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Original article

Anatomy Section

Foramina in Alisphenoid - An Observational Study on Their Osseo-Morphology and Morphometry

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ABSTRACT

Background: Among various foramina affecting alisphenoid (greater wings of sphenoid), Foramen ovale (FO) and Foramen spinosum (FS) are two important foramina concerned to different advanced diagnostic and therapeutic procedures involving middle cranial fossa like placement of electrodes for EEG analysis, trigeminal radiofrequency rhizotomy, microsurgical procedure using middle meningeal artery as graft etc.

Objective: FO and FS vary in shape and size. That's why; we performed this study to provide data from the region of West Bengal, India.

Methods: Forty adult human skulls having 80 intact greater wings collected from different medical colleges in Kolkata were meticulously examined for both morphologic and morphometric parameters about the foramina like shape, anteroposterior diameter, transverse diameter, any bony outgrowth affecting their margins by digital photographs and electronic caliper.

Result: Regarding FO, it was not classically oval in 42.5% cases, somewhere it was irregular (6.25%) or semilunar (2.5%) also. FS other than variation in shape and size was found either partially (3.75%) or completely divided (5%). Emissary sphenoidal foramen was also observed in 5% cases. Appropriate statistical analysis was done.

Conclusion: Considering clinical importance, recognition and knowledge of such possible variation will be definitely helpful in the field of diagnostic medicine and neurosurgery.

Keywords: Foramen ovale, Foramen spinosum, Alisphenoid, Morphology, Morphometry

INTRODUCTION

Foramen ovale (FO) and Foramen spinosum (FS) are two important foramina present at the posterolateral aspect of greater wing of sphenoid which communicate between middle cranial cavity and infratemporal fossa. FO is as an oval shaped foramen present at greater wing of sphenoid posterolateral to foramen rotudum. It gives passage to a number of important structures like mandibular division of trigeminal nerve, accessory meningeal artery, lesser petrosal nerve and emissary vein [1]. Lesser petrosal nerve sometimes does not pass through the above foramen. In such case, canaliculus innominatus is present on the bony bar between FO and FS which transmits the lesser petrosal nerve. Emissary sphenoidal foramen i.e. foramen of Vesalii is sometimes present medial to FO which allows passage to the emissary vein connecting the cavernous sinus to pteygoid venous plexus. FS has been detected as small opening situated posterolateral to FO close to the spine of sphenoid. It transmits middle meningeal artery, nervous spinosus and occasionally posterior trunk of middle meningeal sinus [2]. Middle meningeal artery may arise from ophthalmic artery instead of maxillary artery and enter into cranial cavity through superior orbital fissure in which, FS may be absent [3, 4]. Early division of middle meningeal artery before passing through FS may be the cause of duplication of FS [3-5].

As FO enables access to mandibular division of trigeminal nerve, it has been considered as a portal for trigeminal radiofrequency rhizotomy for the treatment of trigeminal neuralgia [6]. FO used as commonest diagnostic route while performing electroencephalographic analysis of seizure can provide precise information for persons undergoing selective amygdalohippocampectomy [7]. Percutaneous biopsy of cavernous sinus pathology is also done through this route with 84% accuracy [8]. Moreover, FO allows different CT-guided transfacial FNAC technique without approaching for open surgical biopsy to diagnose squamous cell carcinoma, meningioma and Meckel cave's lesion [9]. FO has been found to be an important route of spread of nasopharyngeal carcinoma into cranial cavity [10].

On the other hand, FS has been described as an important landmark for microsurgical procedure involving middle cranial fossa particularly when using middle meningeal artery as a donor graft for either internal carotid artery or posterior cerebral artery bypass surgery [11-13]. Hence detailed anatomical knowledge including developmental aspect is really worthwhile as far as neurosurgery and radiology is concerned.

As per development of sphenoid bone is concerned, it is derived from both intramembranous and intracartilaginous ossification centres. Out of eight post sphenoid ossification centres, first ossification centre appears for greater wing of sphenoid i.e. Alisphenoid at about 8 weak of intrauterine life by membranous ossification. But FO is bordered around the passage for mandibular nerve and other structures passing through it by deposition of cartlilage [1]. FO can be observed earliest by 7th month of intrauterine life and become well visualized latest by three years; on the other hand, FS is visualized earliest by eight month after birth and gradually becomes prominent latest by seven year. In this regard, postnatal changes of FS have been described by Lang et al., [14]. Thus, developmental background of sphenoid bone may explain various asymmetries in shape, size including different bony outgrowth affecting the margins of both these foramina [14].

