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Review Article

Anatomy Section

Literature Review on Morphology and Morphometry of Foramen Ovale in Indian Skulls

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ABSTRACT

Foramen ovale is seen in the base of the skull connecting the infratemporal fossa and middle cranial fossa. Knowledge of the exact location and dimensions of foramen ovale is essential for trigeminal rhizotomy, electroencephalogram of the temporal lobe and endonasal endoscopic trans-sphenoidal approach to the infratemporal fossa. In this literature review, articles reporting morphology, morphometry, and variations of foramen ovale in Indian skulls from standard databases between 1979 and 2022 were selected. The sample size ranged between 20 and 250 skulls. The common shape observed was oval (96.9%) and duplication of foramen ovale was seen commonly on the right-side. The presence of accessory bony structures, namely spine, tubercle, spur, septa and bar was reported but was difficult to compare due to a lack of uniform classification. The length, breadth, and area of foramen ovale ranged from 5.0-8.9 mm, 3.1-6.0 mm, and 19.1-34.2 mm^2, respectively. In the majority of the studies, no significant difference was observed in these parameters between the sides and between the sexes. These data will be useful while attempting surgical or invasive procedures in the skull base of Indian subjects and help to avoid damage to the structures passing through the foramen ovale and the resulting complications.

Keywords: Anatomy, Duplication, Measurements, Variations

INTRODUCTION

The human skull protects the brain and permits it to communicate with other structures. Even though skulls appear similar within a species, they are not identical. Many variations can be observed in the skulls belonging to different populations, age groups and sexes [1]. This intrigues and inspires scientists till date to revisit the skull for further investigation. Among the various structures, the foramina present in the skull are studied for their morphology, morphometry, and variations. Amidst the numerous foramina, foramen ovale is an oval-shaped passage seen in the greater wing of the sphenoid bone with foramen spinosum present posterolateral to it and foramen lacerum present medial to it [2]. Foramen ovale transmits the mandibular nerve, emissary vein, accessory meningeal artery, and lesser petrosal nerve. The exact location and dimensions of the foramen ovale play a vital role as a landmark in endonasal endoscopic transpterygoid approach to the infratemporal fossa, parapharyngeal space, and lateral skull base and help during diagnostic and therapeutic procedures like temporal lobe encephalogram, a percutaneous biopsy of parasellar lesions, percutaneous trigeminal rhizotomy [3]. Knowledge of topography and variations of the foramen ovale will enable clinicians to avoid feasible injury and resulting complications to structures passing through the foramen ovale and in its vicinity by avoiding multiple attempts during cannulation of the foramen [4].

There is plenty of literature available on the morphology and morphometry of foramen ovale on Indian population. Each study has been carried out in a particular population of Indian subcontinent with widely varying sample size. Few selective morphometric parameters were studied in addition to the variations of foramen ovale. However, there is no uniformity in parameters studied and terminologies used to describe the accessory bony structure. There is no review available pooling the available data to arrive at an informed decision about the morphometry of foramen ovale in Indian population. Therefore, the present study reviews the morphology, morphometry, and variations of foramen ovale and its related accessory bony structures reported in the Indian population. This review would be of use to clinicians to plan the diagnostic and therapeutic procedures and researchers to compare the Indian data on foramen ovale with other races.

Literature Search

Articles on foramen ovale were searched in the following databases: PubMed, Science Direct, and Google Scholar between 1979 and 2022. Case reports and review articles were excluded from the study. Studies employing adult Indian dry skulls were included in the study. The place of study, sample size, instruments used for measurement, and the statistical methods employed were recorded. Morphological features namely shape and symmetry and variations like duplication of the foramen, and the presence of accessory bony structures (spine, tubercle, plate, spur, septa, and bar) reported in the studies were tabulated for comparison. Morphometric parameters of foramen ovale, namely length, width, and the area reported in the studies were tabulated. These data were carefully analysed for their concordance and for the presence of possible discordance.

