

**Morphometric evaluation of occipital condyles for sex determination in human skulls**Anuj Ram Sharma<sup>1\*</sup>, Aruna Arya<sup>2</sup>, Rakesh Kumar Agarwal<sup>3</sup>, Vinay Sharma<sup>4</sup>, Vishnu Gupta<sup>5</sup><sup>1</sup>Associate Professor, Department of Anatomy, Muzaffar Nagar Medical College & Hospital, Beghrajpur, Muzaffar Nagar, U.P, India<sup>2</sup>Assistant Professor, Department of Anatomy, Muzaffar Nagar Medical College & Hospital, Beghrajpur, Muzaffar Nagar, U.P, India<sup>3</sup>Professor, Department of Anatomy, Maharashi Markendeshwar Medical College & Hospital, Kumarhatti, Solan, H.P, India<sup>4</sup>Professor, Department of Anatomy, Muzaffar Nagar Medical College & Hospital, Beghrajpur, Muzaffar Nagar, U.P, India<sup>5</sup>Professor & Head, Department of Anatomy, Muzaffar Nagar Medical College & Hospital, Beghrajpur, Muzaffar Nagar, U.P, India

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**Abstract**

**Introduction:** Occipital condyles can be helpful in determining the sex of an individual, this study aim was to determine the morphometric evaluation of occipital condyles for sex determination in human skulls. **Materials and Methods:** The study group includes adult skulls of 50 males and 46 females as determined by visual assessment of non-metrical parameters for sex determination of skull. Only those skulls having full cranial base with intact occipital condyles and foramen magnum for all 12 measurements to be taken were included. Skulls showing any kind of anomalies and skulls with partial damage to foramen magnum area of cranial base were not included. **Results:** There is non-significant difference in length of left occipital condyles, maximum width of left occipital condyles, minimum width of left occipital condyles, minimum distance of left occipital condyles, maximum interior distance of occipital condyles of male and female ( $p > .001$ ). There is significant difference in maximum distance between occipital condyles of male and female ( $p < .001$ ). **Conclusion:** Metric analysis of the basal region of the occipital bone may provide a statistically useful indication as to the sex of an unknown skull.

**Keywords:** Basal region, occipital bone, skull, Morphometry.

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**Introduction**

The basic components of a biological profile are: sex, age, height and ancestry. Among these four components, the first thing that is determined is the sex of an individual. Not only does the identification process begin with the estimation of sex, but other factors such as age or ancestry are much more difficult to assess without first knowing the sex of a given individual[1].

There are two osteological techniques used to determine the sex of an individual; the first is visual assessment to evaluate the morphological sex traits and second is the metrical, in which the skeletal assessment relies on methods based on osteometric measurements. This method reduces the examiner's subjective judgment and has high reproducibility but need well preserved bones and well defined measuring landmarks and techniques[2].

The occipital bone being described as perforated by the foramen magnum which is a unique and complex anatomical region within the basal central region of the occipital bone. The anterior border of the foramen magnum is formed by basilar process of the occipital bone, the lateral borders by the left and right ex-occipitalis and posterior border is formed by the supra-occipital part of the occipital bone[3].

Two convex kidney shaped condylar facets are found on either side of the foramen for articulation with the first cervical vertebra at the synovial atlanto-occipital joint.

The human occipital condyle is the unique bony structure connecting the cranium and the vertebral column.

\*Correspondence

**Dr. Anuj Ram Sharma**

Associate Professor, Department of Anatomy, Muzaffar Nagar Medical College & Hospital, Beghrajpur, Muzaffar Nagar, U.P, India  
E-mail: [dranujlatasharma@gmail.com](mailto:dranujlatasharma@gmail.com)

Due to the thickness of the cranial base and its relatively protected anatomical position, this area of the skull tends to withstand both physical insults and inhumation somewhat more successfully than many other areas of the cranium[4]. Therefore, there is considerable merit in investigating the value of this particular region in the process of sex determination and so in constitution of biological profile.

