

Morphological study of the foramen magnum and occipital condyle and its surgical implications in transcondylar approach

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Abstract: The transcondylar approach is being increasingly used to access lesions ventral to the brain stem and cervicomedullary junction. Understanding the anatomy of the occipital condyles is important for this approach. The present work aimed to clarify the morphometric data of the occipital condyle and its importance in transcondylar approach. The study was performed on 200 occipital condyles of 100 adult human dry skulls of unknown age and sex. Metric and morphological analysis was performed for the specimens. The parameters were, the length, width, height, the anterior and posterior intercondylar distances and the distances from the occipital condyle to the midline of the foramen magnum. In addition, the different locations of the hypoglossal canal orifices relative to the occipital condyle were assessed. The different shapes of the occipital condyles and their rates were detected. The length, width and height of the occipital condyle were found to be 23.5, 13.58 and 9.64 mm in the right and 23.75, 13.62 and 9.5mm in the left respectively. The anterior and posterior intercondylar distances were 20.64 and 41.4mm respectively. The intracranial orifice of hypoglossal canal was found to be present against the junction of the 2nd and quarter or against the 3rd quarter of the occipital condyle in 65%. The extracranial orifice of the hypoglossal canal was found to be present against the junction of the 1st and 2nd quarter or against the 2^d quarter of the occipital condyle in 69%. The more frequent type of occipital condyle detected is kidney shaped. It could be concluded that, the safest area to be drilled in the occipital condyle is the posterior quarter (4.5-78mm from the posterior end) as there is no location for the hypoglossal canal orifice was found against this area. In the other locations the extent of bony resection of the occipital condyle can be anticipated by the available recent radiological techniques by using the morphometric parameters.

Keywords: Occipital condyle, hypoglossal canal, foramen magnum, transcondylar approach.

Introduction

The condylar parts of the occipital bone flank the foramen magnum. The inferior surface of the occipital condyles present for articulation with the superior atlantal facets present on the lateral mass of the atlas. This articulation is the only one between the skull and first cervical vertebra (1). The stability of this craniovertebral

junction depends largely on the morphometric data of the occipital condyles (2, 3). Most of the previous studies were confined to the morphometric analysis of some parts of the occipital condyle (4-8). Morphometric analysis including metric and non metric study for most of the parameters of occipital condyle are rare found. The deep lesions at the

level of foramen magnum can be reached surgically by using ventral and dorsal approach. As the ventral approach is dangerous and has a high rate of morbidity, the dorsal approach is preferred to reach the space occupying lesion ventral to the spinal cord at the craniovertebral junction (2, 8, 10). The far- lateral transcondylar surgical approach have been used to reach lesions at the ventrolateral clivus and jugular foramen (8, 11, 12). Partial resection of the occipital condyle is made during transcondylar surgical approach. The extent of bony removal necessary for optimal exposure is unclear ranging from suboccipital craniectomy to occipital condyle removal. This exposure may be gained through a limited removal (8, 12-14) or complete removal (2). These approaches have been successful in reducing the depth of the surgical field and improving the angle of exposure thereby reducing the amount of brain retraction needed (11, 12). So the transcondylar surgical approaches need adequate information about the metric and morphological aspect of occipital condyle. The objective of the present study was to clarify the morphometric data of the occipital condyle and its surgical implications in transcondylar approach.

Materials and methods

The study was performed on 200 occipital condyles of 100 adult human dry skulls of unknown age and sex. The specimens were obtained as a part

of dry bone collection stored at the department of Anatomy Faculty of Medicine, Cairo University, Cairo, Egypt. Metric and morphological study was performed for the collected specimens.

The metric study: It included 10 parameters as length, width, height and distances related to the occipital condyle (Table 1). The parameters were measured by using a sliging caliper (Fig.1-8). The measurement for each parameter was performed by the two parameter was performed by the two researchers and the mean was taken to minimize the intraobserver and interobserver errors. The height of the occipital condyle was measured at the centre of the condyle which is present at the midpoint of the largest anteroposterior axis of the occipital condyle (9).

