Original Article

DOI: 10.7860/IJARS/2025/74746.3037

Anatomy Section

Morphological and Morphometric Study of Foramen Spinosum in Dry Human Skulls: A Cross-sectional Study from South Bengal, India

ANWESA PAL[1], ANAMIKA GHOSH[2], SOUMALI BISWAS[3]

ABSTRACT

Introduction: The Foramen Spinosum (FS), located posterolateral to the foramen ovale in the middle cranial fossa, provides passage to the middle meningeal vessels and the nervous spinosus. It is a critical landmark both surgically and radiologically. Abnormal morphology and a lack of proper anatomical knowledge of this foramen may interfere with various surgeries performed in cases of middle cranial fossa fractures, tumours and epidural haematomas.

Aim: To study the various morphological variations and morphometric measurements of FS in dry human skulls from the South Bengal, India population.

Materials and Methods: The present Institution-based cross-sectional morphometric study was conducted on 100 dry human skulls of unknown age, collected from the Department of Anatomy, IPGMER, Kolkata, West Bengal, India, from June 2024 to September 2024. The various shapes of the FS, along with its length, width and distance from the spine of the sphenoid, were measured using vernier callipers. The mean, standard deviation, and relevant p-values of these parameters were calculated using Statistical Package for Social Sciences (SPSS) software version 16.0.

Results: Out of 100 dry skulls, 49 were of males and 51 were of females. The round-shaped FS was the most prevalent variety, found in 79 (79%) of the right-sides and 82 (82%) of the left-sides in both sexes bilaterally. Other shapes included almond (3% in both right and left), pear (4% on the right and 2% on the left), pinhole (2% on the right only), and oval (12% on the right and 11% on the left). Accessory FS was found in 2% of cases among females. The mean±Standard Deviation (SD) length was 2.84±0.87 mm for the right-side and 2.64±0.80 mm for the left-side; for width, they were 2.22±0.59 mm for the right-side and 2.25±0.62 mm for the left-side; and for the mean±SD distance between FS and the spine of the sphenoid, they were 4.38±2.11 mm on the right and 4.20±2.01 mm on the left. A significant statistical difference was observed in the male and female parameters on the right-side.

Conclusion: A thorough understanding of the morphology and morphometry of the FS will be beneficial for neurovascular surgeries, ensuring maximum safety with minimal morbidity and mortality.

Keywords: Craniometry, Middle meningeal artery, Neuroanatomy, Neurosurgery

INTRODUCTION

The sphenoid bone is one of the major bones of the cranial cavity and contributes to the formation of the middle cranial fossa. Among the multiple foramina present in the greater wing of the sphenoid, the FS, located at the base of the skull posterolateral to the foramen ovale, is very important both surgically and anatomically, as it can be identified from both the exterior and the interior [1,2]. The history dates back to the 18th century when Jacob Benignus Winslow studied and named this foramen because of its proximity to the spine of the sphenoid [1]. Various important neurovascular structures, such as the middle meningeal artery, the meningeal branch of the mandibular nerve (also known as the 'nervous spinosus'), and the middle meningeal vein, which connects the cavernous sinus with the pterygoid venous plexus, pass through this foramen. The passage of these structures facilitates communication between the middle cranial fossa and the infratemporal fossa [1-4].

The middle meningeal artery usually arises from the maxillary artery and divides into an anterior frontal branch and a posterior parietal branch. An early division of the middle meningeal artery can result in duplication, and if the artery arises from an ophthalmic artery or stapedial artery, both of which are very rare congenital anomalies, which may lead to a small or absent FS [5-7]. These abnormal morphologies of FS due to anatomical variations can interfere with surgeries in the middle cranial fossa [5-10]. Various neurosurgeries, such as those for base of skull fractures, epidural haematomas, pterygoid canal nerve surgeries, interventional surgeries, tension release in the maxillary artery, infratemporal fossa tumours, and bypass creation between the middle meningeal artery and the internal carotid artery, require a thorough knowledge of the topography of the middle meningeal artery and FS, along with its anatomical variations [11,12]. The size and shape of the foramen are of immense importance in various diagnostic procedures, including Computed Tomography (CT) scans and Magnetic Resonance Imaging (MRI).

The anatomical variations of FS can be explained embryologically. FS develops as a ring-shaped bone derived from both intramembranous and intracartilaginous ossification centers (eight in total). The first center appears in the eighth week, and the last one forms seven years after birth. Postnatal changes in this regard have been explained by Lang J et al., [13].

