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Morphometric Analysis of Occipital Condyles Using Multi- Detector Computed Tomography

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ABSTRACT

Aim The purpose of this work was to assess the morphometric analysis of occipital condyles (OCs) using multi-detector computed tomography (MDCT), as these anatomical structures are essential to the cranial base.

Methods The study population comprised 200 OCs from 100 patients, 64 of whom were male and 36 of whom were female, and whose ages ranged from 18 to 70 years. OCs were measured linearly.

Result The average OC width, length, height, and effective height were 10.98±1.47 mm, 15.55±1.86 mm, 9.97±2.28 mm & 6.69±1.16. All measurements were found significantly different between right and left sides Also the average intercondylar anterior distance (ICAD) & inter-condylar posterior distance (ICPD) were 16.04±2.90 & 31.78±3.17 respectively. The morphometric measurements varied significantly between age groups. There was a substantial gender difference in all morphometric parameters.

Conclusion MDCT can be used to assess OCs' morphometric evaluation in an efficient manner. The OCs' linear measurement data from this study could serve as a reference database for morphometric and surgical research in the future.

Keywords: *Occipital condyles, Craniovertebral junction, Forensic anthropology, Condylar measurements, Multi-Detector Computed Tomography (MDCT)*

1. INTRODUCTION

The skull is the skeletal structure of the head. The many bones that make up the cranium are joined together. The mandible, often known as the jaw, is a separate bone known as the lower jaw. However, the terms cranium and skull are often used interchangeably anyway. Protecting the brain, the most important organ in the body, is its main responsibility.(1) All of the face structures are supported by the skull as well. The two main parts of the skull are:

A. Calvaria: The upper part of the skull that surrounds the brain; also called the neurocranium or brain box. It was made up of an upper skull cap/vault and a base (bottom section). The neurocranium encloses the brain nearly completely.

B. Viscerocranium: The mandible and facial bones comprise the rest of the skull.(1)

The following are the names of the 28 bones that comprise the skull.

The calvaria, or brain case, consists of three pairs of ear ossicles and 14 other bones. The facial skeleton is composed of 14 bones. Each of the skull's numerous parts serves a specific purpose. It is the skull that shields the brain. (2) The muscles that move the eyes are shielded by bone sockets. The fragile inner ear structures are shielded by temporal bone. Some face and skull bones have sinuses that provide the voice resonance. Alveolar ridges for teeth are provided by the maxilla and mandible. Chewing is made possible by the lower facial muscles controlling the mandible. A portion of the cranial occipital bone is made up of the occipital condyles. These are protrusions from the bottom of the occipital bone that resemble kidneys.(3) The oval-shaped occipital condyles are located on either side of the foramen magnum's anterior region. On their long axis, they face forward and medially.(4) Together, they engage with the superior articular facets of the atlas vertebra (first cervical

vertebrae) to form the atlantooccipital joints. The atlanto-occipital joint capsules adhere to the outside of the condyle. These capsules help to stabilise the joint. Each condyle has a rough bump or indentation on the medial side where the alar ligament connects. The anterior regions of these invade the basilar region of the bone, whereas the posterior sections attack the same area.(1,2)

Back to the foramen magnum's middle level are the condyles' posterior extremities. The condyles' articular surfaces slope downward and laterally. Near each condyle's base is a short, tunnel-like channel called the hypoglossal canal.(5) The anterior condylar or hypoglossal canal, which is laterally and somewhat forward orientated, punctures the anterosuperior bone. The condylar or posterior condylar canal may occasionally be found beneath the condylar fossa, which is located behind the occipital condyle. The opening is superior to the sigmoid sulcus.(6) The posterior boundary of the jugular foramen is formed by the jugular process of the occipital bone, which is lateral to the occipital condyle. The atlantooccipital joint, a paired, symmetrical articulation between the base of the skull and the cervical spine, is part of the group of craniovertebral joints, which also includes the atlantoaxial joint.(7) The atlantooccipital joint's primary movement is flexion-extension, which enables head nodding. These two ellipsoids (condyloid) joints work in tandem and are mechanically equivalent to a single joint. The synovial articulation connecting the occipital bone, the atlas, and the first cervical vertebra is known as the atlantooccipital joint. The occipital bone's convex surfaces engage the concave articular facets of the C1 vertebra, resulting in oval (elliptical) articular surfaces that are reciprocally concave-convex. Within the inferior articular facets of the first cervical vertebra are situated. These facets are located on the superior surface of the lateral bulk of the vertebra. They are oval in shape, concave, and have a slight medial slope.(7)

