

# To Estimate the Morphometric Parameters of Foramen Ovale in Dry Skull

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## Background:

**Abstract: Purpose:** To analyse the morphometric of the foramen ovale in dry adult human skulls.

**Introduction:** The foramen ovale is an opening in the greater wing of the sphenoid that transmits the mandibular division of the trigeminal nerve along with small vessels and nerves. Its size, shape, and position vary between individuals and between sexes, and these variations can affect percutaneous and stereotactic procedures in the middle cranial fossa. **Objective:** To measure the Anteroposterior diameter (APDFO), mediolateral diameter (MLDFO), distance from the midsagittal midline to the medial margin (DMTFO), and inter-foraminal distance (IFOD) in adult dry skulls. **Materials and Methods:** Fifty dry adult human skulls (25 male, 25 female) were examined, and 100 foramen ovale were measured. Using a digital Vernier calliper (least count 0.01 mm) with skulls in the standard anatomical position, we recorded APDFO, MLDFO, DMTFO, and IFOD. Each measurement was taken bilaterally, repeated when necessary, and averaged. Data were analyzed for the whole sample, and Karl Pearson correlation and one-way ANOVA were used to assess sex differences.

**Results:** The Anteroposterior diameter averaged 7.354 mm on the right and 7.470 mm on the left; the mediolateral diameter averaged 4.024 mm on the right and 4.190 mm on the left; the distance from the midsagittal midline averaged 22.090 mm on the right and 21.674 mm on the left; and the inter-foraminal distance averaged 44.242 mm. Male means were generally slightly larger than female means (for example, FOLR male 7.576 mm vs female 7.132 mm). APDFOR, MLDFOR, APDFOL, MLDFOL, and IFOD showed small but statistically significant sex differences ( $p < 0.05$ ), while right DMTFO was not significant ( $p = 0.088$ ) and left DMTFO was borderline ( $p \approx 0.0496$ ). This morphometric analysis of 100 foramina ovale from 50 dry adult skulls establishes regional reference values for Anteroposterior diameter, mediolateral diameter, distance from the midline, and inter-foraminal distance. Male skulls exhibited slightly larger mean dimensions than female skulls across most parameters, and several linear measures differed significantly between sexes ( $p < 0.05$ ). **Conclusion:** This study provides regional reference values for the Anteroposterior diameter, Mediolateral diameter, midline distance, and inter-foraminal separation of the foramen ovale. While males showed slightly larger dimensions on average, absolute sex differences were modest. These dry-bone norms can aid anatomists, radiologists and surgeons in planning procedures involving the foramen ovale, but patient-specific imaging should guide final stereotactic or percutaneous approaches.

**Keywords:** Foramen ovale, morphometry, skull, anteroposterior diameter, mediolateral diameter.

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## Introduction:

The base of the skull contains several foramina that transmit important neurovascular structures between the intracranial and extracranial compartments and serve as anatomical landmarks. [1] The foramen ovale is located in the posterior part of the greater wing of the sphenoid and transmits the mandibular division of the trigeminal nerve along with small vessels and nerves. [2] The shape and edges of the foramen ovale form as the sphenoid bone ossifies and its parts fuse during craniofacial development. [3] The sphenoid bone comprises the body, lesser wings, greater wings, and pterygoid processes, each contributing to the

bony framework of the middle cranial fossa. [4] During fetal life, the foramen ovale begins as a ring-like opening in unossified cartilage and becomes a distinct bony aperture as the greater wing ossifies in early childhood. [5] Morphologically, the foramen ovale shows considerable variation in shape and margin configuration, ranging from smooth, oval outlines to round, slit-like, or irregular forms. [6] Accessory foramina, bony ridges, spurs, septations, and ossified ligaments are reported and can partially divide or obscure the main aperture. [7] Dry-bone morphometric surveys clarify bony contours and developmental remnants of the foramen ovale. [8] In vivo imaging studies (CT and radiological series) reveal spatial relationships in living subjects and detect accessory openings or ossified structures

