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Original Research Article

Anatomic Evaluation of Foramen Magnum and Occipital Condyles in Dry Human Skulls of Decca Plateau Region and Its Surgical and Medico Legal Significance

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Abstract

Introduction: The Basicranium consist a largest bony aperture foramen magnum (FM), bounded with occipital condyles on its anterolateral aspect. The knowledge on morphology and morphometric dimensions of FM and occipital condyles plays an important role in craniovertebral surgeries. The present study was designed to evaluate the morphology and morphometry of foramen magnum and occipital condyles in the dry human skulls of Deccan plateau region, India

Material and methods: Sixty six adult human dry skulls of unknown gender were collected and evaluated at the Department of Anatomy. The morphologic and morphometric parameters like shape, anteroposterior and transverse diameter of foramen magnum; length and minimum & maximum width of occipital condyles, anterior and posterior intercondylar distance were measured and compared.

Results: The oval shaped (53.03%) FM was more frequent, followed by round (13.63%) and hexagonal shape (13.63%). The FM has higher mean anteroposterior diameter (34.86mm) than transverse diameter (30.42mm). The mean difference of length, maximum width and minimum width of right and left occipital condyles was statistically not significant ($p>0.005$).

Discussion and conclusion: The study results illustrated that the anteroposterior and transverse diameters and area of FM were similar with studies from different regions of India. However, the mean length, minimum and maximum width of occipital condyles was higher than the other regions in India. The present study attempted to evaluate the morphometry of FM and occipital condyles in the dry human skulls is first of its kind. The knowledge about the foramen magnum and occipital condyles is important for surgeons to achieve the convenient exposures at craniovertebral region with effective surgical outcome.

Keywords: Foramen magnum, Occipital condyle, Morphology, Morphometry, Posterior condylar canal

Background

The Foramen magnum (FM) is the immense bony aperture at the basicranium consist laterally placed occipital condyles and transmits spinal cord with meninges, spinal accessory nerves, vertebral artery and its branches [1]. The knowledge on anatomic variations, morphometry and morphology of foramen magnum is important for forensic scientists, anthropologists and surgeons performing craniovertebral junction surgery and also supportive for lateral surgical approaches to gain access to the lesions in middle and posterior cranial fossa [2]. The morphometry of foramen magnum is important to understand few developmental disorders like achondroplasia, Arnold-chiari deformity and acquired craniocervical junction disorders [3]. Studies suggested that various surgical procedures conducting without an extensive anatomical data on basicranium are associated with high morbidity and mortality [4]. The topographic anatomy of basicranium may present developmental and ethnic variations. Skull morphometry is essential for forensic studies and morphometry [5]. With a great surgical significance, and limited availability of morphometric data of FM and occipital condyles in Deccan plateau region, India, the present study was designed to evaluate morphology and morphometry of foramen magnum and occipital condyles in the dry human skulls of Deccan plateau of India.

Materials and Methods

A total of sixty-six adult human dry skulls of unknown gender were measured in the Department of Anatomy, Arundhathi Institute of Medical Sciences, Malkajgiri, Hyderabad. Bones showing wear and tear, damages and abnormalities were restricted. The morphological parameter like shape of the foramen and morphometric parameters such as anteroposterior and transverse diameter of foramen magnum, length and minimum & maximum width of occipital condyles, anterior and posterior intercondylar distance and presence of posterior condylar foramen were measured by using standard vernier sliding calipers.

Quantitative variables were represented by Mean±SD and qualitative variables were represented by frequency and percentages. Mean differences was analyzed by using independent “t” test. $P<0.005$ was considered as statistically significant.