Each facet's two long axes move obliquely in the anteromedial direction until intersecting at the midline, directly in front of the atlas. The superior articular facets are located on the occipital bone's inferior surface, next to the occipital condyles. The oval shape of these two rounded extensions is defined by elongated and convex long and short axes. The occipital condyles point anteromedially, and the anterior section of the foramen magnum is located directly lateral to them.(8)

Atlantooccipital joints are surrounded by a thin, flexible articular capsule. The fibrous tissue inside this capsule is lined with a synovial membrane. It is attached to the margins of the articular facets. In both its lateral and posterior regions, the capsule thickens. By spanning the atlantooccipital joint, several ligaments help to maintain its stability. These consist of the ligamentum nuchae, alar ligament, apical ligament, lateral atlantooccipital ligament, anterior atlantooccipital membrane and ligament, posterior atlantooccipital membrane, and tectorial membrane.(8) The anterior atlantooccipital ligament is a dense band of fibrous tissue that stretches from the top border of the anterior arch of the atlas to the anterior border of the foramen magnum. It is strengthened medially by the anterior longitudinal ligament as the anterior atlantooccipital membrane, but laterally it merges with the joint capsule of the atlantooccipital joint. The posterior atlantooccipital membrane is a thin membrane that covers the posterior part of the atlantooccipital joint. It stretches from the superior posterior boundary of the foramen magnum to the inferior top border of the posterior arch of Atlas. Its lateral margins join the posteromedial joint capsule throughout its course. The proximity of the posterior atlantooccipital membrane to the C1 nerve and vertebral artery is a crucial clinical landmark.(9)

The anterior rami of spinal nerve C1 innervate the atlantooccipital joint. The deep cervical, occipital, and vertebral arteries form an anastomosis that supplies blood to the atlantooccipital joint. The atlantooccipital joint has two degrees of freedom for movement. Lateral flexion and flexion-extension are examples.(10) In the anteroposterior plane, flexion and extension movements revolve around a transverse axis. During flexion, the convex occipital condyles roll forward while sliding posteriorly across the atlas' concave facets. The range of flexion is around 5°-10°. In extension, the opposite motion occurs. The occipital condyles glide anteriorly on the atlantal facets before rolling backward to close the gap between the occipital bone and the posterior arch of the atlas. Extend the range of motion by around 10°.(11) The purpose of this study was to explore morphometric characteristics in the occipital condyle of the skull using CT in the UP western population.

2. MATERIALS AND METHODS

Subjects

In this retrospective study, 100 patients' MDCT images from referrals to Teerthankar Mahaveer Hospital and Research Centre, College of Paramedical Sciences, Moradabad, Uttar Pradesh, were used. Specific cases with insufficient information, such as traumatic, degenerative, and neoplastic pathological entities, have been excluded from this analysis. This study does not involve patients less than 18 years old. A United Imaging 160 slice CT scanner was used to conduct a morphometric investigation. The patients' arms were by their sides as they lay supine on the table. The instrument's field of view measured 5x5 mm. Using the cone beam technique, the instrument was run at conventional levels of 120 kVp and 320 mA. DICOM images were transferred to a DICOM viewer program (RadiAnt DICOM viewer 4.0.2, Medixant, Poznan, Poland) following the reconstruction of the raw data. The RadiAnt DICOM viewer's measurement palette was used for linear measurements.

