



**ORIGINAL RESEARCH PAPER**

**Anatomy**

**MORPHOMETRIC STUDY OF SEXUAL DIMORPHISM OF FORAMEN MAGNUM OF DRY HUMAN SKULLS IN MADHYA PRADESH REGION.**

**KEY WORDS:** Diameters of Foramen Magnum, craniometry, sexual identification, foramen magnum index

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**ABSTRACT**

Morphometry of Foramen magnum is of utmost value because of passage of vital structures through it. Many a time, base of the skull is the only skeletal remain available for forensic identification. So, this study is to validate morphometric parameters of foramen magnum and its index for sex determination along with morphological feature. Results shows mean Antero posterior diameter of foramen magnum 3.56-0.23 and 3.32-0.26, of male and female skulls respectively. Mean transverse diameter 2.92-0.22 and 2.81-0.24 for male and female skulls respectively. Mean Foramen Magnum Index 82.21\_5.86 and 84.93\_7.35 for male and female skulls respectively. These results can be used for sex determination of broken skulls where only base of skull is available for forensic identification. Study is important for anatomists, medicolegal experts, radiologists and neurosurgeons.

**INTRODUCTION -**

The foramen magnum is transitional area between skull and spine which is in close relation to the vital structures such as brain and spinal cord. Foramen magnum is the largest foramen of human skull that lies in an anteromedian position and leads into posterior cranial fossa. Its contents include lower part of medulla oblongata, meninges, vertebral arteries, anterior and posterior spinal arteries, tectorial membrane, alar ligaments and the spinal root of accessory nerve. It is oval in shape with higher anteroposterior diameter than transverse diameter. [1,2]

Dimensions of foramen magnum have clinical importance because of vital structures passing through it. Morphology and morphometry of foramen magnum plays important role in pathophysiology of various disorders of craniovertebral junction. Hence, fundamental knowledge of normal anatomy and its variations along with craniometric measurements of foramen magnum for assessment of craniovertebral relations is extremely important to clinicians and surgeons who diagnose, treat and operate in this region. [3]

**Objective -**

Study was conducted to derive foramen magnum index and demarking point for identification of sex of human skull in Madhya Pradesh region.

**MATERIAL AND METHODS -**

After necessary permission from the Institutional ethics committee, the study was carried out on 260 dry human skulls under the purview of Department of Anatomy, Gandhi Medical college Bhopal from 2020-22. All available dry human skulls were studied from Department of Anatomy, Regional medicolegal Institute, Bhopal, and Department of Forensic Medicine and Toxicology, Gandhi Medical College, Bhopal (MP) after due permissions. All available completely ossified adult dry human skulls without any apparent damage are taken for study purpose. The criteria to decide skull of adult age was dental examination and basi-occiput and basisphenoid suture fusion. The eruption of 3<sup>rd</sup> molar is between 17 to 25 years and suture at the base of skull between sphenoid and occipital bone closes around 18 years in males and 20 years in females. Presence of one of these in the skull is

considered to be of adult male or female. Damaged or broken human skulls with visible loss of skeletal elements affecting the selected morphometric and morphological parameters are excluded from the study. Antero-posterior diameter of foramen magnum is the distance between the basion and opisthon & transverse diameter of foramen magnum is the distance between point of maximum curvature of foramen magnum lateral margins, measured by using digital vernier calliper. Shape of foramen magnum is observed and recorded.

**Foramen Magnum Index (FMI) -**

It is the ratio between transverse diameter and Anteroposterior diameter of Foramen magnum and denoted by formula -

$$\text{Foramen Magnum Index} = \frac{\text{Transverse Diameter of Foramen Magnum}}{\text{Anteroposterior Diameter of Foramen Magnum}} \times 100$$

Identification point is calculated as above or below the maximum or minimum value of particular parameter for skull of opposite sex. Calculated range was derived as mean +\_ 3SD and demarking point is above or below the maximum or minimum value of calculated range of skull of opposite sex. Paired t test applied for significance.

