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Morphometric Assessment Methods for Estimation of Sexual Dimorphism from Cranial Occipital Condyles

Métodos de Evaluación Morfométrica para la Estimación del Dimorfismo Sexual de los Cóndilos Occipitales Craneales

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MEERA J. & BINDHU, S. Morphometric assessment methods for estimation of sexual dimorphism from cranial occipital condyles. *Int. J. Morphol., 40(4)*:1128-1133, 2022.

SUMMARY: Identification of fragmentary human remains is an integral par of medico legal investigations. Occipital region is commonly not affected in traumatic injuries and accidents due to its secluded position which makes it the integral part in determination of sex in the absence of entire skeleton. Occipital condylar region is also the most common area for degenerative and neoplastic diseases. So thorough knowledge of anatomy of occipital condyle is very essential during surgical interventions. 86 skulls were studied from osteological collections of Department of Anatomy, Yenepoya Medical College. Maximum length and breadth of the occipital condyle, anterior intercondylar distance and posterior intercondylar distance was measured with the help of vernier callipers. Descriptive statistics was calculated for the parameters considered. Metric data of right and left sides were compared with student t test and p value was calculated. All data obtained was subjected for discriminant function analysis to derive the statistical model. All the measurements were significantly high in males compared to females. Condylar length and width, anterior and posterior intercondylar distance can be used to derive formula for determination of sex in south Indian population with an accuracy of 66.3 %.

KEY WORDS: Occipital condyle; Sex determination; Discriminant function analysis.

INTRODUCTION

Forensic anthropology is a medico legal discipline where the skeletal remains are used to identify the individual and the cause of death, stature and any pathology to build a biological profile (Albanese *et al.*, 2005). Determination of sex is an important parameter of the biological profile where the structural differences between male and female are identified. Determination of sexual dimorphism is challenging and complicated when only fragmentary remains are available during disasters or severe traumatic accidents. The occipital region of skull is an area that can remain unaffected in such circumstances due to its anatomical location, soft tissue covering and thickness of the bone. Hence, studies on occipital bone to derive standards for sex estimation is required when such remains are recovered. According to Gapert & Last (2005) measurements on occipital condyles for sexual dimorphism have reported to have high accuracy rate of 80 % and also shown variations between populations that will have impact on sex estimation. It was also found during a simulation study that the dimensions of the skull remained unaltered by exposing to temperature equalling fire accidents and it can still be used in sex estimation (Holland, 1989). Few related studies conducted in this area are radiographic analysis of sexual dimorphism of occipital bone (Gülekon & Turgut, 2003) and morphometry of cadaveric occipital region (Kunar & Nagar, 2014). Occipital condyle is a link between the skull and vertebralcolumn and articulates with the superior articular facets of atlas6.this region is predisposed commonly to degenerative and neoplastic disorders. craniovertebral fixation is challenging due to the complexity of craniovertebral junction and it can be complicated due to the neurovascular structures present and any surgical mistakes can lead to craniocervical instability (LeTV. Dakwar *et al*. 2011). Transcondylar approach for tumours at the level of foramen magnum requires partial resection of occipital condyles (Naderi *et al.*, 2005). So thorough knowledge of occipital condyles is utmost necessary before surgical intervention. Aim of the present study is to deter-

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mine the accuracy of sex determinant functions based on occipital condyle dimensions, to augment the existing literature and also for safe surgical instrumentation.

MATERIAL AND METHOD

Present cross-sectional study was conducted in the department of Anatomy, Yenepoya Medical College Mangalore. It included 45 male skulls and 41 female skulls after confirmation of sex from the records maintained in the department. All the intact skulls in good condition were included in the study. Deformed and damaged skulls that can interfere with metric measurements were excluded from the study. Following parameters were measured with the help of vernier callipers with 0.01 mm accuracy (Fig. 1):

1. Maximum length of occipital condyle: Distance between the anterior and posterior ends of occipital condyle along the long axis.
2. Maximum width of occipital condyle: maximum transverse diameter between the lateral and medial margins of occipital condyle perpendicular to the long axis.
3. Anterior intercondylar distance (AICD): Distance between the anterior ends of right and left occipital condyles.
4. Posterior intercondylar distance (PICD): Distance between the posterior ends of right and left occipital condyles.