Measurements

The occipital condyle length (OCL), Occipital condyle width (OCW), Occipital condyle height (OCH), Occipital condyle effective height (OEH), and anterior and posterior intercondylar distances (ICAD and ICPD) were measured (12) **(Fig-1).**

The occipital condyle is measured on three planes using Multi-Detector Computed Tomography (MDCT). On the sagittal plane, OCL was determined along the longest axis. OCW is the width of a line perpendicular to the midpoint of an axial plane's long axis, measured from the medial to lateral borders. The coronal height was measured in this investigation using the technique. OCH was defined as the longest line on the coronal plane that ascends from the condylar cartilage to the hypoglossal canal. Anterior and posterior intercondylar distances were measured on axial plane. The separation between the left and right occipital condyles' anterior apexes was known as the intercondylar anterior distance (ICAD), and the separation between their posterior apexes was known as the intercondylar posterior distance (ICPD).(12)

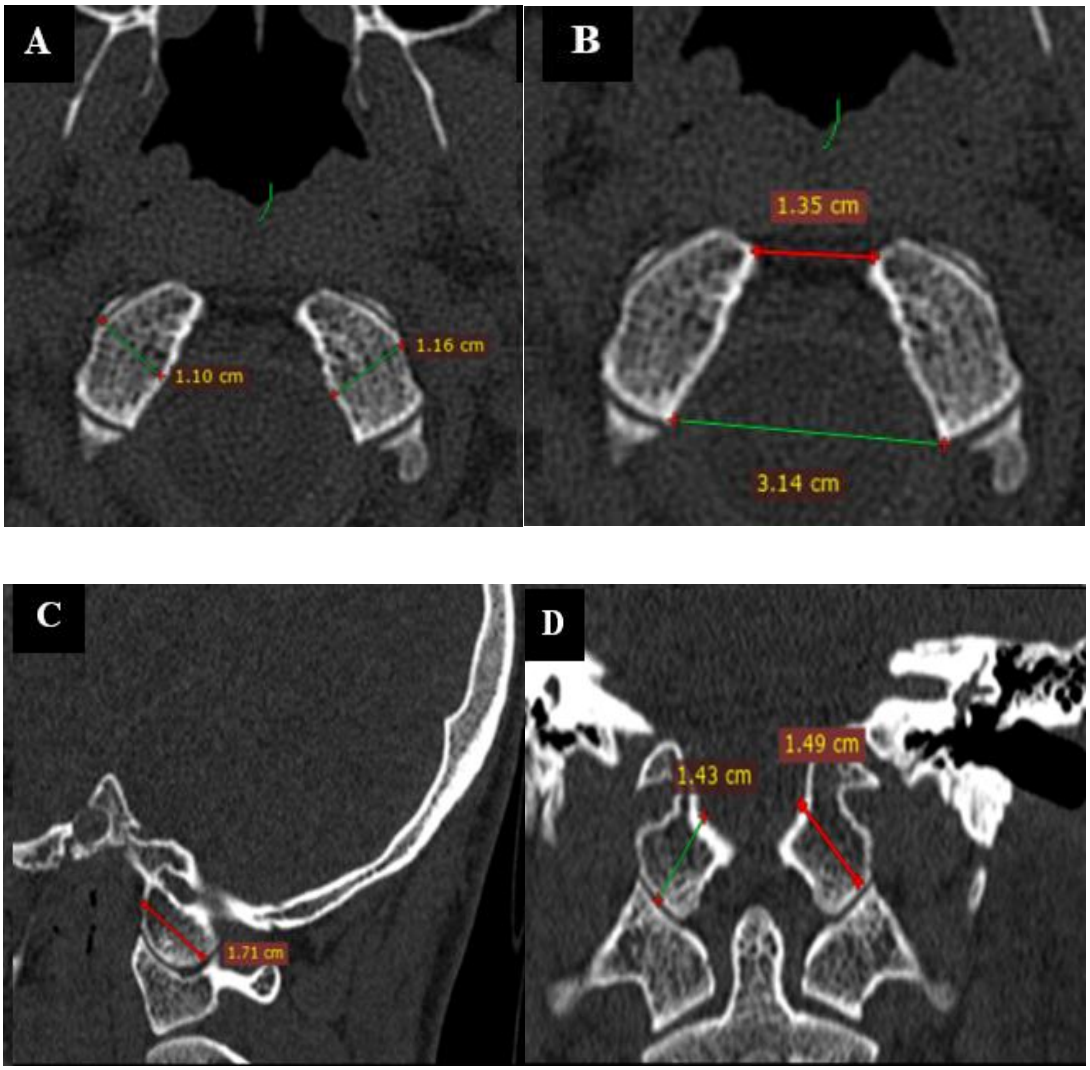

Figure 1 Occipital condyle is measured using these parameters. (A) Width of occipital condyle; (B) Anterior & Posterior Intercondylar distances; (C) Length of occipital condyle and (D) Height of occipital condyle.

Statistical analysis

The collected data were summarized by using the Descriptive Statistics: frequency, percentage; mean and S.D. The Paired "t" test was used to compare OCW, OCL, OCH, and OEH; between right and left sides. The Independent sample "t" test was used to compare the occipital condyle anatomy's characteristics according to gender. The One-way ANOVA was used to compare the occipital condyle anatomy's characteristics according to age groups. The Post hoc analysis, Tukey test was used for the multiple comparisons. The Pearson correlation coefficient: ("r") was used to find the relation between the various parameters of occipital condyle anatomy's characteristics. The p value < 0.05 was considered as significant. Data were analyzed by using the SPSS software (SPSS Inc.; Chicago, IL) version 29.0.10.

3. RESULTS

There were 200 OCs' MDCT scans and 100 patients in the research group. A total of hundred patients—64 males and 36 females—had two-hundred occipital condyles examined.