**RESULTS -**

**Morphometric analysis of Foramen Magnum**

**Table -2- Morphometry of Foramen Magnum-**

	AP Diameter of Foramen Magnum		Transverse Diameter of Foramen Magnum		Foramen Magnum Index	
	Female	Male	Female	Male	Female	Male
Frequency	120	140	120	140	120	140
%	46.15 %	53.85 %	46.15%	53.85%	46.15 %	53.85 %
Mean	3.32	3.56	2.81	2.92	84.93	82.21
Std. Deviation	0.26	0.23	0.24	0.22	7.35	5.86
Variance	0.07	0.05	0.06	0.05	53.99	34.35

Minimum	2.65	2.96	2.27	2.48	67.54	68.93
Maximum	4.15	4.11	3.71	3.93	112.55	107.68
95% Confidence interval of Mean	3.27; 3.36	3.52; 3.6	2.77; 2.85	2.88; 2.96	83.62; 86.24	81.24; 83.18
Mean ± Std.	3.32 ± 0.26	3.56 ± 0.23	2.81 ± 0.24	2.92 ± 0.22	84.93 ± 7.35	82.21 ± 5.86

	AP Diameter of Foramen Magnum		Transverse Diameter of Foramen Magnum		Foramen Magnum Index	
	Female	Male	Female	Male	Female	Male
Frequency	120	140	120	140	120	140
%	46.15%	53.85%	46.15%	53.85%	46.15%	53.85%
Range	2.65-4.15	2.96-4.11	2.27-3.71	2.48-3.93	67.54-112.55	68.93-107.68
Identification Point	<2.962	>4.15	<2.477	>3.7	<68.93	>112.55
Calculated Range	2.554-4.08	2.88-4.24	2.083-3.535	2.25-3.59	62.98-106.88	64.7-99.73
Demarking Point (D.P.)	<2.878	>4.08	<2.249	>3.535	<68.93	>106.88
No. of skulls beyond DP	6	2	0	2	0	0
% of identified Skull	2.3%	0.8%	0	0.8%	0	0

Table shows the range, mean, standard deviation, identification point, demarking point, number and percentage of male and female skulls beyond the demarking point which is mean ± 3SD that indicates 99.7% accuracy in differentiation of sex of skull for a particular parameter.

In the present study, the range of antero-posterior diameter of foramen magnum is 2.96-4.11 cm and 2.65- 4.15 cm in male and female skulls respectively. The calculated range of AP diameter of foramen magnum is 2.88- 4.24 cm and 2.554- 4.08 cm for male and female groups respectively, calculated by mean ± 3SD. The results of the descriptive statistics show that the female group has lower values for the dependent variable Antero-posterior Diameter of Foramen Magnum ( $M = 3.32$ ,  $SD = 0.26$ ) than the male group ( $M = 3.56$ ,  $SD = 0.23$ ). Highest frequency of observed values is in between 3.5 - 4 cm end 3-3.5 cm in male and female skulls respectively. 6 (2.3%) female and 2 (0.8%) male skulls are identified by demarking point. **Two-tailed t-test for independent samples** (equal variances assumed) showed that the difference between female and male skull group with respect to the dependent variable AP Diameter Foramen Magnum was **statistically significant**,  $t(258) = -8.07$ ,  $p = <.001$ , **95% confidence interval [-0.3, -0.18]**.

In the present study, range of transverse diameter of foramen magnum of male skulls is 2.48 - 3.93 cm and in female skulls 2.27- 3.71 cm respectively. The calculated range for maleskulls is 2.25 - 3.59 cm and female skulls is 2.083 - 3.535 cm which is calculated after mean ± 3 SD. The results of the descriptive statistics show that the female group has lower values for the dependent variable Transverse Diameter of Foramen Magnum ( $M = 2.81$ ,  $SD = 0.24$ ) than the male group ( $M = 2.92$ ,  $SD = 0.22$ ). Highest frequencies of observed values for transverse diameter of foramen magnum are in range of 2.75- 3.25 cm for male skulls and 2.5 - 3.0 cm for female skulls. It indicates narrow range of dispersion of observed values with considerable overlapping. 2 (0.8%)

male skulls are identified by demarking point. A **two-tailed t-test for independent samples** (equal variances assumed) showed that the difference between female and male group with respect to the dependent variable Transverse Diameter Foramen Magnum was **statistically significant**,  $t(258) = -3.85$ ,  $p = <.001$ , **95% confidence interval [-0.17, -0.05]**.