Statistical Analysis: Data was statistically analysed using SPSS version20 (statistical package for social sciences).

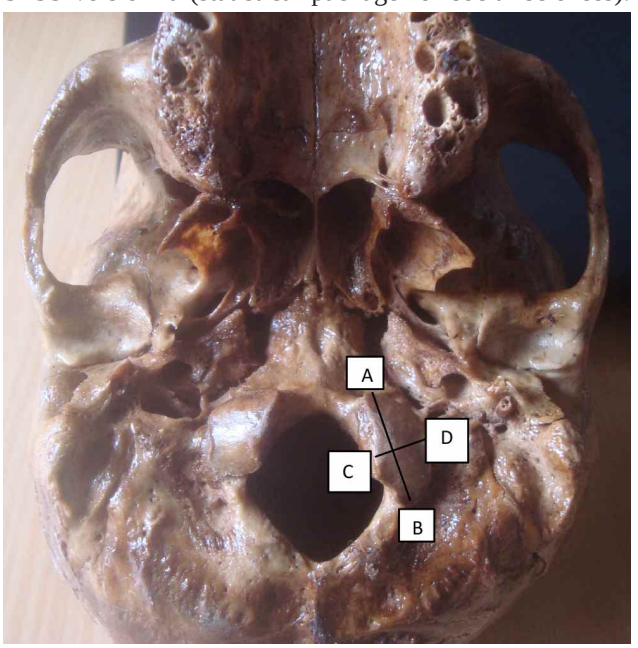

Fig. 1. Base of the skull showing the length and width of occipital condyle .

Morphometric analysis of right and left sides was calculated using student t test in both males and females and p value was calculated. P value less than 0.001 was considered significant. Pearson's correlation coefficient between variables in both males and females were calculated. Fisher's linear discriminant functional analysis was performed. The canonical discriminant function coefficients were analysed to identify the variables that help in prediction of sexual dimorphism. Coefficients and constants obtained indicated the unstandardized scores concerning the independent variables and was used to derive discriminant function equations.

RESULTS

Among 86 skulls, 45 were of males and 41 of females. Table I shows the dimensions of occipital condyles in both males and females. Mean length of right occipital condyle was 24.38±2.84mm in males and 22.17±3.34 in case of females and it was stastically significant. Mean sagittal diameter on left side was 23.68±2.76 in case of males and in females it was 21.51±3.15. Mean sagittal diameter on left side was also stastically significant (p value ≤0.001). Posterior intercondylar distance in males was observed to be 39.78±3.44 when compared to females 37.16±3.36 and it was stastically significant. Table I summarises the mean and standard deviation of the linear measurements. The length of occipital condyle ranges from minimum value of 17 mm to a maximum value of 31 mm in males and in females it ranges from 13 mm to 27 mm on right side and minimum of 15 mm to maximum of 31 in males and 12 mm to 29 mm in females on left side. The width of occipital condyle ranges from minimum of 9 mm to maximum of 16 mm in males and 9 mm to 18 mm in females on right side. Width of left occipital condyle ranges from 9 mm to 16 mm in males and 9 mm to 19 mm in case of females

Pearson's correlation was calculated for all the parameters. Among males, positive correlation was observed between length RC/length LC (r =0.6', Fig. 2A). Among female group positive correlation was observed between length RC/length LC (Fig. 2C).

Table II shows the univariate F ratios for both the sexes. The F statistic values indicated that the condylar measurement expressing the greatest sexual dimorphism were length of occipital condyles on both right and left sides followed by posterior intercondylar distance. Posterior intercondylar distance and occipital condylar length of both the sides have more contribution to the discriminant function with p value less than 0.001 and hence can be considered as important variables in discriminant analysis.

Discriminant function analysis among the parameters for sex determination. 66.3 % of original grouped cases could be correctly classified; males were correctly classified 64 % of the time and females were classified 68.3 % of the time. Overall accuracy of classification is 66.3 %.

