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Morphological Analysis of Occipital Condyles in Dry Human Skulls in Northeast Brazil

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ABSTRACT

Introduction: occipital condyles are anatomical structures that integrate the craniovertebral junction, a region predisposed to a series of traumatic, degenerative and neoplastic diseases. Understanding the morphometry and morphology of this structure is essential for a safe and effective surgical treatment of lesions in this region.

Material and Methods: the present study has analyzed 128 dry adult human skulls. Genders were classified based on morphological features. A digital caliper was used to measure the following morphometric variables of the occipital condyles: length and width of the occipital condyles (OCL and OCW), anterior and posterior intercondylar distances (AID and PID) between the anterior and posterior tips of the occipital condyles, and the distance from the basion to the opisthions (BOD). Student's t-test was applied to evaluate statistical difference between sexes on each side, using GraphPad Prism® for Windows version 6.0. Values of $p < 0.05$ were considered significant.

Results: six types of condyles were identified in the population studied. Type 1 was predominant in the specimens. The right and left OCL measurements were higher in males, while OCW was higher in males only on the right side. Regarding the AID and PID and BOD measurements, there was no significant difference between genders.

Conclusion: the anatomical findings in this study can be useful and serve as a reference database to guide professionals, especially from northeastern Brazil, who will deal with approaches in this region, facilitating and reducing the chances of unforeseen events during surgical interventions.

Keywords: Anatomy; Occipital Condyles; Brazil.

Introduction

The bony structure of the posterior skull base is essentially formed by the occipital bone. There are two large bulges in its outer portion, the occipital condyles, where the skull articulates with the spine through the atlantoccipital joints. These joints allow intrinsic head movements, such as anterior flexion, extension, lateral flexion and rotation[1,2].

Occipital condyles are part of the craniovertebral junction, a region that is predisposed to a wide variety of traumatic, degenerative and neoplastic diseases. Tumors in this region are difficult to remove due to their location and also due to their complex anatomical relationships[3,4].

Surgical treatment of these lesions is commonly performed at the level of the foramen magnum. This intervention can be performed by a dorsal or ventral route. The most indicated is the dorsal one due to the high morbidity rates associated with ventral approach. However, to perform surgery by the dorsal route, a transcondylar approach is necessary, requiring a partial resection of the occipital condyle[2,5].

Consequently, in order to be able to perform such an approach, it is necessary to understand the anatomy of the occipital condyles and structures around them, since surgical intervention can be altered according to the morphology of the occipital condyles. Furthermore, any surgical error made in this region may result in some craniocervical instability and, consequently, compromise the functions of noble structures of the region[3].

There seems to be no mention in the literature about the morphology of the occipital condyles in Brazil, especially in the northeast Brazil, so it is extremely important to conduct studies that indicate an anthropological and anatomical profiles of occipital condyles in this region[6].

Therefore, the aim of this study was to analyze the morphology of the occipital condyles and their sexual

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dimorphism in dry skulls of Northeastern Brazil to allow a more accurate knowledge for professionals working with this body region.

Material and Methods

The present study has analyzed 128 dry adult human skulls (69 males, 59 females), with unknown ages, belonging to the Human Anatomy Laboratory of universities in northeast Brazil. Skulls with infantile conformation or with signs of significant bone degradation in the region were excluded from this study. The present study's sample was selected in accordance to the Brazilian Federal Law 8.501 (November 30, 1992) and an institutional approval was obtained.

First, the skulls were classified according to gender[7]. The types of occipital condyles were analyzed according to the classification of Naderi *et al.*[2]: type 1: oval-like condyle; type 2: kidney-like condyle; type 3: S-like condyle; type 4: eight-like condyle; type 5: triangle condyle; type 6: ring-like condyle; type 7: two-portioned condyle and type 8: deformed condyle (Figure 1).