that are not always evident on isolated skulls. [9] Comparative population studies show regional variation in the shape and position of the foramen ovale and report inconsistent patterns for sex and age. [10] Because the foramen ovale lies at the transition between intracranial and extracranial compartments and transmits clinically important structures, its variable anatomy has direct implications for surgical and diagnostic procedures. [11] Awareness of common variants and regional norms helps reduce procedural complications and improves clinical planning for approaches involving the middle cranial fossa. [12] Combining findings from different study types and regional cohorts strengthens the anatomical reference clinicians and anatomists use. [13]. The findings aim to support both anatomical reference and practical guidance for procedures that involve the mandibular nerve and adjacent cranial base structures. [15] Detailed, population-specific descriptions of foramen ovale shape, margins, and positional relationships are therefore valuable for anatomy, radiology, and surgical practice. [16]

**Aim & Objectives:** To measure and analysed the morphometric parameter of foramen ovale in dry skull.

## Material and Methods:

The present cross-sectional osteological study was carried out on 50 dry adult human skulls obtained from the Department of Anatomy, Pacific Institute of Medical Science, Udaipur, Sai Tirupati University (25 male and 25 female). Specimens with visible fractures, congenital deformities, pathological lesions, or prior surgical alterations of the skull base were excluded to avoid measurement bias.

Bilateral morphometric parameters of the foramen ovale were recorded as APDFOLows:

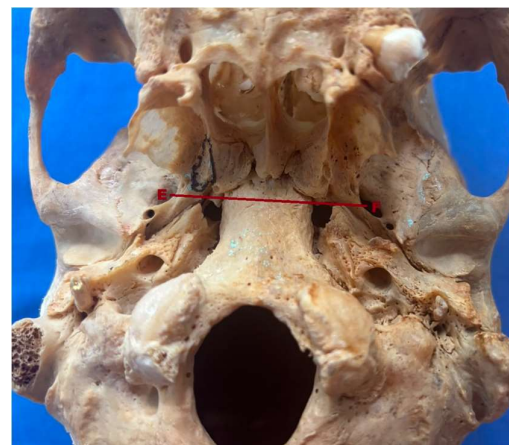
- Anteroposterior diameter (AP) — the maximum distance between the anterior and posterior margins of the foramen [Fig. 1].
- Mediolateral diameter (ML) — the maximum distance perpendicular to the AP axis between the medial and lateral margins [Fig. 1].
- Distance from midline to foramen ovale (DMTFO) — linear distance from the midsagittal plane to the medial margin of the foramen.
- Inter-foraminal distance (IFOD) — linear separation between the right and left

foramina ovale measured across the midsagittal plane [Fig. 2].

For each parameter we took the three times value and taking the mean of it as a final value and recorded in excel sheet. All analysis were performed using SPSS version X. Correlations between linear measures were evaluated with Karl Pearson's correlation coefficient. ANOVA test was applied. The P value <0.05 was considered statistically significant.



**Fig No 1:** Measuring the Anteroposterior diameter (A-B) and mediolateral diameter (C-D) of foramen ovale.



**Fig No 2:** Measuring the Inter-foraminal distance of foramen ovale.

## Results:

We study on 50 dry human skull out of that 25 males and 25 females, in both the sexes we took the measurements of either side of foramen ovale separately.

**Table No. 01:** Depicts the Minimum, Maximum, Mean, and Standard Deviation of different parameters of the foramen ovale in dry Human Skulls.

