Foramen Magnum: A Morphological and Morphometric Study in Dried Human Skull Bones of Rajasthan Population and its Surgical Importance

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ABSTRACT

Introduction: The foramen magnum (FM) is a large opening in the base of the skull. The dimensions of FM are clinically important because many vital structures passing through it, viz., the lower end of medulla oblongata, the vertebral arteries, and spinal accessory nerves. It may endure compression such as in cases of FM herniation, FM meningiomas, and FM achondroplasia. The knowledge of FM diameter is needed to determine some malformations such as the Arnold–Chiari syndrome, which shows expansion of the transverse diameter.

Materials and methods: The present study was carried out on 75 dry human skulls of unknown age and sex belonging to Rajasthan population by the Department of Anatomy at Mahatma Gandhi Medical College and Hospital, Jaipur, Rajasthan. All the measurements were taken with the help of digital vernier calipers.

Results: The mean anteroposterior diameter was 35.11 ± 3.12 mm, the transverse diameter was 29.35 ± 3.48 mm, area was 813.94 ± 146.40 mm², and the FM index was 1.208 ± 0.150. The FM shapes were determined as oval (22.67%), egg-shaped (12.00%), round (14.67%), tetragonal (14.67%), pentagonal (9.33%), hexagonal (16.00%), and irregular (10.67%).

Conclusion: This study will be useful for the anatomists, radiologists, neurosurgeons, and orthopedic surgeons.

Keywords: Achondroplasia, Arnold–Chiari syndrome, Foramen magnum.

INTRODUCTION

The foramen magnum (FM) is a large opening (Latin: great hole) in the base of the skull (Fig. 1). It is an important landmark of the base of skull and is of particular interest for anthropologists, anatomists, forensic medicine, neurosurgeons, and radiologists.

The FM is surrounded by different parts of the occipital bone that has two condylar parts, the squamous part and the occipital part.

The squamous part lies behind and above, basilar part in front, and a condylar part on either side.¹

Border of Foramen Magnum

The anterior border of FM is formed by the basilar process of the occipital bone, the lateral border by left and right ex-occipitalis, and the posterior border is formed by the supraoccipital part of the occipital bone.²

The upper ends of anterior and posterior atlanto-occipital membranes are attached to the FM at its anterior and posterior margins, respectively, and their lower ends are attached to the superior surface of anterior and posterior arch of the atlas, respectively.³

Many authors have classified FM based on its shape, viz., oval, egg-shaped, round, tetragonal, pentagonal, hexagonal, and irregular.⁴–⁶

The FM is a wide communication between the posterior cranial fossa and the vertebral canal.

The alar ligament of dens divides the foramen into anterior “Osseo-ligamentous compartment” and posterior “Neurovascular compartment.”

Both upper fasciculus of the cruciate ligament and membranatectoria are attached to the upper surface of basioccipital bone in front of the FM.

Fig. 1: Norma basalis view showing foramen magnum and occipital condyles

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Its wide posterior part contains the medulla oblongata and its meninges. In the subarachnoid space, spinal rami of the accessory nerve and vertebral arteries with their sympathetic plexus ascend into the cranium.

The posterior spinal arteries descend posterolateral to the brain stem, whereas the anterior spinal artery descends anteromedian to the brain stem. The cerebellar tonsils may project into the FM. The dimensions of the FM are clinically important because the abovementioned vital structures passing through it may endure compression such as in cases of FM herniation, FM meningiomas, and FM achondroplasia.

The transverse diameter of FM will be increased in the Arnold–Chiari syndrome. The evaluation of morphometric of FM is helpful for forensic dentistry and medicine.

The progress in the neuroimaging techniques to diagnose craniovertebral abnormalities accurately has enhanced the field of craniovertebral surgery. Such surgeries are a challenging task for the neurosurgeons because of the close relation of vascular and neural structures within the FM. Advances in skull base surgeries such as the “far lateral transcondylar approach” have improved the better and wider access of surgical exposure leading to successful surgeries in this region. To perform such surgeries, prior analysis of the morphometric dimensions of FM is essential.

