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Original Research Article

MORPHOMETRIC ANALYSIS OF HUMAN OCCIPITAL CONDYLES FOR SEX DETERMINATION IN DRY ADULT SKULLS

Varsha. T. Sholapurkar *[1], R.D.Virupaxi [2], S.P. Desai [3].

[*1] Assistant Professor, Department of Anatomy, Rural Medical College, PIMS, Loni, Maharashtra, India.

[2] Professor and Head, Department of Anatomy, J N Medical College, KLE University, Belagavi, Karnataka, India.

[3] Professor, Department of Anatomy, J N Medical College, KLE University, Belagavi, Karnataka, India.

ABSTRACT

Introduction: Cranium is an excellent indicator for sexual dimorphism by morphometric and morphological analysis. The basi-cranium is protected by a large soft tissue mass comprising of muscles, tendons and ligaments. So in case of fragmentary human remains where no other skeletal remains are preserved the intact occipital region may prove useful for determining the gender. Hence this study was carried out to analyse morphometrically the occipital condyles for sex determination in dry adult skulls.

Material and methods: This study was conducted on 200 occipital condyles of 100 dry adult human skulls (50 male & 50 female). Morphological variants in the shape of occipital condyles were noted. The antero-posterior diameter, transverse diameter and the occipital condyle index of right and left occipital condyles were measured using standard techniques. Students 't' test was employed for statistical analysis.

Results: The commonest shape of right and left occipital condyles was oval. The antero-posterior diameter and the occipital condyle index (right and left) in male skulls was higher than the female skulls. There was no significant difference in the transverse diameter of occipital condyles (right and left) in male and female skulls.

Conclusion: The metric analysis of occipital condyles may be a useful indicator of sex determination of an unknown skull, especially in fragmentary human remains, where no other skeletal remains are preserved.

KEY WORDS: Morphometry, Occipital condyle, Antero-posterior diameter, Transverse diameter, Sex determination.

Address for Correspondence: Dr. Varsha. T. Sholapurkar, Assistant Professor, Department of Anatomy, Rural Medical College, PIMS, Loni, Maharashtra, India. **E-Mail:** varsh212@gmail.com

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INTRODUCTION

Anthropological knowledge of human osteology is one of the important steps in identification of age, sex, living stature and ancestry [1]. Various studies have shown that cranium is an excellent indicator for sexual dimorphism by morphometric and morphological analysis, and it is probably the second best region of the skeleton, next to pelvis for this purpose [2]. In most of the forensic studies the skeleton is incomplete and this makes the sex determination difficult. It is therefore important to establish methods for determining sex from skeletal elements that are likely to be survived and recovered [3]. Due to thickness of the base of skull and its relatively protected anatomical position, this area

of skull tends to withstand both physical insults and inhumation more successfully than any other areas of cranium [4].

The basi-cranium is protected by a large soft tissue mass comprising of muscles, tendons and ligaments. So in cases of fragmentary human remains compromised by different types of inhumation or physical insult like explosion, fire, trauma, the intact occipital region may prove useful for determining the gender [5]. The occipital condyle measurements are also helpful for the neurosurgeons for performing lateral transcondylar approaches for reaching the lesions lying ventral and ventrolateral to foramen magnum because it improves the surgical exposure of the brain stem while markedly reducing the need for brain retraction [6].

There is scanty information about the detailed morphometry in sexual dimorphism of occipital condyles and hence there is a need for more knowledge about morphometric variations of occipital condyles and its relation to sex.

MATERIALS AND METHODS

The study was carried out on 100 dry adult human skulls (50 males and 50 females) available in the Departments of Anatomy and Forensic medicine of KLE University's, Jawaharlal Nehru Medical College, Belagavi, Karnataka. Dried, complete, adult human skulls (i.e skulls with socket for upper third molars & synostosis of spheno-occipital synchondrosis) were included. Fractured, mutilated skulls with gross deformity were excluded from the study. Sex of each skull was determined by meticulously scrutinizing the classic anatomic features. 200 occipital condyles in 100 dry adult human skulls (50 males and 50 females) were studied. All measurements were recorded using digital vernier caliper. The shape of occipital condyles were identified and noted down. Measurements are based on following bony landmarks on the skull:

· Anterior tip of occipital condyle.

· Posterior tip of occipital condyle.

The following parameters were recorded:

Shape of the occipital condyles (Right and Left).
Length of occipital condyles (right and left): From its anterior tip to posterior tip.

