Morphometric Analysis of Foramen Spinosum in South Indian Population

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Abstract- Foramen Spinosum (FS) is one of the chief foramens in the infratemporal surface of greater wing of the sphenoid which is situated just posterior and lateral to foramen ovale. It is a significant landmark in cases of damage to the base of skull particularly in the middle cranial fossa and infratemporal fossa. It is usually needed as a landmark in neurosurgery because of its adjacent relations with other cranial foramina. So, this study was undertaken to determine the precise range of dimensions, the variations, asymmetry, and dissimilarity of the size seen in the foramen spinosum in the South Indian population. Sixty eight dry skulls of unknown sex were used for the study. Various measurements and distance from various surgical landmarks were taken to assess the position of foramen spinosum on both sides of skull. We also calculated the area of foramen spinosum. Various shapes of foramen spinosum were also noted, i.e. round, oval, pin hole or irregular. Statistical Analysis was done for the all the measurements using spss software. The mean anteroposterior diameter of foramen spinosum was 2.955±1.132 mm, 3.226±0.813 mm on the right and left sides. The mean transverse diameter of foramen spinosum came out to be 2.169±0.804 mm on right side and 2.274±9.174 mm on left side. There was no statistical significance in any parameter measured on the right and left side. This study will be helpful for neurosurgeons while doing surgery in the middle cranial fossa.

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Keywords: Foramen spinosum; Foramen ovale; Carotid canal; Root of zygoma; Shape; Neurosurgeries

Introduction

The Foramen Spinosum (FS) is one of the chief foramens in the infratemporal surface of greater wing of the sphenoid, lying posterior and lateral to foramen ovale and anteromedial to the spine of sphenoid. It transmits middle meningeal artery, the middle meningeal vein and the meningeal branch of mandibular nerve (1). Embryological studies showed that the perfect ring-shaped development of the foramen spinosum is seen by the 8th month after birth and can form late maximum up to 7 years after birth (2). The foramen is very tiny when we compared it with foramen ovale and is frequently circular in shape. The foramen spinosum is a significant landmark during base of skull damage mainly in the middle cranial fossa and infratemporal fossa. Numerous studies have stated the clinical significance of this foramen during surgeries when we use the middle meningeal artery as a graft in bypass operation which involves the petrous part of the internal carotid artery or posterior cerebral artery (3).

It is frequently needed as a landmark in neurosurgery, due to its proximity with other cranial foramina. Foramen spinosum transmits the middle meningeal vein, therefore, any variation in this foramen or the vessels or nerves passing through it should be well-known to the radiologist or surgeon (4).

Finding the precise position of foramen spinosum using numerous measurements and its relations to various structures nearby it would be useful beforehand in different intervention techniques. Knowledge regarding regional or ethnic disparities in the morphometric analysis of the foramen spinosum from the existing literature, provoked us to do the present study in South Indian population.

So, the aim of this study was to determine the precise range of dimensions, the variations, asymmetry and dissimilarity of size, seen in the foramen spinosum in the South Indian population.

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Materials and Methods

A total of 68 dry skulls of unknown sex were used for the study. Skulls showing damage in and around foramen spinosum were excluded from the study. These measurements were taken to assess the position of foramen spinosum on both sides of skull (Figure 1):

1. Antero-posterior diameter of foramen spinosum (L).
2. Transverse diameter of the foramen spinosum (B).
3. The shortest distance from the tubercle of the root of zygoma (ZA) to center of foramen spinosum (FS).
4. The shortest distance from the center of foramen spinosum (FS) to midline of base of skull (Mid)
5. The shortest distance from the center of foramen ovale (FO) to the center of foramen spinosum (FS).
6. The shortest distance from the center of carotid canal (CC) to the center of foramen spinosum (FS).

All measurements were taken using screw adjusted compass and Vernier calipers. The measurements were taken thrice by the same person and mean found which increases the accuracy of the data. Using the values obtained above, we also calculated the area (A) of foramen spinosum using the formula A= (π x L x B)/4. Various shapes of foramen spinosum were also noted, i.e. round, oval, pin hole or irregular.

Statistical Analysis was done for all the measurements, mean and standard deviation (mean±SD), median (range), and mode were calculated. Data was analyzed using Statistical Package for Social Sciences (SPSS) 19 version, and $P<0.05$ was considered to be statistically significant.