In the present study, range of foramen magnum index is 68.93 -107.68 and 67.54 -112.55 for male and female skulls respectively. The calculated range with mean ± 3SD is 64.7-99.73 and 62.98-106.88 for male and female skulls respectively. The demarking point is above 106.88 for male skulls and below 68.93 for female skulls. The results of the descriptive statistics show that the Female group has higher values for the dependent variable Foramen Magnum Index ( $M = 84.93$ ,  $SD = 7.35$ ) than the male group ( $M = 82.21$ ,  $SD = 5.86$ ). Majority of observed values falls in the range of 80-90 with considerable overlapping between the 2 groups. Female group has higher values for foramen magnum index. A **two-tailed t-test for independent samples** (equal variances assumed) showed that the difference between female and male skull group with respect to the dependent variable Foramen Magnum Index was **statistically significant**,  $t(258) = 3.31$ ,  $p = .001$ , **95% confidence interval [1.09, 4.34]**.

**DISCUSSION -**

**Table –3 – Comparison with other researchers for Antero-posterior and transverse diameter of Foramen Magnum -**

S.No.	Researcher	No. of Skulls/ observations	Antero-Posterior Diameter of Foramen Magnum(mm)			Transverse Diameter of Foramen Magnum(mm)		
			Male	Female	Unified	Male	Female	Unified
1.	Olivier et al (1975)[3]	125			35.7±2.			30.34±2
					72			.15
2.	Mursed et al (2003)[4]	110			35.9±3.			30.4±2.
					29			59
3.	Suazo et al (2009)[5]	211	36.5±2.	35.6±2.		30.6±2.	29.5±1.	
			6	5		5	9	
4.	Monoel et al(2009)[6]	215	35.7±0.	35.1±0.		30.3±0.	29.4±0.	
			29	33		2	23	
5.	Kumar et al (2015)[7]	36	36.7±0.	33.22±0.		30.0±0.	29.4±0.	
			.35	.49		.54	04	
6.	Chovalopo ulou et al (2017)[8]	154	36.6±2.	34.87±2.		32.4±2.	30.6±2.	
			.47	.41		.7	.18	
7.	Ilhan P (2017)[10]	100			35.18±2.94			29.73±2.54
8.	Mahajan et al(2011)[9]	126			32.83±2.62			27.47±2.25
9.	Radhakrishna et al (2012)[11]	100			34.04±2.36			28.63±1.89
10.	Chethaneta l (2012)[12]	53			31±2.4			25.2±2.4
11.	Kanchan etal(2013) [13]	118	34.5±2.	27.36±2.09		33.6±2.	26.7±2.	
12.	Sherpur et al (2014)[14]	150	33.4-2.60	33.10-2.7		28.5-2.2	27.3-2.0	

13.	Vedanayagam et al (2015)	420	18.4±0.7	17.6±1.0		28.2±0.6	21.8±0.7
14.	Veeramani et al (2018)[15]	100	37.03±0.3	35.23±0.23		33±0.23	32±0.43
15.	Raikwar et al (2018)[16]	150			34.19±3.57		31.77±3.59
16.	Sharma et al (2018)	75			35.11±3.12		29.35±3.46
17.	Present study	260	35.6±0.0	33.2±0.0		29.2±0.0	28.1±0.0
			23	26		22	24

In the present study, the bisexual variation in Antero-posterior and transverse diameter of foramen magnum of male and female skulls is highly significant as the 't' test was -8.07 and -3.85 respectively (p < 0.001).