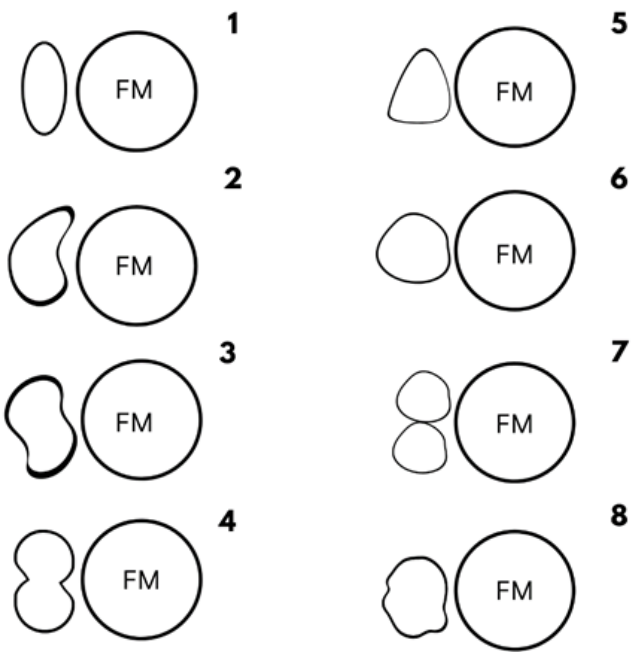

Figure 1. Types of occipital condyles: type 1: oval-like condyle; type 2: kidney-like condyle; type 3: S-like condyle; type 4: eight-like condyle; type 5: triangle condyle; type 6: ring-like condyle; type 7: two-portioned condyle and type 8: deformed condyle. FM: Foramen Magnum (Naderi et al.[2]).

Then, morphometric measurements were taken using a digital caliper (Eccofer®, João Pessoa, Paraíba, Brazil) with an accuracy of 0.01 mm. The parameters measured included length and width of the occipital condyles (OCL and OCW), anterior and posterior intercondylar distances (AID and PID) between the anterior and posterior tips of the occipital condyles, as well as the distance from the basion to the opisthions (BOD) (Figure 2).

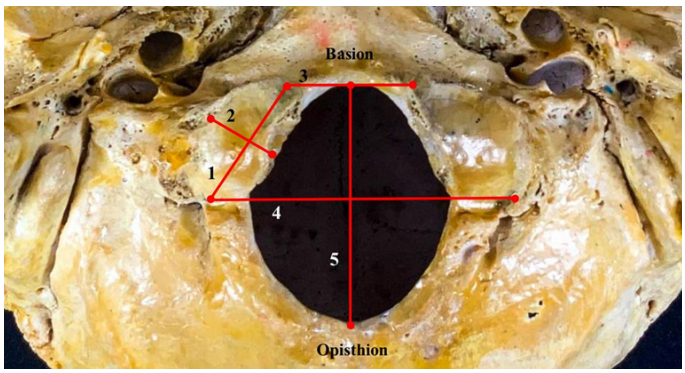

Figure 2. Inferior view of the skull showing the morphometric parameters analyzed in the study. (1) OCL: occipital condyle length; (2) OCW: occipital condyle width; (3) AID: anterior intercondylar distance; (4) PID: posterior intercondylar distances, (5) BOD: basion-opisthion distance.

The Student's t-test was applied to evaluate the existence of statistical difference between sexes and right and left antimeres. Statistical analysis was carried out using GraphPad Prism® for Windows version 6.0. Values of $p < 0.05$ were considered as significant.

Results

One hundred and twenty-eight (128) skulls were analyzed in this study, corresponding to 256 occipital condyles. Six types of condyles were identified in the population studied. In the male skulls there was predominance of type 3 (9.76%), followed by type 1 (7.42%), type 6 (7.42%), type 4 (1.6%) and type 8 (0.78%) on the right side. On the left side there was also prevalence of type 3 (9.76%), followed by type 1 (5.07%), type 6 (4.68%), type 5 (3.12%), type 8 (2.34%) and type 4 (1.95%). Regarding the female condyles, type 6 was predominant in 10.55% of the samples on the right side, followed by type 3 (6.25%), type 1 (4.30%) and type 4 (1.95%). On the left side, type 1 (12.50%) was more prevalent, followed by type 6 (6.25%), type 4 (2.74%) and type 8 (1.56%) (Table 1).