Occipital condyles can be helpful in determining the sex of an individual. Gapert et al[5], created regression formulae for sex determination from six measurements on the occipital condyles from a historic population. While the formulae lack the statistical strength necessary for regular use, they do provide some insight for the utility of occipital condyles for sexual dimorphism. Sex determination from occipital condyles could be used in conjunction with other techniques. The occipital condyles are among the classical morphological indicators of sexual dimorphism described by Krogman (1955) and Krogman & Iscan (1986)[6,7].

**Materials and methods**

This study was conducted on 96 human adult skulls. Skulls were collected from museum of anatomy Department of Muzaffarnagar Medical College, Muzaffarnagar and also from adjacent medical colleges of same geographical area.

The study group includes adult skulls of 50 males and 46 females as determined by visual assessment of non-metrical parameters for sex determination of skull<sup>7</sup>. Only those skulls having full cranial base with intact occipital condyles and foramen magnum for all 12 measurements to be taken were included. Skulls showing any kind of anomalies and skulls with partial damage to foramen magnum area of cranial base were not included.

A total of 12 measurements were taken from each intact cranial base with sliding calipers. Each measurement was taken in millimeters

(mm) to an accuracy of 0.5 mm to allow for instrument error. The following measurements were taken following Holland (1986a)[8]:

1. **Left occipital condyle length** – maximum length of the left occipital condyle taken along the articular surface perpendicular to the left occipital condyle width (Figure-1).
2. **Left occipital condyle maximum width** – maximum width of the left occipital condyle taken along the articular surface perpendicular to the left occipital condyle length (Figure-2).
3. **Left occipital condyle minimum width** – minimum width of the left occipital condyle taken along the articular surface perpendicular to the left occipital condyle length (Figure-3).
4. **Maximum distance between occipital condyles** – maximum distance between the lateral edges of the articular surfaces of the occipital condyles perpendicular to the midsagittal plane (Figure-4).
5. **Minimum distance between occipital condyles** – minimum distance between the lateral edges of the articular surfaces of the occipital condyles perpendicular to the midsagittal plane (Figure-5).
6. **Maximum internal distance of the occipital condyles** – maximum distance between the medial margins of the occipital condyles perpendicular to the midsagittal plane (Figure-6).
7. **Right occipital condyle length** – maximum length of the right occipital condyle taken along the articular surface perpendicular to the right occipital condyle width (Figure-7).
8. **Right occipital condyle maximum width** – maximum width of the right occipital condyle taken along the articular surface perpendicular to the right occipital condyle length (Figure-8).
9. **Right occipital condyle minimum width** – minimum width of the right occipital condyle taken along the articular surface perpendicular to the right occipital condyle length (Figure-9).
10. **Foramen magnum length** – maximum internal length of the foramen magnum along the midsagittal plane, from opisthion to basion (White 2000) (Figure-10).
11. **Foramen magnum width** – maximum internal width of the foramen magnum along the transverse plane (Figure-11).
12. **Length of the basilar process** – maximum length of the basilar process measured from basion to sphenion (White 2000) (Figure-12)