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| Parameter | AP DF OR (m m) | ML DF OR (m m) | AP DF OL (m m) | ML DF OL (m m) | DM TF OR (m m) | DM TF OL (m m) | IF O D (m m) |
|-----------|----------------|----------------|----------------|----------------|----------------|----------------|--------------|
| Min       | 6.1            | 3              | 6.4            | 3.2            | 19.6           | 19.2           | 36           |
| Max       | 8.9            | 5.2            | 8.4            | 4.9            | 24.9           | 24.2           | 52           |
| Mean      | 7.354          | 4.024          | 7.47           | 4.19           | 22.09          | 21.674         | 44.242       |
| SD        | 0.7279         | 0.6097         | 0.5635         | 0.5036         | 1.5175         | 1.3673         | 4.38113      |

The mean and SD value of Anteroposterior diameter of foramen ovale (APDFO) are  $7.354 \pm 0.727$  (right) and  $7.47 \pm 0.563$  (left) ; mediolateral diameters (MLDFO) are  $4.024 \pm 0.609$  (right) and  $4.19 \pm 0.503$  (left) ; distance from midline to foramen ovale (DMTFO) are  $22.09 \pm 1.517$  (right) and  $21.674 \pm 1.367$  (left) ; inter-foraminal distance (IFOD) are  $44.242 \pm 4.381$  respectively.

**Table No. 02:** Depicts the Minimum, Maximum, Mean, and Standard deviation of different parameters of foramen ovale in male dry Human Skulls.

| Parameter | AP DF OR (m m) | ML DF OR (m m) | AP DF OL (m m) | ML DF OL (m m) | DM TF OR (m m) | DM TF OL (m m) | IF O D (m m) |
|-----------|----------------|----------------|----------------|----------------|----------------|----------------|--------------|
| Min       | 6.2            | 3.1            | 6.6            | 3.4            | 19.6           | 19.2           | 36           |
| Max       | 8.7            | 5.2            | 8.4            | 4.9            | 24.9           | 24.2           | 52           |
| Mean      | 7.576          | 4.216          | 7.676          | 4.34           | 22.456         | 22.052         | 45.604       |
| SD        | 0.6923         | 0.6051         | 0.5425         | 0.4966         | 1.5948         | 1.4058         | 4.55343      |

The mean and SD value of Anteroposterior diameter of foramen ovale in male (APDFO) are  $7.576 \pm 0.692$  (right) and  $7.676 \pm 0.542$  (left) ; mediolateral diameters in male (MLDFO) are  $4.216 \pm 0.605$  (right) and  $4.34 \pm 0.496$  (left) ; distance from midline to foramen ovale in male (DMTFO) are  $22.456 \pm 1.594$  (right) and  $22.052 \pm 1.405$  (left) ; inter-foraminal distance of foramen ovale in male (IFOD) are  $45.604 \pm 4.553$  respectively.

**Table No. 03:** Depicts the Minimum, Maximum, Mean, and Standard deviation of different parameters of foramen ovale in Female dry Human Skulls.

| Parameter | F O L R (m m) | ML DF OR (m m) | AP DF OL (m m) | ML DF OL (m m) | DM TF OR (m m) | DM TF OL (m m) | IF O D (m m) |
|-----------|---------------|----------------|----------------|----------------|----------------|----------------|--------------|
| Min       | 6.1           | 3              | 6.4            | 3.2            | 19.6           | 19.2           | 36           |
| Max       | 8.9           | 5.2            | 8.3            | 4.8            | 24.6           | 23.9           | 50           |
| Mean      | 7.132         | 3.832          | 7.264          | 4.04           | 21.724         | 21.296         | 42.88        |
| SD        | 0.70694       | 0.56252        | 0.51468        | 0.47346        | 1.37061        | 1.24281        | 3.81969      |

The mean and SD value of Anteroposterior diameter of foramen ovale in female (APDFO) are  $7.132 \pm 0.706$  (right) and  $7.264 \pm 0.514$  (left) ; mediolateral diameters in female (MLDFO) are  $3.832 \pm 0.562$  (right) and  $4.04 \pm 0.473$  (left) ; distance from midline to foramen ovale in female (DMTFO) are  $21.724 \pm 1.370$  (right) and  $21.296 \pm 1.242$  (left) ; inter-foraminal distance (IFOD) are  $42.88 \pm 3.819$  respectively.