The present study aims at collecting morphological and morphometric data on FM, which might help neurosurgeons to plan surgeries and add to the preexisting literature on FM.

**Materials and Methods**

The study was conducted on 75 adult dry human skulls of unknown age and sex belonging to Rajasthan population by the Department of Anatomy of Mahatma Gandhi Medical College, Jaipur, and Sawai Man Singh Medical College, Jaipur.

All the measurements were taken with the help of digital vernier calipers (Fig. 2).

Following metric parameters were noted:

- **Shapes of FM**: The different shapes of the FM were macroscopically noted and classified according to Zaidi et al. as oval, egg-shaped, round, tetragonal, pentagonal, hexagonal, and irregular (Fig. 3).
- **Anteroposterior diameter (APD)**: It is the distance between basion (midpoint of the anterior margin of the FM) and opisthion (midpoint of the posterior margin of the FM) (Fig. 4).
- **Transverse diameter (TD)**: It is the distance between the lateral margins of the FM at the point of greatest lateral curvature (Fig. 5).
- **Foramen magnum index (FMI)**: It is calculated by dividing the anteroposterior diameter by the transverse diameter (APD/TD).
- **Area of FM by Radinsky’s formula**: $A = \frac{1}{4} \pi W \times L$

$\pi = \text{pi (22/7 or 3.14)}
W = \text{width (transverse diameter)}
L = \text{length (anteroposterior diameter)}$

Hence, area will be calculated as follows:

Area of FM $= \frac{1}{4} \pi \times \text{transverse diameter} \times \text{anteroposterior diameter}$

**Results**

The morphological and morphometric observations of the FM in 75 dried human skulls belonging to Rajasthan population are as follows (Table 1):

- The most common shape was oval (22.67%) and the least common shape was pentagonal (9.33%) (Fig. 6).
- The mean anteroposterior diameter was 35.11 ± 3.12 mm. The maximum anteroposterior diameter was 43.14 mm and the minimum anteroposterior diameter was 27.01 mm observed in the present study (Table 2).
- The mean transverse diameter was observed to be 29.35 ± 3.46 mm. The maximum transverse diameter was 38.11 mm, and the minimum transverse diameter was 25.49 mm.
- The mean values of APD and TD are represented in the form of bar diagrams (Fig. 7).
- In the present study, the mean value of FM index was found to be 1.208, with minimum value of 0.969 and maximum being 1.740 with standard deviation of 0.150 mm for 75 specimens (Table 3). When the FMI is greater than 1.2, the foramen is found to be ovoid (Radhika et al.) (Table 4).
- Around 45.33% of skulls studied exhibited an ovoid FM.
- The mean value of area of FM was calculated to be 813.94 ± 146.40 mm$^2$. The maximum area was 1105.70 mm$^2$, and the minimum area was 559.54 mm$^2$ (Table 5).
**Discussion**

In the present study, oval-shaped FM was the commonest shape, which is comparable to findings of researchers of ethnic groups, Kumar et al., Piras et al., and Pelinilhan et al. (Table 6).
### Table 6: Various shapes of FM studied by various authors