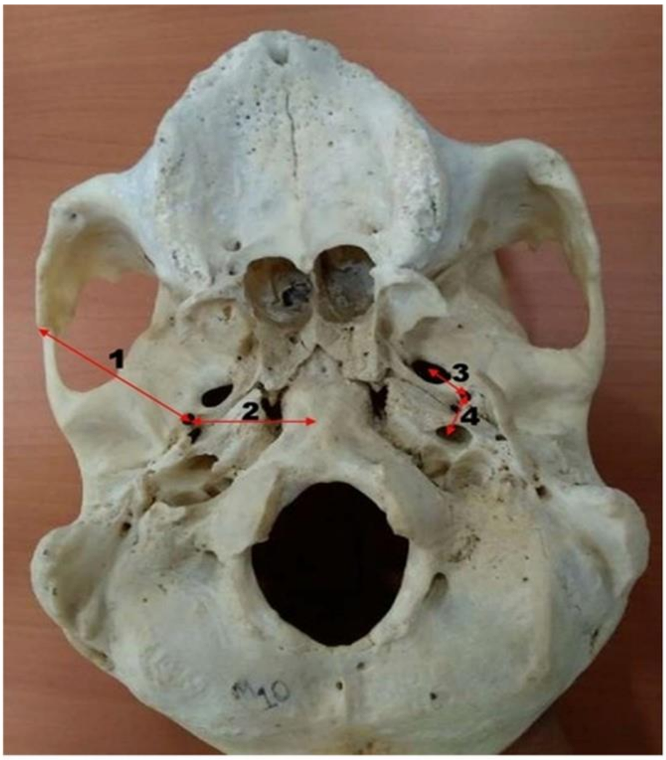

Figure 1. Showing various measurements done for foramen spinosum. 1. Distance from center of foramen spinosum (FS) to root of tubercle of zygoma (ZA), 2. Distance between center of foramen spinosum (FS) to midline of base of skull (Mid line), 3. Distance from center of foramen spinosum (FS) to center of foramen ovale (FO), 4. Distance from center of foramen spinosum (FS) to center of the carotid canal (CC)

Results

Total number of skulls examined are 68. Number of sides which were not examined due to destruction are right- 6, left- 4. So, a total number of sides which were examined are 126.

The Mean±SD, *P*. value, Median, Mode, and Range of various measurements done on foramen spinosum are shown in table 1.

Table 1. Mean±SD, *P*, Median, Mode and Range of various measurements of foramen spinosum

Parameters	Mean ± SD		*P*	Median		Mode		Range	
	Right	Left		Right	Left	Right	Left	Right	Left
L(mm)	2.955±1.132	3.226±0.813	0.110	3	3	3	3	1-6	1-5
B (mm)	2.169±0.804	2.274±9.174	0.431	2	2	2	2	1-4	1-5
A(mm^2)	5.511±3.566	5.982±3.039	0.298	--	--	--	--	--	--
CFS-ZA (mm)	36.662±2.4172	37.169±2.700	0.207	37	37	35	36	31.3 -43	31.5 - 43.5
CFS-Mid (mm)	27.810±1.8191	28.411±1.596	0.057	27.5	28.25	24-36	25-33.2	28	29
CFS-CFO (mm)	3.694±1.600	3.331±1.565	0.130	3.5	3.25	3	4	1-9	1-8
CFS-CC (mm)	9.666±2.028	9.379±1.889	0.354	9.75	9.75	10	10	8-15	7-15

In our study, we found that in all measurements done on foramen spinosum there was no statistical significance between right and left side as $P>0.05$.

Percentage of specimens showing various shapes of foramen spinosum on right and left side is shown in table 2.

Table 2. Shape of foramen ovale on right and left side

Shape of the foramen	Right(n=62)	Left(n=64)	Total(126)
Irregular	2 (3.23%)	3 (4.69%)	5 (3.96%)
Pinhole	4 (6.45%)	5 (7.81%)	9 (7.143%)
Oval	20 (32.26%)	22 (34.38%)	42 (33.33%)
Round	36 (58.065%)	34 (53.13%)	70 (55.56%)

Discussion

The foramen spinosum is one of the significant foramina present in the skull base, in the greater wing of sphenoid, posterolateral to foramen ovale. It transmits the middle meningeal artery and veins along with the meningeal branch of mandibular nerve (nervus spinosus) (3). Occasionally, foramen ovale and foramen spinosum are confluent or the posterior edge of foramen spinosum may be abnormal. Yanagi *et al.*, mentioned that perfect ring- shaped development of foramen spinosum was first noticed in the 8^{th} month after birth and it can form as late as up to 7 years after birth. They observed that majority of the foramina they studied were round (2). Our study, in line with several other studies on foramen spinosum also found that nearly 55.56% were round. Comparision of various shapes of foramen ovale with shapes mentioned by different authors is shown in table 3.