**Table No. 04:** Depicts the R-values and P-values comparing the parameters of foramen ovale of males and females in dry skulls, analysed using Karl Pearson correlation and ANOVA tests.

| Parameters | r (Pearson) | p (ANOVA) |
|------------|-------------|-----------|
| FOLR       | 0.38044     | 0.029515  |
| MLDFOR     | 0.350855    | 0.024434  |
| APDFOL     | 0.296676    | 0.008279  |
| MLDFOL     | 0.295913    | 0.033722  |
| DMTFOR     | 0.278709    | 0.088121  |
| DMTFOL     | 0.238153    | 0.049567  |
| IFOD       | 0.27742     | 0.026357  |

APDFOL, MLDFOR, APDFOR, MLDFOL and IFOD show modest positive correlations with sex and reach statistical significance ( $p < 0.05$ ). DMTFOR is not significant ( $p = 0.088$ ) while DMTFOL is borderline ( $p$ -value 0.0496). Effect sizes ( $r$ ) are small to moderate; statistically significant differences are modest in absolute magnitude.

## Discussion

We examined **100 foramina ovale from 50 dry adult skulls** and measured Anteroposterior Diameter (APDFO), Mediolateral diameter (MLDFO), distance from the midline (DMTFO) and the distance between the right and left foramina (IFOD). Our sample means were: FO Anteroposterior diameter **7.354 mm (right)** and **7.470 mm (left)**, FO mediolateral diameter **4.024 mm (right)** and **4.190 mm (left)**, DMTFO **22.090 mm (right)** and **21.674 mm (left)**, and IFOD **44.242 mm**. When we looked at males and females separately, males tended to have slightly larger values for most measures (for example APDFO male **7.576 mm** vs female **7.132 mm**), and statistical tests showed small but significant sex differences for several linear measures and for IFOD; DMTFOR was not significant and DMTFOL was borderline.

**Table No. 05: Depicts the comparison of distance from midline to foramen ovale between previous study and present study.**

| Auth<br>ors                                     | FO → midline<br>Right (mm) |            |           | FO → midline<br>Left (mm) |            |           |
|-------------------------------------------------|----------------------------|------------|-----------|---------------------------|------------|-----------|
|                                                 | Mal<br>e                   | Fem<br>ale | Tota<br>l | Mal<br>e                  | Fem<br>ale | Tot<br>al |
| Mishr<br>a et<br>al. <sup>1</sup>               | 21.4                       | 21.6       | -         | 22.0                      | 21.0       | -         |
| Patil<br>et al. <sup>2</sup>                    | 22.1<br>3                  | 21         |           | 21.7<br>1                 | 21         |           |
| Khair<br>nar &<br>Bhus<br>ari<br>(2013<br>) [3] | 22.5<br>8                  | 21         |           | 22.1<br>5                 | 21         | -         |
| B. S.<br>Rao<br>et al.<br>(2017<br>) [7]        | -                          | -          | 24.2<br>8 | -                         | -          | 24.2<br>4 |
| Sank<br>aran<br>et al.<br>(2018<br>) [8]        | -                          | -          | 22.0<br>2 | -                         | -          | 21.8<br>8 |
| Prese<br>nt<br>study                            | 22.4<br>56                 | 21.7<br>24 |           | 22.0<br>52                | 21.2<br>96 | -         |

In the present study, the mean distance of the foramen ovale from the midline was found to be 22.456 mm in males and 21.724 mm in females on the right side, and 22.052 mm in males and 21.296

mm in females on the left side. In previous study done by Mishra et al. reported values of 21.4 mm in males and 21.6 mm in females on the right, and 22.0 mm in males and 21.0 mm in females on the left. In past study done by Patil et al. they observed the midline value of foramen ovale 22.13 mm in males and 21 mm in females on the right, and 21.71 mm in males and 21 mm in females on the left. Past study done by Khairnar & Bhusari they noted the midline value of foramen ovale was 22.58 mm in males and 21 mm in females on the right, and 22.15 mm in males and 21 mm in females on the left. So, our finding is similar with the previous study was done by Mishra et al, Patil et al, Khairnar & Bhusari et al study. Whereas in Rao et al. study, they found the midline value of foramen ovale was 24.28 mm on the right and 24.24 mm on the left. So our finding is lesser then the Rao et al study. Overall, the reported values across studies range between 21.0 mm and 24.28 mm, and our findings fall well within this spectrum, confirming consistency across different populations. These morphometric observations are clinically significant, as precise knowledge of the foramen ovale relation to the midline is essential for neurosurgical approaches and diagnostic interventions involving the cranial base.