The FS shows wide variations in its morphology and morphometry concerning sex, age, ethnicity and geographical location [14]. In the present study, apart from morphology and morphometric measurements of FS, the authors have also measured the distance of FS from the spine of the sphenoid in dry human skulls from the South Bengal, India population. The spine of the sphenoid is a very important landmark for surgeons, and this distance serves as a guiding point for accessing the structures entering through FS. This distance has not been measured in any previous papers from Eastern India.

MATERIALS AND METHODS

The present study was an Institution-based cross-sectional morphometric study conducted in the Department of Anatomy at IPGMER, Kolkata, West Bengal, India, from June 2024 to September 2024. With the necessary permissions from the Institutional Ethics Committee (IEC) (IPGMER/IEC/2024/0602) and the Director of the Institution, and under the guidance of the Head of the Department (HOD), dry human skulls of unknown age were collected from the museum of the Department of Anatomy, IPGMER, Kolkata, India. It was presumed that the bones were disarticulated from the skeletons of donated cadavers belonging to the South Bengal population. HODs of Anatomy from other medical teaching institutes in Kolkata were also approached for their kind permission to access the dry adult human skull bones.

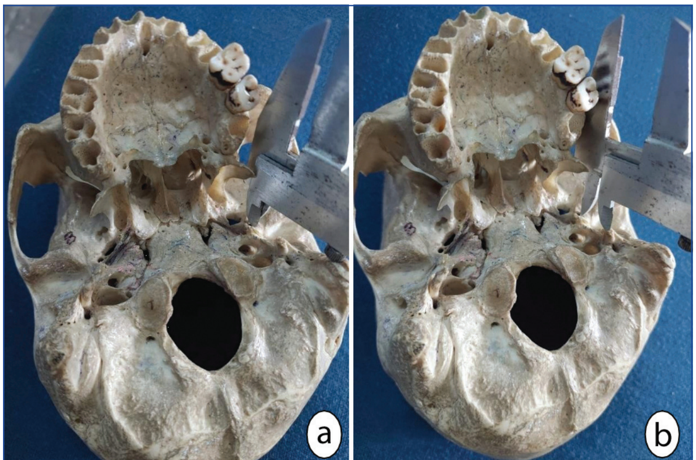
Inclusion criteria: Adult skulls of both sexes were included in the study.

Exclusion criteria: Skulls with malformations, fractures, or those that had undergone craniotomy were excluded from the study.

Study Procedure

Total 200 specimens of dry FS from 100 skulls were collected. Out of a total of 200 specimens, 100 belonged to the right-side and 100 to the left-side, respectively.

Measurements of the length of the FS and the distance between the tip of the spine and the center of the FS were recorded [Table/Fig-1a,b]. Measurements were taken in millimeters using Vernier calipers with a precision of up to 0.02 mm. Each measurement was taken three times by two observers, and the mean value of each measurement was considered to avoid observer bias. The shape of the FS was noted, as well as, the location of the foramen in relation to the spine of the sphenoid and its distance from the spine.



[Table/Fig-1]: Showing technique of taking measurements. a) Measurement of length of the FS; b) Distance between tip of the spine and center of the FS.

STATISTICAL ANALYSIS

The mean and standard deviation for each parameter were calculated using SPSS software version 16.0. A comparison of both sides in both sexes was conducted with the help of the Student's t-test.

RESULTS

The total number of specimens is 200, with 100 belonging to each side. Out of the 100 dry human skulls, 49 were males and 51 were females.