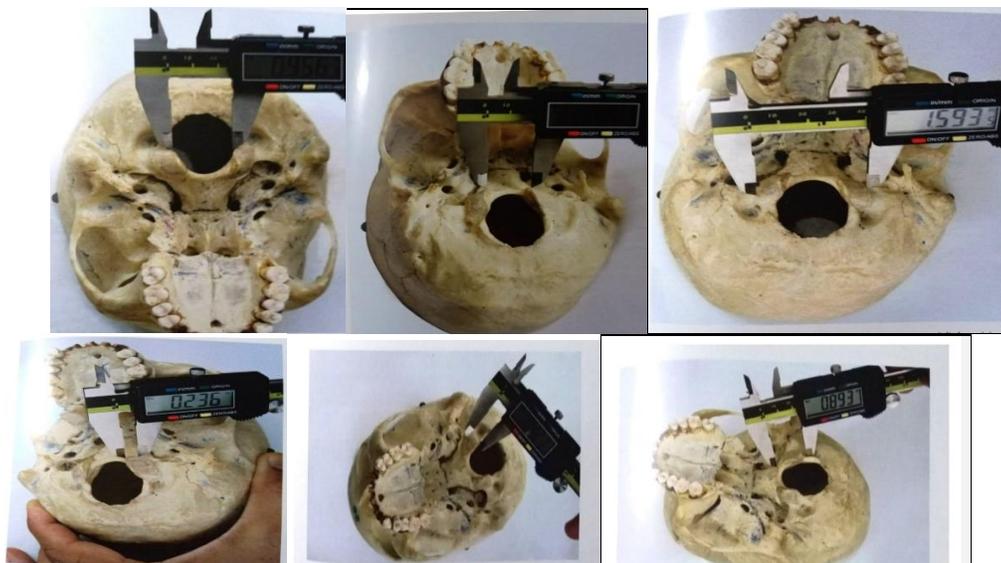


Figure 1.a Max. internal distance of occipital condyles, b:Minimum distance between occipital condyles, c.Maximum distance between occipital condyles, d:Left occipital condyle minimum width, e:Left occipital condyle maximum width, f:Left occipital condyle Length

**Results**

*P* <0.001 values were accepted as statistically significant. For each measurement, the minimum and maximum diameters were obtained and mean values with standard deviations for both sexes.

**Table-1. Showing the measurements of 12 parameters in male skulls (Male n=50)**

S.N.	Parameter	Min	Max	Mean	SD
1	LOC LENGTH	23.5	24.1	23.8	± 0.1
2	LOC MAX WIDTH	11.7	12.1	12.0	±0.11
3	LOC MIN WIDTH	6.3	6.6	6.4	±0.1
4	MAX DIS BETWEEN CONDYLES	49.9	50.9	50.7	±0.25
5	MIN DIS BETWEEN CONDYLES	35.6	36.1	35.8	±0.13
6	MAX INTERIOR DISTANCE BETWEEN CONDYLES	34.9	35.3	35.0	±0.12
7	ROC LENGTH	24.5	25.2	24.6	±0.17
8	ROC MAX WIDTH	11.9	12.5	12.3	±0.19
9	ROC MIN WIDTH	6.3	6.9	6.7	±0.14
10	LENGTH OF FM	35.9	36.9	36.3	±0.27
11	WIDTH OF FM	29.9	30.5	30.3	±0.2
12	LENGTH OF BP	31.7	31.9	31.8	±0.09

**Table-2 Showing the measurements of 12 parameters in female skulls (FEMALE n=46)**

S.N.	Parameter	Min	Max	Mean	SD
1	LOC LENGTH	20.2	24.5	22.3	±1.06
2	LOC MAX WIDTH	10	13.3	11.6	±0.85
3	LOC MIN WIDTH	4.9	6.5	5.58	±0.45
4	MAX DIS BETWEEN CONDYLES	46.9	51.8	50	±1.18
5	MIN DIS BETWEEN CONDYLES	30.2	37.2	34.2	±1.59
6	MAX INTERIOR DISTANCE BETWEEN CONDYLES	28.9	34.9	30.8	±1.46
7	ROC LENGTH	18.5	24.9	21.2	±1.71
8	ROC MAX WIDTH	9.5	13.2	11.1	±1.01
9	ROC MIN WIDTH	4.6	6.2	5.44	±0.49
10	LENGTH OF FM	27.2	36.9	31.3	±2.08
11	WIDTH OF FM	26.2	31.5	28.9	±1.72
12	LENGTH OF BP	23.7	32.7	27.6	±2.53

