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# Comparison of Occipital Condyle Morphometry in Various Populations with Respect to Skull Base Surgery

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## ABSTRACT

**Background:** The craniovertebral junction is made up of the occiput, upper two cervical vertebrae. Occipital condyle is one the landmarks on the skull base. Morphometric values of these condyles in a specific population is to be known by surgeons to deal with pathologies affecting the cranial base without disturbing the neurovascular structures by doing appropriate condylectomy and to ensure occipito-cervical fusion in case of instability. **Methods:** The study was performed by comparing the morphometric values of occipital condyles with other populations (Greek, Turkish, Korean, Chinese, American, European and Indian). The data regarding the morphometric values of occipital condyles was taken from our previously published article with a sample of hundred occipital condyles of unsexed dry human skulls of unknown age and compared with the studies of other population. The measurements compared were the length, breadth and thickness of the occipital condyle, intercondylar distance in anterior, middle and posterior parts of the occipital condyles, the angle of the occipital condyle to the sagittal plane and coronal planes and shape of the occipital condyles. **Results:** Most of the morphometric values of OC in South Indian were lesser than the other populations like breadth, thickness,anterior intercondylar distance, posterior intercondylar distance, angle of the occipital condyle to the sagittal plane. **Conclusion:** This information has to borne in mind while performing surgical procedures like occipito-cervical screw fixation, condylar drilling in cranial base surgery in South Indian population.

***Keywords:*** *Craniovertebral junction, Morphometry, Occipital condyle, Skull base, Screw fixation*

## INTRODUCTION

One of the prominent features in occipital bone is the occipital condyle (OC). Each OC is usually oval shaped and arranged obliquely on either side of foramen magnum which constitute the craniovertebral junction (CVJ) along with first two cervical vertebrae.[1] It contains vital structures such as lower part of medulla, upper cervical segments of spinal cord, cerebellum, vertebral artery and venous plexus surrounding it, posterior inferior cerebellar artery,[2] and lower four cranial nerves.[3] There are number of pathologies affecting CVJ such as tumours (meningioma, schwannoma),[4] glossopharyngeal neuralgia and vertebral artery aneurysm.[5,6] Tumours at the CVJ pose a challenge to the surgeons because of the complexity of the anatomical relation. Till now various surgical techniques have evolved for treating these pathologies effectively as well as to save adjacent neurovascular structures. One of the approach is posterolateral approach which involves the excision of condylar fossa, posterior part of jugular tubercle without the removal of occipital condyle which mimics transcondylar fossa approach.[7,8] which is needed in case of intradural lesions along the lateral margin of foramen magnum. One of the modified posterolateral approach is transcondylar approach which involves the whole or partial removal of OC. If the OC is not considered in skull base surgical approach, then it is called as far lateral approach which is the extension of posterior

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midline.[4,9] Intradural tumours at lower clivus or anterior margin of foramen magnum creates hindrance to access as it lies over a narrow space. The posterolateral approach gives a proper visualisation of the pathology and reduces the stretching of the spinal cord. Extreme lateral approach involves extensive removal of bone lateral to foramen magnum.[10]

Even though various cranial base surgical techniques are employed, most of them did not satisfy the demand because the basic make up of CVJ is narrow and intricate and requires a sound knowledge of the anatomy. Usually, this anatomy differs from individual to individual, population to population and race to race. Therefore a proper understanding about the measurement of CVJ will decide the successful outcome of the surgery without post operative complications. The precise metric values of the occipital condyle should be borne in mind before the area is ventured. The aim of the present study is to compare the metric values of the occipital condyles in various populations and to discuss its importance in transcondylar approach and screw placement into the OC in case of occipito cervical fusion in South Indian population.

## MATERIALS ANDMETHODS

The data regarding the morphometric values of occipital condyles was taken from previously published article with a sample of hundred occipital condyles of unsexed dry human skulls of unknown age and compared with the studies of other population.

The parameters of OC considered are the length, breadth and thickness of the occipital condyle, intercondylar distance in anterior, middle and posterior parts of the occipital condyles, the angle of the occipital condyle to the sagittal plane and the angle of the occipital condyle to the coronal plane and shape of the occipital condyles .

## RESULTS

The previous study was performed on hundred occipital condyles of fifty unsexed dry human skulls of unknown age. [Table 1] represents the mean value of length, breadth and thickness of the OC.[11] Significant difference was observed regarding the length between the right and left side (0.001). According to the length, 15% of OC were short (2 or less than 2cm), 46% were medium-sized (2.1-2.5cm), 39% of them had maximum length (more than 2.5cm). From the [Table 1], significant differences were observed regarding the breadth of OC at its middle part on the right and left sides (0.029). The results from the breadth of the OC at its anterior part was not significant while the breadth of the OC at its posterior part was significant (0.016). Statistically significant difference was observed for the thickness of the OC (0.009). The results from the angle of OC to coronal plane was also found to be significant (0.009) while the angle of OC to sagittal plane was not significant.

