolism,* 5**,** 49.
31. SARDI, M. L., NOVELLINO, P. S. & PUCCIARELLI, H. M. 2006. Craniofacial morphology in the Argentine Center-West: consequences of the transition to food production. *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists,* 130**,** 333-343.
32. SARVAIYA, B. J., CHAUDHARI, J. S. & FICHADIYA, N. C. 2019. Morphometric analysis of pterion in adult human dry skull of gujarat region. *Int J Anat Res,* 7**,** 6204-10.
33. UABUNDIT, N., CHAIYAMOON, A., IAMSAARD, S., YURASAKPONG, L., NANTASENAMAT, C., SUWANNAKHAN, A. & PHUNCHAGO, N. 2021. Classification and morphometric features of pterion in Thai population with potential sex prediction. *Medicina,* 57**,** 1282.
34. UKOHA, U., ORANUSI, C., OKAFOR, J., UDEMEZUE, O., ANYABOLU, A. & NWAMARACHI, T. 2013. Anatomic study of the pterion in Nigerian dry human skulls. *Nigerian Journal of Clinical Practice,* 16**,** 325-328.
35. WALULKAR, S., DEHANKAR, R., WALULKAR, M. & KSHEERSAGAR, D. 2016. Pterion formation and its variations in Human Skull in Vidarbha Region. *J Cont Med A Dent,* 4**,** 4-10.
36. WANG, Q., OPPERMAN, L. A., HAVILL, L. M., CARLSON, D. S. & DECHOW, P. C. 2006. Inheritance of sutural pattern at the pterion in Rhesus monkey skulls. *The Anatomical Record Part A: Discoveries in Molecular, Cellular, and Evolutionary Biology: An Official Publication of the American Association of Anatomists,* 288**,** 1042-1049.