| Authors            | Year | Population | N  | Sex | Oval (%) | Egg-shaped (%) | Round (%) | Tetragonal (%) | Pentagonal (%) | Hexagonal (%) | Irregular (%) |
|--------------------|------|------------|----|-----|----------|----------------|-----------|---------------|---------------|--------------|--------------|
| **Zaidi et al.**   | 1998 | Kanpur     | 200| –   | 64       | –              | 0.5       | –             | 7.5           | 24.5         | 3.5          |
| **Murshed et al.** | 2003 | Turkish    | 110| –   | 8.1      | 6.3            | 21.8      | 12.7          | 13.6          | 17.2         | A: 10.9, B: 9.09 |
| Chethan et al.     | 2012 | Mangaluru  | 53 | –   | 15       | 18.9           | 22.6      | 18.9          | 3.8           | 5.6          | 15.1         |
| Radhakrishna et al.| 2012 | Mangaluru  | 100| –   | 39       | –              | 28        | 19            | 14            | –            | –            |
| Sumana et al.      | 2014 | Kerala     | 100| Male| 10.7     | 17.86          | 39.29     | 7.14          | 3.57          | 10.7         | 0.0          |
|                    |      |            |    |     |          |                |           |               |               |              |              |
| Radhika et al.     | 2014 | Bengaluru  | 150| –   | 40       | 10             | 20        | 6             | 2             | 6            | 16           |
| Rathva et al.      | 2015 | Gujarat    | 210| –   | 28.75    | 11.90          | 16.66     | 10.47         | 2.38          | 4.76         | 11.71        |
| Kumar et al.       | 2015 | USA        | 36 | –   | 50       | –              | 20        | 6             | –             | 8            | 16           |
| Riyaz et al.       | 2015 | Maharashtra| 61 | –   | 31.14    | –              | 29.50     | 18.03         | 1.63          | 8.19         | 11.47        |
| Gopalakrishna et al.| 2015 | Kerala    | 55 | –   | 41       | –              | 25        | 14            | –             | –            | 20           |
| Sharma et al.      | 2015 | Tundla     | 50 | –   | 16.0     | 16             | 22        | 12            | 8             | 8            | 18           |
| Vinutha et al.     | 2016 | Karnataka  | 200| –   | 32       | 11             | 10        | 12            | 5             | 11           | 10           |
|                    |      |            |    |     |          |                |           |               |               |              |              |
| Pires et al.       | 2016 | Brazil     | 77 | –   | 53.24    | 2.36           | 24.67     | 16.88         | 1.29          | 1.29         | –            |
| Rohindevi et al.   | 2016 | Tamil Nadu | 35 | –   | 18       | 4              | 26        | 11            | 6             | 6            | 22           |
| Fathima et al.     | 2016 | Chennai    | 53 | –   | 26       | 36             | 13        | –             | 4             | 21           | –            |
| Devadas et al.     | 2017 | Telangana  | 100| –   | 45       | –              | 29        | 14            | 12            | –            | –            |
| Rajkumar et al.    | 2017 | Rajasthan  | 298| –   | 66       | –              | 24.83     | 3.35–         | 2.68–         | 4.02–        | –            |
| Remya et al.       | 2017 | Mangaluru  | 50 | –   | 46       | 14             | 16        | 20            | –             | 2            | 2            |
| Singh et al.       | 2017 | Varanasi   | 50 | –   | 34       | –              | 20        | 16            | 4             | 18           | 8            |
| Arora et al.       | 2017 | Bareilly   | 40 | –   | 60       | –              | 40        | –             | –             | –            | –            |
| Sampada et al.     | 2017 | Karnataka  | 100| –   | 58       | 11             | 9         | 8             | 1             | 3            | 10           |
| Pehlivan et al.    | 2018 | Turkish    | 100| –   | 10       | 12             | 6         | 24            | 2             | 21           | 22           |
| Raikar et al.      | 2018 | Karnataka  | 150| –   | 10.45    | 28             | 26        | 3.67          | 14.1          | 2.33         | 15.45        |
| Mishra et al.      | 2018 | Lucknow    | 71 | –   | 37.8     | –              | 30.9      | 7.04          | 7.04          | 11.2         | 9.85         |
| Veeramani et al.   | 2018 | Puducherry | 100| –   | 6        | 12             | 15        | 11            | 3             | 21           | 32           |
| **Present study**  | 2019 | Rajasthan  | 75 | –   | 22.67    | 12             | 14.67     | 14.67         | 9.33          | 16           | 10.67        |