Development of foramen ovale: Foramen transmits structures in and out of the skull. During embryological development, foramina present in the base of the skull are formed in species-specific topographical locations by endochondral ossification surrounding the developing neural or vascular structures. The size, shape and area of the foramina suggest the functional status of the neurovascular structures passing through them [5]. Evolutionarily, the foramen ovale is acquired during the maturation of the mammalian embryo, and the trigeminal ganglion exists as an extracranial structure until the development of the foramen ovale [6].

During development, a true foramen ovale for the passage of the mandibular nerve develops as the nerve courses between the internal carotid artery and the stapedial artery in the greater wing of the sphenoid. The foramen ovale starts as a groove, later forms a notch and ends up in a foramen [7]. Therefore, in humans, the foramen ovale is located on the greater wing of the sphenoid bone. All existing literature reported the presence of foramen ovale bilaterally. Except for two studies, each reported one case of unilateral absence of foramen ovale on the right-side [8] and the left-side [9].

Geographical data: A review of the literature revealed 44 studies on foramen ovale using adult skulls of Indian origin ranging from the year 1979 to 2022. The maximum number of studies were reported in the years 2014 and 2017 (n=6). Among the different states and union

territories of India, maximum studies were reported from Karnataka (n=seven) [2,9-14], followed by Tamil Nadu (n=six) [15-20] and Maharashtra (n=five) [8,21-24]. Three studies each came from Gujarat [25-27] and Kerala [28-30]. Two studies were reported from Andhra Pradesh [31,32], Delhi [33,34], Punjab [35,36], Uttar Pradesh [37,38] and West Bengal [39,40]. One study each from Bihar [41], Jammu and Kashmir [42], Jharkhand [43], Madhya Pradesh [44], Odisha [45], Pondicherry [46], Rajasthan [47], Sikkim [48] and Telangana [49] was published. One article did not explicitly stated the state from which the bones were collected other than mentioning it as of South Indian [50] origin [Table/Fig-1].

Sample size: Study samples ranged from a minimum of 20 skulls [42] to a maximum of 250 skulls [50]. There were around 13 studies with less than 50 samples [14-17,19,31,36,37,39-43], 16 studies with a sample size between 50 and 100 [2,9,13,18,21,22,25,29, 30,34,35,38,45,47-49] and 13 studies with a sample size between 100 and 150 [8,10-12,20,23,24,26-28,32,33,46]. There were two studies [44,50] each with 200 and 250 samples [Table/Fig-1]. All these studies were carried out on dry skulls and the usage of imaging modalities was scarce. A study done by Gupta T and Gupta SK was the only exception where X-rays of dry adult skulls were used for recording the measurements between foramen ovale and various anatomical landmarks to aid in intraoperative radiological imaging [35]. A large number of studies had sample sizes between 50 and 100 skulls. This could be ascribed to the mandatory National Medical Commission's (formerly Medical Council of India) requirement of 37 (Articulated skeleton-7, Disarticulated-30 sets) and 51 (Articulated skeleton-11, Disarticulated-40 sets) skulls for the admission of 150 and 250 students respectively in Indian medical schools [51,52].

Instruments employed: A divider and ruler, a vernier caliper, a digital vernier caliper and computerised software were used for measurement. A study done by Kumar A et al., used photography and Image J software for measurement [34]. Among various studies, variations observed between similar parameters may be due to the difference in the accuracy level of the instrument used. Therefore, employing imaging modalities or computerised software will be beneficial to obtain precise and consistent results.

Shape of foramen ovale: Various shapes of foramen ovale are reported. Namely-oval, almond, round, D-shaped, elongated, slit-like, triangular, irregular, semilunar, elliptical, pear shaped, comma shaped and kidney shaped. In accordance with the name, oval shape is the most common shape ranging as high as 96.9% [18]. However, a study by Daimi S et al., reported 46.2% of D-shaped foramen ovale [21]. Studies reported the decreasing frequency of shape of foramen ovale in the following order: Oval>Almond>Round [Table/Fig-1]. The asymmetrical size and shape of the foramen ovale between the right and left-sides were attributed to the asymmetry of the emissary veins connecting the cavernous sinus and pterygoid venous plexus [53,54]. It could be the plausible reason for the various shapes observed in the foramen ovale.