The data were statistically analyzed and tested for significance between the right and left sides. Also, the locations of the hypoglossal canal orifices (extracranial and intracranial) in relation to the occipital condyles were assessed. The largest anteroposterior axis of the occipital condyle was measured and divided into 7 equal portions from anterior to posterior ends. According to Naderi et al (9). there are 7 locations for the hypoglossal canal orifice in relation to the occipital condyle (Table 2).

Morphological study: The occipital condyles were classified according to their shapes and the percentage of each particular one was assessed.

Table 1: measured parameters

<i>The measured parameters</i>	
1-	The length of occipital condyle (right and left).
2-	The width of occipital condyle (right and left)
3-	The height of occipital condyle (right and left).
4-	Anterior intercondylar distance (distance between the anterior tips of the right and left occipital condyles).
5-	posterior intercondylar distance (distance between the posterior tips of the right and left occipital condyles).
6-	Distances between the anterior tips of the occipital condyles (right and left) and the anterior midline of foramen magnum.
7-	Distances between the posterior tips of the occipital condyles (right and left) and the posterior midline of foramen magnum.
8-	Distances between the posterior tips of the occipital condyles (right and left) and the anterior midline of foramen magnum.
9-	Distances between the posterior tips of the occipital condyles (right and left) and the posterior midline of foramen magnum.
10-	The anteroposterior diameter of foramen magnum.

Table 2: locations of the hypoglossal canal orifice relative to the occipital condyle

<i>location</i>	<i>Position of the orifice relative to occipital condyle</i>
Location1	1 st one-fourth of occipital condyle.
Location2	Junction of the 1 st and 2 nd one-fourth of occipital condyle.
Location3	2 nd one- fourth of occipital condyle.
Location4	Junction of 2 nd and 3 rd one- fourth of occipital condyle.
Location5	3 rd one- fourth of occipital condyle.
Location6	Junction of 3 rd and 4 th one- fourth of occipital condyle
Location7	4 th one-fourth of occipital condyle.

Results

The results obtained from the present study are shown in table 3. The mean length, width and height of the measured occipital condyle were found to be 23.5 mm (right) and 23.75 mm (left) for the length. 13.58 mm (right) and 13.62 mm (left) for the width and 9.64 mm (right)

and 9.5 mm (left) for the height. The mean anterior and posterior intercondylar distances were found to be 20.64 and 41.4 mm respectively. The mean distance between the anterior tip of the occipital condyle and anterior midline of foramen magnum was found to be 11.1 mm (right)

and 11.3 mm (left). The mean distance between the anterior tip of occipital condyle and the posterior midline of the foramen magnum was found to be 39.9 mm (right) and 40.1 mm (left). The mean distance between the posterior tip of the occipital condyle and anterior midline of the foramen magnum was found to be 27.38 mm (right) and 27.97 mm (left). The mean distance between the posterior

tip of occipital condyle and the posterior midline of the foramen magnum was found to be 27.87 mm (right) and 27.94 mm (left). The mean anteroposterior diameter of the foramen magnum was found to be 34.94 mm. There were no significant differences for the measured parameters between the right and left sides.

Table 3: the results of the measured parameters for occipital condyle

<i>Measured parameters</i>	<i>Side</i>	<i>Mean (mm)</i>	<i>S.D</i>	<i>Range</i>	<i>T. test</i>
Length of O.C	Rt	22.5	2.32	17-33	0.47
	Lt	22.75	2.52	19.3-27.4	
Width of O.C	Rt	11.50	1.80	8.5-18	0.10
	Lt	11.50	1.70	9.2-15.6	
Height of O.C	Rt	10.64	1.41	7-14	0.45
	Lt	10.50	1.71	7-13	
Anterior intercondylar distance		22.60	2.80	12.5-25.5	
Posterior intercondylar distance		42.45	3.45	36.5-49.5	
D. between anterior tip of O.C and anterior midline of F.M	Rt	12.1	2.3	8-17	0.50
	Lt	12.3	2.1	6.8-14.5	
D. between anterior tip of O.C and posterior midline of F.M	Rt	40.9	2.80	33.5- 47.5	0.35
	Lt	42.10	3.15	33.3- 49.02	
D. between posterior tip of O.C and anterior midline of F.M	Rt	28.35	2.18	25.3-35.5	1.40
	Lt	28.90	2.50	23.2-33.5	
D. between posterior tip of O.C and posterior midline of F.M	Rt	27.87	3.37	21.6-42	0.10
	Lt	27.94	3.21	21.5-41.5	
Anteroposterior diameter of F.M		35.94	2.51	31-40.2	