Available literatures reveal that both FO and FS can exhibit a wide range of variations, but no such data were observed from the region of West Bengal, India. Therefore, we performed this study in order to establish a source of reliable data and thus minimizing hazards of modern diagnostic and therapeutic procedures involving middle cranial fossa.

OBJECTIVE

1. To explore the variation in osseo-morphology of foramen ovale and foramen spinosum present in the sphenoid bones studied in different medical colleges of Kolkata.
2. To assess the variations of different morphometric measurements of foramen ovale and foramen spinosum present in the sphenoid bones studied in different medical colleges of Kolkata.

MATERIALS AND METHODS

The study was conducted in the department of Anatomy, R.G. Kar Medical College, Kolkata, India on 40 dry adult human skulls of unknown sex with removed calvaria having 80 intact greater wings of sphenoid, though some of them were collected from different medical colleges in Kolkata. Skulls with poor condition particularly affecting either or both greater wings were excluded in this study.

Cerebral surface of both greater wings were carefully observed to locate the presence of both foramina and patency were confirmed by passing stainless steel-wire through them to reach the infratemporal fossa. Then, shapes of the foramina were observed meticulously by naked eye examination. Maximum antero-posterior diameter (length) and transverse diameter (width) were measured by placing divider across the margins of the foramina. Electronic digital caliper was applied for taking the final reading nearest to millimeter (mm). Photographs were taken by Canon digital camera using optimal transmitted light for all morphological analysis and to confirm presence of any irregularity in the form of bony processes like spicule or notch affecting the margin. Areas of foramina were calculated by using the formula of $\varpi \times$ length $\times$ width /4 [15]. The findings were tabulated and appropriate statistical analysis was done using SPSS (version 12.0) software under supervision of statistician. Significance was considered when p- value ≤ 0.05.

RESULTS

Present study was done on bilateral sides of 40 skulls and revealed following data.

Morphologic analysis

We observed FO of various shapes like oval (57.5%), almond (21.25%), elliptical (6.25%), irregular (6.25%), round (3.75%), semilunar (2.5%) and intercommunicating FO with FS (2.5%). Among 80 sides, oval shaped foramen [Table/Fig-1] was found in 46 sides (right – 24 and left 22), almond shaped [Table/Fig-2] in 17 sides (right – 9 and left 8), elliptical [Table/Fig-3] in 5 sides (right – 3 and left 2), irregular [Table/Fig-4] in 5 sides (right 2 and left 3), round [Table/Fig-5] in 3 sides (right – 1 and left 2), semilunar [Table/Fig-6] in 2 sides (right 1 and left 1) and intercommunicating FO with FS [Table/Fig-7-9]. In case of oval shaped foramen, bilateral involvement was found in 30%, whereas bilateral almond and elliptical shaped foramina were in 10% and 1% skull respectively. Among irregular shaped foramina, we observed various bony outgrowths in the form of bony spine and notch. We also noted that the margins of some foramina were thicker as compared to others.

In the present study, occurrence of emissary sphenoidal foramen was observed in 4 cases (2 on left and 2 on right side, n= 80).

Regarding FS, incidence of round (51.25%), oval (30%), irregular shaped and intercommunicating with FO (7.5%) and very small i.e. ≤ 1mm. diameter (2.5%) have been found. Among 40 skulls 35% skull showed bilateral round foramen while 15% bilateral oval foramen. Bony bar was clearly visible arising from margins of FS which led to compartmentalize the foramen either partially (3.75%) or completely into double foramina (5%). We also observed both FO and FS as intercommunicating in 2 (2.5%) cases (n=80) as the margins of both foramina were incomplete.