**Table No. 06: Depicts the comparison of Inter-foraminal distance of foramen ovale between previous study and present study.**

| Authors                       | Male   | Female | Total |
|-------------------------------|--------|--------|-------|
| Sthapak & Bedi (2022, CT) [4] | 30.94  | 24.86  | -     |
| Sankaran et al. (2018) [8]    | -      | -      | 44.29 |
| B. S. Rao et al. (2017) [7]   | -      | -      | 48.52 |
| Present study                 | 45.604 | 42.88  | 44.24 |

Our overall inter-foraminal distance was **44.242 mm** (male **45.604 mm**, female **42.880 mm**), a result that closely matches Sankaran et al.'s dry-skull value of **44.29 mm**, indicating good agreement between independent osteological series when comparable measurement endpoints are used [8]. Rao et al. reported a larger calculated inter-foraminal distance, which may be due to different endpoint choices (for example margin-to-margin rather than center-to-center) or to sample differences [7]. CT-based reports such as Sthapak & Bedi show more variability and sometimes smaller values, likely because imaging factors (slice selection, reconstruction parameters) affect measured distances on scans [4]. For bilateral procedures that depend on accurate lateral coordinates, our dry-bone IFOD provides a reliable

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population reference, but final stereotactic coordinates should always be verified and adjusted using the patient's own imaging.

**Table No. 07: Depicts the comparison of foramen ovale Anteroposterior diameter between previous study and present study**

| Author<br>s                  | Right    |            |           | Left     |            |           |
|------------------------------|----------|------------|-----------|----------|------------|-----------|
|                              | Ma<br>le | Fem<br>ale | Tot<br>al | Ma<br>le | Fem<br>ale | Tot<br>al |
| Mishra et al. [1]            | 7.5      | 7.7        |           | 7.5      | 7.7        |           |
| Patil et al [2]              | 7        | 6.8        |           | 6.8      | 6.7        |           |
| Khairnar & Bhusari et al [3] | 7.05     | 7.11       |           | 7.29     | 7.29       |           |
| Supriya Garapati et al [5]   |          |            | 6.99      |          |            | 6.59      |
| Prem Lata et al [6]          |          |            | 7.64      |          |            | 7.52      |
| B. Sadana Rao et al [7]      |          |            | 7.24      |          |            | 7.11      |
| Sankaran et al [8]           |          |            | 7.45      |          |            | 7.61      |
| Our study                    | 7.576    | 7.132      | 7.354     | 7.676    | 7.264      | 7.47      |

In the present study, the average Anteroposterior of the foramen ovale to be 7.576 mm in males and 7.132 mm in females on the right side (mean 7.354 mm), and 7.676 mm in males and 7.264 mm in females on the left side (mean 7.47 mm). Mishra et al. reported values of about 7.5–7.7 mm (Mishra et al., 2018), while Patil et al. observed slightly smaller dimensions (7.0 mm right, 6.7–6.8 mm left) (Patil et al., 2013). Khairnar & Bhusari noted 7.05–7.11 mm on the right and 7.29 mm on the left (Khairnar & Bhusari, 2013). Garapati et al. found 6.99 mm right and 6.59 mm left (Garapati et al., 2024), whereas Prem Lata et al. reported 7.64 mm right and 7.52 mm left (Prem Lata et al., 2026). Rao et al. recorded 7.24 mm right and 7.11 mm left (Rao et al., 2017), and Sankaran et al. reported 7.45 mm right and 7.61 mm left (Sankaran et al., 2018). Overall, the values across studies range between 6.59 mm and 7.64 mm, and our findings lie well within this spectrum. These morphometric observations are clinically relevant, as precise

knowledge of foramen ovale dimensions aids neurosurgeons in procedures involving the middle cranial fossa.