**Note:**
- **N** = no. of skulls studied
- Other ethnic groups—italic
- Indian population—regular
- Present study—bold

**Shapes of foramen magnum**
- Oval
- Egg-shaped
- Round
- Tetragonal
- Pentagonal
- Hexagonal
- Irregular

**Other Information:**
- The authors have varied from different regions of India, including Kanpur, Malayalam, and other parts of India.
- The proportions of each shape vary significantly across different studies, indicating cultural and geographic variations.
- The present study from 2019 in Rajasthan has specific emphasis on the morphological and morphometric study of dried human skull bones.
In the present study, oval-shaped FM was the commonest shape, which is comparable to findings of Indian researchers, Zaidi et al., Radhakrishna et al., Radhika et al., Rathva et al., Riyaz et al., Gopalkrishna et al., Vinutha et al., Devadas et al., Rajkumar et al., Remya et al., Singh et al., Arora et al., Sampada et al., and Mishra et al. In the present study, the oval-shape was observed in 22.67% of dry skull specimens in contrast to highest 64% reported by Zaidi et al. and lowest 6% reported by Veeramani et al. (Tables 7 and 8).

The mean anteroposterior diameter observed in the present study was 35.11 mm, which is comparable to findings of ethnic researchers, Olivier et al., Mursed et al., Suazo et al., Monoel et al., and Lyrtizis et al. They observed the mean values of the anteroposterior diameter as 35.7 mm, 35.6 mm, 35.9 mm, 35.6 mm (in female), 35.7 mm (in male) and 35.1 mm (in female), and 35.05 mm, respectively.

The mean transverse diameter reported in the present study was 29.35 mm, which is similar to findings of ethnic researchers, Suazo et al., Monoel et al., Kumar et al., Lyrtizis et al., Pires et al., and Peliminilhan et al., i.e., 29.5 mm, 29.5 mm (in female), 29.4 mm, 29 mm, 29.49 mm (in female), 30.19 mm, 28.62 mm, and 29.73 mm, respectively.

The mean anteroposterior diameter observed in the present study was 35.11 mm, which is comparable to findings of Indian researchers, Kanchan et al., Radhika et al., Sahoo et al., Rohinidevi et al., Arora et al., Sampada et al., Veeramani et al., and Feridoz et al. They observed the mean values of the anteroposterior diameter as

Table 7: Anteroposterior and transverse diameter of FM of ethnic groups

| Authors          | Year | Population | N   | Sex | APD ± SD (mm) | TD ± SD (mm) |
|------------------|------|------------|-----|-----|---------------|--------------|
| Olivier et al.   | 1975 | French     | 125 | --  | 35.7 ± 2.72   | 30.34 ± 2.15 |
| Mursed et al.    | 2003 | Turkish    | 110 | --  | 35.9 ± 3.29   | 30.4 ± 2.59  |
| Suazo et al.     | 2009 | Brazil     | 211 | Male| 36.5 ± 2.6    | 30.6 ± 2.5   |
|                  |      |            |     | Female| 35.6 ± 2.5 | 29.5 ± 1.9 |
| Monoel et al.    | 2009 | Brazil     | 215 | Male| 35.7 ± 0.29   | 30.3 ± 0.20  |
|                  |      |            |     | Female| 35.1 ± 0.33 | 29.4 ± 0.23 |
| Gruber et al.    | 2009 | Europe     | 348 | --  | 36.6 ± 2.8    | 31.1 ± 2.7   |
| Tubbs et al.     | 2011 | Spanish    | 13  | --  | 31            | 27           |
| Kumar et al.     | 2015 | USA        | 36  | Male| 36.78 ± 0.35  | 30.05 ± 0.54 |
|                  |      |            |     | Female| 33.22 ± 0.49 | 29.49 ± 0.04 |
| Lyrtizis et al.  | 2016 | Greek      | 141 | --  | 35.05 ± 2.57  | 30.19 ± 2.69 |
| Pires et al.     | 2017 | Brazil     | 77  | --  | 34.23 ± 2.54  | 28.62 ± 2.83 |
| Chovalopoulou et al. | 2017 | Greece     | 154 | Male| 36.69 ± 2.47  | 32.48 ± 2.70 |
|                  |      |            |     | Female| 34.87 ± 2.41 | 30.62 ± 2.18 |
| Farid et al.     | 2018 | Egyptian   | 75  | --  | 47.1 ± 0.34   | 43.6 ± 2.5   |
| Peliminilhan et al. | 2018 | Turkish    | 100 | --  | 35.18 ± 2.94  | 29.73 ± 2.54 |
| **Present study** | 2019 | Rajasthan  | 75  | --  | **35.11 ± 3.12** | **29.35 ± 3.46** |

