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# Computed Tomography-Based Occipital Condyle Morphometric Analysis in the Turkish Population: A Trajectory Analysis for Optimal Screw Selection

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## ABSTRACT

**AIM:** To provide a comprehensive analysis for accurate screw size selection and insertion angle during surgical procedures.

**MATERIAL and METHODS:** In this retrospective study, a total of 120 patients participated, resulting in the analysis of 240 occipital condyles using coronal, sagittal, and axial planes on CT scans. Statistical evaluation was performed using the Wilcoxon rank-sum test, with $p<0.05$ considered statistically significant.

**RESULTS:** The mean sagittal length and height were measured at 17.2 ± 1.7 mm and 9.1 ± 1.5 mm, respectively. The average condyle angle, a crucial factor for screw insertion, was assessed at 38.0 ± 5.5 mm in length, 19.6 ± 2.6 mm in width, and 9.5 ± 1.0 mm in height. Condyle height in the anterior and posterior hypoglossal canals was measured at 10.8 ± 1.4 mm and 9.0 ± 1.4 mm, respectively. Screw angle and condyle width were statistically smaller in females compared to the male population.

**CONCLUSION:** The OC is a significant anatomical structure in the craniovertebral junction, playing a crucial role in stability. The obtained morphological values are applicable to the Turkish population and offer statistically significant findings for preoperative planning involving occipital condyle screw instrumentation.

**KEYWORDS:** Occipital condyle, Occiput-cervical junction, Morphometric trajectory analysis, Occipital condyle screws

**ABBREVIATIONS: CT:** Computed tomography, **HGCH:** Hypoglossal canal height, **OC:** Occipital condyle, **OCA:** Occipital condyle angle, **OCH:** Occipital condyle height, **OCL:** Occipital condyle length, **OCW:** Occipital condyle width, **L:** left, **R:** right

## INTRODUCTION

Occipital condyles (OC) are the undersurface protrusions of the occipital bone that act as articulating elements with the atlas. The foramen magnum is located between both condyles (20). This articulation enables the head to flex and extend (16). The dimensions and morphology of the OC play a pivotal role in the movement of the antlanto-occipital junction movement, functioning as a complex dynamic joint. Restoring the integrity and stability of this region is crucial, as pathologies such as trauma, tumors, rheumatoid arthritis, infections, and congenital malformations can lead to occiputocervical instability (22). The OC instrumentation technique was initially described by Uribe et al. in 2008 and has become the gold standard in cases unsuitable for traditional instrumentation techniques (24). The stability of the occiputocervical junction relies heavily on the morphological parameters of the OC (24). The surgeon must analyze the OC

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structure before initiating surgery (28). Numerous cadaveric and radiological studies have investigated OC anatomy (1,9,10,13,23). This study aimed to evaluate the morphology of the Turkish population and provide statistical standardization for length, width, and angle based on age and gender. This data is expected to offer valuable insights for accurate screw selection in OC instrumentation, which remains unreported in the literature.

## MATERIAL and METHODS

This retrospective study was conducted at our clinic from January 2021 to March 2022 following the standards of the Helsinki Declaration (Memorial Bahçelievler Hospital, Date: 27.07.2022, No: 46). This study included all cervical computed tomography (CT) scans obtained at our institution during this period using 1.25 mm thin-sectioned axial, sagittal and coronal planes. Siemens Somatom Drive 256 (Siemens, Germany) was used to acquire the scans. This study excluded images displaying fractures, craniocervical anomalies, neoplastic diseases or infections. The analysis included 120 patients and 240 condyles, categorized by gender and age. We recorded the condyle length, height, width, medial angle and distance to the hypoglossal canal using the Surgimap software (Globus Medical, Methued/MA, USA). Two separate spinal surgeons conducted all assessments, and the results were concealed to mitigate bias. The initial assessment randomly selected 50 cases for re-evaluation.