The mean anteroposterior diameter (L) of foramen spinosum in our case was 2.955±1.132 mm and 3.226 ±0.813 mm on the right and left sides, respectively. This is similar to results by Somesh *et al.*, where mean anteroposterior diameter was 3.425±0.637 mm on right side and 3.339±0.660 mm on the left side (7). Anju *et al.*, found the mean anteroposterior diameter in males was 3.31±0.84mm (left) and 3.73±0.63mm (right), and that in female was 3.20±0.83mm (left) and 3.81±0.71mm (right) (4). However, there was no statistical significance found between the sides and sexes. A similar study by Kwathai *et al*., concluded that the mean anteroposterior diameter in males was 2.82±0.72mm, whereas in females it was 2.51±0.55 mm (5). There was no significant difference related to the skull sides (2.70±0.77 mm on right side and 2.71±0.58 mm on the left side). However there was significant difference when sex was considered**.** Lang *et al*., noted that anteroposterior diameter of foramen spinosum in newborns is about 2.25 mm, while in adults it is 2.56 mm (1). The comparison of the range of the anteroposterior diameter of foramen spinosum between the present study and the study done by different authors is shown in table 4.

Table 3. Comparison of various shapes of foramen ovale with results of studies done by different authors

Authors	No. of Skulls	Round (%)	Oval (%)	Irregular (%)	Pin-Hole (%)
Anju *et al*., [4]	35	57	34.2	2.8	5.7
Kwathai *et al*., [6]	103	49.5	39.8	10.7	--
Desai *et al*., [14]	125	52	42	6	--
Sophia *et al*., [3]	40	52.5	30	12.5	2.5
Somesh *et al*., [5]	82	53.65	35.36	4.26	6.70
Krishnamurthy *et al*., [11]	50	55	40	2	--
Present study	68	55.56	33.33	3.96	7.143

Table 4. Comparison of range of anteroposterior diameter of foramen spinosum between the present study and the study done by different authors

Comparative ranges of antero-posterior diameters of foramen spinosum					
Authors		**Minimum(mm)**		**Maximum(mm)**	
Kwathai *et al*., [6] (extracranial view)		1.24		5.26	
Kulkarni *et al*., [8]		2		4	
Osunwoke *et al*., [7]		1		4	
Lang *et al*., [1]		1.05		2.1	
Somesh *et al*., [5]		2 (right) and 1.5 (left)		5(right) and 3.5(left)	
Anju *et al*., [4]	**Male**	3(right)	2(left)	4(right)	4.5(left)
	Female	3.5(right)	3(left)	4(right)	4 (left)
Present study		1(right) and 1(left)		6(right) and 5(left)	

In the present study the mean transverse diameter (B) of foramen spinosum came out to be 2.169±0.804 mm on right side and 2.274±9.174 mm on left side. However, our results were lesser than those of Somesh *et al*., i.e. 2.687±0.487 mm (right) 2.675±0.46 mm (left) (7). Kwathai *et al.*, reported that there was a significant difference between male (2.02±0.39mm) and female (1.85±0.36mm) skulls with regards to transverse diameter also (5). However, Osunwoke *et al*., reported that transverse diameter of foramen spinosum ranges from 1-2 mm only (10). This clearly demonstrates the ethnological and racial differences in the morphology of foramen spinosum and possibly, other anatomical structures. In our study, the mode of the anteroposterior and transverse diameters on both sides of the skull was 3 mm, similar to results by Kulkarni *et al.,* (9).

We also calculated the area of foramen spinosum and it was 5.511±3.566 mm^2 and 5.982±3.039 mm^2 on the right and left sides, respectively. But this is considerably lesser than results obtained by Somesh *et al*., (7.357±2.195 mm^2 on right side and 7.110±2.103 mm^2) (7).

The distance from the midline of the base of the skull to the center of foramen spinosum (CFS-Mid line) was measured, which came out to be 27.810±1.8191 mm (right) and 28.411±1.596 mm (left). Additionally, we measured the distance between foramen spinosum and the root of tubercle of zygoma that would help in extracranial localization of the foramen spinosum. In our study, the mean distance of FS-ZA was 36.662±2.4172mm 37.169±2.7009 mm on the right and left sides respectively, similar to Kwathai *et al.*, where the mean distance was 34.19 mm (range 26.80-43.37 mm) (5).