O.C: occipital condyle, Rt: right , Lt: left, S.D.: standard deviation, D: distance, F.M: foramen magnum.

The locations of the intracranial and extracranial orifices of the hypoglossal canal in relation to the occipital condyle are present in table 4 and figures (9 - 17). It was found that, the intracranial orifice of hypoglossal canal is present from location 2 to the location 6 with the maximum percentage for locations 4 and 5. The total percentage for location 4 and 5 was 65% (35% + 30%). The

percentage for other locations was extremely less, 8% for location 2, 16% for location 3 and 11% for location 6. On the other hand, the locations of the extracranial orifice were found to be present from location 1 to location 5 with the maximum percentage for locations 2 and 3. the total percentage for location 2 and 3 was 69% (39% + 30%). The percentage for other locations was less, 24% for location 1, 5% for location 4 and 1% for location 5.

Table 4: The locations of intracranial and extracranial orifices of hypoglossal canal relative to the occipital condyle

Location	Intracranial orifice					Extracranial orifice				
	Right		Left		Total	Right		Left		Total
	N	%	N	%	%	N	%	N	%	%
Location 1	0.0	0.0	0.0	0.0	0.0	28	28	20	20	24
Location 2	10	10	6	6	8	42	42	36	36	39
Location 3	18	18	14	14	16	28	28	32	32	30
Location 4	38	38	32	32	35	2	2	8	8	5
Location 5	30	30	30	30	30	0.0	0.0	4	4	2
Location 6	4	4	18	18	11	0.0	0.0	0.0	0.0	0.0
Location 7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

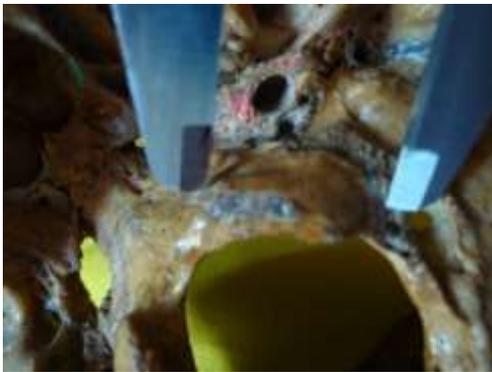
N: Number

The shapes of the occipital condyles of the specimens studied were found to have 8 different types as shown in figures (18 - 23). These types are, type 1: kidney shaped condyle, type 2: S- like condyle, type 3: oval condyle, type 4: two portioned condyle, type 5: 8- shaped condyle, type 6: ring - like condyle, type 7: triangular condyle and type 8: quadrilateral condyle. The most common type as shown in table 5 was the type 1: kidney shaped condyle (22%). The most unusual type was the type 8: quadrilateral condyle (5%). When the right and left occipital condyles of the same skull were

compared, a symmetrical shape was found in 46 skulls (46%) and an asymmetrical shape was found in 54 skulls (54%). Also, the occipital condyle was classified according to its length into 3 categories. The condyle shorter than 20 mm was called as type 1 (short), the condyle ranged from (20 - 26 mm) was called as type 2 (moderate) and the condyle longer than 26 mm was called type 3 (long). In the present study the occipital condyles were found to be short in 14 condyles (7%), moderate in 160 condyles (80%) and long in 26 condyles (13%).

Table 5: The rate of different shapes of the occipital condyle.