### Radiological OC assessment

1. OC length (OCL): the distance between the anterior and posterior medial points on the axial planes (Figure 1A).
2. OC width (OCW): the distance between the medial and lateral borders on the axial planes (Figure 1B).
3. OC angle (OCA): the angle from the longitudinal axis to the central vertical line on the axial planes (Figure 1C).
4. OC height (OCH): A vertical line from the hypoglossal canal to the condylar cartilage is drawn and measured on coronal planes (Figure 1D).
5. Hypoglossal canal height (HGCH): the distance between the inferior border of the condyle to the hypoglossal canal base (Figure 1E).

### Criteria for choosing the most suitable trajectory

1. The posterior wall of the outer cortex of the condyle and the anterior outer cortex were measured in the axial planes to determine the screw length.
2. A line was drawn from the median part of the hypoglossal canal junction on the sagittal plane, and the atlanto-occipital condyle joints were used to determine the craniocaudal trajectory. Screw entrance points were set 2 mm away from the C0–C1 joints with a 5° craniocaudal angle.
3. The angle from the line measured the condylar length to the midline was used to set the medial trajectory.
4. The screw size was set as 3.5 for condyles with a height of > 6.5 mm and a length of 8 mm (15).
5. The occipital condyle screw insertion points were 4–5 mm laterally from the condyle and the posteriormedial border of the occipital bone (28).

### Statistical Analysis

Categorical variables were presented as percentages and continuous variables were expressed as mean ± standard deviation. Histograms and Kolmogorov–Smirnov test were used to assess the normal distribution compliance of the numerical values. Paired sample t-tests were used to compare measurements between the right and left sides. Pearson's correlation test was used to evaluate the strength of the linear relationship between variables. Student's t-test was used to compare means. We considered an overall p-value of $<0.05$ as statistically significant. The IBM Statistical Package for the Social Science Statistics (SPSS) for Windows, version 26 (IBM Corp., Armonk, N.Y., USA) was used for all statistical analyses.

## RESULTS

This study included 120 patients (57 females [47.5%] and 63 males [52.5%]). The mean age was 47.3 ± 20.5 years, ranging from 11 to 90 years. The measurements of OCL, OCW, OCA, OCH, and HGCH were 22.2 ± 2.2 mm, 10.3 ± 1.2 mm, 34.5 ± 4.2°, 9.3 ± 1.1 mm, and 9.1 ± 1.3 mm for the right side and 22.1 ± 1.9 mm, 10.2 ± 1.1 mm, 34.9 ± 4.1°, 9.4 ± 1.1 mm, and 8.9 ± 1.3 mm for the left side, respectively. No statistically significant differences were found in OC diameter between age and gender on both the right and left sides (Table I). Age correlation with any other parameters was not observed. Positive correlations were noted among combinations of ROCL, ROCW, ROCH, RHGCH, LOCL, LOCW, LOCH, and LHGCH. ROCA and LOCA demonstrated a positive connection, which did not correlate with any other parameter combination. Table II shows the association between the variables. Table 3 presents the gender-based variable comparisons. Parameters including ROCL, ROCW, ROCH, RHGCH, LOCL, LOCW, and LHGCH were statistically higher in males than in females ($p<0.001$, $p=0.006$, $p=0.007$, $p=0.009$, $p<0.001$, $p=0.025$, and $p=0.012$, respectively). LOCH variables were higher in males although not statistically significant ($p=0.063$).

## DISCUSSION

The OC plays a pivotal role in the craniovertebral junction, which is located between the occipital bone and the atlas, and ensures craniovertebral junction stability (7). However, stabilizing the complex OC is difficult because of its proximity to vital structures. The OC is positioned anterolaterally to the foramen magnum. The lateral atlanto-occipital ligament and lateral rectus capitis muscle separate it from the jugular foramen, which houses the internal jugular vein and cranial nerves IX, X, and XI (17). OC stabilization uses two primary techniques. The La Marca technique involves setting the condylar entry point 3 mm below the condylar emissary vein foramen, using a trajectory of 30° caudally and 10° medially (13). Conversely, the Uribe technique, establishes the entry point 5 mm lateral to the posteromedial corner of the OC's