Table 1: shows the mean, SD and P values of different parameters of our previous study.

| Parameters | Mean | SD | P value |
|---|---|---|---|
| Length (cm) | R-2.49 L-2.39 | R-0.45 L-0.25 | 0.001* |
| Breadth –Anterior (cm) | R -0.46 L -0.44 | R-0.29 L-0.25 | 0.7127 |
| Breadth-Posterior (cm) | R-0.84 L-0.68 | R-0.37 L-0.23 | 0.016* |
| Breadth-Middle (cm) | R-1.14 L-1.01 | R-0.30 L-0.29 | 0.0299* |
| Thickness (cm) | R-0.53 L-0.45 | R-0.17 L-0.13 | 0.0096* |
| Angle of occipital condyle to sagittal plane in degrees | R-30.52 L-29.6 | R-5.49 L-7.01 | 0.0901 |
| Angle of occipital condyle to coronal plane in degrees | R-57.64 L-55.33 | R-7.54 L-10.98 | 0.0096* |

*marked areas show the significant P values less than 0.05. R-Right L-Left

Table 2: shows the ICD in our previous study.

| Researcher | Year | Population | AICD(cm) | MICD(cm) | PICD(cm) |
|---|---|---|---|---|---|
| Somanath D, Sudha R | 2017 | Indian | 1.52 | 2.02 | 2.77 |

Table 3: shows the comparison of length, breadth and height in different populations.

| Researcher | Year | Population | Length(cm) | Breadth(cm) | Height(cm) |
|---|---|---|---|---|---|
| Previous study (Somanath D,Sudha R) | 2017 | South-Indian | R -2.49 L-2.39 | R -0.81 L-0.71 | R -0.53 L-0.45 |
| Lyrtzis C et al | 2016 | Greek | Male- R -2.43 L-2.40 Female- R -2.29 L-2.32 | Male- R -1.21 L-1.22 Female- R -1.14 L-1.14 | - |
| Saluja S | 2016 | Indian | R –2.29 L-2.26 | R -1.29 L-1.29 | R -0.93 L-0.91 |
| Verma R et al | 2016 | Indian | R -2.32 L-2.27 | R -1.29 L-1.33 | R -1.12 L-0.89 |
| Tong H et al | 2015 | Chinese | R -1.66 L-1.60 | R -0.78 L-0.79 | R -1.28 L-1.37 |
| Abdel-karim RI et al | 2015 | Egyptian | Male- R -2.69 L-2.7 Female- R -2.40 L-2.36 | Male- R -1.22 L-1.19 Female- R -1.11 L-1.07 | |
| Kalthur SG et al | 2014 | Indian | 2.2 | 1.1 | 0.9 |
| Bayat P et al | 2014 | Iranian | R- 1.94 L-1.92 | R-0.92 L-0.94 | R- 0.72 L- 0.73 |

| | | | | | |
|---|---|---|---|---|---|
| Yu Z et al | 2014 | Chinese | Male- R -2.27 L-2.26<br>Female-R -2 L-2.08 | - | |
| Saralaya VV et al | 2012 | Indian | 2.19 | 1.12 | 1.02 |
| Ozer MA et al | 2011 | Turkish | R -2.39 L-2.4 | R -1.19 L-1.07 | - |
| Le TV et al | 2011 | American | 2.23 | 1.11 | 0.99 |
| Hong JT et al | 2011 | Korean | 2.29 | 1.41 | Anterior-1.45<br>Posterior-0.81 |
| Avci E et al | 2010 | Turkish | R -2.37 L-2.4 | R -1.22 L-1.24 | - |
| Uribe JS et al | 2008 | Chinese | 2.36 | 1.05 | 0.92 |
| Zhou J et al | 2016 | American | M-2.31<br>F-2.08 | M-1.25<br>F-1.15 | M-0.96<br>F-0.90 |

R-right L-left M-Male F-Female

Table 4: shows the ICD in different population.

| Researcher | Year | Population | AICD(cm) | MICD(cm) | PICD(cm) |
|---|---|---|---|---|---|
| Previous study (Somanath D,Sudha R) | 2017 | Indian | 1.52 | 2.02 | 2.77 |
| Saluja S et al | 2016 | Indian | 1.78 | - | 3.89 |
| Lyrtzis C et al | 2016 | Greek | M-2.11<br>F-2.00 | - | M-4.33<br>F-4.12 |
| Bayat P et al | 2014 | Iranian | 1.53 | - | 3.56 |
| Kalthur SG et al | 2014 | Indian | 2.1 | - | 3.9 |
| Saralaya VV et al | 2012 | Indian | 1.87 | - | 3.87 |
| Ozer MA et al | 2011 | Turkish | 2.09 | - | 4.31 |