Morphometric analysis

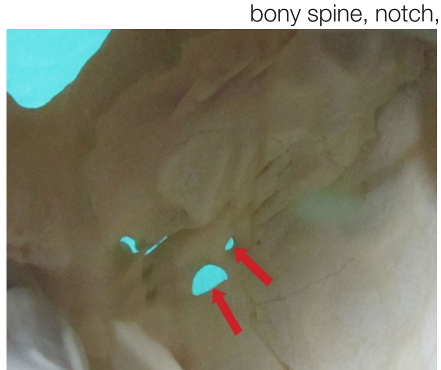
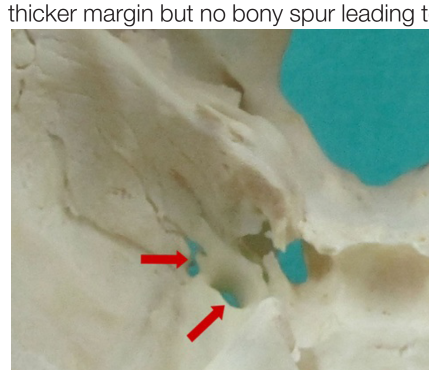
In our study, length of FO was varying from 5.6 - 10.1 mm on right side and 5.6 - 10.3 mm on the left side with mean of 7.75 ± 1.16 mm and 7.70 ±1.14 mm respectively. On the right side, the width was from 2.6 -5.6 mm and on the left side; the value was from 2.5 - 6.1 mm with mean of 3.41 ± 0.70 mm and 3.56 ± 0.89 mm respectively. Area of FO was calculated as previously stated and found as 20.93 ± 6.00 for right side and 21.62 ± 6.60 for left side [Table/Fig-10]. The observed mean values on both sides were not statistically significant ($p \geq 0.05$). But, positive correlation was observed between both length & width with area on both sides of FO [Table/Fig-11].

In the present study, length of right FS was varying from 1.6 - 2.9 mm while on the left side it was 1.6 -2.6 mm with a mean of 2.01 ± 0.31 mm and 2.03 ± 0.29 mm respectively. The width was between 1.2 - 2.0 mm on right side and 1.3 - 2.0 mm on left side with a mean of 1.65 ±0.25 mm and 1.70 ± 0.19 mm respectively. Area of FS was observed as 2.62 ± 0.67 for right side and 2.72 ± 0.53 for left side [Table/Fig-11]. In this case also, difference between observed mean values on both sides was not statistically significant ($p \geq 0.05$). But there was a positive correlation between length & width of FS with area of same side [Table/Fig-12].

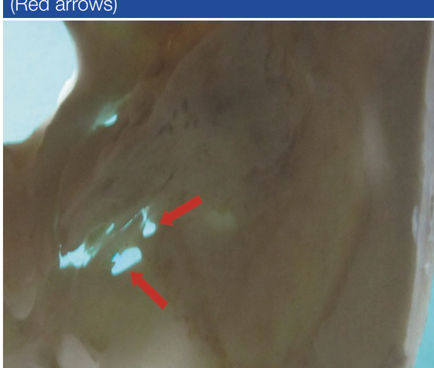
DISCUSSION

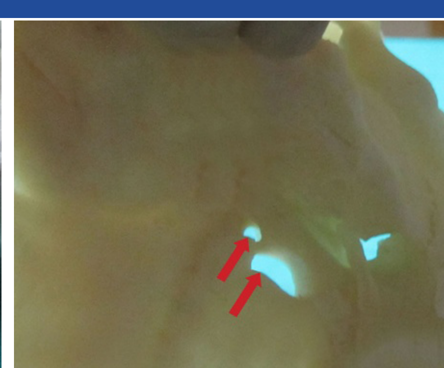
Morphologic and morphometric variation of FO and FS is of great clinical importance in the field of modern diagnostic medicine and neurosurgery involving middle cranial fossa. Regarding the variation of shape, Ray et al., informed FO as almond shaped (34.2%) followed by round (2.8%) and slit like (1.4%) next to classical oval shaped foramen (61.4%) out of total 35 skulls [16].

In addition to above mentioned shape of FO, Somesh and Desai et al., described irregular shaped foramina in their studies [17,18]. Both the results are comparable to the present study. Though Agarwal et al., favoured only for classical oval shaped FO [19]. Intercommunicating FO and FS with incomplete margins as we have mentioned in our study was also confirmed by earlier reports [3, 5]. Khan et al., described a semilunar pattern of FO [5] similar to the present study. According to Tubbs and Reymond et al., ossification of pterygospinous and pterygoalar ligaments may result into 2-3 divisible components of FO [20, 21]. Even absence of typical FO was reported by Skrzat et al., [22], but neither of these findings were present in this study. But regarding the margin of FO, we observed various bony outgrowths in the form of bony spine, notch, thicker margin but no bony spur leading to