N = no. of skulls studied
Indian population—regular
Present study—bold

Table 8: Anteroposterior and transverse diameter of FM of Indian population

| Authors             | Year | Population | N   | Sex | APD ± SD (mm) | TD ± SD (mm) |
|---------------------|------|------------|-----|-----|---------------|--------------|
| Mahajan et al.      | 2011 | Chandigarh | 126 | --  | 32.83 ± 2.62  | 27.47 ± 2.25 |
| Radhkrishna et al.  | 2012 | Mangaluru  | 100 | --  | 34.04 ± 2.36  | 28.63 ± 1.89 |
| Chethan et al.      | 2012 | Mangaluru  | 53  | --  | 31 ± 2.4      | 25.2 ± 2.4   |
| Jain et al.         | 2013 | Moradabad (North Indian) | 68 | Male| 36.9 ± 0.2    | 31.5 ± 0.27  |
|                     |      |            |     | Female| 32.9 ± 0.3  | 29.5 ± 0.28  |
| Kanchan et al.      | 2013 | Mangaluru  | 118 | Male| 34.51 ± 2.77  | 33.60 ± 2.63 |
|                     |      |            |     | Female| 27.36 ± 2.09 | 26.74 ± 2.36 |
| Patel et al.        | 2014 | Surat      | 100 | --  | 42.2          | 28.29        |
| Shepur et al.       | 2014 | Karnataka  | 150 | Male| 33.40 ± 2.60  | 28.50 ± 2.20 |
|                     |      |            |     | Female| 33.10 ± 2.70 | 27.30 ± 2.00 |
| Radhika et al.      | 2014 | Bengaluru  | 150 | --  | 35.30 ± 2.7   | 29.49 ± 2.6  |
| Ganapathy et al.    | 2014 | Puducherry | 100 | --  | 33.9          | 28.7         |
| Vedanayagam et al.  | 2015 | Chennai    | 420 | Male| 18.4 ± 0.7    | 28.2 ± 0.6   |
|                     |      |            |     | Female| 17.6 ± 1.0  | 21.8 ± 0.7   |
| Rathva et al.       | 2015 | Gujarat    | 210 | Male| 33.5 ± 0.45   | 22.5 ± 0.20  |