Using discriminant functional analysis, 29 of 45 skulls were correctly classified as male skulls which is 64 % accuracy for male sex while 28 of 41 skulls were classified as female skulls correctly which is 68 % accuracy for female sex. The results of discriminant function analysis and the influence of length, width and intercondylar distance on the sexual dimorphism of the skull was calculated on the given sample. Determination of sex can be done with the equations provided by this analysis using 6 linear dimensions. For classifying the bone as male or female the maximum value of the 2 equations can be considered. The bone is considered as male if Dmale value is greater than Dfemale and vice versa.

Dmale[{0.195×Length_R}+{3.184×Width_R}+{2.229×Length_L}+{1.797×Width_L}+{1.554×AICD}+{2.314×PICD}]-114.722

DFemale[{0.234×Length_R}+{3.255×Width_R}+{2.069×Length_L}+{1.710×Width_L}+{1.514×AICD}+{2.161×PICD}]-103.451

Table I. Descriptive statistics on linear dimensions of occipital condyle and their significance on south Indian population.

	Sex	N	Minuto.	Maximum	Mean	Std. Deviation	T value	pvalue
LENGTH-R	Male	45	17	31	24.38	2.844	3.310	**0.001**
	Female	41	13	27	22.17	3.343		
WIDTH-R	Male	45	9	16	12.33	1.467	-0.058	0.954
	Female	41	9	18	12.35	1.976		
LENGTH-L	Male	45	15	31	23.68	2.763	3.386	**0.001**
	Female	41	12	29	21.51	3.157		
WIDTH-L	Male	45	9	16	12.89	1.764	0.792	0.431
	Female	41	9	19	12.57	2.020		
AICD	Male	45	9.10	37.10	16.4660	4.48004	0.613	0.542
	Female	41	11.97	23.20	15.9717	2.68638		
PICD	Male	45	34.57	50.00	39.7800	3.44109	3.551	**0.001**
	Female	41	32.00	43.17	37.1680	3.36858		

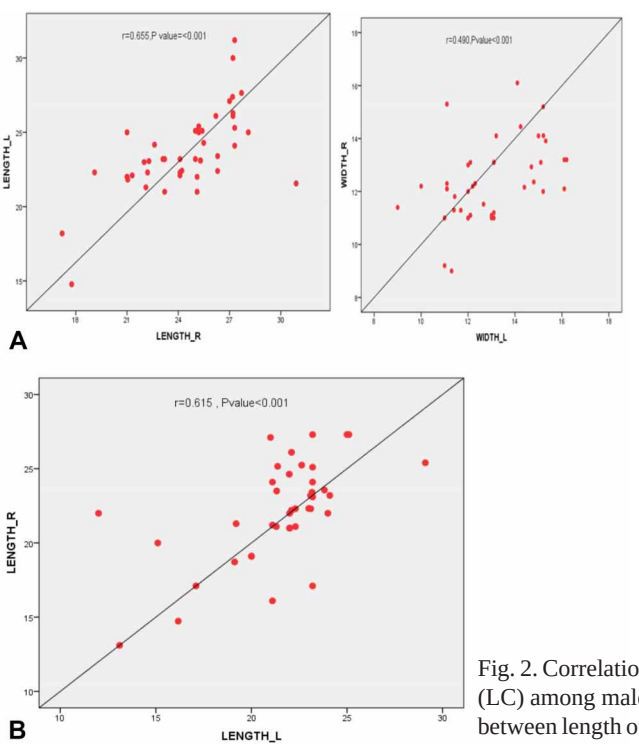

Table II. Influence of various parameters on predictability of sexual dimorphism.

	Wilks' Lambda	F	df1	df2	Pvalue
LENGTH-ROC*	.885	10.958	1	84	.001
WIDTH-ROC	1.000	.003	1	84	.954
LENGTH-LOC**	.880	11.467	1	84	.001
WIDTH-LOC	.993	.627	1	84	.431
AICD	.996	.376	1	84	.542
PICD	.869	12.611	1	84	.001

*ROC-right occipital condyle, **LOC-left occipital condyle, AICD- anterior intercondylar distance, PICD- posterior intercondylar distance.

Table III. The accuracy of the function analysis to predict sex among south Indian population.