Duplication of foramen ovale: The duplication of foramen ovale reported in the literature is shown in [Table/Fig-2]. Five studies

Study	Year	Place of study	Sample size	D-shape	Oval	Round	Elon-gated	Slit	Almond	Irregular	Triangular
Daimi S et al., [21]	2011	Maharashtra	90	46.2%	29.9%	12.5%	10.4%	1.0%			
Somesh M et al., [13]	2011	Karnataka	82		56.7%	10.9%			28.7%	3.7%	
Wadhwa A et al., [36]	2012	Punjab	30		69.7%	9.9%		4.9%	14.9%		
Desai S et al., [10]	2012	Karnataka	125		62.8%	11.8%			23.2%	2.2%	
Gupta N and Rai AL [37]	2013	Uttar Pradesh	35		54.3%	8.6%		1.4%	35.7%		
Khairnar KB and Bhusari PA [24]	2013	Maharashtra	100		76.5%	7.0%		6.0%	10.5%		
Srimani P et al., [39]	2014	West Bengal	40		57.5%	3.8%			21.3%	6.3%	
Patel R and Mehta C [27]	2014	Gujarat	100		59.8%	27.5%		1.0%	12.0%		
Patil G and Shishirkumar AD [30]	2014	Kerala	60		70.0%	13.3%		7.5%	5.0%		
Sridhar S et al., [31]	2014	Andhra Pradesh	34		42.6%	5.9%		5.9%		14.7%	7.4%
Murugan M and Saheb SH [50]	2014	South India	250		69.0%	2.0%			29.0%		
John DA and Thenmozhi [16]	2015	Tamil Nadu	30		80.0%	6.7%		1.7%	11.7%		
Raval BB et al., [26]	2015	Gujarat	150		76.5%	1.5%			7.5%	13.5%	1.0%
Mishra SR et al., [38]	2016	Uttar Pradesh	50	2.0%	66.0%	3.0%		4.0%	22.0%	3.0%	
Kumar A et al., [34]	2016	Delhi	50		96.9%		2.0%				2.0%
Devi K and Thenmozhi M [17]	2016	Tamil Nadu	40		56.5%	12.5%			27.5%	3.8%	
Naqshi B et al., [42]	2017	Jammu & Kashmir	20		70.0%	10.0%		2.0%	18.0%		
Katara P et al., [47]	2017	Rajasthan	60		74.0%						
Poornima B et al., [12]	2017	Karnataka	100		60.0%	13.0%		2.0%	25.0%		
Hema L [32]	2017	Andhra Pradesh	100		59.5%	27.5%		1.0%	12.0%		
Ashwini NS and Venkateshu KV [9]	2017	Karnataka	55		66.4%	4.6%			12.7%	16.4%	
Saurjyaranjan D et al., [45]	2018	Odisha	50		70.0%	8.0%			18.0%		4.0%
Kumar B et al., [41]	2018	Bihar	40	1.3%	60.0%	10.0%			28.8%		
Punitha Rani M [20]	2018	Tamil Nadu	100		57.5%	16.0%		9.0%	17.5%		
Sankaran P et al., [18]	2018	Tamil Nadu	64		96.9%	3.1%					
Das S et al., [40]	2019	West Bengal	38	3.9%	53.9%	21.1%			21.1%		
Lakshmi KNV et al., [44]	2019	Madhya Pradesh	200	4.0%	53.5%	11.5%		6.5%	12.5%	2.0%	2.0%
Shankar G and Muthukumaravel N [46]	2019	Pondicherry	100	7.0%	70.0%	4.5%			8.0%	8.5%	
Chanda C et al., [43]	2020	Jharkhand	46	8.7%	76.1%				5.4%		9.8%
Yoganandham J et al., [19]	2023	Tamil Nadu	40	35%	11%	4%	15%	5%	21%	9%	

[Table/Fig-1]: Details of the Indian studies and the prevalence of various shapes of foramen ovale [9,10,12,13,16-21,24,26,27,30-32,34,36-47,50].