M-Male F-Female

Table 5: shows the sagittal angle of OC to the midline in different populations.

| Researcher | Year | Population | Sagittal angle of OC to the midline (degrees) |
|---|---|---|---|
| Previous study (Somanath D,Sudha R) | 2017 | Indian | R-30.52<br>L-29.6 |
| Saluja S et al | 2016 | Indian | R-41.1<br>L-44.04 |
| Zhou J et al | 2016 | American | M-27.34<br>F-29.05 |
| Yu Z et al | 2014 | Chinese | M-R-21.4 L-23.3<br>F-R-20.0 L-22.7 |
| Hong JT et al | 2011 | Korean | 33.5 |
| Ozer MA et al | 2011 | Turkish | R-32.9<br>L-38.2 |

R-right L-left M-Male F-Female

[Table 2] shows the posterior intercondylar distance (PICD) which was found to be a maximum of 2.77 cm amomg other ICD.[11]

**Shape of the OC**

16% were oval shaped, 10% were S-shaped, 9% were dumb-bell shaped, 8% were round- shaped, 6% were comma-shaped, 4% were triangular-shaped and 2% were kidney-shaped.

## DISCUSSION

The development of the cranial base begins by 11-12th week from the cartilaginous template.[12] There are two components involved in the development of CVJ, the first one is appearance of the central pivot made up of odontoid process, the body of axis vertebra and the basiocciput. The second component consists of two ring structures which are foramen magnum, OC, ring of the atlas vertebra encircling the pivot. The central pillar develops from the axial part of the first two cervical and occipital sclerotomes, the ring structures arise from the lateral part of those sclerotomes and hypochordal bow. This embryological process is regulated by 39 Hox genes which are located in 4 linkage clusters-Hox A,B,C,D on 6,11,15,2 chromosomes.[13]

Various surgical techniques that approach the cranial base need a thorough knowledge of anatomy particularly involving anterior foramen magnum or clivus necessitate the partial or complete removal of OC to have a roomy working space.[14] To achieve a successful surgical outcome without the involvement of vital structures, one has to understand the morphometry of OC in a given population.

The procedures that involve the screw or rod placement into the OC depend on its length and breadth in order to avoid rupture of the occipital condylar wall, hypoglossal nerve injury.[15,16] [Table 3]. Despite this, the length and thickness of the OC have to be considered during partial condylectomy or else it would result in occipitocervical instability.[14,17,18] In our previous study, the mean length of right and left occipital condyles were 2.49 cm and 2.39 cm respectively which were comparable to other Indian population,[19,20] as well as to other races like

Greek, Turkish, Korean.[21,22,14,23] However in other studies in Indian population by Kalthur et al and Saralaya et al,[24,25] the length of the OC was much lesser than our findings. OC length is lesser than our findings in Chinese population,[26,15] Iranian population,[27] but in the same Iranian population, Uribe et al showed similar findings as our previous study.[28] Le TV et al documented the measurements which were found to be slightly lesser in American population than ours while the length of OC was more in Egyptian population.[29,30]

Mazur et al in a cadaveric study identified that one-third of OC resection (29%) causes limited movements at the atlanto-occipital joint, neck stiffness and occipitocervical instability.[17] Bruneu et al expressed that less than 20% of OC resection would not lead the case to undergo CVJ fixation.[7] However some authors believe in resection of one third or one half of the OC would not result in instability of CVJ but few say that one fifth of OC resection must be performed.[9] Based on the above observations we can conclude that the preferable extent of partial condylectomy in Indian population is less than one-third of the condyle. Since the length of OC is shorter in Chinese population, removal of one third of OC would lead to occipitocervical instability. In Egyptians, even the partial condylectomy would not disturb the CVJ. Tong et al insisted in his study that to achieve occipito-cervical stability, the recommended length of the screw should be 1.6 mm in Chinese population which was similar to the length of the OC.[26] Regarding the types of OC pertaining to length, we found higher percentage of short OC (15%) in our study when compared to other findings.[24] Verma et al also documented short OC of 13% which is similar to our study.[20]

Regarding the breadth of OC, the findings were R -0.81, L-0.71 which were similar to the Chinese, Iranian population.[26,27] Those findings were lesser than other country's population (Greek and Egyptian),[21,30] and to our surprise, when compared to other Indian population, the breadth was lesser which might be because of regional difference.[19,24,25] In case of fixation of screws into OC, the ideal breadth of the screw should be 10-14 mm,[26,16] however Matsushima et al recommended screw with optimum diameter of 3.5-4 mm.[8]