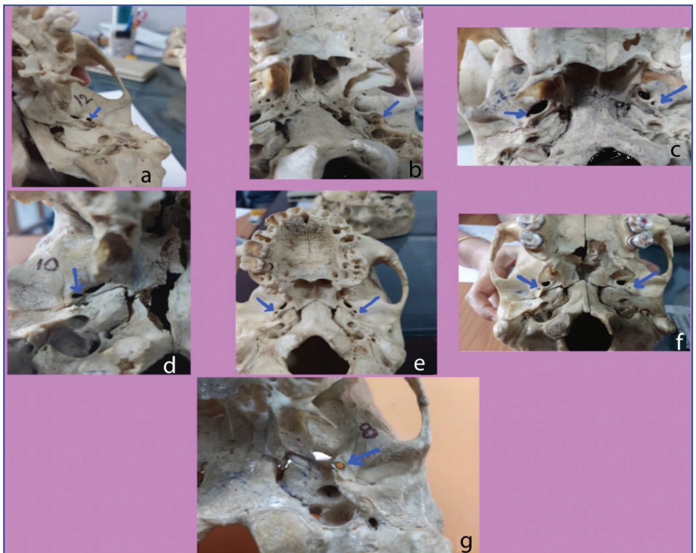
The round-shaped FS was the most prevalent variety in both sexes bilaterally, with 79 (79%) specimens on the right-side and 82 (82%) specimens on the left-side. Other shapes included almond, with 3 (3%) specimens found on both the right and left-sides, and pear, with 4 (4%) specimens on the right-side and 2 (2%) specimens on the left-side [Table/Fig-2-4]. Accessory FS was found on the left-side in only 2 female skulls. Septate FS was found in two males, but only on the left-side. The authors did not find any specimens in either sex on either side with absent FS. The most common location of the FS is medial to the spine of the sphenoid in both sexes [Table/Fig-5].

Shape	Male (n=49)	Female (n=51)	Total (n=100)
Round	36	43	79
Oval	10	02	12
Pinhead	00	02	02
Almond	01	02	03
Pear	02	02	04
Heart	00	00	00

[Table/Fig-2]: Prevalence of different shapes of Foramen Spinosum (FS) on Right-side (n=100).
Values presented as n

Shape	Male (n=49)	Female (n=51)	Total (n=100)
Round	36	46	82
Oval	09	02	11
Pinhead	00	00	00
Almond	02	01	03
Pear	02	00	02
Heart	00	02	02

[Table/Fig-3]: Prevalence of different shapes of Foramen Spinosum (FS) of left-side (n=100).
Values presented as n



[Table/Fig-4]: Showing various shapes of Foramen Spinosum (FS) observed. a) The heart-shaped Foramen Spinosum (FS) with accessory FS in left-side; b) The septate FS on the left-side; c) The Foramen Ovale (FO) and FS merged with each other on right-side and is differentiated by a bony spicule on the left-side; d) The pear-shaped FS on the right-side; e) Almond-shaped FS on the left-side; f) Bilateral FS lateral to spine of sphenoid; g) The round-shaped FS bilaterally present.

Position of Foramen Spinosum (FS) in relation to spine of sphenoid	Male (n=49)	Female (n=51)
Lateral to the spine of sphenoid bilaterally	19	13
Medial to the spine of sphenoid bilaterally	24	30
Within the spine bilaterally	0	03
Left-side within the spine of sphenoid and right-side lateral to it	03	05
Left-side medial to the spine of sphenoid and right-side within it	03	0

[Table/Fig-5]: Position of Foramen Spinosum (FS) in relation to spine of sphenoid in both genders (n=100).

There is no statistically significant difference bilaterally between the parameters of the right and left-sides [Table/Fig-6]. There is a significant statistical difference between the male and female parameters on the right-side [Table/Fig-7].

Parameters	Right (n=100) (Mean±SD)	Left (n=100) (Mean±SD)	p-value
Length (mm)	2.84±0.87	2.64±0.80	0.09
Width (mm)	2.22±0.59	2.25±0.62	0.81
Distance between the spine of sphenoid to Centre of FS (mm)	4.38±2.11	4.20±2.01	0.53

[Table/Fig-6]: Comparison of different parameters between right and left.

Parameters	Gender	Right-side (n=100)	p-value	Left-side (n=100)	p-value
Length (Mean±SD)	Male	3.19±0.88	0.0001*	2.78±0.72	0.06
	Female	2.49±0.73		2.50±0.80	
Width (Mean±SD)	Male	2.35±0.55	0.0396*	2.30±0.64	0.51
	Female	2.10±0.62		2.22±0.59	
Distance of centre of FS from spine of sphenoid (Mean±SD)	Male	4.83±1.88	0.0338*	3.91±2.37	0.15
	Female	3.94±2.24		4.49±1.54	

[Table/Fig-7]: Mean and standard deviations bilaterally in both the gender along with p-values between males and females.
*The p-value <0.05 was considered statistically significant

DISCUSSION

The FS shows wide variations in its morphology and morphometric measurements. Various studies conducted previously also highlight this fact. Regarding the morphology of FS, Chandan CB et al., found that the shapes included round (26%), oval (15%), pinhole (5%) and irregular (4%) in right-sided FS, while the left-sided FS showed round (23%), oval (17%), pinhole (6%) and irregular (4%). When considered bilaterally, round (49%), oval (32%), pinhole (11%) and irregular (8%) shapes were found [15].