The average patient was 34.93 years old.

1. Length: The individuals under study had an occipital condyle length of (15.47 ± 2.44) mm on average. There was a significant 1 mm difference in occipital condyle between males and females (P = 0.009). The average length of the left and right occipital condyles was (15.83 ± 1.95) mm and (15.68 ± 1.99) mm, respectively.
2. Width: Male occipital condyles were wider than those of females.
3. Height: The average height was larger in males than females at both sides but average effective height is more in females this difference was statistically significant at both sides (P = 0.017 and P = 0.012)
4. Inter-condylar distance: The average distance between anterior & posterior occipital condyles was (16.04 ± 2.90) mm and (31.78 ± 3.17) mm, respectively.

Table 1 displays the morphometric parameters of OC together with their mean values and standard deviations. **Table 2** lists the morphometric parameters and demographic information of the study population categorised by age.

Table-1: Results of morphometric measurements on occipital condyles in study

		Mean	S.D.	"t"	p value
OCW (R) mm	Male	11.44	1.63	2.32	0.023*
	Female	10.69	1.37		
OCW (L) mm	Male	11.12	1.65	2.83	0.006*
	Female	10.23	1.20		
OCW (T) mm	Male	11.28	1.55	2.74	0.007*
	Female	10.46	1.16		
OCL (R) mm	Male	15.87	2.00	2.57	0.012*
	Female	14.84	1.77		
OCL (L) mm	Male	15.90	1.95	2.38	0.019*
	Female	14.95	1.88		
OCL (T) mm	Male	15.91	1.86	2.65	0.009*
	Female	14.91	1.70		
OCH (R) mm	Male	10.43	2.63	2.10	0.038*
	Female	9.36	2.04		
OCH (L) mm	Male	10.33	2.46	2.45	0.016*
	Female	9.15	2.03		
OCH (T) mm	Male	10.38	2.39	2.42	0.017*
	Female	9.26	1.90		
OEH (R) mm	Male	6.47	1.13	-2.78	0.006*
	Female	7.13	1.16		
OEH (L) mm	Male	6.47	1.12	-2.34	0.021*
	Female	7.02	1.16		
OEH (T) mm	Male	6.47	1.12	-2.57	0.012*
	Female	7.08	1.14		
ICAD mm	Male	16.27	3.12	2.82	0.006*

	Female	14.50	2.82		
ICPD mm	Male	31.56	2.88	2.36	0.020*
	Female	29.95	3.86		

R right, L left, T total, SD standard deviation, OCW occipital condyle width, OCL occipital condyle length, OCH occipital condyle height, OEH occipital condyle effective height, ICAD inter-condylar anterior distance, ICPD inter-condylar posterior distance.