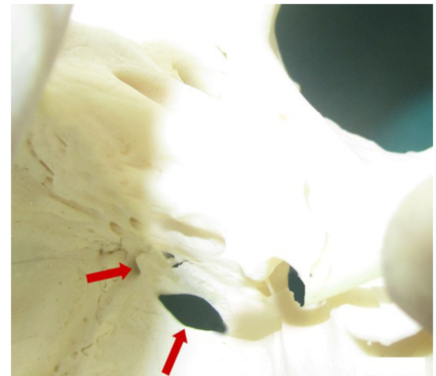
[Table/Fig-1]: Middle cranial fossa showing oval foramen ovale and small round foramen spinosum (Red arrows)
[Table/Fig-2]: Middle cranial fossa showing almond shaped foramen ovale and small oval foramen spinosum (Red arrows)
[Table/Fig-3]: Middle cranial fossa showing elliptical foramen ovale and foramen spinosum incompletely divided by bony spicules arising from margin (Red arrows)





[Table/Fig-4]: Middle cranial fossa showing foramen ovale with bony spicule and a notch arising from the posterior margin and foramen spinosum with irregular and incomplete margin (Red arrows)
[Table/Fig-5]: Middle cranial fossa showing round foramen ovale and round foramen spinosum (Red arrows)
[Table/Fig-6]: Middle cranial fossa showing semilunar foramen ovale and semilunar foramen spinosum (Red arrows)





[Table/Fig-7]: Middle cranial fossa showing foramen ovale communicating to foramen spinosum (Red arrows) with an emissary sphenoidal foramen
[Table/Fig-8]: Middle cranial fossa showing elliptical foramen ovale and foramen spinosums divided in two by a bony bar (Red arrows)
[Table/Fig-9]: Middle cranial fossa showing elliptical foramen ovale and one very small foramen spinosum (Red arrows)

Parameters		Foramen ovale		Foramen spinosum	
		Right	Left	Right	Left
Length (mm.)	Maximum	10.10	10.30	2.90	2.60
	Minimum	5.60	5.60	1.60	1.60
	Mean ± SD	7.75 ± 1.16	7.70 ±1.14	2.01 ± 0.31	2.03 ± 0.29
Width (mm.)	Maximum	5.60	6.10	2.00	2.00
	Minimum	2.60	2.50	1.20	1.30
	Mean ± SD	3.41± 0.70	3.56 ± 0.89	1.65 ± 0.25	1.70 ± 0.19
Area (Sq. mm.)	Maximum	37.29	40.45	4.33	3.93
	Minimum	12.76	12.51	1.70	1.76
	Mean ± SD	20.93 ± 6.00	21.62 ± 6.60	2.62 ± 0.67	2.72 ± 0.53

[Table/Fig-10]: Dimensions of Foramen ovale and Foramen spinosum

		LTL	LTW	LTA	RTL	RTW	RTA
LTL	Pearson Correlation	1	.136	.675 (**)	.911 (**)	.213	.687 (**)
	Sig. (2-tailed)	.	.404	.000	.000	.187	.000
LTW	Pearson Correlation	.136	1	.812 (**)	.262	.434 (**)	.477 (**)
	Sig. (2-tailed)	.404	.	.000	.102	.005	.002
LTA	Pearson Correlation	.675 (**)	.812 (**)	1	.712 (**)	.481 (**)	.777 (**)
	Sig. (2-tailed)	.000	.000	.	.000	.002	.000
RTL	Pearson Correlation	.911 (**)	.262	.712 (**)	1	.238	.749 (**)
	Sig. (2-tailed)	.000	.102	.000	.	.139	.000
RTW	Pearson Correlation	.213	.434 (**)	.481 (**)	.238	1	.810 (**)
	Sig. (2-tailed)	.187	.005	.002	.139	.	.000
RTA	Pearson Correlation	.687 (**)	.477 (**)	.777 (**)	.749 (**)	.810 (**)	1
	Sig. (2-tailed)	.000	.002	.000	.000	.000	.