A study conducted by Desai SD et al., found that the shapes of the foramina sphenoidale (FS) were bilaterally round (52%), oval (42%) and irregular (6%) [16]. A similar study from Karnataka by Saheb SH et al., found bilaterally prevalent FS shapes to be round (58%), oval (38%) and irregular (4%) [17]. In 2015, Somesh MS et al., from South India found the right-sided FS shapes to be round (56%), oval (34.1%), pinhole (6%) and irregular (3.6%), while the left-sided FS shapes were round (51.2%), oval (36.5%), pinhole (7.3%) and irregular (4.8%). When considered bilaterally, they reported round shapes at 53.65%, oval at 35.36%, pinhole at 6.70% and irregular at 4.26% [18].

Sophia MM and Kalpana R, from Chennai found that the right-sided FS shapes consisted of round (26.2%), oval (12.5%), pinhole (1.25%) and irregular (5%), while the left-sided FS shapes were round (26.2%), oval (12.5%), pinhole (1.25%) and irregular (7.5%). When considered bilaterally, they reported round shapes at 52.5%, oval at 30%, pinhole at 2.5% and irregular at 12.5% [19].

Chanda C et al., from Ranchi in 2019 found bilaterally prevalent FS shapes to be round (53.3%), oval (40%) and irregular (6.66%) [20]. In 2014, Srimani P et al., conducted a study in West Bengal and found bilaterally prevalent round shapes at 51.25% and oval shapes at 30% [21]. In 2024, Vasanthi A et al., reported bilaterally round shapes at 62.5%, oval shapes at 32.3%, and irregular shapes at 5.2% [22].

When considering studies outside India, Sugano GT et al., found round shapes at 42.1%, oval shapes at 32.8%, drop-shaped at 12.5%, and irregular shapes at 12.5% [23]. Worku GM and Clarke E in their study found right-sided FS shapes to be round (53.12%), oval (31.25%), pinhole (9.37%) and irregular (6.25%), while left-sided FS shapes were round (46.87%), oval (34.37%), pinhole (12.5%) and irregular (6.25%). When considered bilaterally, they reported round shapes at 50%, oval at 32.81%, pinhole at 10.94% and irregular at 6.25% [24]. Consistent with the findings of the aforementioned studies, the present study also found that the majority of FS shapes were round (80.5%), and any irregularly shaped FS was not observed.

Regarding the position of the FS in relation to the spine of the sphenoid, Sophia MM and Kalpana R, recorded the position of the FS as lateral to the spine in 16.25% of cases on the right-side and 10% on the left-side, while it was medial to the spine in 2.5% and 1.25% on the right and left-sides, respectively; the remainder were anteromedial to the spine [19].

In the present study, the authors found the FS to be lateral to the spine in 32%, medial to the spine in 54%, bilaterally within the spine in three cases (only in males), and unilaterally within the spine in 11%.

Septations were found by Sophia MM and Kalpana R, [19]. They also identified duplications in FS in three cases. Additionally, 13.3% of cases with duplicate FS were recorded by Sugano GT et al., [23]. The mean and standard deviation of length, width and distance of FS from the spine of the sphenoid on both sides with that of previous studies conducted was compared [Table/Fig-8].

Study (year)	Place of study (sample size, N)	Length (mm) (Mean±SD)		Width (mm) (Mean±SD)	
		Right	Left	Right	Left
Chandan CB et al., [15] (2024)	Bihar (100)	3.91±1.54	3.30±1.39	3.18±1.20	2.91±1.41
Vasanthi A et al., [22] (2024)	Andhra Pradesh (96)	2.72±0.42	2.56±0.56	2.16±0.29	2.08±0.22
Worku GM and Clarke E [24] (2020)	Ethiopia (64)	3.72±1.33	3.37±1.26	3.30±1.19	2.97±1.15
Chanda C et al., [20] (2019)	Jharkhand (30)	2.05±1.09	2.05±0.60	1.33±0.90	1.67±0.53
Somesh MS et al., [18] (2015)	Karnataka (82)	3.42±0.64	3.34±0.66	2.69±0.49	2.68±0.47
Sophia MM and Kalpana R, [19] (2015)	Tamil Nadu (40)	2.37±0.60	2.32±0.67	2.32±0.28	1.73±0.34
Srimani P et al., [21] (2014)	West Bengal (40)	2.01±0.31	2.03±0.29	1.65±0.25	1.70±0.19
Present study (2024)	West Bengal (100)	2.89±0.87	2.64±0.80	2.22±0.60	2.25±0.62

[Table/Fig-8]: Comparison of the mean and standard deviation of length, width and distance of FS from the spine of the sphenoid on both sides with that of previous studies conducted.