Results

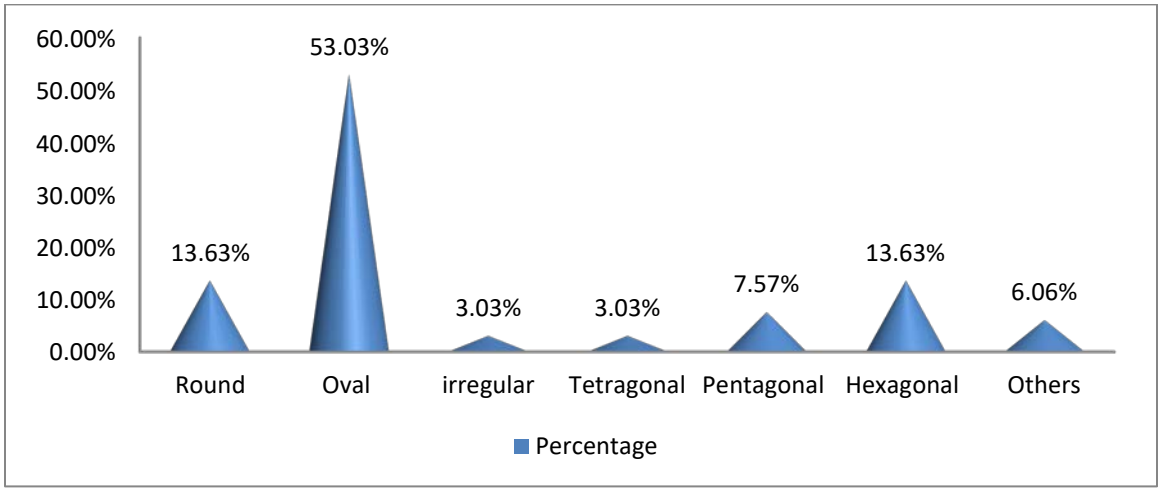

Figure 1: Percentage of various shapes of foramen magnum

The oval shaped foramen magnum was more common in 53.03%, followed by round type in 13.63%, hexagonal type in 13.63% and pentagonal type in 7.57% (Figure 1). The mean value of anteroposterior diameter (34.86±2.50) of foramen magnum was more than transverse diameter (30.42±2.35) (Table 1).

Table 1: Morphometric values of foramen magnum (n=66).

Parameters (In mm)	Foramen magnum		
	Minimum	Maximum	Mean±SD
Anteroposterior diameter	25.32	39.78	34.86±2.50
Transverse diameter	23.98	37.24	30.42±2.35
Area of foramen magnum	651.35	1045.32	784.18±121.30

Table 2: Morphometric values of occipital condyles (n=66).

Parameters (In mm)		Occipital condyles			t-value	p-value
		Minimum	Maximum	Mean±SD		
Maximum length	Right	17.86	33.06	24.23±2.28	0.33	0.538
	Left	17.15	32.46	24.52±2.42		
Maximum width	Right	9.52	17.34	13.87±2.02	0.62	0.422
	Left	9.64	17.72	14.08±2.26		
Minimum width	Right	3.51	10.75	7.01±1.47	0.87	0.278
	Left	4.48	10.98	7.79±1.58		

Table 3: Morphometric values of anterior and posterior intercondylar distance.

Parameters (In mm)	Intercondylar distance		
	Minimum	Maximum	Mean±SD
Anterior intercondylar distance	15.07	26.18	20.78±2.69
Posterior intercondylar distance	40.27	46.48	43.22±2.38

The mean difference of length, maximum width and minimum width of right and left occipital condyles was statistically not significant (p>0.005) (Table 2). The higher intercondylar distance

was observed on posterior level (43.22±2.38) than anterior (20.78±2.69) (Table 3). The posterior condylar canal was seen on right side in 56.06% skulls and on left side 53.03% skulls (Figure 2).