The male OCL and OCW on the right side were 22.37 ± 2.55 mm (range from 14.36 to 28.00 mm) and 12.13 ± 1.45 mm (range from 9.00 to 15.36 mm), respectively. On the left side were 22.40 ± 2.71 mm (range from 16.00 to 29.55 mm) and 12.15 ± 1.50 mm (range from 9.00 to 16.00 mm), respectively. The mean AID and PID of the male condyles were 19.59 ± 5.15 mm (range from 11.30 to 27.80 mm) and 38.17 ± 5.15 mm (range from 24.04 to 48.46 mm). The BOD of the male condyles was 36.15 ± 3.26 mm (range from 29.06 to 45.85 mm) (Table 2).

The female OCL and OCW on the right side were 20.9 ± 2.75 mm (range 14.21 to 28.60 mm) and 11.26 ± 1.50 mm (range 8.00 to 15.00 mm), respectively. On the left side were 19.78 ± 2.73 mm (range 13.21 to 25.18 mm) and 11.62 ± 1.74 mm (range 8.00 to 15.70 mm), respectively. The mean AID and PID of the female condyles were measured, respectively, as 20.42 ± 4.41 mm (range 12.10 to 27.00 mm) and 37.67 ± 4.29 mm (range 31.70 to 47.05 mm). The BOD of female condyles was 35.18 ± 2.21 mm (range 31.34 to 41.00 mm) (Table 2).

Table 1. Occipital condyle's type percentage in both sexes. N=256 occipital condyles.

Types of occipital condyle's*	Male skulls		Female skulls		TOTAL
	Right	Left	Right	Left	
Type 1	19 (7.42%)	13 (5.07%)	11 (4.30%)	32 (12.50%)	75 (29.29%)
Type 3	25 (9.76%)	25 (9.76%)	16 (6.25%)	0 (0%)	66 (25.77%)
Type 4	4 (1.6%)	5 (1.95%)	5 (1.95%)	7 (2.74%)	21 (8.24%)
Type 5	0 (0%)	8 (3.12%)	0 (0%)	0 (0%)	8 (3.12%)
Type 6	19 (7.42%)	12 (4.68%)	27 (10.55%)	16 (6.25%)	74 (28.9%)
Type 8	2 (0.78%)	6 (2.34%)	0 (0%)	4 (1.56%)	12 (4.68%)
TOTAL	138 (53.90%)		118 (46.10%)		256 (100%)

Type 7 condyle was not found in this study.

Table 2. Mean (mm) ± SD values of occipital condyle measurements in both sexes. N=128 skulls.

	MALE				FEMALE			
	Right side		Left side		Right side		Left side	
Para meters	Min - Max	Mean (SD)	Min - Max	Mean (SD)	Min - Max	Mean (SD)	Min - Max	Mean (SD)
OCL	14.36-28.00	22.37 (2.55)	16.00-29.55	22.40 (2.71)	14.21-28.60	20.09 (2.75)	13.21-25.18	19.78 (2.73)
OCW	9.00-15.36	12.13 (1.45)	9.00-16.00	12.15 (1.50)	8.00-15.00	11.26 (1.50)	8.00-15.70	11.62 (1.74)
AID	11.30-27.80 19.59 (5.15)				12.10-27.00 20.42 (4.41)			
PID	24.04-48.46 38.17 (5.15)				31.70-47.05 37.67 (4.29)			
BOD	29.06-45.85 36.15 (3.26)				31.34-41.00 35.18 (2.21)			

OCL: length of the occipital condyle; OCW: width of the occipital condyle; AID: anterior intercondylar distance; PID: posterior intercondylar distance: BOD: distance from the basion to the opisthion N: number of sides with occipital condyles; Min: minimum; Max: Maximum; SD: standard deviation.