In 2024, Vasanthi A et al., found the mean±SD of length to be 2.82±0.61 mm and 2.24±0.53 mm, and for width, it was 2.06±0.36 mm and 1.96±0.28 mm in males and females, respectively [22].

In 2022, Sugano GT et al., found the mean length and width on the right-side for males to be 8.48 mm and 2.69 mm, and for females, it was 7.72 mm and 2.45 mm [23]. For the left-side, the length and width for males were recorded as 8.26 mm and 2.62 mm, while for females, they were 9.09 mm and 2.89 mm. No standard deviation was measured by them. They did not find any significant difference between males and females on either side of FS. However, in our present study, we found a significant statistical difference in the width of the right-side between males and females (p-value=0.0396) and an extremely statistically significant difference in the length of the right-side (p-value=0.0001).

The distance between the spine of the sphenoid and FS was not measured in any previous study. In the present study, the authors found this distance to be statistically significant (p-value=0.0338) on the right-side for both males and females.

The variations in the morphology and morphometry of FS may be due to alterations in the course of the structures passing through it. Considering the tremendous clinical importance that this foramen carries, thorough knowledge of it is necessary for successful middle cranial fossa surgeries.

The study could be strengthened by increasing the sample size and including more samples to study racial and ethnic variations.

Additionally, correlating the findings of the study with radiological findings and with other foramina of the middle cranial fossa would further enrich the study.

Limitation(s)

The major limitation of the present study was the scarcity of specimens. Additionally, the skulls under study were of unknown age, which was a significant drawback of the research.

CONCLUSION(S)

The variations in size and shape of the FS may be part of an ongoing evolutionary process. The present study was aimed to provide a clear understanding of FS anatomy and its morphometry in the South Bengal population. Knowledge of this is very helpful for surgeons dealing with various middle cranial fossa pathologies. Good preoperative imaging of the foramen is recommended to avoid injury to its contents. Understanding these variations holds special importance for surgeons and neurosurgeons to prevent mortality and morbidity.