Width of occipital condyles (right and left): Maximum distance measured at the right angles to the line joining its anterior and posterior tip.

With these measurements the condylar index was calculated:

Condylar Index: Calculated for right and left occipital condyle respectively by dividing length of occipital condyle with width of occipital condyle. (Length/Width). The data obtained was analyzed statistically by computing descriptive statistics, the mean, standard deviation and percentages of each variable. The inferential statistics was done using student t–test. The results were considered statistically significant whenever $p \leq 0.05$.

RESULTS

Study was done on 100 dry adult human skulls (50 males and 50 females) i.e 200 occipital condyles.

The incidence of S-shaped, triangular and eight-shaped occipital condyles (right sided) was higher in male skulls while the incidence of oval, kidney- shaped, quadrangular, round, two-portioned & deformed occipital condyles was higher in female skulls with statistical significant difference ($p<0.05$) (Table 1).

The incidence of oval, quadrangular & two- portioned condyles (left sided) was higher in female skulls but the difference was not statistically significant ($p>0.05$). Similarly the incidence of triangular, S-shaped & 8-shaped condyles was higher in male skulls but the difference was not statistically significant ($p>0.05$) (Table 2).

Table 3 shows comparison of Right sided occipital condyle parameters in male and females skulls. The antero-posterior diameter of occipital condyle of male skulls was higher than the female skulls with statistical significant difference ($p<0.05$). The transverse diameter of right sided occipital condyle was slightly higher in female skulls but the difference was not significant. The occipital condyle index (APD/TD) was higher in male skulls with ($p<0.05$) statistical significant difference.

Similarly Table 4 shows comparison of Left sided occipital condyle parameters in male and females skulls. The antero-posterior diameter

of occipital condyle of male skulls was higher than the female skulls with statistical significant difference ($p<0.05$). The transverse diameter of left sided occipital condyle was slightly higher in male skulls but the difference was not statistically significant. The occipital condyle index (APD/TD) was higher in male skulls with ($p<0.05$) statistical significant difference.

Table 1: Incidence of shapes of occipital condyles (Right side) in male and female skulls. (n=100).

SHAPE	Male	Female	Total
Oval	9 (18%)	17 (34%)	26
S-shaped	12 (24%)	10 (20%)	22
Triangular	10 (20%)	4 (8%)	14
Kidney-shaped	6 (12%)	7 (14%)	13
Eight-shaped	11 (22%)	1 (2%)	12
Quadrangular	1 (2%)	6 (12%)	7
Round	0 (0%)	2 (4%)	2
Two-portioned	0 (0%)	2 (4%)	2
Deformed	0 (0%)	2 (4%)	2

Using Fisher Exact test for r x c table, $p < 0.001$*
Statistical significance (Fisher Exact test), $p<0.05$

Table 2: Incidence of shapes of occipital condyles (Left side) in male and female skulls.(n=100).

SHAPE	Male	Female	Total
oval	8 (16%)	15 (30%)	23
Triangular	12 (24%)	6 (12%)	18
8-shaped	12 (24%)	6 (12%)	18
S-shaped	10 (20%)	8 (16%)	18
Kidney-shaped	4 (8%)	4 (8%)	8
Quadrangular	1 (2%)	7 (14%)	8
Deformed	2 (4%)	1 (2%)	3
Round	1 (2%)	1 (2%)	2
Two-portioned	0	2 (4%)	2

Using Fisher Exact test for r x c table, $p = 0.109$
Statistical significance (Fisher Exact test), $p<0.05$

Table 3: Occipital condyle parameters (Right sided) in male and female skulls. (n=100).

PARAMETERS	Antero-posterior Diameter in mm	Transverse Diameter in mm	Index (APD/TD)
Male	22.95 ± 2.98 (16.46 - 28.12)	11.36 ± 1.77 (7.83 - 16.34)	2.07 ± 0.43 (1.40 - 3.21)
Female	21.07 ± 3.09 (14.46 - 30.38)	11.43 ± 1.67 (7.67 - 14.80)	1.88 ± 0.39 (1.17 - 3.04)
t-value	3.107	0.193	2.249
p value	0.002*	0.847	0.027*

Values are Mean ± SD, Statistical significance (Student t-test) *p<0.05

Table 4: Occipital condyle parameters (Left sided) in male and female skulls. (n=100).