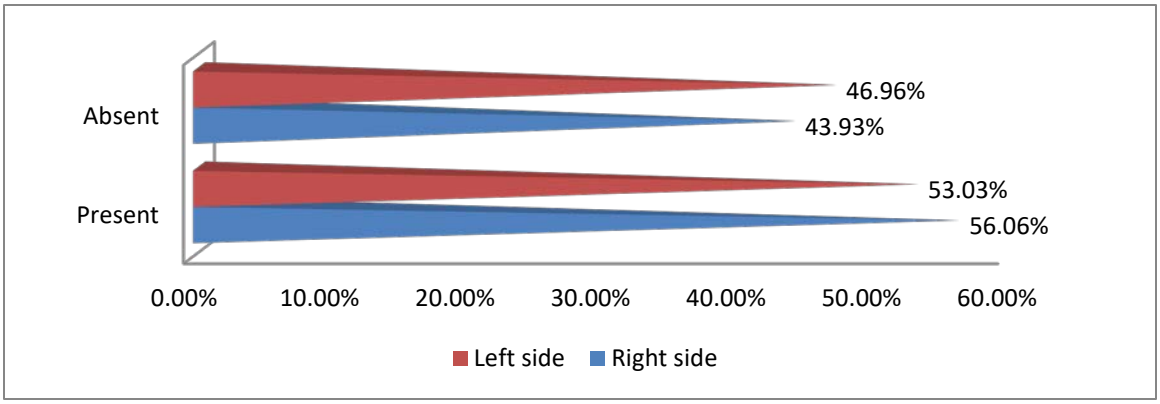

Figure 2: The incidence of posterior condylar canal.

Discussion

The present study consist a total of sixty six dry human unknown skulls. The oval shape (53.03%) foramen magnum is the commonest shape followed by round (13.63%) and hexagonal shape (13.63%). The above findings were in consistent with different Indian studies by Amit Singh B *et al*., [6], Suresh Sharma *et al*.,[7] SK Revankar *et al*.,[8] Giridhar D *et al*.,[9] Arjun Kumar *et al*.,[10] Singh D *et al*.,[11] Archana Singh et al.,[12] Sampada PK *et al*., [13] (Table 4). The various shapes of FM may have embryological basis, due to the different location of the endochondral ossification points during ossification [6,14]. Matthew JZ *et al*., stated that the shape of FM is inversely related to its anteroposterior, transverse diameters and oblique axis [15].

Table 4: Comparison of shape of foremen magnum in present study with previous studies

Author	Country	Round	Oval	Irregular	Tetragonal	Pentagonal	Hexagonal	Others
Present study (n=66)	Deccan plateau, India	13.63 %	53.03 %	3.03%	3.03%	7.57%	13.63%	6.06%
Amit Singh B *et al* (2021) (n=40) [6]	South India	32.5%	35%	-	25%	-	7.5%	-
Suresh Sharma *et al* (2020) (n=62) [7]	Northwest India	17.74 %	35.48 %	4.84%	11.29%	1.61%	9.68%	19.35 %
SK Revankar *et al* (2020) (n=40) [8]	Northwest India	17.5%	22.5%	12.5%	12.5%	12.5%	10%	12.5%
Giridhar D *et al* (2020) (n=64) [9]	South India	12%	30%	27%	-	5%	3%	23%
Arjun Kumar *et al* (2019)	North India	12%	58%	-	-	4%	10%	16%

(n=50) [10]								
Singh D *et al* (2019) (n=84) [11]	North India	26.19 %	29.76 %	5.95%	16.67%	4.76%	5.95%	10.71 %
Archana Singh *et al* (2019) (n=120) [12]	North India	13%	33.3%	-	16.6%	13.3%	16.6%	6.6%
Raveendranath V *et al* (2018) (n=100) [14]	South India	15%	6%	32%	11%	3%	21%	12%
Sampada PK *et al* (2017) (n=100) [13]	South India	9%	58%	10%	8%	1%	3%	11%
Ilhan P *et al*. (2017) (n=100) [16]	Turkey	6%	10%	22%	24%	2%	21%	12%
Aragoa JA *et al* (2014) [17]	Brazil	15.5%	5.5%	6.4%	10.9%	2.7%	1.8%	48.2%
Chethan P *et al* (2012) (n=53) [18]	South India	22.6%	15.1%	15.1%	18.9%	3.8%	5.6%	18.9%