**Contd...**
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| Authors                  | Year | Population | N  | Sex   | APD ± SD (mm) | TD ± SD (mm) |
|--------------------------|------|------------|----|-------|---------------|--------------|
| Sahoo et al.47           | 2015 | Orissa     | 150| Female| 31.0 ± 0.30   | 20.4 ± 0.15  |
| Riyaz et al.38           | 2015 | Maharashtra| 61 |       | 35.30 ± 2.709 | 29.49 ± 2.572|
| Khanday et al.58         | 2016 | Chennai    | 60 |       | 33.4 ± 2.5    | 28.5 ± 2.2   |
| Jasuja et al.59          | 2016 | Mumbai     | 100|       | 33.6          | 28.5         |
| Fathima et al.24         | 2016 | Chennai    | 53 |       | 38.22         | 35.15        |
| Rohinidevi et al.23      | 2016 | Tamil Nadu | 35 |       | 34.80         | 28.5         |
| Naqshi et al.50          | 2017 | Srinagar   | 25 |       | 31.6 ± 0.21   | 26.5 ± 0.21  |
| Singh et al.28           | 2017 | Varanasi   | 50 |       | 33.76 ± 2.18  | 28.09 ± 1.92 |
| Rajkumar et al.26        | 2017 | Rajasthan  | 298|       | 33.98 ± 2.75  | 28.16 ± 2.15 |
| Remya et al.27           | 2017 | Mangaluru  | 50 |       | 33.64 ± 0.228 | 27.04 ± 0.214|
| Arora et al.29           | 2017 | Bareilly   | 40 |       | 35.42 ± 3.22  | 27.90 ± 2.58 |
| Sampada et al.30         | 2017 | Karnataka  | 100|       | 34.84 ± 2.32  | 29.391.73    |
| Veeramani et al.34       | 2018 | Puducherry | 100| Male  | 37.03 ± 0.3   | 33 ± 0.23    |
|                          |      |            |    | Female| 35.23 ± 0.23  | 32 ± 0.43    |
| Ashwini et al.51         | 2018 | Karnataka  | 162|       | 33 ± 1.4      | 27 ± 1.6     |
| Mishra et al.33          | 2018 | Lucknow    | 71 |       | 34.09 ± 2.33  | 28.22 ± 2.19 |
| Raikar et al.32          | 2018 | Bengaluru  | 150|       | 34.19 ± 3.57  | 31.77 ± 3.59 |
| Feridoz et al.52         | 2018 | Chennai    | 50 |       | 35 ± 2.8      | 29.4 ± 2.9   |
| Present study            | 2019 | Rajasthan  | 75 | –     | 35.11 ± 3.12  | 29.35 ± 3.46 |

N = no. of skulls studied
Indian population—regular
Present study—bold

Table 9: Foramen magnum index

| Authors                  | Year | Population | N  | Sex   | FMI   |
|--------------------------|------|------------|----|-------|-------|
| Chethan et al.6          | 2012 | Mangaluru  | 53 | –     | 1.2   |
| Radhika et al.15         | 2014 | Bengaluru  | 150| –     | 1.20 ± 0.1075|
| Sahoo et al.47           | 2015 | Orissa     | 150| –     | 1.2028 ± 0.1075|
| Dubey et al.55           | 2017 | Sagar and Jabalpur | 80 | Male | 1.18 ± 0.11 |
| PelinIlhan et al.31      | 2018 | Turkish    | 100| –     | 1.19 ± 0.09 |
| Veeramani et al.34       | 2018 | Puducherry | 100| –     | 1.13 ± 0.11 |
| Present study            | 2019 | Rajasthan  | 75 | –     | 1.208 ± 0.15 |

N = no. of skulls studied
Other ethnic groups—italic
Indian population—regular
Present study—bold

34.51 mm, 35.30 mm, 35.30 mm, 34.80 mm, 34.42 mm, 34.84 mm, 35.23 mm (in female), and 35 mm, respectively.

The mean transverse diameter was reported as 29.35 mm in the present study, which is similar to the findings of Indian researchers, Radharkrishna et al., Jain et al., Shepur et al., Radhika et al., Vedanayagam et al., Saini et al., Sahoo et al., Riyaz et al., Rohinidevi et al., Sampada et al., Mishra et al., and Feridoz et al., i.e., 28.63 mm, 29.5 mm (in female), 28.50 mm (in male), 29.49 mm, 28.5 mm, 29.39 mm, 28.22 mm, and 29.4 mm, respectively.

The foramen magnum index of 1.2 has been reported in the present study in Rajasthan population, FMI was also 1.2.

The foramen magnum index was relatively lower in Madhya Pradesh population (Dubey et al.) and Puducherry population (Veeramani et al.). In ethnic group studies only, PelinIlhan et al. (Turkish population) have reported lower FMI.