Study	Right side	Left side	Bilateral	Total
Daimi S et al., [21]	1.1%	-	-	
Karan B et al., [23]*	-	-	-	3.0%
Chandra Philips X and Bilodi AKS [48]	1.0%	-	-	
Khairnar KB and Bhusari PA [24]*	-	-	-	1.5%
Patil GV et al., [28]	1.4%	2.9%	-	4.3%
Kumar A et al., [34]*	-	-	-	1.0%
Devi K and Thenmozhi M [17]	-	2.5%	-	1.3%
Poornima B et al., [12]	1.0%	-	-	0.5%
Ashwini NS and Venkateshu KV [9]*	-	-	-	2.7%
Saurjyaranjan D et al., [45]	2.0%	-	-	1.0%
Yoganandham J et al., [19]	25%	17.5%	10%	32.5%

[Table/Fig-2]: Duplication of foramen ovale reported in different studies [9,12,17,19,21,23,24,28,34,45,48].
*Studies have stated only the total percentage of duplication and not stated the side of occurrence explicitly

reported the occurrence of duplication of foramen ovale with a higher frequency on the right-side. Irrespective of the side, the occurrence ranged from 0.5-32.5%. Though duplication of foramen ovale was reported in both juvenile and adult skulls, chances for ossification of fibrous bands between the vein and other structures in the foramen ovale increases with age. This postulate by Patil GV et al., probably explains the occurrence of duplication in these adult skulls [28].

Accessory bony structures: Regarding the accessory bony structures, namely spine, tubercle, plate, spur, septa and bar, there was no uniformity in reporting their occurrence. There was no clear protocol to classify the bony projection as spine, spur and tubercle. Similarly, plate, septa and bar also lack clear distinction. As a result, various researchers could label the same bony structure differently. The available data is exhibited in [Table/Fig-3,4].

The occurrence of bony spine ranged between 1.7% [36] and 13.3% [16], bony tubercle ranged between 3.1% [13] and 8.0% [23] and bony plate between 0.5% [46] and 38.0% [38]. The occurrence of bony spur ranged between 0.5% [8] and 47.5% [19] and bony septum between 0.5% [27] and 7.5% [19]. One study by Kumar A et al., reported the presence of a bony bar (2%) [34].

The foramen ovale is located in the greater wing of the sphenoid. During development, primitive foramen lacerum medius present between the alisphenoid, the basisphenoid, and the petrous bone is found to accommodate the mandibular nerve within a sunken notch in its proximity [55]. This primitive foramen lacerum medius transforms to foramen ovale [56]. The epigenetic play of genetically determined growth processes of surrounding muscles, vessels and nerves influencing bone formation may have resulted in variations in the shape and the presence of accessory bony structures in the foramen ovale [57]. Further, structures passing through the foramen ovale might be separated by dense fibrous connective tissues. These fibrous bands might occasionally ossify, creating duplications of foramen ovale or may present as lamina or bony septum dividing the foramen into compartments of unequal sizes [38].

Study	Bony spur			Bony septum			Bar
	Unilateral	Bilateral	Total	Unilateral	Bilateral	Total	Total
Daimi S et al., [21]	4.4%	2.2%	6.7%				
Sharma NA and Garud RS [22]				R 2.0%			
Somesh M et al., [13]				L 1.2%	1.2%		
Karan B [23]			2.0%				
Khairnar KB and Bhusari PA [24]			1.0%				
Kulkarni S and Nikade V [8]			0.5%				
Patel R and Mehta C [27]						0.5%	
Mishra SR et al., [38]						2.0%	
Kumar A et al., [34]			1.0%				2.0%
Rao BS et al., [49]						4.0%	
Ashwini NS and Venkateshu KV [9]			6.4%				
Sankaran P et al., [18]				1.6%		0.8%	
Chanda C et al., [43]						4.4%	
Yoganandham J et al., [19]	R 32.5% L 22.5%	7.5%	47.5%	7.5%		7.5%	

[Table/Fig-4]: Occurrence of bony spur, septum or bar within the margin of foramen ovale [8,9,13,18,19,21-24,27,34,38,43,49].
R: Right; L-Left

