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Evaluating The Morphometric-Topographic Features of the Occipital Condyle and the Clinical Significance

Condylus Occipitalis'in Morfometrik-Topografik Özelliklerinin ve Klinik Öneminin Değerlendirilmesi

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ABSTRACT

Aim: To reduce morbidity and mortality in surgical operations to be applied to the craniovertebral junction, it is important to know the anatomical structures in the skull base and the topographical relationship between these structures. Lateral suboccipital craniotomy and occipital condyle resection are among the preferred methods. Surrounding neurovascular structures may be damaged during occipital condyle resection. The aim of study was to develop regression formulas that will determine the precise location of the occipital condyle and estimate the distances to the surrounding anatomical structures, based on the skull morphometry of the person.

Material and Methods: The study was carried out on 22 condylus occipitalis (11 skulls) at Harran University, Medical Faculty Anatomy Laboratory. The determined 27 parameters were measured via the Image J program on the skulls' inferior, anterior, lateral and posterior aspect photographs. Multiple linear regression analysis was performed.

Results: To determine the morphometric and topographic features of the occipital condyle, the equations have been developed such as; The occipital condyle length= -2.142 + (0.330 x P15) – (0.468 x P19) – (0.748 x P20) + (0.807 x P21); Adjusted R2= 0.911, Standard Error of the Estimation= 0.938.

Conclusion: Considering the difference between the minimum and the maximum values observed in descriptive statistics, the distribution between these values, the different findings in the studies in the literature, there may be erroneous applications in the attempts to be made over the mean values. We believe that the formulas we have developed will be beneficial in personal-specific approaches.

Keywords: Occipital condyle, Skull base, Lateral suboccipital craniotomy

ÖZ

Amaç: Kraniyovertebral bileşkede uygulanacak cerrahi operasyonlarda morbidite ve mortaliteyi azaltmak için kafa tabanında yer alan anatomik yapıların ve bu yapılar arasındaki topografik ilişkinin bilinmesi önemlidir. Lateral suboksipital kraniotomi ve condylus occipitalis rezeksiyonu tercih edilen yöntemler arasındadır. Condylus occipitalis rezeksiyonu sırasında etrafında yer alan nörovasküler yapılar hasar görebilir. Çalışmanın amacı, kişinin kafa iskeleti morfometrisinden yola çıkarak, condylus occipitalis'in tam olarak yerini belirleyecek ve etrafındaki anatomik yapılara olan uzaklıkları tahmin edecek regresyon formüllerini geliştirmektir.

Gereç ve Yöntemler: Çalışma Harran Üniversitesi Tıp Fakültesi Anatomi Laboratuvarında bulunan 22 condylus occipitalis (11 kafatası) üzerinde gerçekleştirildi. Belirlenen 27 parametre kafataslarının alt, ön, yan ve arka fotoğrafları üzerinde Image J programı ile ölçüldü. Çoklu doğrusal regresyon analizi yapıldı.

Bulgular: Condylus occipitalis'in morfometrik ve topografik özelliklerini belirlemek için; Condylus occipitalis uzunluğu= -2,142 + (0,330 x P15) – (0,468 x P19) – (0,748 x P20) + (0,807 x P21) Düzeltilmiş R2= 0,911; Tahminin Standart Hatası= 0,938 şeklinde formüller geliştirilmiştir.

Sonuç: Tanımlayıcı istatistik bulgularında gözlenen en küçük en büyük değer arasındaki fark ve bu değerler arasındaki dağılım ile literatürde yer alan çalışmalardaki farklı bulgular dikkate alındığında ortalama değerler üzerinden yapılacak girişimlerde hatalı uygulamalar olabilir. Geliştirmiş olduğumuz formüllerin kişiye özgü yaklaşımlarda fayda sağlayacağı kanaatindeyiz.

Anahtar Sözcükler: Condylus occipitalis, Kafa tabanı, Lateral suboksipital kraniotomi

INTRODUCTION

The occipital condyle is the condylar protrusions located in the lower part of the occipital bone, on both sides of the foramen magnum, near important anatomical structures such as the jugular foramen laterally, the condylar canal posteriorly, and the hypoglossal canal on the anterolateral side (1,2). The occipital condyle is located on the vertebral column, providing wide movement to the skull. Thus, it forms the craniovertebral joint, which is the joint that connects the skull to the vertebral column (2,3). The occipital condyle is closely associated with the vertebral artery, cerebellar artery, jugular vein, caudal aspect of the medulla oblongata, rostral aspect of the spinal cord, the lower part of the vermis, cerebellar tonsils, C1, C2 spinal nerves, cranial nerves (CN) such as the glossopharyngeal nerve (CN IX.), the vagus nerve (CN X), the accessory nerve (CN XI) and the hypoglossal nerve (CN XII) (4-8).