Table 5: Comparison of anteroposterior, transverse diameter and total area of foramen magnum in present study with previous studies

Author	Country/Population	AP Diameter	Transverse diameter	Total area
Present study (n=66)	Deccan plateau, India	34.86	30.42	784.18
Amit Singh B *et al* (2021) (n=40) [6]	South India	36.78	30.05	616.39
Suresh Sharma *et al* (2020) (n=62) [7]	Northwest India	34.17	28.86	-
SK Revankar *et al* (2020) (n=40) [8]	Northwest India	34.36	28.48	773.536
Giridhar D *et al* (2020) (n=64) [9]	South India	34.1	28.07	-
Arjun Kumar *et al* (2019) (n=50) [10]	North India	34.08	28.17	757.41
Singh D *et al* (2019) (n=84) [11]	North India	33.57	27.49	728.12
Archana Singh et al (2019) (n=120) [12]	India	33.79	28.25	-
Raveendranath V *et al* (2018) (n=100) [14]	South India	37/35 (M/F)	33/32 (M/F)	788-1113
Matthew JZ *et al*	AFRIC (African negro)	39.27	32.78	919

(2017a) (n=152) [15]				
Matthew JZ *et al* (2017b) (n=152) [15]	BENGA (Bengal, India)	39.09	32.99	919.5
Matthew JZ *et al* (2017c) (n=152) [15]	EASIA (China, Japan)	38.38	33.53	918.2
Matthew JZ *et al* (2017d) (n=152) [15]	EUROP (Europe)	38.55	33.27	922.6
Matthew JZ *et al* (2017e) (n=152) [15]	MALAY	38.59	33.31	916.4
Matthew JZ *et al* (2017f) (n=152) [15]	PERUV (Peru)	35.43	32.28	818.1
Sampada PK *et al* (2017) (n=100) [13]	South India	34.84	29.39	-
Ilhan P *et al*. (2017) (n=100) [16]	Turkey	35.18	29.73	-
Berjina Farooq *et al* (2017) (n=15) [19]	North India	31.6	26.5	660
Cirpan *et al* (2016) (n=150) [20]	Turkey	34.38	28.95	-
Kamath VG *et al* (2015) (n=72) [21]	South India	32.26	26.29	715.32
Sanjukta Sahoo *et al* (2015) (n=150) [2]	Eastern India	35.30	29.49	-
Chethan P *et al* (2012) (n=53) [18]	South India	31	25.2	-

In this study, anteroposterior diameter of foramen magnum was higher than transverse diameter. Similar trend was observed in the studies conducted at different regions in India and worldwide (Table 5). However, the mean values of AP and transverse diameters reported in Indian studies were lower than study by Matthew JZ *et al*., who reported in different geographical locations worldwide [15]. The morphometry of FM is always influenced by age, gender, size of brain, intracranial content [15,19]. Several studies reported that males have higher anteroposterior, transverse diameter and area of FM than females [16,20]. The anteroposterior and transverse dimensions of FM is influenced by the age. The fact is basicranium is the first to reach adult size in the cranial region. The mean adult anteroposterior diameter of FM was achieved at the age of 5 years, whereas mean adult transverse diameter of FM was achieved by 10 years of postnatal age [22,23]. With this fact, the shape of FM has inverse relationship with changes occurring in the AP and transverse dimensions of FM between 5-10 years of post natal age. The foramen magnum measurements can be used in gender determination in forensic medicine.