<i>Type</i>	<i>Right</i>	<i>Left</i>	<i>Total</i>
1- kidney shaped	20%	24%	22%
2- S- like	20%	18%	19%
3- Oval	12%	20%	16%
4- Two portioned	14%	12%	13%
5- 8- shaped	14%	10%	12%
6- Ring- like	12%	2%	7%
7- Triangular	2%	10%	6%
8- Quadrilateral	6%	4%	5%

**Figure 1****Figure 2**

Figures 1 & 2: Demonstration for measurement of different parameters of occipital condyle.

Figure 1: The length and Figure 2: The width.

**Figure 3****Figure 4**

Figures 3 & 4: Demonstration for measurement of different parameters of occipital condyle.

Figure 3: The height and Figure 4: The anterior intercondylar distance.



Figure 5



Figure 6

Figures 5 & 6: Demonstration for measurement of different distances related to occipital condyle and foramen magnum.

Figure 5: The posterior intercondylar distance and Figure 6: The distance between the posterior end of occipital condyle and posterior midline in foramen magnum.



Figure 7



Figure 8

Figures 7 and 8: Demonstration for measurement of different distances related to occipital condyle and foramen magnum.

Figure 7: distance between the anterior end of occipital condyle and anterior midline of foramen magnum and Figure 8: The anteroposterior diameter of foramen magnum.



Figure 9



Figure 10

Figure 9, 10 and 11: Demonstration for the locations of the intracranial orifice (as indicated by the rubber tubes).

Figure 9: location 2, Figure 10: location 3 and Figure 11: Location 4



Figure 11



Figure 12



Figure 13

Figures 12 & 13: Demonstration for the locations of the extracranial orifice of hypoglossal canal (as indicated by the rubber tubes).

Figure 12: Location 1 and Figure 13: Location 2.



Figure 14



Figure 15

Figures 14 & 15: Demonstration for the locations of the extracranial orifice of hypoglossal canal (as indicated by the rubber tubes).

Figure 14: Location 3 and Figure 15: Location 4.



Figure 16



Figure 17

Figures 16 and 17: Demonstration for the different shapes of the occipital condyle. Figure 16: Kidney shaped and Figure 17: S- Shaped.



Figure 18



Figure 19

Figures 18 and 19: Demonstration for the different shapes of the occipital condyle. Figure 18: Oval shaped and Figure 19: Two portioned.

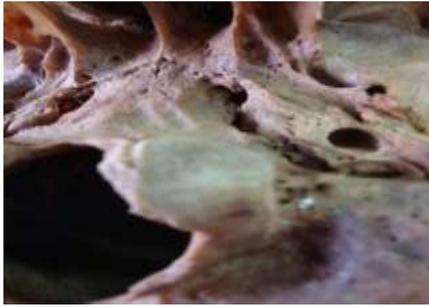


Figure 20



Figure 21

Figures 20 and 21: Demonstration for the different shapes of the occipital condyle. Figure 20: 8-shaped and Figure 21: Ring-shaped

**Figure 22****Figure 23**

Figures 22 and 23: Demonstration for the different shapes of the occipital condyle.

Figure 22: Traingular and Figure 23: Quadrilateral.

Discussion

The transcondylar approach directed through the occipital condyle provides access to the lower clivus and premedullary area. The partial transcondylar approach is performed to treat lesions that are located predominantly anterior to the spinomedullary junction and the posterior one-third of the occipital condyle is drilled away. The hypoglossal canal is the anterior limit of the condylar resection. The complete transcondylar approach is performed to treated extraduarl lesions. Resection of the posterior half of the occipital condyle leads the hypoglossal canal to be exposed and by extending superior and inferior to this canal, most of the jugular tubercle and the entire condyle are removed (8, 10). So, the configuration and orientation of the occipital condyle as well as the locations of the intra and extracranial orifices of the hypoglossal canal may affect the transondylar approach. In the present study, the length of the occipital condyle was found to range from 18 to 31 mm and the mean is 23.5 mm in right and 23.75 mm in left. This measured length is comparable to was found by Naderi et al. (9), Muthukumar et al. (16) and Kizilkanat (17) who reported the length as 23.6 mm, 23.6 mm and 24.5 mm, respectively, but far-away from the result obtained by Down et al. (15) who reported the

length as 30 mm. the occipital condyles were classified according to their lengths into 3 types, which are short, moderate and long. The length of the occipital condyle is an important surgical issue. The anatomical and biomechanical results of partial condylectomy in short type are different from the results obtained in long type occipital condyle. The same amount of partial condylectomy may cause greater occipitocervical instability in short occipital condyle, whereas the long condyle may require a more extensive resection for optimal visualization (9).