PARAMETERS	Antero-posterior Diameter in mm	Transverse Diameter in mm	Index (APD/TD)
Male	22.34 ± 3.35 (11.6 - 27.63)	11.99 ± 1.31 (8.45 - 17.07)	1.90 ± 0.39 (0.99 - 2.94)
Female	22.25 ± 2.65 (14.05 - 28.71)	11.94 ± 1.75 (7.49 - 15.68)	1.74 ± 0.38 (1.15 - 3.21)
t-value	3.454	0.167	2.103
P value	0.001*	0.868	0.038*

Values are Mean ± SD, Statistical significance (Student-test) *p<0.05

Fig. 1: Measurements of occipital condyles.

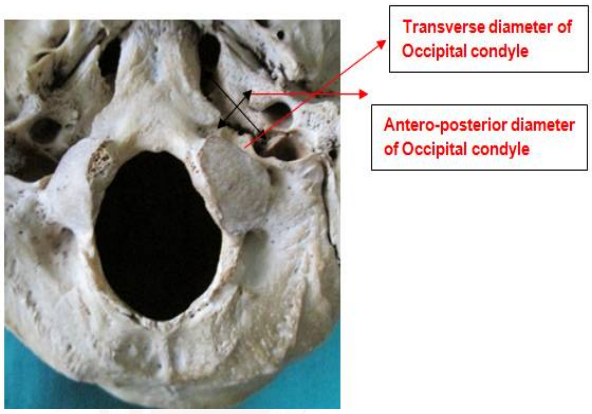

Fig. 2: Kidney shaped occipital condyle.

Fig. 3: Triangular occipital condyle.

Fig. 3: Eight shaped occipital condyle.

Fig. 4: 'S' – shaped occipital condyle.

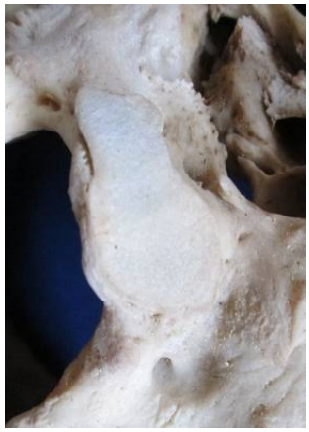

Fig. 5: Two portioned occipital condyle.

Fig. 6: Quadrangular occipital condyle.

Fig. 7: Oval occipital condyle.

Fig. 8: Deformed occipital condyle.

DISCUSSION

Different studies have quoted different facts and figures which have led to spectrum of findings. In a study conducted by Sait et al the commonest shape of right occipital condyles was found to be oval followed by S-shaped, triangular, eight-shaped, deformed, kidney-shaped, round and two-portioned while the commonest shape of left occipital condyles was oval followed by S-shaped, triangular, deformed, round, kidney-shaped, eight-shaped and two-portioned [7]. The commonest shape of occipital condyles was oval in both the studies but there was variation in the incidence of other shapes of occipital condyles in both the studies. (Table 5) In addition to this incidence of different shape of occipital condyles in male and female skulls separately was observed in the present study. (Table 1 & 2)

In the present study the mean antero-posterior diameter of right and left occipital condyles in male skulls was higher than the female skulls with statistically significant difference. ($p<0.05$) (Table 3 & 4). These finding were in corroboration with the study done in Brazil by Oliviera et al. [8] (Table 6) The mean antero-posterior diameter of right occipital condyle of male skulls in the present study (22.95 ± 2.98) was lower than the Brazilian male skulls (26.74 ± 2.96) [8] while that of female skulls (21.07 ± 3.09) in the present study was also lower than the Brazilian population (25.45 ± 3.21) [8]. Similarly the mean antero-posterior diameter of left occipital condyle of male skulls in the present study (22.34 ± 3.35) was lower than the Brazilian skulls (26.85 ± 2.97) [8] and that of female skulls in the present study (22.25 ± 2.65) was also lower than the Brazilian population (24.65 ± 3.23) [8]. (Table 6)

From the results obtained in our study it was observed that the mean transverse diameter of right occipital condyles of male skulls (11.36 ± 1.77 mm) was slightly lower than female skulls (11.43 ± 1.67 mm) but the difference was not statistically significant. (Table 3). The mean transverse diameter of left occipital condyles in male and female skulls was 11.99 ± 1.31 mm & 11.94 ± 1.75 mm respectively. Though the measurements in male skulls were slightly higher than the female skulls the difference was not statistically significant (Table 4). In contrast to the present study, a study done in Brazil by Oliveira et al shows that the average transverse diameter of right occipital condyle in male & female skulls was 13.51 ± 1.38 mm & 12.68 ± 1.56 mm respectively while the transverse diameter of the left occipital condyles in male & female skulls was 13.79 ± 1.39 mm & 12.71 ± 1.75 mm respectively and the difference was statistically significant [8]. (Table 7)

Table 5: Comparison of incidence of different shapes of occipital condyles with other study.