**In males**

The value of LOC LENGTH ranged from minimum 23.5mm to maximum 24.1mm with mean value of 23.8 mm and SD of ±0.1. The value of LOC MAX WIDTH ranged from minimum 11.7mm to maximum 12.1mm with mean value of 12.0 mm and SD of ±0.11. The value of LOC MIN WIDTH ranged from minimum 6.3mm to maximum 6.6 mm with mean value of 6.4mm and SD of ±0.1. The value of MAX DIS BETWEEN OCCIPITAL CONDYLES ranged from minimum 49.9mm to maximum 50.9 mm with mean value of 50.7 mm and SD of ±0.25. The value of MIN DIS BETWEEN OCCIPITAL CONDYLES ranged from minimum 35.6mm to maximum 36.1 mm with mean value of 35.8mm and SD of ±0.13. The value of MAX INT DIS BETWEEN OCCIPITAL CONDYLES ranged from minimum 34.9mm to maximum 35.3 mm with mean value of 35.0 mm and SD of ±0.12. The value of ROC LENGTH ranged from minimum 24.5mm to maximum 25.2 mm with mean value of 24.6 mm and SD of ±0.17. The value of ROC MAX WIDTH ranged from minimum 11.9mm to maximum 12.5 mm with mean value of 12.3 mm and SD of ±0.19. The value of ROC MIN WIDTH ranged from minimum 6.3mm to maximum 6.9 mm with mean value of 6.7 mm and SD of ±0.14. The value of LENGTH OF FM ranged from minimum 35.9mm to maximum 36.9 mm with mean value of 36.3 mm and SD of ±0.27. The value of WIDTH OF FORAMEN MAGNUM ranged from minimum 29.9mm to maximum 30.5 mm with mean value of 30.3 mm and SD of ±0.2. The value of LENGTH OF BASILAR PROCESS ranged from minimum 31.7mm to maximum 31.9 mm with mean value of 31.8 mm and SD of ±0.09

**In females**

The value of LOC LENGTH ranged from minimum 20.2mm to maximum 24.5mm with mean value of 22.3 mm and SD of ±1.06. The value of LOC MAX WIDTH ranged from minimum 10.0mm to maximum 13.3mm with mean value of 11.6 mm and SD of ±0.85. The value of LOC MIN WIDTH ranged from minimum 4.9mm to maximum 6.5 mm with mean value of 5.58mm and SD of ±0.45. The value of MAX DIS BETWEEN OCCIPITAL CONDYLES ranged

from minimum 46.9mm to maximum 51.8 mm with mean value of 50.0 mm and SD of ±1.18. The value of MIN DIS BETWEEN OCCIPITAL CONDYLES ranged from minimum 30.2mm to maximum 37.2mm with mean value of 34.2 mm and SD of ±1.59. The value of MAX INT DIS BETWEEN OCCIPITAL CONDYLES ranged from minimum 28.9mm to maximum 34.9 mm with mean value of 30.8 mm and SD of ±1.46. The value of ROC LENGTH ranged from minimum 18.5mm to maximum 24.9 mm with mean value of 21.2 mm and SD of ±1.71. The value of ROC MAX WIDTH ranged from minimum 9.5mm to maximum 13.2 mm with mean value of 11.1 mm and SD of ±1.01. The value of ROC MIN WIDTH ranged from minimum 4.6mm to maximum 6.2 mm with mean value of 5.44 mm and SD of ±0.49. The value of LENGTH OF FM ranged from minimum 27.2mm to maximum 36.9 mm with mean value of 31.3 mm and SD of ±2.08. The value of WIDTH OF FORAMEN MAGNUM ranged from minimum 26.2mm to maximum 31.5 mm with mean value of 28.9 mm and SD of ±1.72. The value of LENGTH OF BASILAR PROCESS ranged from minimum 23.7mm to maximum 32.7 mm with mean value of 27.6 mm and SD of ±2.53.

A Student's t-test was conducted to determine if there were significant differences between male and female parameters. The Maximum Distance between Occipital Condyles is significantly different for male and females, all other parameters were not significantly different.

There is non-significant difference in length of left occipital condyles, maximum width of left occipital condyles, minimum width of left occipital condyles, minimum distance of left occipital condyles, maximum interior distance of occipital condyles of male and female ( $p > .001$ ). There is significant difference in maximum distance between occipital condyles of male and female ( $p < .001$ ). There is non-significant difference in length of right occipital condyles, maximum width of right occipital condyles, minimum width of right occipital condyles of male and female ( $p > .001$ ). There is non-significant difference in length & width of foramen of male and female ( $p > .001$ ). There is non-significant difference in length of basilar process male and female ( $p > .001$ ).