Study	Bony spine			Bony tubercle			Bony plate		
	Right	Left	Total	Right	Left	Total	Right	Left	Total
Somesh M et al., [13]	6.1%	2.4%	4.3%	3.7%	2.4%	3.1%			
Wadhwa A et al., [36]	3.3%		1.7%	6.7%	3.3%	4.9%	13.3%	6.7%	9.9%
Karan B et al., [23]						8.0%			4.0%
Chandra Philips X and Bilodi AKS [48]	3.0%	2.0%			1.0%		1.0%	1.0%	
Gupta N and Rai AL [37]			4.3%			5.7%			8.6%
Khairnar KB and Bhusari PA [24]						4.0%			2.0%
John DA and Thenmozhi [16]			13.3%			6.7%			1.7%
Mishra SR et al., [38]			7.0%			5.0%			38.0%
Naqshi B et al., [42]	5.0%	5.0%	5.0%						2.5%
Poornima B et al., [12]			11.0%			5.0%			10.0%
Rao BS et al., [49]			4.0%						
Ashwini NS and Venkateshu KV [9]			3.6%						
Saurjyaranjan D et al., [45]			10.0%			4.0%			
Punitha Rani M [20]	4.0%	7.0%	5.5%	6.0%	6.0%	6.0%	8.0%	8.0%	8.0%
Das S et al., [40]			3.8%						
Lakshmi KNV et al., [44]	2.0%	4.0%	3.0%	8.0%	6.0%	7.0%	10.0%	8.0%	9.0%
Shankar G and Muthukumaravel N [46]							1.0%		0.5%
Chanda C et al., [43]			9.8%						

[Table/Fig-3]: Occurrence of spine, tubercle and bony plates on the margin of foramen ovale [9,12,13,16,20,23,24,36-38,40,42-46,48,49].

The presence of accessory bony structures such as bony spurs, and ossified ligaments in the vicinity of the foramen ovale leads to the narrowing of the foramen resulting in entrapment neuropathy and venous blood flow restriction in the emissary vein leading to ischaemia of the trigeminal ganglion. It also interferes with diagnostic or therapeutic procedures like percutaneous biopsy of parasellar lesions, percutaneous trigeminal rhizotomy performed in that region [58].

Morphometry: Regarding the morphometry of the foramen ovale, the most common measurements made were the length and width of the foramen ovale. Of the 44 Indian studies, except four [16,28,33,42] 40 studies recorded these measurements. Seven studies [10,11,13,19,29,39,44] calculated the area of foramen ovale using the following Radinsky's formula [59].

Area = $\frac{(\pi xLxB)}{4}$ (Where, π=3.1, L is the length and B is the width of foramen ovale)

However, Kumar A et al., used the Image J software for calculating the area [34]. Few studies had estimated the distance between foramen ovale and various other anatomical landmarks like the anterior root of the zygomatic process of the temporal bone, zygomatic point, foramen lacerum and foramen spinosum. The significance of these landmarks and their distance from foramen ovale are out of the scope of this review, these landmarks help in placing radiological markers to gain easy access to the foramen and in placing the electrodes during electroencephalography and treatment of mesial temporal lobe epilepsy.

Very few studies [11,23,34,37,38,50] had considered the sex of the skulls for analysis. Though there were slight differences between the measurements of male and female skulls they were not statistically significant in most of the studies [11,23,37,50] except two [34,38]. Mishra SR et al., [38] and Kumar A et al.,[34] reported that female had significantly higher dimensions and lower area than males, respectively. Only one study used these measurements to predict the sex of the skulls [11]. They have predicted that if the area of foramen ovale was greater than 34.5 mm^2, then it was a male skull and if it is less than 31.6 mm^2, then it was a female skull. Only one study has considered the age of the skulls and found that duplication of foramen ovale was seen only in skulls aged above 40 years (4.29%) and not in younger skulls [28].