Shape of occipital condyle	Right side		Left side	
	Sait et al [7] (n=202)	Present study (n=100)	Sait et al [7] (n=202)	Present study (n=100)
Oval	96 (23.8%)	26 (26%)	106 (26.2%)	23 (23%)
S-shaped	47 (11.6%)	22 (22%)	47 (11.6%)	18 (18%)
Triangular	22 (5.5%)	14 (14%)	14 (3.5%)	18 (18%)
Eight-shaped	12 (3.0%)	12 (12%)	5 (1.2%)	18 (18%)
Deformed	10 (2.5%)	2 (2%)	12 (3.0%)	3 (3%)
Kidney-shaped	8 (2.0%)	13 (13%)	6 (1.5%)	8 (8%)
Round	6 (1.5%)	2 (2%)	10 (2.5%)	2 (2%)
Two-portioned	1 (0.3%)	2 (2%)	2 (0.5%)	2 (2%)
Quadrangular	-	7 (7%)	-	8 (8%)

Table 6: Comparison of antero-posterior diameter of occipital condyles in male and female skulls with other study.

Antero-posterior diameter	Right occipital condyle		Left occipital condyle	
	Male skulls	Female skulls	Male skulls	Female skulls
Oliveira et al [8] (2013)	26.74 ± 2.96	25.45 ± 3.21	26.85 ± 2.97	24.65 ± 3.23
Present study (2014)	22.95 ± 2.98	21.07 ± 3.09	22.34 ± 3.35	22.25 ± 2.65

Table 7: Comparison of Transverse diameter of occipital condyle in male & female skulls with other study.

Transverse diameter	Right occipital condyle		Left occipital condyle	
	Male skulls	Female skulls	Male skulls	Female skulls
Oliveira et al [8] (2013)	13.51 ± 1.38	12.68 ± 1.56	13.79 ± 1.39	12.71 ± 1.75
Present study (2014)	11.36 ± 1.77	11.43 ± 1.67	11.99 ± 1.31	11.94 ± 1.75

Occipital condyle index: The occipital condylar index in our study was calculated by dividing the antero-posterior diameter of the condyle with the transverse diameter. The average index of right sided occipital condyles in male and female skulls was found to be 2.07 ± 0.43 & 1.88 ± 0.39 (Table 3) respectively and the difference was statistically significant. Similarly the index of left sided occipital condyles in male and female skulls was 1.90 ± 0.39 & 1.74 ± 0.38 with statistical significant difference. (Table 4)

In contrast to the present study, Oliveira et al applied the Baudoin condylar index for sex determination and evaluated its reliability. Baudoin condylar index = (maximum width of the condyle/ maximum length of the condyle) x 100. The results obtained by Oliveira et al showed that the percentage of success in applying the Baudoin index was 44.83% to males and 51.93% to females, amounting to 47.5% matching. He thus concluded that the accuracy of the Baudoin index to sex determination was quite low for the Brazilian sample and that was the reason why this method was disregarded as criterion to sexing skulls in forensic experts [8].

CONCLUSION

After studying 100 dry adult human skulls (50 male & 50 female), i.e 200 occipital condyles the following conclusions were drawn.

The commonest shape of right side occipital condyle was oval (26%).

The incidence of S-shaped, triangular and eight-shaped occipital condyles (right sided) was higher in male skulls while the incidence of oval, kidney- shaped, quadrangular, round, two-portioned & deformed occipital condyles was higher in female skulls.

The commonest shape of left side occipital condyle was also oval (23%).

Statistical significant difference was not observed in the incidence of different shapes of left occipital condyles in male and female skulls.

The antero-posterior diameter of right & left occipital condyles was higher in male skulls than in female skulls.

Statistical significant difference was not observed in the transverse diameter of right & left occipital condyles of the male and female skulls.

The occipital condyle index (Right & left sided) of male skulls was higher than the female skulls.

With the data obtained from the present study we conclude that, metric analysis of occipital condyles may be a useful indicator of sex determination of unknown skulls, especially in fragmentary human remains, where no other skeletal remains are preserved. This study is also useful for anthropologists, morphologists, forensic experts for sex determination in medico-legal cases and for the neurosurgeons in dealing with lesions of posterior cranial fossa during surgery.

Conflicts of Interests: None

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