**Table-3 Showing the comparison of measurements of 12 parameters between male and female skull**

M=50 Female=46	Minimum		Maximum		Mean ±SD	
	M	F	M	F	M	F
LOC LENGTH	23.5	20.2	24.1	24.5	23.8 ±0.1	22.3 ± 1.06
LOC MAX WIDTH	11.7	10	12.1	13.3	12.0 ±0.11	11.6 ±0.85
LOC MIN WIDTH	6.3	4.9	6.6	6.5	6.4 ±0.1	5.58 ±0.45
MAX DIS BETWEEN CONDYLES	49.9	46.9	50.9	51.8	50.7 ±0.25	50 ±1.18
MIN DIS BETWEEN CONDYLES	35.6	30.2	36.1	37.2	35.8 ±0.13	34.2 ±1.59
MAX INTERIOR DISTANCE BETWEEN CONDYLES	34.9	28.9	35.3	34.9	35.0 ±0.12	30.8 ±1.46
ROC LENGTH	24.5	18.5	25.2	24.9	24.6 ±0.17	21.2 ±1.71
ROC MAX WIDTH	11.9	9.5	12.5	13.2	12.3 ±0.19	11.1 ±1.01
ROC MIN WIDTH	6.3	4.6	6.9	6.2	6.7 ±0.14	5.44 ±0.49
LENGTH OF FM	35.9	27.2	36.9	36.9	36.3 ±0.27	31.3 ±2.08
WIDTH OF FM	29.9	26.2	30.5	31.5	30.3 ±0.2	28.9 ± 1.72
LENGTH OF BP	31.7	23.7	31.9	32.7	31.8 ±0.09	27.6 ±2.53

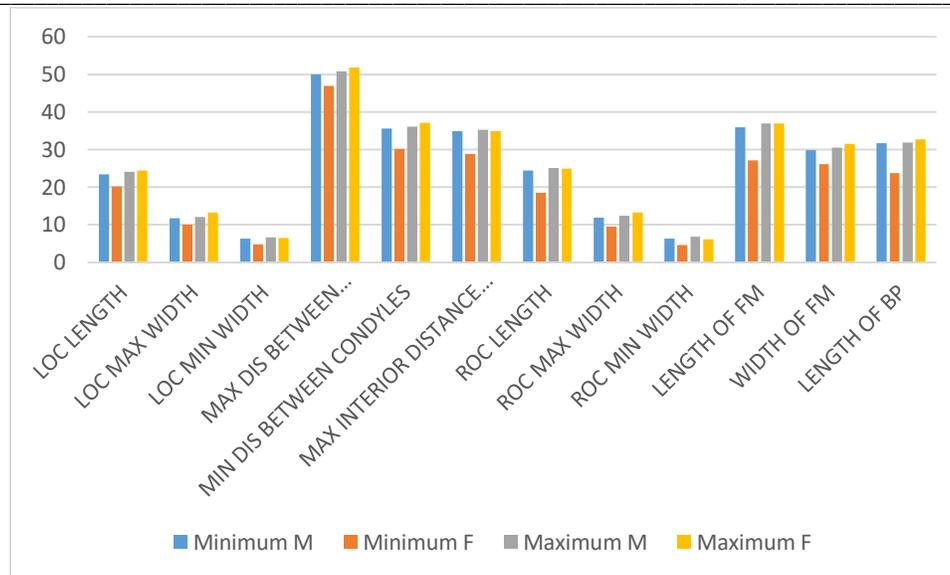


Figure 2: comparison of measurements between male and female skull

### Discussion

The comparison of the morphometric analysis obtained in this study with the results of other studies showed that the length of the foramen magnum (male) in the present study is  $(36.3 \pm 0.27)$  as compared to South Indian male skulls  $(34.04 \pm 2.36)$  [9,10], Brazilian male skulls  $(35.7 \pm 0.29)$  [11], the Turkish  $(37.2 \pm 3.43)$  [12], English populations [5].  $(35.91 \pm 2.41)$ , and the Indian population [13]  $(35.5 \pm 2.8)$ .

Similarly length of foramen magnum of female skulls of present study  $(31.3 \pm 2.08)$  as compared to the South Indian population  $(31.72 \pm 2.14)$  [9,10], Brazilian population  $(35.1 \pm 0.33)$  [11] Turkish  $(34.6 \pm 3.16)$  [12], Indian  $(32.0 \pm 2.8)$  [13] and English populations  $(34.71 \pm 1.91)$  [5].