Table 2: Results of morphometric measurements on occipital condyles in study population stratified according to age.

	Age groups	Male		Female		"t"	p value
		Mean	S.D.	Mean	S.D.		
OCW (R) mm	18-20	11.21	1.69	10.22	1.11	0.95	0.362
	21-30	10.91	1.59	10.50	1.21	0.75	0.457
	31-40	11.59	1.58	11.84	0.83	-0.33	0.745
	41-50	11.88	1.44	9.92	1.13	3.32	0.004*
	51-60	12.76	1.37	10.76	1.39	2.17	0.067
	61-70	12.40	2.55	11.83	1.92	0.32	0.767
OCW (L) mm	18-20	10.55	1.70	9.93	0.99	0.59	0.566
	21-30	10.79	1.51	9.92	1.07	1.71	0.097
	31-40	10.85	1.69	11.06	1.16	-0.25	0.805
	41-50	11.67	1.13	9.80	1.41	3.30	0.004*
	51-60	12.66	2.05	10.74	1.25	1.64	0.146
	61-70	12.70	1.98	10.71	1.01	1.74	0.157
OCW (T) mm	18-20	10.88	1.62	10.07	1.05	0.80	0.439
	21-30	10.85	1.46	10.21	1.01	1.31	0.200
	31-40	11.22	1.56	11.45	0.97	-0.30	0.765
	41-50	11.77	1.14	9.86	1.04	3.89	0.001*
	51-60	12.71	1.69	10.75	1.30	1.91	0.098
	61-70	12.55	2.26	11.27	1.32	0.92	0.411
OCL (R) mm	18-20	16.28	3.04	14.03	2.15	1.19	0.258
	21-30	15.30	1.57	14.56	1.17	1.39	0.173
	31-40	15.89	2.01	15.86	2.34	0.03	0.979
	41-50	16.34	2.03	15.29	1.34	1.33	0.200
	51-60	16.84	1.02	14.20	1.28	3.46	0.011*
	61-70	15.20	0.99	14.53	3.37	0.26	0.805
OCL (L) mm	18-20	15.49	1.96	13.67	2.27	1.39	0.191
	21-30	15.61	1.95	14.57	1.21	1.62	0.114

	31-40	16.18	2.37	16.00	1.16	0.16	0.875
	41-50	16.42	2.03	15.32	1.60	1.32	0.204
	51-60	16.38	1.16	14.98	1.86	1.39	0.206
	61-70	16.10	1.56	14.75	4.07	0.43	0.688
OCL (T) mm	18-20	15.91	2.41	13.87	2.23	1.32	0.212
	21-30	15.47	1.60	14.58	0.95	1.70	0.099
	31-40	16.06	2.12	15.96	1.72	0.10	0.925
	41-50	16.40	1.98	15.33	1.11	1.44	0.168
	51-60	16.64	1.07	14.60	1.53	2.37	0.050*
	61-70	15.70	1.27	14.65	3.68	0.37	0.728
OCH (R) mm	18-20	10.15	2.22	7.96	1.77	1.57	0.143
	21-30	9.81	2.47	9.41	2.26	0.46	0.646
	31-40	10.58	2.88	8.74	2.31	1.25	0.231
	41-50	11.93	3.04	9.56	1.47	2.13	0.047*
	51-60	11.01	0.96	9.70	3.27	0.86	0.416
	61-70	8.79	5.11	10.28	1.31	-0.62	0.571
OCH (L) mm	18-20	9.72	1.66	7.19	0.49	2.54	0.026*
	21-30	10.02	1.92	9.17	2.38	1.13	0.267
	31-40	10.96	2.83	8.14	1.48	2.08	0.056
	41-50	10.74	4.07	9.61	1.63	0.78	0.445
	51-60	10.92	0.98	10.07	2.74	0.65	0.534
	61-70	10.06	2.04	9.85	1.84	0.13	0.903
OCH (T) mm	18-20	9.94	1.88	7.57	1.12	2.04	0.064
	21-30	9.92	2.13	9.29	2.11	0.81	0.422
	31-40	10.77	2.77	8.44	1.74	1.72	0.108
	41-50	11.34	3.25	9.59	1.48	1.49	0.154
	51-60	10.97	0.92	9.89	2.94	0.79	0.458
	61-70	9.43	3.57	10.07	1.46	-0.34	0.752
OEH (R) mm	18-20	6.32	1.33	7.36	1.69	-1.15	0.273
	21-30	6.47	1.08	7.58	0.94	-2.93	0.006*
	31-40	7.08	0.99	6.28	1.02	1.49	0.160
	41-50	5.99	0.99	7.13	1.39	-2.15	0.045*
	51-60	6.66	1.39	6.36	1.04	0.36	0.733
	61-70	6.10	0.83	7.53	0.39	-3.11	0.036*
OEH (L) mm	18-20	6.31	1.32	7.34	1.70	-1.15	0.274