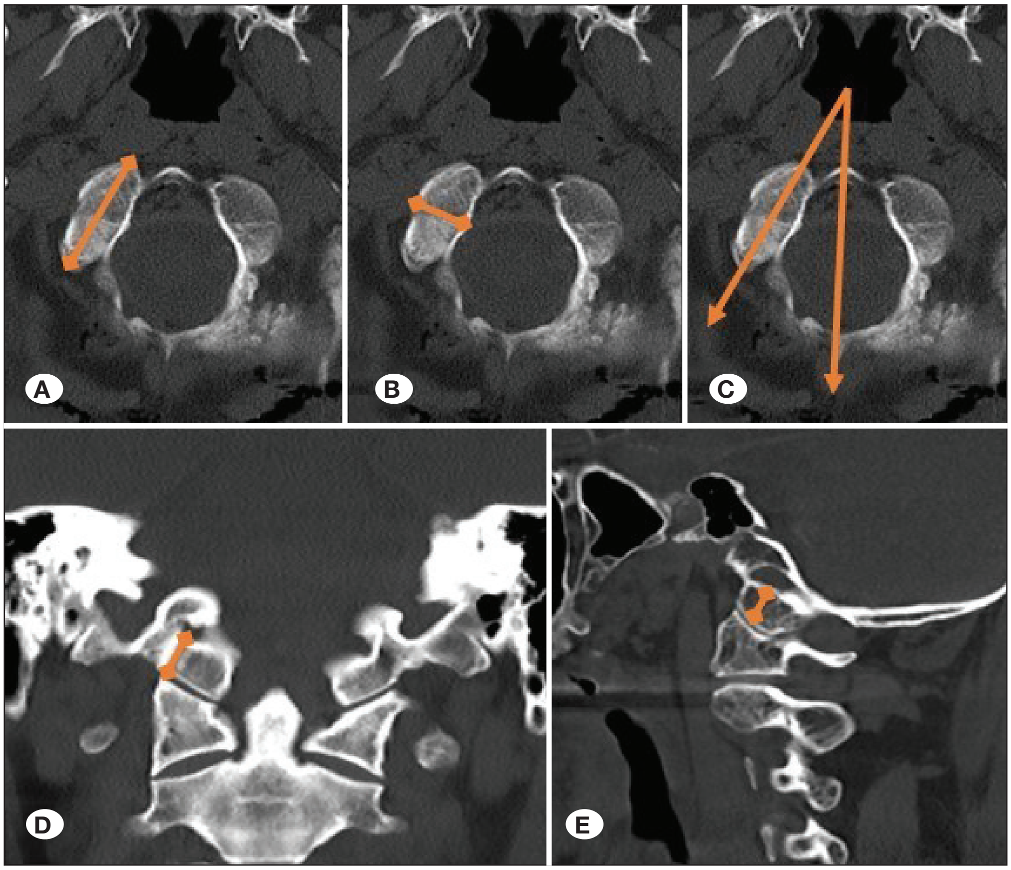

**Figure 1:** CT-based morphological characteristics of the OC. **A)** occipial condyle length (OCL), **B)** occipital condyle width (OCW), **C)** Occipital condyle angle (OCA), **D)** Occipital condyle heigh (OCH), **E)** Hypoglossal canal height (HGCH).

**Table I:** Statistical Data of Right Occipital Condyle and Left Occipital Condyle

| | Mean | SD | p |
|---|---|---|---|
| ROCL | 22.2 | 2.2 | 0.201 |
| LOCL | 22.1 | 1.9 | |
| ROCW | 10.3 | 1.2 | **0.049** |
| LOCW | 10.2 | 1.1 | |
| ROCA | 34.5 | 4.2 | 0.060 |
| LOCA | 34.9 | 4.1 | |
| ROCH | 9.3 | 1.1 | 0.389 |
| LOCH | 9.4 | 1.1 | |
| RHGCH | 9.1 | 1.3 | 0.132 |
| LHGCH | 8.9 | 1.3 | |