The occipital condyle width was found to range from 9.5 to 18 mm and the mean is 13.58 mm in right and 13.62 in left. This measured width is comparable with the results obtained by Kizilkanat (17) who reported the width as 13.1 mm, but away from the results obtained by Muthukumar et al. (16) and Naderi et al. (9) who reported the width as 14.72 mm and 10.6 mm respectively. The height of the occipital condyle was found to range from 6 to 14 mm and the mean is 9.6 mm in right and 9.5 mm in left. This measured height is approximate to the result obtaine by Naderi et al. (9) who reported the height as 9.2mm and more than the result obtained by Oliver (5) who reported the height

as 8.8 mm. The occipital condyles were found to converge ventrally. The anterior and posterior intercondylar distances were found to be 20.64 and 41.4 mm, respectively. These measured distances are comparable to the results obtained by Naderi et al. (9) who reported these distances as 21 and 41.6 mm, respectively and away from the results obtained by Kizilkanat (17) who reported them as 22.6 and 44.2 mm respectively. This wide difference between the anterior and posterior intercondylar distances leads the occipital condyle to have different anterior and posterior angles. The anteroposterior orientation and narrow intercondylar space would require a more bony removal (15).

The distance between the anterior tip of occipital condyle and the anterior midline of the foramen magnum was measured as 11.1 mm in right and 11.3 mm in left. Also, the distance between the posterior tip of occipital condyle and the anterior midline of the foramen magnum was measured as 27.38 mm in right and 27.97 in left. These measured distances are comparable to the results obtained by Naderi et al. (9) who reported them as 10.8 and 28 mm respectively. The distance between the anterior tip of the occipital condyle and the posterior midline of the foramen magnum was measured as 39.9 mm in right and 40.1 mm in left. Also, the distance between the posterior tip of the occipital condyle and the posterior midline of the foramen magnum was measured as 27.87 mm in right and 27.94 mm in left. These measured distances deviate slightly from the results obtained by Naderi et al. (9) who reported them as 39 and 26.4 mm respectively. On the other hand, Down et al.(15) measured the distances from the posterior midline of the foramen magnum to both lateral and medial edges of the occipital condyle and reported these distances as 40 and 27 mm respectively which are comparable to the results of the present study. The distance between the posterior tip of occipital condyle and the posterior midline of foramen magnum is also an important anatomical factor. The larger the distance, the free the space for the posterolateral approach (9). The anteroposterior diameter of the foramen magnum was found to

be 34.94 mm. this measured parameter is comparable to the results obtained by Naderi et al. (9) and Kizilkanat (17) who found it as 34.7 and 34.8 mm respectively. On the other hand, Muthukumar et al. (16) found it as 33.3 mm.

The intracranial orifice of the hypoglossal canal is located medial to the occipital condyle. In the present study, the intracranial orifice of the hypoglossal canal was found to locate principally at location 4 and 5 with a total percentage of 65% (35% and 30% respectively). The other location were less frequent. This means that the intracranial orifice of hypoglossal canal is located mainly against the junction between the 2nd and 3rd one- fourth or against the 3rd one- fourth of the occipital condyle. No location for hypoglossal canal orifice was found against the posterior one- fourth of occipital condyle (location 7). As the resection of the occipital condyle depends on the intracranial location of the hypoglossal canal orifice, so this posterior one- fourth can be resected safely. The posterior one- fourth of the occipital condyle can be calculated to range from 4.5 to 7.8 mm from the total length of the occipital condyle which ranges from 18 to 31mm. in the other locations, the occipital condyle can be resected more. This is nearly similar to that reported by Wen et al. (8) in that, the intracranial orifice of the hypoglossal canal is located approximately above the junction of the posterior and middle one third of the occipital condyle and the average distance between the posterior edge of the occipital condyle and the intracranial orifice of hypoglossal canal is 8.4mm (range 6-10mm). they added that, the lateral aspect of the intracranial end of hypoglossal canal is reached after removal of approximately the posterior one-third of occipital condyle (8.4 mm of 21 mm). further drilling of the occipital condyle can be performed after reaching the lateral aspect of the intracranial end of hypoglossal canal because the canal is directed anteriorly and laterally permitting the lateral portion of posterior two- third of the condyle to be removed without entering the hypoglossal canal. On the other hand, Muthukumar et al. (16) and Kizilkanat (17) reported that, the distance from the intracranial end of