In the present study (Jaipur region, Rajasthan), area was calculated as 813.94 mm², which is similar to the study of Jaitley et al. in female (812.22 mm²) in the Indore region of Madhya Pradesh (Table 10).

The highest area was reported by Faridoz et al., i.e., 1598 mm², and the least was reported by Khanday et al., i.e., 576 mm².

In another study by Rajkumar et al., the Udaipur region of Rajasthan has reported much lower area of FM (754.32 mm²).
Table 10: Area of FM

| Authors                  | Year | Population | N  | Sex  | Area         |
|--------------------------|------|------------|----|------|--------------|
| Murshed et al.3          | 2003 | Turkish    | 110| Male | 931.7 ± 144.29 |
|                          |      |            |    | Female | 795.0 ± 99.32 |
| Sing and Talwar54        | 2013 | Chandigarh | 50 | Male | 733.32 ± 9.40 |
|                          |      |            |    | Female | 692.64 ± 13.20 |
| Patel et al.43           | 2014 | Surat      | 100| –   | 756.37       |
| Shepur et al.44          | 2014 | Karnataka  | 150| Male | 862.0 ± 119  |
|                          |      |            |    | Female | 758.0 ± 109  |
| Sharma et al.20          | 2015 | Tundla     | 50 | –   | 970.57       |
| Rathva et al.16          | 2015 | Gujarat    | 210| Male | 853 ± 020    |
|                          |      |            |    | Female | 718 ± 015    |
| Kumar et al.17           | 2015 | USA        | 36 | Male | 876.88 ± 88.83 |
|                          |      |            |    | Female | 776.87 ± 68.51 |
| Riyaz et al.18           | 2015 | Maharashtra| 61 | –   | 747.92       |
| Jaitley et al.53         | 2016 | Indore     | 280| Male | 916 ± 145    |
|                          |      |            |    | Female | 812.22 ± 95.9 |
| Khanday et al.58         | 2016 | Chennai    | 60 | –   | 576          |
| Lyrtzis Ch et al.57      | 2016 | Greek      | 141| –   | 778.15 ± 125.11 |
| Fatima et al.24          | 2016 | Chennai    | 53 | –   | 1102         |
| Rohinidevi et al.23      | 2016 | Tamil Nadu | 35 | –   | 820.53       |
| Naqshi et al.30          | 2017 | Srinagar   | 25 | –   | 660 ± 090    |
| Devadas et al.25         | 2017 | Telangana  | 100| Male | 1089.99      |
|                          |      |            |    | Female | 837.84       |
| Singh et al.28           | 2017 | Varanasi   | 50 | –   | 834.45 ± 75.79 |
| Rajkumar et al.26        | 2017 | Rajasthan  | 298| –   | 754.32 ± 105.16 |
| Remya et al.27           | 2017 | Mangaluru  | 50 | –   | 714.99 ± 0.844 |
| Chovalopoulou et al.28   | 2017 | Greek      | 154| Male | 938.12 ± 123.20 |
|                          |      |            |    | Female | 839.82 ± 99.91 |
| Sampada et al.30         | 2017 | Karnataka  | 100| –   | 803.8 ± 83.42 |
| Raikar et al.32          | 2018 | Bengaluru  | 150| –   | 800.72 ± 86.85 |
| Faridoz et al.52         | 2018 | Chennai    | 50 | –   | 1598 ± 182   |
| Present study            | 2019 | Rajasthan  | 75 | –   | 813.94 ± 146.40 |

N = no. of skulls studied
Other ethnic groups—italic
Indian population—regular
Present study—bold

CONCLUSION

The morphological and morphometric analysis of FM and its variations is important not only to anatomists but also to the neurosurgeons, anesthetists, orthopedicians, and radiologists. These variations have become significant because of newer imaging techniques such as computed tomography and magnetic resonance imaging in the field of diagnostic medicine.

This study will also be a help to forensic medicine experts since ethnic variations as seen and compared with research of other ethnic region population researchers may help in identification of different races.

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