The observations of antero-posterior of foramen magnum in male skulls in the present study are similar to the observations of Moneal et al (2009). Observations of Suazo et al, Veeramani et al, Kumar et al, and Chovalopolou et al 2009 are higher to results of the present study. The results recorded by Kanchan et al, Sherpur et al, Vedanava et al are lower than observations in present study. In female skulls the observations of antero-posterior diameter of foramen magnum by Kumar et al and Sherpur et al is similar to present study. The observations of Suazo et al and Moneal et al are higher and Kanchan et al and Vedanava et al are lesser than the observations of our study. [3,4,5,6,10,11,12] The observations of transverse diameter of Foramen magnum of our study is similar to the results recorded by Suozo et al, Moneal et al and Kumar et al for male skulls. Observations of Sherpur et al and Vedanava et al are lower than present study. Observations of Veeramani et al (2018) and Kanchan et al (2013) are higher to the observations of present study. In the female skulls, the results of transverse diameter of foramen magnum are similar to Sherpur et al and Kanchan et al. Observations of Suazo et al, Veeramani et al, Monoel et al, kumar et al, Chovalopolou et al are higher to the observations of our study in female skulls. [13,14,16,18] In all the studies, the values of male skulls are marginally higher to corresponding female skull values. There are regional, racial and genetic variations, so observations are similar in the representative sample of skulls and may be considered as one of the important reasons for the similarities and differences in observed values.

**Foramen Magnum Index – (FMI)**

In present study on 260 skulls (M=140, F=120), the foramen magnum Index of male skulls observed to be 82.21 ± 5.86 (range – 68.93 – 107.68) and those of female skulls to be 84.93 ± 7.35 (range – 67.54 – 112.55). In the present study the bisexual variation in foramen magnum index of male and female skulls is highly significant as the 't' test was 3.31 (p=0.001).

**Table -4 - Comparison of present study with various studies for foramen magnum Index**

S. No.	Researcher	Place / No. of skull	Male		Female	
			Mean	S.D.	Mean	S.D.
1.	Murshed et al (2003)	Turkey				
2.	Gobbur et al (2013)	India	90.95	0.09	88.98	0.8
3.	Madadin et al (2017)	Saudi Arabia	85.22	6.35	84.96	6.39
4.	Vidisha et al (2019)[25]	India	88.17	6.33	88.09	5.79
5.	Abo El etta et al (2020)[26]	Egypt	117.45	10.38	119.85	9.38
6.	Present Study	India	82.21	5.86	84.93	7.35

Foramen magnum Index is represented by various researchers in two ways. One as proportion to the anteroposterior diameter and transverse diameter of foramen magnum and other as percentage of transverse and AP diameter. Secondly, the technique used to calculate Foramen magnum Index also differs, some studies are on dry human skulls, some are radiological and formula derivations. The observations of the present study are near to the observations of other studies in Indian context of Vidisha et al and Madadin et al of Saudi Arabia. The observations of El etta et al and Gobbur et al higher than present study. Our study observations are comparable to the results of the other Indian observations as well, Chethan et al, Radhika et al, Sahoo et al, Dubey et al, Patelet al, Vinutha et al, Veeramani et al and Sharma et al. [12,15,20,23,24]

**CONCLUSION –**

The present study concludes with the following craniometric measurements of the foramen magnum of dry human skulls that will be helpful in determining the sex of unknown skull or part of skull in central India Region.

	Parameter	Sex	Mean	S.D.	Range	t-value	P-value
1.	Antero-Posterior Diameter Of Foramen Magnum	M	3.56	0.23	2.96-4.11	-8.07	<0.001
		F	3.32	0.26	2.65-4.15		
2.	Transverse Diameter Of Foramen Magnum	M	2.92	0.22	2.48-3.93	-3.85	<0.001
		F	2.81	0.24	2.27-3.71		
3.	Foramen Magnum Index	M	82.21	5.86	68.93-107.68	3.31	=0.001
		F	84.93	7.35	67.54-112.55		

After a detailed study and comparison of the present study with the earlier researchers, it can be concluded that the demarking point and identification point help in identification of the sex of the skull with higher accuracy than non metric morphological methods. The demarking point of antero-posterior and transverse diameter of foramen magnum is valid and reliable measured indicator and foramen magnum index is statistically significant for the determination of sex of skull. Cluster sampling technique can also be used in study of unknown skull. Hence, measured indicators of foramen magnum can be used for the anatomical, forensic and medicolegal purposes where partial broken skull or only the base of the skull is available for examination.

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