REFERENCES

[1] Krayenbühl N, Isolan GR, Al-Mefty O. The foramen spinosum: A landmark in middle fossa surgery. Neurosurg Rev. 2008;31:397-401.
[2] Reymond J, Charuta A, Wysocki J. The morphology and morphometry of the foramina of the greater wing of the human sphenoid bone. Folia Morphol. 2005;65(4):396-99.
[3] Ustan ME, Buyukmumcu M,Ulku CH, Guney O, Salbacak A. Transzygomatic subtemporal approach for middle meningeal artery to P2 segment of posterior cerebral artery bypass; an anatomical and technical study. Skull base. 2006;16(1):39-44.
[4] Kwathai L, Namonta K, Rungruang T, Chaisuksunt V, Aphinhasmit W, Chompoopong S. Anatomic and morphometric consideration for external landmarks of foramen spinosum in thai dry skulls. Siriraj Med. J, 2012;64(Suppl):S26-S29.
[5] Ellwanger JH, Campos Dd. Abnormality of the foramen spinosum due to a variation in the trajectory of the middle meningeal artery: a case report in human. J Neurol Surg Rep. 2013;74(2):73-76.
[6] Shotar E, Premat K, Lenck S, Degos V, Marijon P, Pouvelle A, et al. Angiographic anatomy of the middle meningeal artery in relation to chronic subdural hematoma embolization. Clin Neuroradiol. 2022;32:57-67.
[7] Rai AL, Gupta N, Rohtagi R. Anatomical variations of foramen spinosum. Innovative Journal of Medical and Health Sciences. 2012;2(5):86-88.
[8] Carvalho BV, Gaiotti JO, Diniz RLFC, Ribeiro MA, Motta EGPC, Moreira W. Persistence of stapedial artery: A case report. Radiol Bras. 2013;46:184-86.
[9] Lazarus L, Naidoo N, Satyapal KS. An osteometric evaluation of the foramen spinosum and venosum. Int J Morphol. 2015;33:452-58.
[10] Dilenge D, Ascherl GF. Variations of the ophthalmic and middle meningeal arteries: Relation to the embryonic stapedial artery. Am J Neuroradiol. 1980;1:45-54.
[11] Kuruvilla A, Aguwa AN, Lee AW, Xavier AR. Anomalous origin of the middle meningeal artery from the posterior inferior cerebellar artery. J Neuroimaging. 2011;21:269-72.
[12] Hoskin KL, Zagami AS, Goadsby PJ. Stimulation of the middle meningeal artery leads to Fos expression in the trigeminocervical nucleus: A comparative study of monkey and cat. J Anat. 1999;194:579-88.
[13] Lang J, Maier R, Scafhauser O. Postnatal enlargement of the foramina rotundum, ovaleet spinosum and their topographical changes. Anat Anaz. 1984;156:351-87.
[14] Berge JK, Bergman RA. Variations in size and symmetry of foramina of the human skull. Clin Anat. 2001;14(6):406-13.
[15] Chandan CB, Prasad P, Kumari P, Kumar A. A morphological and morphometric study of Foramen Spinosum in North Indian adult skulls. Azerbaijan Pharmaceutical and Pharmacotherapy Journal. 2024;23(3):01-05.
[16] Desai SD, Shaik SH, Shepur MP, Thomas ST, Mavishetter GF, Haseena S. Morphometric analysis of foramen spinosum in South Indian skulls. Journal of Pharmaceutical Sciences and Research. 2012;4(12):2022-24.
[17] Saheb SH, Khaleel N, Havaldar PP, Shruthi BN. Morphological and morphometric study of foramen spinosum. Int Journal of Anatomy and Research. 2017;5(4.1)4523-26.
[18] Somesh MS, Murlimanju BV, Krisnamurthy A, Sridevi HB. An anatomical study of foramen spinosum in South Indian dry skulls with its emphasis on morphology and morphometry. Int Journal of Anatomy and Research. 2015;3(2):1034-38.
[19] Sophia MM, Kalpana R. A study on foramen spinosum. International Journal of Health Sciences and Research. 2015;5(2):187-93.
[20] Chanda C, Singh KKP, Ranjan R, Prasad R. Anatomical variations of foramen spinosum in adult human skulls of Jharkhand population. IOSR Journal of Dental and Medical Sciences. 2019;1894:01-07.
[21] Srimani P, Mukherjee P, Sarkar M, Roy H, Sengupta SK, Sarkar AN, et al. Foramina in Allisphenoid-an observational study on their osseomorphology and morphometry. International journal of Anatomy, Radiology and surgery. 2014;3(1):01-06.
[22] Vasanthi A, Sushma M, Sailaja LL, Saheb SH. Morphological and morphometric study on foramen spinosum and its clinical importance. African Journal of Biological Sciences. 2024;6(1):6638-41.
[23] Sugano GT, Pauris CC, Silva YBE, Pandini FE, Palermo RBS, Buchaim DV, et al. Topographic and morphometric study of the foramen spinosum of the skull and its clinical correlation. Medicina. 2022;58(12):1740.
[24] Worku GM, Clarke E. Morphometric analysis of the foramen spinosum and variations of it shape, number and relation to the spine of the sphenoid bone. Translational Research in Anatomy. 2021;(24):01-06.

PARTICULARS OF CONTRIBUTORS:
1. Assistant Professor, Department of Anatomy, IPGMER, Kolkata, West Bengal, India.
2. Demonstrator, Department of Anatomy, IPGMER, Kolkata, West Bengal, India.
3. Assistant Professor, Department of Anatomy, IPGMER, Kolkata, West Bengal, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Soumali Biswas,
C/o Sanat Kumar Majumdar, Opposite Duilya Panchayat Office, Charaktala,
Mourigram, Howrah-711302, West Bengal, India.
E-mail: drsoumali.biswas26@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Aug 05, 2024
- Manual Googling: Dec 03, 2024
- iThenticate Software: Dec 11, 2024 (19%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: Aug 03, 2024
Date of Peer Review: Oct 12, 2024
Date of Acceptance: Dec 12, 2024
Date of Publishing: Jan 01, 2025