The male and female OCL and OCW between the right and left sides had no differences ($p > 0.05$). When the genders were compared, the OCL on both the right side ($p < 0.0001$) and the left side ($p < 0.0001$) were higher in males when compared to females. Regarding OCW, the male occipital condyles were larger than the female son on the right side ($p < 0.0013$), while on the left side there were no differences between the studied genders ($p > 0.0681$).

Regarding the AID and PID and BOD measurements, there was no significant difference between the studied genders ($p > 0.05$).

Discussion

The occipital condyles are anatomical structures that integrate the craniovertebral junction, a region predisposed to traumatic, degenerative and neoplastic diseases. In Northeastern Brazil there is a high prevalence of malformations related to the craniovertebral junction that can lead to occipitocervical instability and compromise the structural and functional integrity of this topography, such as basilar impression, Chiari malformation and syringomyelia[8].

Considering the susceptibility of diseases that affect the craniovertebral junction and, consequently, the need to have a precise anatomical knowledge about the occipital condyles to perform surgical approaches successfully and safely, previous publications analyzed this region to understand its morphometry and morphology. Among the studies, six performed the analysis of cadaveric parts[2,3,6,9,10,11], and three by imaging exams[12,13,14]. In the present study, 256 dry occipital condyles were analyzed and measured to establish an average profile of the condyles in Northeast Brazil in order to compare with the findings of other studies carried out around the world.

Despite previous works describing different classifications on the forms of the occipital condyles, the present study followed the classification of Naderi

et al.[2] and observed the predominance of type 1 in 29.29% of the condyles analyzed, being comparable to the presentation of an Indian study[9] (22.50%). However, this predominance is different from two studies in the Turkish population that found type 1 in more than 50% of the analyzed condyles[2,10], maybe because they analyzed more skulls than the present study.

When comparing the genders, the present study presented type 1 as the most common only among female specimens, while in the Indian population[9] both sexes presented this type as prevalent. Outros trabalhos obtiverem diferentes formas de côndilos, como o tipo 4 em uma população indiana (22.50%) e uma população de outro estado brasileiro (19.20%)[6,9]. Although this last study was also carried out in Northeastern Brazil, it did not have the prevailing format of the current study. Type 3 was more common in only one of the Indian studies[11] (25%) (Table 3). There is, therefore, a variability in the type of condyles found in populations within Brazil and abroad. The different methodologies used, the anthropological characteristics of each population and the sample size may partially explain these differences.

Taking this into account, the study carried out by Ozer *et al.*[10] revealed the importance of these qualitative data in surgical procedures. They pointed out that type 1 condyles have a greater perimeter, so these condyles have a greater chance of success in the insertion of surgical rods. Other authors[2,9] have also reported that during other procedures, such as condylectomy, surgical instrumentation can be altered according to the morphology of the occipital condyles. Among the types of condyles already mentioned, there is the possibility that types 2, 5 and 8 require a more extensive condylectomy to gain access to the ventral lesions. Although not predominant, types 5 and 8 occipital condyles represent 7.8% of the samples in this study.

A Turkish study[2] also categorized the occipital condyles according to their length. Condyles measuring 23±3 mm were called "moderate", "short" when smaller than 20 mm and "long" when larger than 26 mm. In the present study, the mean OCL was 21.16±2.68 mm, representing moderate condyles. Other populations showed similar results or were close to the short-type values[2,3,9,11,12,13,14] (Table 4). This quantitative data is critical during a condylectomy procedure, as shorter condyles may be more susceptible to occipitocervical instability, while long condyles may require a more extensive resection for better visualization[2,9].

When comparing the genders, the length of both the right and left sides was greater in males ($p < 0.0001$). These results are similar to the findings of other Indian[9,13] and Turkish[12] researchers, however, not all studies performed the classification by gender[2,3,10,14].