	Predicted Group Membership		
Sex	Male	Female	Total
Male (45)	29	16	45
Female (41)	13	28	41
Male (100 %)	64.4	35.6	100.0
Female (100 %)	31.7	68.3	100.0

Fig. 2. Correlation between A: length of right condyle (RC) and length of left condyle (LC) among males. B: between width of right condyle and left condyle in males. C: between length of right condyle (RC) and length of left condyle (LC) among females.

DISCUSSION

One of the important aspects of forensic medicine is to determine se from fragmented human remains. Several studies are reported from different parts of the globe for sex determination from different human bones like pelvis, long bones of the limb's scapula etc. (Is¸can, 2005). The present study was conducted to assess the sexual dimorphism of the occipital condyles by manually measuring the dimensions and these measurements were subjected to discriminate function analysis to develop a stastical model in estimation of sex. Earlier study conducted by Holland in 20th century on African American and European American crania showed that the cranial base metrics are 70-85 % accurate in determining sex by regression analysis3. This study was tested by Wescott & Moore-Jansen (2001) on American dead body series and achieved an accuracy rate of 76 %.

In the present study length of right condyle (24.38±2.84) and length of left condyle (23.68±2.76mm) were higher when compared to females with p value less than 0.001. another study conducted by Kunar & Nagar (2014) showed similar results that the length of right condyle was 23.88± 1.5 mm in males and 22.6±1.30mm for females and length of left condyle was 24.99±1.82mm for males and 24.20 ±1.62mm in females.

Present study will help to develop a database which can enable the identification of osteological remains of Indian origin. This database can also be used in designing implants and screws for Indian population. El-Barrany *et al*. (2016) reported similar values on Sudanese population as shown in Table IV.

Table IV. Comparison of occipital condyle length with previous studies.

Researchers	Population	Sex	Parameter	Dimensions (mm)
Present study	Indian	Male	LRC	24.38±2.84
			LLC	23.68±2.76
		Female	LRC	22.17±3.34
			LLC	21.51±3.15
Kunar & Nagar (2014)	Indian	Male	LRC	23.88±1.5
			LLC	24.99±1.82
		Female	LRC	22.6±1.30
			LLC	24.20±1.62
El-Barrany *et al.,* (2016)	Sudanese	Male	LRC	25.52±2.68
			LLC	25.40±3.04
		Female	LRC	21.41±2.05
			LLC	21.50±2.19

LRC- Length right condyle, LLC -Length left condyle

Present study shows that the width of right and left occipital condyles are 12.33±1.46 mm, 12.35±1.97 mm, 12.89±1.76, 12.57±2.02 mm respectively. Kumar *et al*., reported slightly.

Higher values on transverse diameter of condyles where the width of occipital condyles in males and females were 12.97±1.43 mm and 11.65±1.33 mm, 14.11±1.01 mm and 13.85±1.02 mm respectively. Lower values were obtained by El-Barrany *et al*. (2016) where the measurements were 11.39±1.51 mm, 10.62±1.34 mm, and 11.33±1.71 mm and 10.38±1.33 mm in both males and females. The reason for this can be geographic and ethnic variation.

Anterior intercondylar distance and posterior intercondylar distance that demonstrates the convergence of occipital condyle. Anterior intercondylar distance in the present study was 16.46±4.48 and posterior intercondylar distance was 37.16± 3.36 respectively. According to the study done by Ozer *et al*. (2011) anterior intercondylar distance had a mean of 20.9mm and posterior intercondylar distance was 43.1 mm, these dimensions are prerequisite for screw fixation at level of craniovertebral junction.

Significant correlation was seen between length of left occipital condyle and length of right occipital condyle and posterior intercondylar distance in males and in females in the study population with an accuracy of 66.3 %. Based on the length of occipital condyles and posterior intercondylar distance, sex determination was possible with 68 % accuracy for females and 64 % for male sex. Study conducted by Zirahei *et al*. (2018) among 110 CT images of patients showed that the size of occipital condyles and intercondylar distance were high in men. Baudoin index was calculated which predicted sexual dimorphism with 52.92 % accuracy for males and 46.67 % accuracy for females. According to Oliveira *et al*. (2013) in their study showed that the length and width of occipital condyles will determine male sex with 44.83 % accuracy and female sex with 51.93 % accuracy.