	21-30	6.49	1.10	7.35	1.07	-2.14	0.040*
	31-40	7.03	0.97	6.29	1.03	1.39	0.185
	41-50	5.99	0.98	7.13	1.35	-2.19	0.042*
	51-60	6.64	1.38	6.07	0.69	0.74	0.482
	61-70	6.10	0.81	7.50	0.47	-2.83	0.047*
OEH (T) mm	18-20	6.32	1.32	7.35	1.69	-1.15	0.274
	21-30	6.49	1.09	7.47	0.95	-2.56	0.015*
	31-40	7.06	0.98	6.29	1.02	1.44	0.171
	41-50	5.99	0.98	7.13	1.37	-2.17	0.044*
	51-60	6.65	1.38	6.22	0.85	0.55	0.602
	61-70	6.10	0.82	7.52	0.43	-2.97	0.041*
ICAD mm	18-20	15.03	2.38	17.13	1.43	-1.44	0.176
	21-30	16.82	2.53	14.36	2.71	2.61	0.014*
	31-40	16.05	3.56	12.10	2.52	2.22	0.043*
	41-50	16.08	4.69	14.27	2.62	1.03	0.315
	51-60	17.78	2.46	15.38	3.73	1.17	0.282
	61-70	15.05	1.20	15.53	2.59	-0.24	0.825
ICPD mm	18-20	31.57	2.06	29.10	2.82	1.72	0.111
	21-30	31.74	2.65	29.12	3.24	2.54	0.016*
	31-40	30.86	3.33	27.84	3.20	1.70	0.111
	41-50	31.57	3.63	30.62	4.39	0.53	0.602
	51-60	31.48	3.97	34.55	3.86	-1.17	0.281
	61-70	33.30	0.99	29.43	3.64	1.40	0.233

R right, L left, T total, SD standard deviation, OCW occipital condyle width, OCL occipital condyle length, OCH occipital condyle height, OEH occipital condyle effective height, ICAD inter-condylar anterior distance, ICPD inter-condylar posterior distance.

4. DISCUSSION

Conventional CT and prospective investigations were typically used for the morphometric assessment of OC. Examining the cerebral structures with CT has been feasible since the development of computerised tomography. OCs are articular surfaces of the occipital bone on either side of the foramen magnum, created by the anterior portion of the atlas in human embryos. The superior articular surfaces of the atlas and the facets on the inferior surfaces of OCs work together in articulation. The OCs are a cranial component of the occipitoatlantal joint and the lowest portions of the skull. OC morphometry was investigated in a number of earlier radiological studies (Ismail Gumussoy, Suayip B. Duman. Sneha Guruprasad Kalthur et al. Serdar babacan et al. Isaac Cheruiyot et al.)