***SD:** Standard deviation, **ROCL:** Right Occipital Condyle Length (mm), **ROCW:** Right Occipital Condyle Width (mm), **ROCA:** Right Occipital Condyle Angle (degrees), **ROCH:** Right Occipital Condyle Height (mm), **RHGCH:** Right Hypoglossal Channel Height (mm), **LOCL:** Left Occipital Condylel Length (mm), **LOCW:** Left Occipital Condyle Width (mm), **LOCA:** Left Occipital Condyle Angle (degrees), **LOCH:** Left Occipital Condyle Height (mm), **LHGCH:** Left Hypoglossal Channel Height (mm).*

posterior surface midpoint, with a trajectory of 15° medially and 5° cranially (25). Understanding the morphological structures is crucial for surgical planning in this area. Previous clinical and anatomical studies have emphasized the wide range of variations in OC diameters and phenotypic characteristics (2,4,16). Bernstein et al. conducted a study involving 500 CT scans and revealed that mean OC measurements, including length, width, height, and sagittal angle were 18.7 ± 1.7 mm, 10.5 ± 1.2 mm, 11.4 ± 1.3 mm, and 23 ± 3.5° for the right side and 18.6 ± 1.7 mm, 10.4 ± 1.1 mm, 11.3 ± 1.3 mm, and 24 ± 3.5° for the left side, respectively. Notably, the right and left OC measurements demonstrated no statistically significant difference, consistent with our findings (3). Kumar and Nagar revealed statistically higher OCL and OCW in males (12), which is similar to other publications, including ours (5,28). Gumussoy and Duman revealed no statistically significant changes between morphometric parameters and age (8). Variations in OC diameter have been observed across different ethnic groups. In particular, Saluja et al. reported an OCL of 22.75 ± 2.90 mm and OCW of 12.97 ± 1.53 mm in the Indian population (23). Zhou et al. documented OCL, OCW, and OCH as 22.2 ± 1.7 mm, 12.1 ± 1 mm, and 9.4 ± 1.5 mm in the Chinese population (28). El-Gaidi et al. recorded measurements of 24.2 ± 3.6 mm, 14.2 ± 1.9 mm, and 10.7 ± 2 mm in the Egyptian population, and Ramos-Davila et al. revealed 20.58 mm, 9.42 mm, and 9.02 mm in the Mexican population (6,21). Our study's OCL and OCH findings paralleled those of the Chinese and Indian populations, although OCW was narrower in the

**Table II:** Correlations Between the Vaiables

| | Age | ROCL | ROCW | ROCA | ROCH | RHGCH | LOCL | LOCW | LOCA | LOCH |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | 1 | | | | | | | | | |
| ROCL | -0.081 | 1 | | | | | | | | |
| ROCW | -0.063 | .362** | 1 | | | | | | | |
| ROCA | -0.012 | 0.098 | -0.013 | 1 | | | | | | |
| ROCH | -0.070 | .402** | .415** | 0.035 | 1 | | | | | |
| RHGCH | -0.039 | .356** | .321** | 0.027 | .663** | 1 | | | | |
| LOCL | -0.047 | .884** | .338** | -0.010 | .297** | .303** | 1 | | | |
| LOCW | -0.082 | .275** | .827** | -0.021 | .328** | .238** | .324** | 1 | | |
| LOCA | 0.031 | 0.127 | 0.040 | .734** | 0.052 | 0.085 | 0.081 | 0.117 | 1 | |
| LOCH | -0.072 | .324** | .360** | 0.000 | .905** | .716** | .249** | .333** | 0.033 | 1 |
| LHGCH | 0.008 | .291** | .289** | -0.023 | .639** | .944** | .248** | .232* | 0.006 | .706** |

***ROCL:** Right Occipital Condylel Length (mm), **ROCW:** Right Occipital Condyle Width (mm), **ROCA:** Right Occipital Condyle Angle (degrees), **ROCH:** Right Occipital Condyle Height (mm), **RHGCH:** Right Hypoglossal Channel Height (mm), **LOCL:** Left Occipital Condyle Length (mm), **LOCW:** Left Occipital Condyle Width (mm), **LOCA:** Left Occipital Condyle Angle (degrees), **LOCH:** Left Occipital Condyle Height (mm), **LHGCH:** Left Hypoglossal Channel Height (mm) (* p<0.05, ** p<0.01).*