Also, we have measured the distance between foramen ovale and foramen spinosum. The foramen ovale lies anteromedial to the foramen spinosum in the greater wing of sphenoid. It is important for various diagnostic techniques like electroencephalographic analysis, percutaneous trigeminal rhizotomy and percutaneous biopsy of cavernous sinus tumors. During such procedures, injuries may be sustained by foramen spinosum as it is located very close to foramen ovale. This can damage the middle meningeal vessels or the nervus spinosus. We calculated this distance to be 3.69±1.60 mm and 3.33±1.565 mm on the right and left sides, respectively.

We have also measured the distance from the center of the carotid canal to foramen spinosum (CC-FS). The mean distance was 9.666±2.028 mm on the right side and 9.379±1.889 mm on the left side. This is important because sometimes the middle meningeal artery can originate from pre petrous and suprasellar portion (an extradural portion of the carotid siphon) of the internal carotid artery (11). But there was no statistical significant difference in any of the parameters on both the sides.

The comparison of mean distances from foramen spinosum to the median sagittal plane between the present study and the study done by different authors is shown in table 5.

Table 5. Comparison of mean distances from center of foramen spinosum to median sagittal plane between the present study and the study done by different authors

Comparative mean distances from center of foramen spinosum to median sagittal plane(mm)		
Authors	**Right**	**Left**
Lang *et al*., [1]	28.08	29.76
Somesh *et al*., [5]	30.39± 1.79	30.86± 1.5
Present study	27.810±1.819	28.411±1.596

Usually, the irregular spine of sphenoid projects posterior and lateral to foramen spinosum. Any changes in this relation may affect the course of middle meningeal vessels (12). In the present study also, it was noted that in most skulls foramen spinosum was anteromedial to the spine of the sphenoid. But, two skulls on the left side showed foramen spinosum to be posterior to the spine of sphenoid and in three skulls it was situated laterally to the spine of the sphenoid. The spine of sphenoid is related to chorda tympani nerve medially and auriculotemporal nerve laterally. Such variations can cause damage to the auriculotemporal or chorda tympani nerve during surgeries. Foramen spinosum is an important landmark in microsurgeries of the middle cranial fossa. The knowledge about the variations of normal and abnormal position of foramen spinosum is helpful in computerized tomography and magnetic resonance imaging examinations. In supratentorial hematomas, surgical management comprises of making a bone flap over the bigger diameter of the clot and exposing the foramen spinosum (8,13). That is why relation of foramen spinosum with the spine of sphenoid is important.

A single foramen spinosum was present bilaterally in all the skulls that were used for our study, similar to Osunwoke *et al.*, (10). But in the study by Khaimar at al on 100 skulls, it was absent in one skull and duplicated in six skulls (14). Table 6 shows the comparison between the present studies and previous studies regarding absent and duplicated foramen spinosum. The anatomical variations regarding foramen spinosum are related either to incomplete osteogenesis or abnormal development of the middle meningeal artery. Sometime foramen spinosum can be absent as seen in 3% skull base CT studies (4).

Table 6. Comparison of various studies regarding absent and duplicated foramen spinosum

Authors	No. of skulls	Absent foramen spinosum	Duplicated foramen spinosum
Anju *et al*., [4]	35	2.85	2.85
Khaimar *et al*., [15]	100	0.5	3
Mandavi *et al*., [10]	312	0.3	2.56
Khan *et al*., [16]	25	2	2
Kulkarni *et al*., [8]	100	2.5	0
Osunwoke *et al*., [7]	87	0	0
Sophia *et al*., [3]	40	2.5	3.75
Somesh *et al*., [5]	82	2	--
Present study	68	0	0

The stapedial middle meningeal artery is a rare occurrence, in which case middle meningeal artery arises from the persistent stapedial artery which is a branch of the intrapetrous portion of the internal carotid artery. Middle meningeal artery may partly (i.e., anterior branch only) or entirely come from ophthalmic artery. Under such conditions, it passes through the lateral part of the superior orbital fissure or a foramen in the greater wing of the sphenoid (foramen meningo-orbitale) (13,16).

Our results highlight the ethnic discrepancies in the existence of foramen spinosum as mentioned by previous studies. We consider that the diversity could be a result of factors such as age, sex or race as validated by Kwathai *et al.*, and Osunwake *et al*., and differences in the reference points, which are taken as criteria in the measurements (5,10). Also, our study provides valuable information on the location of foramen spinosum with respect to the surrounding anatomical landmarks in adult Indian skulls.

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