Table 6: Comparison of length, minimum and maximum width of occipital condyles of present study with previous studies

Author	Country/Population	Length	Maximum width	Minimum width

		Right	Left	Right	Left	Right	Left
Present study (n=66)	Deccan plateau, India	24.23	24.52	13.87	14.08	7.01	7.79
Priya A *et al* (2019) (n=60) [24]	North India	19.9	22.3	13.2	13.7	-	-
Aju Bosco *et al* (2018) (n=70) [25]	South India	18.8		10.3		-	-
Zhou J *et al* (2018) (n=27) [26]	Chinese	18.8		12.1		-	-
Ilhan P *et al*. (2017) (n=100) [16]	Turkey	23.47		11.4		-	-
Ranjana Verma *et al* (2016) (n=100) [27]	North India	23.22	22.76	12.93	13.37	-	-
Sandeep Saluja *et al* (2016) (n=114) [28]	North India	22.90	22.60	12.98	12.97	-	-
Sanjukta Sahoo *et al* (2015) (n=150) [2]	Eastern India	22.45	22.65	-	-	-	-
El-Gaidi MA *et al* (2014) (n=50) [29]	Egypt	24.2	24.2	-	-	-	-
Salih AM *et al* (2014) (n=123) [30]	Sudan	20.66		12.81		-	-
Yu Z *et al* (2014) (n=20) [31]	China	22.75		12.97		-	-

In this study, the mean length of left occipital condyle (24.52) was slightly higher than the right condyle (24.23). The Mean width of occipital condyle was higher on left side (14.08) than right side (13.87) (Table 6). The present findings were in agreement with findings of Egyptian study and higher than the finding from other regions of India and worldwide. The recorded mean values of length, width, anterior intercondylar distance and posterior intercondylar distance was higher than other studies from India and worldwide (Table 7).

Table 7: Comparison of anterior and posterior intercondylar distance of present study with previous studies

Author	Country/Population	Anterior intercondylar distance	Posterior intercondylar distance
Present study (n=66)	Deccan plateau, India	20.78	43.22
Priya A *et al* (2019) (n=60) [24]	North India	19.5	36.6
Ilhan P *et al*. (2017) (n=100) [16]	Turkey	22.47	41.54
Ranjana Verma *et al* (2016) (n=100) [27]	North India	21.22	40.46
Sandeep Saluja *et al* (2016) (n=114) [29]	North India	17.81	38.91
Sanjukta Sahoo *et al* (2015) (n=150) [2]	Eastern India	20.13	41.17
Kalthur SG *et al* (2015) (n=71)	South India	21	39

[32]			

The dimensions of foramen magnum are the effective indicator for the sex determination of the skeletal remains in emergency context [21]. However, few studies opined that the area of FM is not an effective parameter for sex determination and can be considered only as supportive finding [33]. Uysal *et al*., stated that with accuracy rate of 81%, FM can be considered as effective tool for the sex determination [34]. Knowledge about the sexual dimorphism and topographic anatomy of the basioccipital region and FM is vital to neurosurgeons following transcondylar approach to access cervicomedullary junction and ventral aspect of brain stem [14]. The knowledge about the occipital condyles is important for condylar drilling in transcondylar approach to avoid craniocervical instability. This study focused on morphological and morphometric analysis of foramen magnum in dry human skulls of Deccan plateau, India and further approaches are required to use different methods to evaluate the foramen magnum and correlate with radiological assessment.

Conclusion

The knowledge about basicranium is important because vital structure passing through it. The morphological and morphometric evaluation of foramen magnum and occipital condyles is important prior to craniovertebral junction surgery to prevent adverse surgical events like craniocervical instability and complication associated with vital structures passing through it. In this study, oval shape FM was most common type and mean anteroposterior diameter of FM was higher than transverse diameter. The mean length, maximum and minimum width was higher in left occipital condyles than right. Hence, the adequate anatomical knowledge of the foramen magnum and occipital condyles is important for surgeons to diminish regrettable surgical errors, and to achieve the convenient exposures with effective surgical outcome. The metric analysis of base of skull may facilitate a statistically useful indication to determine the sex of an unknown skull.

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