Ismail Gumussoy, Suayip B. Duman (12) assessed the height, width, length, and effective height of the occiptal condyle and computed the anterior and posterior intercondylar distances. The mean occipital condyle dimensions: length, width, height & effective height were 19.6±2.0 mm, 10.3±1.3 mm, 9.1±1.4 mm and 7.4±1.7 mm respectively. Anterior and posterior intercondylar distances were 20.9±1.5 mm and 44.0±2.0 mm. No significant difference between the right and left sides was observed in the ICAD and ICPD measurements. OCL, EH, OCW, ICAD, and ICPD were significantly greater in males than in females ($p<0.05$). Age-group differences in the morphometric measures OCL, OCW, EH, ICAD, and ICPD were not statistically significant. **Sneha Guruprasad Kalthur et al.**(13) determined that the OC's average length, width, and height

were 22±2 mm, 11±2 mm, and 9±1 mm. The distances between the anterior and posterior intercondylar surfaces were 21±3 mm & 39±03 mm, respectively. **Serdar babacan et al**.(14) The average length, width, and height of the OC were found to be 22.91±3.16 mm, 10.85±1.25 mm, and 9.1±1.6 mm, respectively. There were 18.42±5.39 and 37.93±7.44 mm between the anterior and posterior intercondylar surfaces, respectively.

Isaac Cheruiyot et al.(15) It was determined that the OC's average height, width, and length were 8.65±1.08 mm, 12.23±1.28 mm, and 20.59±2.05 mm. As for the anterior and posterior intercondylar surfaces, they were 19.66±2.70 and 38.52±3.09 mm apart, respectively. Current study findings indicate that the L, H, W & EH in the occipital condyle of adults are 15.41 ±1.78 mm, 9.82±2.14 mm, 16.87±1.35 mm & 6.77±1.13 mm. In contrast, the anterior and posterior intercondylar surfaces were separated by 15.38±2.97 mm & 30.75±3.37 mm.

Table 3: Comparison of OC measurements of current study with other studies

AUTHOR	OCL	OCW	OCH	OEH	ICAD	ICPD
Ismail Gumussoy, Suayip B. Duman(12)	19.6±2.0 mm	10.3±1.3 mm	9.1±1.4 mm	7.4±1.7 mm	20.9±1.5 mm	44.0±2.0 mm
Sneha Guruprasad Kalthur et al.(13)	22±2 mm	11±2 mm	9 ±1 mm	-	21±3 mm	39±03 mm
Serdar babacan et al.(14)	22.91±3.16 mm	10.85±1.25 mm	9.1±1.6 mm	5.0±1.3 mm	18.42±5.39 mm	37.93±7.44 mm
Isaac Cheruiyot et al.(15)	20.59±2.05 mm	12.23±1.28 mm	8.65±1.08 mm	-	19.66±2.70 mm	38.52±3.09 mm
Our study	15.41 ±1.78 mm	9.82±2.14 mm	16.87±1.35 mm	6.77±1.13 mm	15.38±2.97 mm	30.75±3.37 mm

5. CONCLUSION

The occipital condyle of males and females differed by a significant 1 mm (P = 0.009). Both the left and right occipital condyles had average lengths of 15.83 ± 1.95 and 15.68 ± 1.99 mm, respectively. Compared to females, males had wider occipital condyles. The difference was statistically significant on both sides (P = 0.017 and P = 0.012). Males were taller on average than females, while females were taller on average. The anterior and posterior occipital condyles were separated by an average of 16.04 ± 2.90 mm and 31.78 ± 3.17 mm, respectively. MDCT imaging is an effective way to do morphometric study of OCs. For morphometric examination of OCs, MDCT might be a new imaging modality compared to traditional CT, skull, and cadaveric studies. Forensic medicine may benefit from the sex-related variations in the observed parameters, and the measured linear dimensions of the OCs in this study served as a reference database for additional anatomical research in UP Western populations. It is crucial to understand the precise morphometry of OCs in order to provide effective surgical techniques and protect critical structures. Thus, the study's findings might offer helpful further information to UP Western's spine doctors.

6. LIMITATION

We have addressed some limitations of this study. First of all, in this study, we have not assessed the occipital condyle according to BMI, which could also be variable for further study. The second option is to use a high sample size, which could lead to different results. Participants under the age of 18 and those beyond 70 may be included for additional research. Since there are fewer female candidates than male candidates in this study, altering this ratio could have varying effects on the outcome.

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