The mean length of the foramen ovale ranged between 5.0 (millimetre) mm and 8.9 mm [Table/Fig-5] [32,50]. Only two studies reported the right-side being significantly longer than the left [11,47]. One study reported females had significantly longer foramen than males [38]. Likewise, the mean width of the foramen ovale ranged between 3.1 mm [23,45] and 6.0 mm [14] [Table/Fig-5]. Only two studies reported the right-side being significantly wider than the left [11,47]. One study reported that males had significantly wider foramen than females [38]. The area of foramen ovale ranged between 19.1 mm^2 and 34.2 mm^2 [Table/Fig-5]. Only two studies reported significant differences [34,44]. One study showed the area was higher on the left-side with a male preponderance [34]. The other reported the foramen ovale with a higher area on the right-side [44]. These observations reveal the existence of a wide range in terms of morphometric parameters. However, researchers suggest to suspect trigeminal neurinoma and parasellar tumours in case of foramen ovale larger than the normal range as the tumour growth is associated with the erosion of bone [60].

Liu P et al., found that in trigeminal neuralgia patients without any vascular compressions, the foramen ovale was narrow on the affected side [58]. It reveals that even if the morphometric difference between the sides may not be statistically significant, it can be clinically relevant. Further, to perform a successful trigeminal ganglion block, the shape and size of the foramen ovale are considered the key factors. It is reported that puncturing foramen ovale would be difficult if the width is less than three millimetres [61].

Statistics used in studies: Most studies used Student's t-test to analyse the differences between the right and left-sides and between males and females of metric parameters [2,12,13,17, 20,29,30,37,38,43,44,46,62]. Only one study used Analysis of Variance (ANOVA) for statistical analysis [34]. Only three studies used Pearson's correlation coefficient to calculate the association between different parameters [13,19,39]. Two studies found a strong positive correlation between length as well as width and the area of foramen ovale on both sides [19,39]. However, Somesh M et al., found positive correlation between length and area and found no correlation between width and the area of foramen ovale [13].

Clinical significance: Foramen ovale is a communication between the middle cranial fossa and the infratemporal fossa. Its position helps in approaching the intracranial structures percutaneously

Study	Length (in mm) Mean±S.D		Width (in mm) Mean±S.D		Area (in mm^2) Mean±S.D	
	Right	Left	Right	Left	Right	Left
Sharma NA and Garud RS [22]	7.1		3.9			
Somesh M et al., [13]	7.6±1.2	7.6±1.1†	5.1±0.8	5.2±0.9†	30.8±7.5	31.3±8.3†
Karan B [23]	6.2	5.9	3.4	3.1		
Desai S et al., [10]	8.1±1.4	7.9±1.9	5.3±0.9	5.9±1.0	31.6±9.8	32.1±9.1
Srimani P et al., [39]	7.8±1.2	7.7±1.2†	3.4±0.7	3.6±0.9†	29.0±6.0	21.6±6.6†
Murugan M and Saheb SH [50]	8.9±1.7	8.5±1.3†	3.7±1.3	3.9±0.9†		
Ahmed MM et al., [11]	5.3	4.8 *	5.2	4.9 *	19.9	19.9†
Mishra SR et al., [38]	M 7.6±1.2 F 8.0±1.2	M 7.5±1.0 F 8.0±1.1†‡	M 4.4±1.0 F 4.0±1.0	M 4.1±1.0 F 4.0±1.0†‡		
Kumar A et al., [34]	8.2±2.1	8.1±2.3 †			29.9±14.5	34.2±6.3*‡
Katara P et al., [47]	7.9	7.1 *	4.2	3.8 *		
Hema L [32]	5.0	5.1†	3.8	2.7†		
Saurjyaranjan D et al., [45]	7.1±1.7	6.5±1.3†	3.1±0.7	3.2±0.7†		
Lakshmi KNV et al., [44]	6.7±1.6	6.2±1.3†	4.1±0.8	3.9±0.7†	21.2±6.1	18.7±5.0 *
Prakash KG et al., [29]	7.7±1.9	7.6±1.3†	5.2±0.9	5.4±0.9†	31.1±9.5	32.5±7.5†
Srikantaiah VC and Shetty H [14]	7.5±3.1	6.8±1.5†	6.0±1.7	5.6±1.4†		
Yoganandham J et al., [19]	6.5±1.2	6.6±1.3†	3.7±0.8	3.8±0.7†	19.1±5.7	17.9±5.9†