Another point analyzed in this study was the width of the occipital condyles. The study by Naderi *et al.*[2] did not categorize the occipital condyles according to width, however, the Indian study by Kalthur *et al.*[9] called "intermediate" condyles those with 11±2.0 mm, "narrow" those with 9.0 mm and "wide" when greater than 13 mm. In the present study, the mean width was 11.79±1.54 mm, similar to other populations[2,3,9,11,12,13], representing intermediate condyles. Only one American study[14] was classified as large because it had a higher value (Table 4). This quantitative data is of surgical relevance, as the surgeon must have knowledge about how much the condyle can be resected medially. In addition, surgeries on wider condyles can be more demanding[2,9,14]. The work carried out by Kalthur *et al.*[9] also highlighted that men tend to have narrower

Table 3. Occipital condyle types in different populations.

Researchers	Year	Population	Type	%
Present study	2022	Brazilian	1	29.29
Aragão *et al.*[6]	2017	Brazilian	4	19.20
Kalthur *et al.*[9]	2014	Indian	1 e 4	22.50
Sinha *et al.*[11]	2014	Indian	3	25.00
Ozer *et al.*[10]	2010	Turkish	1	59.70
Naderi *et al.*[2]	2005	Turkish	1	50.00

Table 4. Occipital condyle dimensions in different populations.

Researchers	Year	Population	Length (mm)	Width (mm)	AID (mm)	PID (mm)	BOD (mm)
Present study	2022	Brazilian	21.16 ± 2.68	11.79 ± 1.54	20.00 ± 4.78	37.92 ± 4.72	35.67 ± 2.73
Gumussoy *et al.*[12]	2019	Turkish	19.60 ± 2.00	10.30 ± 1.30	20.90 ± 1.50	44.0 ± 2.00	-
Bosco *et al.*[13]	2016	Indian	18.80 ± 2.30	10.30 ± 1.50	-	-	-
Saluja *et al.*[3]	2016	Indian	22.75 ± 2.90	12.70 ± 1.53	17.81 ± 2.93	38.91 ± 4.16	-
Kalthur *et al.*[9]	2014	Indian	22.00 ± 2.00	11.00 ± 2.00	21.00 ± 3.00	39.00 ± 3.00	-
Sinha *et al.*[11]	2014	Indian	22.49 ± 2.69	11.87 ± 1.37	19.78 ± 2.45	41.81 ± 3.80	-
Hong *et al.*[14]	2011	American	22.90 ± 2.50	14.10 ± 1.80	-	-	-
Naderi *et al.*[2]	2005	Turkish	23.40 ± 2.50	10.50 ± 1.40	21.00 ± 2.80	41.60 ± 2.90	34.70 ± 2.30

AID: anterior intercondylar distance; PID: posterior intercondylar distance: BOD: distance from the basion to the opisthion.

condyles than women, leading us to understand that surgeries performed on male condyles are likely to be less demanding.

In the current study, the means of AID and PID were respectively 20.00±4.78 mm and 37.92±4.72 mm. The AID average is in agreement with the findings of other Indian[3,9,11] and Turkish[2,12] researchers. However, regarding the PID, only one Turkish population[12] presented higher measures, the other authors[2,3,9,11] obtained comparable measures. The BOD measurement obtained in this study was 35.67±2.73 mm, but only a Turkish study[2] analyzed this distance with similar values (Table 4). It is important to highlight that the anterior and posterior intercondylar distances are relevant morphometric data because they demonstrate the orientation and convergence of the occipital condyle, a primordial condition for the placement of screws during an occipitocervical fixation[3].

Thus, comparisons with different studies show that there is great variability in the types and shapes of occipital condyles. Perhaps this could be related to methodological limitations, such as measurement methods and sample sizes, or anthropological variability between different countries and within the same country.

Conclusion

The occipital condyle morphology is of great importance for performing interventions at the craniocervical junction. In our study, six types of occipital condyles were found, with the type 1 condyle being predominant. It was also possible to observe a morphometric variability in this study compared to others in Brazil or other countries of the world. Further studies are needed to establish a recognized pattern of the occipital condyles morphology, especially in Northeastern Brazil. Despite the limitations of this study and the available anatomical data of the occipital condyle morphology in the literature, this analysis can be considered a useful anatomical parameter to guide health professionals to perform safer procedures in this region.

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7. Jalles Dantas de Lucena: discussion of the results and writing of the manuscript, conception and design of the study.

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