The study conducted by Uysal *et al*. (2005) in Turkish crania reported higher accuracy rate of 81 % with computed tomography. According to Macaluso Jr. (2011), length of left occipital condyle has low discriminatory power in estimation of sex in French population. But according to Gapert & Last (2005) sexual dimorphism can be estimated from basiocciput, even though discriminant function analysis is slightly lower.

Note on occipital condylar dimensions with geneteic predisposition and related complications. According to Smith (2011) the morphometry of occipital condyle between Kenyans and Caucasians attributed to the changes in genetic composition. Sherwood *et al*. (2011) noted that the genetic loci involved in development of basicranial length is loci 12q13.11 located in chromosome 12 and loci 2q243 in chromosome 2 contributed to anterior basicranial length variations in nucleotide polymorphisms can lead to variations in cranial sizes and occipital condylar dimensions and can be due to differential remodelling at atlantooccipital joint. It was also suggested by Callewaert *et al*. (2010) that the changes in bone dimensions are due to hormonal difference where androgens will cause high periosteal bone formation compared to estrogen. This parameter play a role in occipito condylar surgeries where the partial removal of bone stock can result in occipito cervical instability in females with shorter occipital condyles than in males.this can be very fatal when associated with nuerological complications(Callewaert *et al*., 2010; Sinnesael M 2017). Present study shows that females have shorter occipital condyles than males so they are more vulnerable to atlantooccipital joint instability. Wider intercondylar distance is important in accessing the craniovertebral junction which requires less bone resection occipital condylectomy. So, sex differences in condylar distance is important in craniovertebral junction surgeries (Naderi *et al*., 2005).

CONCLUSIONS

- Our study population had similar occipital condylar dimensions when compared with other studies of Indian origin. Females had significantly smaller length and width of occipital condyles. This can be considered for preoperative planning of craniovertebral junction surgeries.
- Length of occipital condyle and posterior intercondylar distance of occipital condyles showed a statistically significant effect on sexual dimorphism ($p \leq 0.001$)
- According to the present study discriminant function analysis of occipital condyles can be used as a tool for sex determination among Indian population. Discriminant function analysis showed an overall accuracy of 66.3 %. Sex determination from length and posterior intercondylar distance were highly accurate for females with 68 % and 64 % for male sex.
- Further studies on diverse populations can be performed to standardise the method for sex estimation in forensic analysis.

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MEERA J. & BINDHU, S. Métodos de evaluación morfométrica para la estimación del dimorfismo sexual de los cóndilos occipitales craneales. *Int. J. Morphol., 40(4)*:1128-1133, 2022.

RESUMEN: La identificación de restos humanos fragmentarios es una parte integral de las investigaciones médico legales. La región occipital comúnmente no se ve afectada en lesiones traumáticas y accidentes debido a su posición apartada que la convierte en parte integral en la determinación del sexo en ausencia de un esqueleto completo. La región condilar occipital es también el área más común de enfermedades degenerativas y neoplásicas. Por lo tanto, el conocimiento integral de la anatomía del cóndilo occipital es esencial durante las intervenciones quirúrgicas. Se estudiaron 86 cráneos de colecciones osteológicas del Departamento de Anatomía, Facultad de Medicina de Yenepoya. Se midió el largo y ancho máximo del cóndilo occipital, la distancia intercondilar anterior y la distancia intercondilar posterior con la ayuda de un calibrador vernier. Se calculó la estadística descriptiva para los parámetros considerados. Los datos métricos de los lados derecho e izquierdo se compararon con la prueba t de Student y se calculó el valor de p. Todos los datos obtenidos se sometieron a análisis de función discriminante para derivar el modelo estadístico. Todas las medidas fueron significativamente altas en los hombres en comparación con las mujeres. La longitud y el ancho del cóndilo, la distancia intercondilar anterior y posterior se pueden utilizar para derivar la fórmula para determinar el sexo en la población del sur de la India con una precisión del 66,3 %.

PALABRAS CLAVE: Cóndilo occipital; Determinación del sexo; Análisis de funciones discriminantes.

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