The thickness of OC was very less compared to other Indian population and other races.[19,20,24,25,27,28,29,26,23] Among all, Chinese population had the most thickness of OC.[26] If the breadth and thickness of OC is not taken into account, that would cause pulled-out screw or neurovascular injury.[16] Thickness of OC is a crucial parameter in the screw fixation. Zhou et al described that the height available for the screw is the height of the OC between the bottom of hypoglossal canal to its articular surface.[31] According to him the available height is almost two-third of the thickness. If this is not considered the screw entry would injure the hypoglossal nerve cranially and atlanto occipital joint caudally.

In Indian population, OCs converge more ventrally than dorsally.[19] In this study, AICD was 1.52 cm which was lesser than the other Indian studies,[19,24,25] [Table 4] as well as other races.[27,22,21] Intradural lesions like meningioma at the anterior rim of foramen magnum creates difficulty in surgeries by not allowing enough working space for surgeons.[32] This necessitates the removal of OC when transcondylar or posterolateral approaches are used, even though some surgeons are in controversy.[4,32] AICD was very less in this population which may urge the surgeon to remove the condyle which might result in occipito-cervical instability.

Ozer et al commented that wider the distance between the opisthion and posterior tip of OC, easier the posterolateral approach.[22] If more the distance between the basion and anterior tip of OC, greater the difficulty in surgical approaches.[8] PICD in our case was 2.77 cm which was lesser than the other findings.[19,24,25,27,22,21] If PICD is less, that would impose hindrance to the access of cranial base. In this study, we found the PICD to be very less, thus making posterolateral approach difficult.

As the OCs are directed anteromedially, there are possibilities for the OC to have different anterior and posterior sagittal angles.[22] The sagittal angle was found to be 30.52, 29.6 degrees on the right and left side respectively which were less than the other studies and more than the findings reported by Yu Z et al [Table 5] in Chinese population. The maximum benefit of the screw fixation into the OC depends on the optimum angulation which should be greater than 20 degrees from sagittal midline.[15] According to Zhou et al, the angulation of the screw can be kept as much as parallel to the sagittal angle of the OC in order to achieve the longest screw length.[31] However, Tong et al placed the screw with an angulation of 10 to 15 degrees to the sagittal plane by making an entry point at the centre of the posterior surface of cranio-cervical complex.[26] Similarly, Uribe et al considered the placement of screw with a mean sagittal angle of 17 degrees (12-22 degree).[28] From our study we can infer that screw fixation in this population would be easier to bring about the best result. Presence of wider sagittal condylar angle would give easy access to the foramen magnum.[22] Since this angulation is less in our study, it might complicate the posterolateral approach.

The location and orientation of the OC along the lateral margin of foramen magnum resulted in minimal AICD and PICD in South Indian population. Hence the angulation of OC to the coronal plane on the right and left sides were 57.64, 55.33 degrees respectively which were statistically significant. These findings could not be compared with other studies as they were not available. We hypothesise that if this angulation increases, then it would allow a narrow pathway to

approach the cranial cavity with posterolateral technique.

Several studies have been reported previously regarding the shape of the OC. Few Indian authors have reported the commonest shape to be oval Similarly our study also observed the above finding.[20,24] Triangular, comma-shaped OC need an elaborate drilling. Moreover the oval shaped type is suitable for screw or rod fixation and partial condylectomy, provided the length of OC is optimum.

There are many factors that can result in unusual size of OC. Disturbance in the signalling pathway during the development of ring structures would result in dysplasia of OC, lateral masses of C1 with its ring and C2 vertebra. Hyperplasia of lateral sclerotome of proatlas may cause enlarged OC. Unilateral or bilateral massive OC leads to cervicomedullary compression followed by deterioration of neurological activity. In such circumstances, condylectomy becomes necessary.[13] Hence, such congenital anomaly of OC beckon the surgeons to understand the morphometric values of OC in a particular population to differentiate the dysplasia and hyperplasia from normal.

## CONCLUSION

In this study, over all, most of the morphometric values of OC were lesser than the other populations. Such data of OC would really help the surgeons during planning and execution of cranial base surgeries or occipito cervical fixation,even though computed tomography and magnetic resonance imaging do the needful regarding the bony values in case of South Indian population.

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***Abbreviations***

OC-Occiptal Condyle
CVJ- CranioVertebral Junction
AICD- Anterior Intercondylar Distance
MICD- Middle Intercondylar Distance
PICD- Posterior Intercondylar Distance

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