Regarding the width of the foramen magnum, in present study male skulls  $(30.3 \pm 0.2)$  as compared to values of the South Indian male skulls  $(28.63 \pm 1.89)$  [9,10], Brazilian male skulls  $(30.3 \pm 0.20)$  [11], Indians  $(29.6 \pm 1.9)$  [13] Turkish  $(31.6 \pm 2.99)$  [12] and English populations  $(30.51 \pm 1.77)$  [5].

The same measure for the female skulls of the present study  $(28.9 \pm 1.72)$  as compared to the South Indian population  $(26.59 \pm 1.64)$  [9,10], Brazilian population  $(29.4 \pm 0.23)$  [11] Indian  $(27.1 \pm 1.6)$  [5] Turkish populations  $(29.3 \pm 2.19)$  [12] and English populations  $(29.36 \pm 1.96)$  [20].

These results demonstrate that sexual dimorphism is present in the foramen magnum. In incomplete skeletons, metric analysis of the foramen magnum may provide a statistically useful indication as to sex of the unknown skull.

These aspects can be attributed to the racial mixing, which is common in Brazil and less frequent in other populations [14].

There was a statistically significant difference between males and females for both length (mean: 22.8mm for males and 20.8 mm for females) and width (mean: 12.5 mm for males and 11.8mm for females) of right condyle and width of the foramen magnum (mean: 30.8mm for males and 28.9mm for females) ( $p < 0.001$ ). All dimensions were larger in the male, as compared to females, same is true for our study [15].

Authors have developed a discriminant-function technique that utilized cranial measurements in intact skulls, with 82–89% accuracy in predicting the sex [16]. Previous work by Holland suggests that the measurements of the region of occipital condyles and the foramen magnum are useful for determining the sex, with an accuracy of 70–90%

Morphological methods can be more problematic than metric methods, as determinations utilizing visual observations are based on

traits with degrees of expression that vary by sex, age, and ancestry, as well as through time. Assessment of these traits can also differ between observers. Determinations made based on the presence or absence of a trait that also has an intermediate form can be tricky as well. However,

Comparing the values of different parameters (males) as used in this study and comparing it with Crider's study (2005) [17] we found that LOC length, Max. distance between condyles, Minimum distance between condyles and ROC length were smaller in the present study while values of LOC max width, LOC minimum width, Max. interior distance between condyles, ROC Maximum width, ROC Minimum width and length of basilar process were higher as compared to Crider's [17]. However values of length of foramen magnum and width of foramen magnum were equal in both the studies.

Uysal et al [15], found all dimensions were larger in males than females, with the length and width of the right occipital condyle and the width of the foramen magnum reflecting the greatest differences same results are found in this study.

Comparing the values of different parameters (female) as used in this study and comparing it with Crider, s (2005) [17]. Study we found that values of LOC length and Min distance between condyles were equal in both the studies while values of LOC max width, LOC min width, Max. distance between condyles, Min. distance between condyles, ROC Maximum width were higher in present study and values of Max interior distance, ROC length, ROC minimum width, length of foramen magnum, width of foramen magnum and length of basilar process are lower in the present study.

The occipital condyle is an important part of the craniovertebral junction. It is the only articulation between the occiput and the atlas. It has a ball-pivot relation with lateral mass of C1. This unique anatomical feature results in a unique biomechanical characteristic. Its integrity is of vital importance for the stability of the cranio vertebral junction [18].

### Conclusion

Looking at the overall accuracy rates in the present study it can be inferred that morphometric analysis of foramen magnum region dimensions cannot be regarded as a very reliable method for determining sex in the present collection on complete skulls. However, in case of highly fragmentary remains, where no other skeletal remains are preserved, metric analysis of the basal region of the occipital bone may provide a statistically useful indication as to the sex of an unknown skull.

Since the present study was based on a limited sample, it is suggested that further research based on larger samples of documented Indian skulls should be undertaken to check the reliability of morphometric measurements of foramen magnum region in sex determination.

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