**Table III:** Comparison of the Variables Between Genders

| | Woman, n=57 | | Men, n=63 | | |
|---|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** | **p** |
| Age | 48.9 | 20.7 | 45.8 | 20.4 | 0.405 |
| ROCL | 21.2 | 1.4 | 23.1 | 2.3 | **<0.001** |
| ROCW | 10.0 | 1.0 | 10.6 | 1.2 | **0.006** |
| ROCA | 34.3 | 4.2 | 34.6 | 4.1 | 0.737 |
| ROCH | 9.0 | 0.9 | 9.6 | 1.2 | **0.007** |
| RHGCH | 8.7 | 1.2 | 9.4 | 1.4 | **0.009** |
| LOCL | 21.3 | 1.3 | 22.9 | 2.1 | **<0.001** |
| LOCW | 9.9 | 0.9 | 10.4 | 1.2 | **0.025** |
| LOCA | 35.3 | 3.9 | 34.7 | 4.2 | 0.448 |
| LOCH | 9.1 | 1.0 | 9.5 | 1.2 | 0.063 |
| LHGCH | 8.7 | 1.2 | 9.3 | 1.4 | **0.012** |

***ROCL:** Right Occipital Condyle Length (mm), **ROCW:** Right Occipital Condyle Width (mm), **ROCA:** Right Occipital Condyle Angle (degrees), **ROCH:** Right Occipital Condyle Height (mm), **RHGCH:** Right Hypoglossal Channel Height (mm), **LOCL:** Left Occipital Condyle Length (mm), **LOCW:** Left Occipital Condyle Width (mm), **LOCA:** Left Occipital Condyle Angle (degrees), **LOCH:** Left Occipital Condyle Height (mm), **LHGCH:** Left Hypoglossal Channel Height (mm).*

Turkish population. Additionally, OC parameters in the Turkish population were lower than those in Egypt but higher than those in Mexico. In previous studies, Özer et al. assessed OC morphological in 144 cadavers, and reported measurements of OCL, OCW, and sagittal angles as 23.9 ± 3.4 mm (right), 24 ± 3.3 mm (left), 11.9 ± 2.3 mm (right), 10.7 ± 2.3 mm (left), 32.9 ± 7.6° (right), and 38.2 ± 7.3° (left) (19). Naderi et al. and Kızılkanat et al. also conducted OC morphology studies on cadavers (18,11). In contrast, our study used CT findings to assess parameters, with distinct age groups and gender specifications separated. Notably, our OCL and OCW findings were lower than those of other Turkish studies. Based on our findings, we propose that the Uribe technique is the most suitable approach for the Turkish population. Setting the entrance point 5 mm lateral to the foramen magnum on axial planes and 2 mm rostrally from the antlanto-axial joint, with a screw length of 20-24 mm, width of 3.5 mm, and a trajectory angle of 15° medially and 5° cranially, would align well with the anatomical morphology of the Turkish population (14,25,26).

Our study had limitations. All measurements were conducted within the same institution, which potentially affects the homogeneity across the entire Turkish population. Istanbul is a diverse city that represents various immigrants from across the country, but it might not fully represent the entire population. Furthermore, this study only included participants without trauma or congenital abnormalities, which potentially limits the applicability of the parameter distributions to individuals with morphological OC changes due to other pathologies. Nevertheless, we consider our findings as a valuable benchmark for future studies on OC and craniocervical junctions, which provides comprehensive insights into the morphological OC characteristics of the Turkish population.

## CONCLUSION

Our research emphasizes the significance of OC morphological parameters for the meticulous planning of craniocervical junction surgeries in the Turkish population. These variables are of paramount importance in promoting the use of OC screws as a viable alternative to traditional surgical methods that involve the atlantoaxial junction. We propose that the Uribe technique stands as the most suitable approach for stabilizing the OC in Turkish patients after evaluating the morphological structure within the Turkish population.

**AUTHORSHIP CONTRIBUTION**

Study conception and design: SS

Data collection: TA, GO

Analysis and interpretation of results: KP

Draft manuscript preparation: IA

Critical revision of the article: OY

All authors (KP, IA, GO, TA) reviewed the results and approved the final version of the manuscript.

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