**Table No. 08: Depicts the comparison of Mediolateral diameter of foramen Ovale between previous study and present study**

| Mediolateral diameter        |          |            |           |          |            |           |
|------------------------------|----------|------------|-----------|----------|------------|-----------|
| Author<br>s                  | Right    |            |           | Left     |            |           |
|                              | Ma<br>le | Fem<br>ale | Tot<br>al | Ma<br>le | Fem<br>ale | Tot<br>al |
| Mishra et al [1]             | 4.2      | 3.9        |           | 4.1      | 4          |           |
| Patil et al [2]              | 5        | 4.7        |           | 4.7      | 4.6        |           |
| Khairnar & Bhusari et al [3] | 3.99     | 3.6        |           | 4.06     | 4.06       |           |
| Supriya Garapati et al [5]   |          |            | 4.17      |          |            | 4.09      |
| Prem lata et al [6]          |          |            | 4.21      |          |            | 4.16      |
| B. Sadana Rao et al [7]      |          |            | 3.99      |          |            | 4.6       |
| Sankaran et al [8]           |          |            | 3.99      |          |            | 4.6       |
| In the present study         | 4.216    | 3.832      | 4.024     | 4.34     | 4.04       | 4.19      |

In the present study, the average width of the foramen ovale to be 4.216 mm in males and 3.832 mm in females on the right side (mean 4.024 mm), and 4.34 mm in males and 4.04 mm in females on the left side (mean 4.19 mm). Mishra et al. reported values of about 4.2 mm in males and 3.9 mm in females on the right, and 4.1 mm in males and 4.0 mm in females on the left (Mishra et al., 2018). Patil et al. observed slightly larger dimensions (5.0 mm right, 4.7 mm left in males; 4.7 mm right, 4.6 mm left in females) (Patil et al., 2013). Khairnar & Bhusari noted 3.99 mm right and 3.6 mm left in males; 4.06 mm right and left in females (Khairnar & Bhusari, 2013). Garapati et al. reported 4.17 mm on the right and 4.09 mm on the left (Garapati et al., 2024), while Prem Lata et al. found 4.21 mm right and 4.16 mm left (Prem Lata et al., 2026). Rao and Sankaran both recorded 3.99 mm on the right and 4.6 mm on the left (Rao et al., 2017; Sankaran et al., 2018). Overall, the reported values across studies range between 3.6 mm and 5.0 mm,

and our findings fall well within this spectrum, confirming consistency across different populations. These morphometric observations are clinically important, as accurate knowledge of foramen ovale width supports safe neurosurgical and diagnostic procedures involving the cranial base.

## Conclusion:

This morphometric analysis of 100 foramina ovale from 50 dry adult skulls establishes regional reference values for Anteroposterior diameter, mediolateral diameter, distance from the midline, and inter-foraminal distance. Male skulls exhibited slightly larger mean dimensions than female skulls across most parameters, and several linear measures—including inter-foraminal distance (IFOD)—differed significantly between sexes ( $p < 0.05$ ), while right midline distance (DMTFOR) did not reach significance and left midline distance (DMTFOL) was borderline. Although statistically significant, the absolute magnitudes of sex-related differences are modest and should be interpreted in clinical context. The reported midline distances (DMTFO) and inter-foraminal distance (IFOD) are clinically important because they influence needle trajectory, bilateral symmetry assessment, and spatial planning for percutaneous procedures targeting the mandibular nerve or the middle cranial fossa. These table-backed normative values therefore provide practical reference ranges for anatomists, radiologists, and neurosurgeons. Further studies with larger, demographically characterized samples and radiological correlation are recommended to refine these normative ranges and to clarify how midline and inter-foraminal variability affect procedural safety and accuracy.

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