[Table/Fig-11]: Relation between continuous variables of Foramen ovale by Pearson Correlation. **Correlation is significant at the 0.01 level (2-tailed). LTL: Left length, LTW: Left width, LTA: Left area, RTL: Right length, RTW: Right width, RTA: Right area

		LTL	LTW	LTA	RTL	RTW	RTA
LTL	Pearson Correlation	1	.205	.818 (**)	.272	-.021	.148
	Sig. (2-tailed)	.	.253	.000	.162	.914	.453
LTW	Pearson Correlation	.205	1	.725 (**)	.235	.108	.227
	Sig. (2-tailed)	.253	.	.000	.229	.585	.246
LTA	Pearson Correlation	.818 (**)	.725 (**)	1	.349	.060	.257
	Sig. (2-tailed)	.000	.000	.	.069	.762	.187
RTL	Pearson Correlation	.272	.235	.349	1	.323	.828 (**)
	Sig. (2-tailed)	.162	.229	.069	.	.072	.000
RTW	Pearson Correlation	-.021	.108	.060	.323	1	.794 (**)
	Sig. (2-tailed)	.914	.585	.762	.072	.	.000
RTA	Pearson Correlation	.148	.227	.257	.828 (**)	.794 (**)	1
	Sig. (2-tailed)	.453	.246	.187	.000	.000	.

[Table/Fig-12]: Relation between continuous variables of Foramen spinosum by Pearson Correlation. ** Correlation is significant at the 0.01 level (2-tailed). LTL: Left length, LTW: Left width, LTA: Left area, RTL: Right length, RTW: Right width, RTA: Right area division of FO as described in earlier studies [3, 16, 17].

While studying other foramina in close proximity to FO, emissary sphenoidal foramen (foramen of Vesalii) is considered to be present in approximately in 40% skull [1]. When it is present, surgical approach through FO may cause puncture of cavernous sinus, Meckel's cave resulting in bleeding in temporal lobe [23, 24]. In the present study, occurrence of emissary sphenoidal foramen was observed unilaterally in 5% cases.

Lindblom K [25] studied vascular channels of the skull and informed that FS was very small or altogether absent which has been later on confirmed by means of high resolution CT as absent FS in 3.2% cases [26]. But in this study, we observed FS as a permanent feature in both sides of skull similar to the findings reported in other studies [21, 27]. In the present study, other than round, oval and irregular shaped FS, both incompletely divided FS (5 % cases) and completely divided leading to double FS (3.75% cases) were observed like previous studies [3,4,5,25]. The finding of very small (≤1mm in diameter) foramina in 2.5% cases observed in the present study shows similarity with study done by Rai et al., also [4]. Wood Jones [28] described FS as more or less incomplete in 44% cases while confluence of FS with FO was reported in 3 cases out of 100 skulls by Karan et al., [3] and in 1 case among 25 skulls by Khan et al., [5] similar to our observations in which we found irregular shaped FS intercommunicating with adjacent FO in 2.5% cases.

Developmental studies done by Yanagi S [15] revealed that mean length of FO was 3.85mm and 7.2mm and mean width was 1.81mm and 3.7mm in newborn and adult respectively and in fluoroscopically assisted study targeting FO has reported average length and width as 6.9 and 3.4 mm for right; 6.8 and 3.8 mm for left side [29]. Though Neto et al., [30] has pointed out greater incidence of trigeminal neuralgia on right side due to significant narrowing of right sided FO but statistical significant differences for mean values of both sides were neither observed by other studies [16, 17, 19, 27] nor by us. In the present study, area was calculated as previous study [17,18,31] and we observed mean area of 20.93 ± 6.00 and 21.62 ± 6.60 for right and left side respectively.

Lang et al., has already mentioned in their studies on postnatal enlargement and topographical changes of FS the length of FS as about 2.25mm in newborn and 2.56mm in adult with width extended from 1.05-2mm in adults [14] whereas mean diameter was observed as 2.3-2.5mm on right side and 2.4-2.3mm on left side in male and female skulls respectively by Karan et al., [3]. In this regard, our observations corroborated with other studies [4,19,27].

Different studies have shown morphometric variation of both foramina between male and female skull, but as sex determination of the skulls were not done, we did not get such type of data in the present study [3,4,16].

CONCLUSION

Variations in shape, size and irregularity affecting the margins of both FO and FS as observed in our study can be attributed to the abnormality during ossification of alisphenoid from initial to final stage of ring formation. Existence of such altered morphology may be due to variation in the course of the structures passing through these foramina. Considering the immense clinical importance, recognition and knowledge of their possible variation is really worthwhile as it could interfere during approach to middle cranial fossa for diagnosis of various vascular pathology and performing safe surgery of trigeminal neuralgia.

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