[Table/Fig-5]: Comparison of Length, Width and Area of foramen ovale between different studies [10,11,13,14,19,22,23,32,34,38,39,44,45,47,50].
MM: Millimetre; S.D: Standard deviation; M: Male; F: Female;
*-Statistically significant; †Not significant; ‡Significant between sexes

through the transjugular-transovale route of Härtel [63]. The method introduced by Mullan and Lichtor employs introduction of 14G needle through the foramen ovale and then introduction of Fogharty 4F balloon catheter to perform percutaneous balloon compression in the treatment of Trigeminal neuralgia. Anatomical variations such as spines, tubercles, and bony plates on the margins of the foramen ovale make cannulation difficult [64]. In similar lines, the knowledge of shape and size of the foramen ovale is essential during cannulation in percutaneous trigeminal rhizotomy, a percutaneous biopsy of parasellar lesions and an electroencephalogram of the temporal lobe in selective amygdalo-hippocampectomy [65].

The mandibular nerve at the level of foramen ovale serves as a landmark in the endonasal endoscopic transpterygoid approach to the infratemporal fossa, parapharyngeal space, and lateral skull base. This approach was reported to be helpful in the management of schwannomas and juvenile angiofibromas in the infratemporal fossa [3]. Morphological differences such as small foramen or foramen with accessory bony structures were outlined as contributing factors causing difficulty in cannulating foramen ovale with a routine 14G needle having an outer diameter of 2.1 mm [64]. Difficulty during cannulation was reported to result in multiple attempts of cannulation and failure. Multiple attempts were associated with vascular complications such as formation of haematoma, intracranial haemorrhage and carotid-cavernous fistula [4,65].

Currently these invasive procedures are performed with the help of computed tomography and other navigation technology. However, these are not free from risks. It is reported that there is 5% overall failure rate of cannulation [64]. Improper cannulation was reported to cause blindness, brain stem haematoma, cavernous sinus puncture and carotid artery haemorrhage [63]. Therefore, knowledge of morphological variations is vital in addition to understanding the topography and morphometry of foramen ovale to perform diagnostic and surgical procedures. Realising the presence of these variants is essential to understand the regional anatomy. Failure to recognise these variants can lead to misinterpretation during surgical intervention resulting in trauma to the adjacent neurovascular structures.

In total, data on foramen ovale from 3,266 skulls were reported from these 44 studies. Knowledge of morphology and morphometry of foramen ovale will be a valuable resource to clinicians to plan surgical procedures on Indian subjects. Further, awareness about the presence of accessory bony structures concerning foramen ovale necessitates a thorough radiological investigation of the area to evaluate the occurrence of any variation before maxillofacial or skull base surgery [66]. The prior knowledge and preoperative evaluation will avert multiple attempts and failure of cannulating foramen ovale and thereby minimise surgical complications. In addition, these data can be compared with other populations, and attempts can be made to develop a repository of morphometric data on foramen ovale.

Limitation(s)

The skeletal or osteological collections in Indian medical schools are not from documented human cadavers. Therefore, Indian studies suffer from limitations like a lack of demographic details, such as age, sex and race. Except for a few studies, most studies included in this review also suffer from these constraints [8,11,23,28,34,37,38,50]. The readers need to be cautious about these limitations while considering these data.

CONCLUSION(S)

This review brings about the morphological and morphometric data on foramen ovale of 3,266 Indian skulls. Much of these data lacks demographic details such as age and sex due to lack of documentation of human cadavers. Though various shapes are reported, oval was the most common shape. Duplication of foramen ovale was found more common on right-side and its occurrence can be high irrespective of the side. Accessory bony structures related to foramen ovale were reported with no uniform nomenclature leading to difficulty in comprehending the structures and their comparison. Nevertheless, occurrence of accessory bony structures is well documented and could be a possible cause for reduction in the size of foramen ovale. Therefore, in the light of available literature, surgeons should be cautious while surgically approaching the foramen ovale of Indian adult males especially on the right-side. Occurrence of foraminal duplication and accessory bony structures could be the possible risk factors reducing the dimensions of foramen ovale and making performance of procedures like percutaneous cannulation difficult. These data shall create awareness about the morphology and variations of foramen ovale among the clinicians and can be used for comparative analysis with other populations.

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