hypoglossal canal to the posterior margin of the occipital condyle is 12.2 mm. They added that, the occipital condyle can be drilled safely for a distance of 12 mm from the posterior margin before encountering the hypoglossal canal. Naderi et al. (9) reported the intracranial orifice of hypoglossal canal in location 4 in more than 55%. Among these variability of the distance between the intracranial orifice of hypoglossal canal and the posterior end of occipital condyle, it could be concluded that, the safest area to be drilled in the occipital condyle is the posterior quarter (4.5- 7.75 mm) as there is no location for the hypoglossal canal against the posterior quarter of occipital condyle (location 7 is 0.0%). In the other locations, the extent of bony resection can be anticipated by the available recent imaging techniques in each individual case by using the mentioned metric study.

As regards the extracranial orifice of the hypoglossal canal in relation to the occipital condyle, it was found that the extracranial orifice of hypoglossal canal is present mainly in location 2 and 3 with a total percentage of 69% (39% and 30% respectively). This means that, the orifice is present mainly against the 2nd one-fourth or at the junction between the 1st and 2nd one-fourth of the occipital condyle. This is in agreement with the result recorded by Wen et al. (8) who found that the extracranial end of hypoglossal canal is located immediately above the junction of the anterior and middle one-third of occipital condyle. Also, Naderi et al. (9) found that the extracranial orifice of hypoglossal canal is present in location 1 and 2 in more than 90% of specimens. So, the location of the intracranial and extracranial orifices of hypoglossal canal is important during condylectomy. Too dorsally located intracranial orifice of hypoglossal canal is important during condylectomy. Too dorsally located intracranial orifice of hypoglossal canal may complicate and limit the transcondylar approach.

In the studied specimens, different shapes of the occipital condyle were found and the percentage of each one was assessed. These different shapes were, kidney shaped: 22%, S-like: 19%, oval: 16%, two portioned: 13%, 8-shaped: 12%, ring-like: 7%, triangular: 6% and quadrilateral: 5%. The kidney shaped occipital condyle was found to be the most common type. Many previous studies reported different classifications for the shapes of the occipital condyle (5). Oliver classified the occipital condyle as (1) normal constricted and (2) subdivided. Guidotti (6) classified the occipital condyle as (1) flat, (2) partitioned without interruption of the articular surface and (3) partitioned with a clear angle but without separation of the surface. Bozbuga et al. (18) classified the occipital condyle as two semicircles type, oval type, rhombus type, bean-shaped type, prismatic type, flattened type, convex type, flattened convex type, short and broad type, flat and long type and small and convex type. All the previous classifications did not mention the rate of each type and they are either too simple or too complex. On the other hand, Naderi et al. (9) found that, the occipital condyle is most commonly oval shaped (more than 50%) followed by S-shaped condyle (23%) and the other types including kidney shaped, triangular, 8-like, ring-like, two portioned and deformed are much less frequent. They added that, among the different types of occipital condyle, the triangular, the deformed and kidney shaped types may require a more extensive condylectomy to reach the ventral lesions. Duplication of the occipital condyles has been mentioned by Tubbs et al. (19) and reported it as a rare variety and mostly accompanied by congenital abnormalities as a small third occipital condyle, elongation of the styloid process and septation of hypoglossal canal.

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