The craniocervical malformations, some rheumatoid diseases, extradural tumours, intradural tumors, and vertebral artery lesions can be seen in the craniovertebral junction region. The complex anatomical structure of the region makes the surgery of such lesions difficult. It is very important to know the anatomy of the region very well in terms of reducing morbidity and mortality in craniovertebral surgery (2,8,9). To reach lesions in this region, the lateral suboccipital craniotomy, the supracondylar, the paracondylar, and the transcondylar approaches are usually preferred. An occipital condyle resection can be required for better visualization of the region (1,2,4,10). In addition, traumas, rheumatoid arthritis, various infections, congenital malformations, tumors and some degenerative conditions that may occur in the craniovertebral region may cause occipitocervical instability (11). For many years, spine surgeons have refused to use them as suitable structures for screw placement due to the complex anatomical structures with which the occipital condyles are closely related (12).

One of the most important stages of surgical operations is planning the surgical method to be applied. For planning, the location of the lesion to be surgically applied and its relationship with neighboring anatomical structures should be determined very well.

While expressing the relationship between anatomical structures the distances between them are mostly given as mean and standard deviation in the literature. These mean values may give erroneous results in terms of treatment. We believe that calculating the distances between anatomical structures according to the morphometric characteristics of the individual's skull can reduce morbidity and mortality. Therefore, our study aims to develop regression formulas to estimate the distances between the occipital condyle and adjacent anatomical structures.

MATERIAL and METHODS

Ethics Committee approval was obtained for the study from the Harran University Clinical Research Ethics Committee (HRU122/15/22). The study was carried out on 22 occipital condyles (11 skulls of unknown age and gender) preserved in Harran University Medical Faculty Anatomy Laboratory. Broken skulls and skulls belonging to non-adult individuals were not included in the study. Photographs of the skulls taken from the inferior, front, and lateral aspects were transferred to digital media. The following parameters were measured on the photographs that were transferred to digital media with the Image J (Ver. 1.51 23 April 2018) measurement software (13). Fourteen parameters including the morphometric features of the occipital condyle and the distances between adjacent anatomical structures and eleven parameters for the general morphometric features of the skull were measured bilaterally on the skuls. All measurements were made by the same researcher. Measurement results were evaluated in millimeters (mm).

As a result of the power analysis, when the effect size was chosen as the significance level with 0.5 (α=0.05) and 0.80% power to examine the relationship between dependent variables and independent variables with the regression model, the sample size was determined as approximately 20 (n=20) occipital condyles. Multiple linear regression models were built with variables empirically and/or theoretically associated with the dependent variable. We performed statistical analyzes of the obtained data using IBM SPSS ver. 20.0 (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.)

The parameters measured on photographs taken from the inferior aspect (P1-P14) were given in Table 1 and Figure 1. The parameters measured on photographs taken from the front aspect (P15-P22) were given in Table 2 and Figure 2,3. The parameters measured on photographs taken from the lateral aspect (P23-P25) were given in Table 3 and Figure 4.

RESULTS

We evaluated the findings in 3 categories. In the first two categories, we considered the findings of descriptive statistics as a minimum, maximum, mean and standard deviation values. In the first category, we discussed the descriptive

Table 1: Parameters measured on photographs taken from the inferior aspect

Parameters	The descriptions of the parameters
P1	The occipital condyle length
P2	The occipital condyle width
P3	Distance between anterior ends of the occipital condyle
P4	The most protruding interregional distance between the medial edges of the occipital condyle
P5	Distance between posterior ends of the occipital condyle
P6	Distance between the occipital condyle and the basion
P7	Distance between the occipital condyle and the opisthion
P8	Distance between the occipital condyle and the carotid canal
P9	Distance between the occipital condyle and the jugular foramen
P10	Distance between the occipital condyle and the posterior root of the zygomatic arch root
P11	Distance between the occipital condyle and the outer edge of the mandibular fossa
P12	Distance between the occipital condyle and external auditory meatus
P13	Distance between the occipital condyle and the tip of the mastoid process
P14	Distance between the occipital condyle and posterior edge of the mastoid process

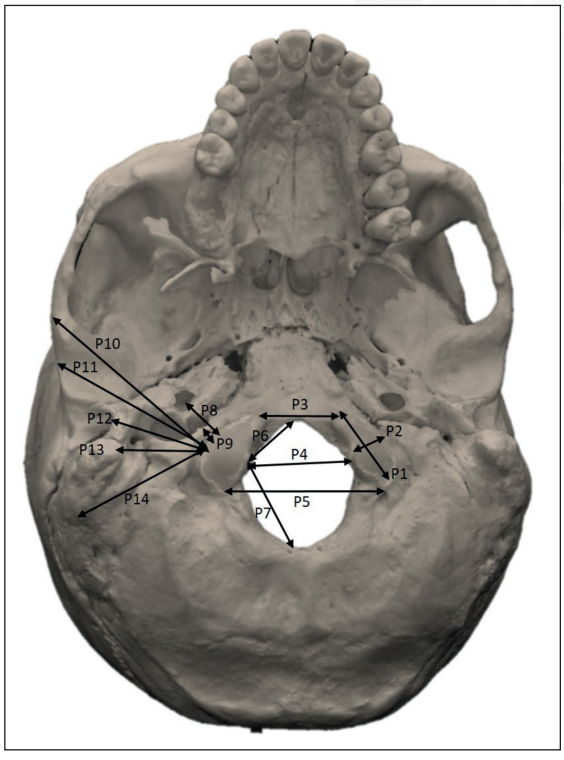

Figure 1: The parameters measured on the inferior aspect of the skull.

Table 2: Parameters measured on photographs taken from the front aspect

Parameters	The descriptions of the parameters
P15	Maximum width of the skull
P16	Skull width (Eu-Eu)
P17	Distance between the frontozygomatic suture
P18	Orbital width
P19	Bizygomatic width
P20	Orbital height
P21	Distance between the glabella to the supradentale
P22	Distance between the lower edge of the maxilla and the lower edge of the orbit

Table 3: Parameters measured on photographs taken from the lateral aspect

Parameters	The descriptions of the parameters
P23	Head width (Op-G)
P24	Distance between the mastoid process and the ophistocranion
P25	Distance between the mastoid process and external auditory meatus

statistical findings of the morphometric structure of the occipital condyle and the distances between the occipital condyle and the surrounding anatomical structures, which it is closely related (Table 4), and in the second category, we gave the descriptive statistical findings that include the morphometric features of the skull (Table 5). In the third category, we developed regression formulas to estimate the occipital condyle morphometry appropriate to an individual's skull and the distance between the occipital condyle and the surrounding anatomical structures to which it is closely related (Table 6). The adjusted R^2 values of the regression formulas and the standard error of the estimation of the equations we have developed reveal the power of the formulas.

Table 4: Morphometric features of the occipital condyle and distances between the occipital condyle and adjacent anatomical structures (mm)

Morphometric features (mm)*	**Findings (n=22)**	
P1- The occipital condyle length	22.91±3.16	23.37 (18.06-8.90)
P2- The occipital condyle width	10.85±1.25	10.88 (8.51-13.97)
P3- Distance between anterior ends of the occipital condyle	18.42±5.39	17.45 (6.36–28.71)
P4- Distance between medial edges of the occipital condyle	25.61±4.31	26.77 (16.89-31.29)
P5- Distance between posterior ends of the occipital condyle	37.93±7.44	37.02 (26.27 - 52.82)
P6- Distance between the occipital condyle and the basion	16.8±2.74	16.40 (12.07-21.23)
P7- Distance between the occipital condyle and the opisthion	28.47±4.87	27.68 (22.05-37.06)
P8- Distance between the occipital condyle and the carotid canal	8.77±3.46	8.12 (1.92-14.97)
P9- Distance between the occipital condyle and the jugular foramen	6.21±7.37	4.67 (2.05-38.23)
P10- Distance between the occipital condyle and the zygomatic arch root	46.5±5.12	46.89 (39.01-59.52)
P11- Distance between the occipital condyle and the outer edge of the mandibular fossa	36.70±4.74	36.36 (27.61-44.46)
P12- Distance between the occipital condyle and external auditory meatus	26.23±4.04	24.48 (20.56-35.32)
P13- Distance between the occipital condyle and the tip of the mastoid process	29.87±5.98	29.44 (19.46-38.65)
P14- Distance between the occipital condyle and posterior edge of the mastoid process	38.08±8.28	37.76 (23.38-53.75)

* Descriptive statistics were given as mean±standard deviation (SD), median (minimum (Min.) and maximum (Max.)).

Figure 2: The transverse parameters measured on the inferior aspect of the skull.

Figure 3: The vertical parameters measured on the inferior aspect of the skull.

Table 5: Descriptive statistics of skull measurements

Morphometric features (mm)*	**Findings (n=22)**	
P15- Maximum width of the skull	91.11±8.99	88.12 (77.34-105.17)
P16- Skull width (Eu-Eu)	89.07±8.84	85.58 (77.10-102.79)
P17- Distance between the frontozygomatic suture	93.19±8.29	88.91 (85.16-105.92)
P18- Orbital width	33.69±3.02	32.02 (30.22-39.01)
P19- Bizagomatic width	92.36±9.25	89.54 (81.45-107.77)
P20- Orbital height	33.96±4.01	32.41 (30.08-41.14)
P21- Distance between the glabella to the supradentale	78.71±8.31	77.26 (68.08-95.27)
P22- Distance between the lower edge of the maxilla and the lower edge of the orbit	31.97±10.61	34.31 (3.52-45.28)
P23- Head width (Op-G)	138.23±16.74	138.84 (116.12-160.16)
P24- Distance between the mastoid process and the ophistocranion	67.90±18.13	63.31 (43.64-99.68)
P25- Distance between the mastoid process and external auditory meatus	83.59±7.65	85.85 (71.31-93.00)

* Descriptive statistics were given as millimeter, mean, standard deviation (SD), minimum (Min.), and maximum (Max.).

Table 6: Multiple linear regression equations for estimating the morphometric features of the occipital condyle and distances to adjacent anatomical structures

Equations	**Adjusted R^2**	**Standard Error of the Estimate**	**F**	**p**
P1= -2.142 + (0.330 x P15) – (0.468 x P19) – (0.748 x P20) + (0.807 x P21)	0.911	0.938	54.869	<0.001
P2= -1.632 – (0.160 x P16) + (0.187 x P17) + (0.598 x P18) – (0.265 x P19) + (0.174 x P21)	0.744	0.632	13.216	<0.001
P3=-170.797 – (10.908 x P15) + (14.569 x P16) – (6.380 x P17) + (11.285x P18) – (0.367 x P19) – (7.119 x P20) + (3.376 x P21) – (2.221 x P22) + (2.163 x P25)	0.802	2.398	10.455	<0.001
P4=-104.199 – (5.764 x P15) + (7.716 x P16) – (4.048 x P17) + (7.316 x P18) – (0.269 x P19) – (4.681 x P20) + (2.597 x P21) – (1.405 x P22) + (1.470 x P25)	0.921	1.208	28.368	<0.001
P5=--36.325 – (2.160 x P20) + (1.434 x P21) + (0.415 x P25)	0.888	2.49	56.546	<0.001
P6= 6.973 – (0.855 x P20) + (0.494 x P21)	0.672	1.56	22.538	<0.001
P7=-17.050 + (0.288 x P17) – (1.540 x P20) + (0.659 x P21) + (0.138 x P23)	0.804	2.15	22.603	<0.001
P8= 24.122 – (2.028 x P15) + (4.285 x P16) – (1.399 x P17) + (0.628 x P18) – (0.714 x P19) – (2.066 x P20) + (0.671 x P21) – (0.389 x P22) – (0.246 x P23) + (0.320 x P25)	0.803	1.537	9.537	<0.001
P9= -11.050 – (5.405 x P15) + (9.239 x P16) – (2.744 x P19) – (4.783 x P20) + (1.876 x P21) – (0.934 x P22) – (0.224 x P24)	0.317	6.093	2.392	0.078
P10=-226.914 – (13.542 x P15) + (12.078 x P16) – (6.429 x P17) + (20.433 x P18) + (1.581 x P20) + (2.141 x P21) – (2.410 x P22) + (0.630 x P23) + (2.297 x P25)	0.715	2.733	5.131	0.005
P11=31.796 – (5.179 x P15) + (8.461 x P16) – (2.268 x P19) – (3.886 x P20) + (1.237 x P21) – (0.744 x P22) + (0.545 x P23) – (0.545 x P24) – (0.567 x P25)	0.836	1.917	12.925	<0.001
P12=-9.971 – (1.520 x P15) + (4.321 x P16) – (0.993 x P17) – (1.584 x P19) – (1.394 x P20) + (0.943 x P21) – (0.440 x P22) – (0.424 x P23) + (0.889 x P25)	0.732	2.092	7.364	0.001
P13=-66.423 – (1.004 x P15) – (2.163 x P16) + (0.694 x P17) + (4.983 x P18) + (0.913 x P19) + (0.459 x P23)	0.801	2.666	15.111	<0.001
P14=-39.036 + (2.894 x P15) – (4.218 x P16) + (2.407 x P17) – (2.006 x P18) + (0.522 x P22) + (0.144 x P23)	0.937	2.078	53.101	<0.001

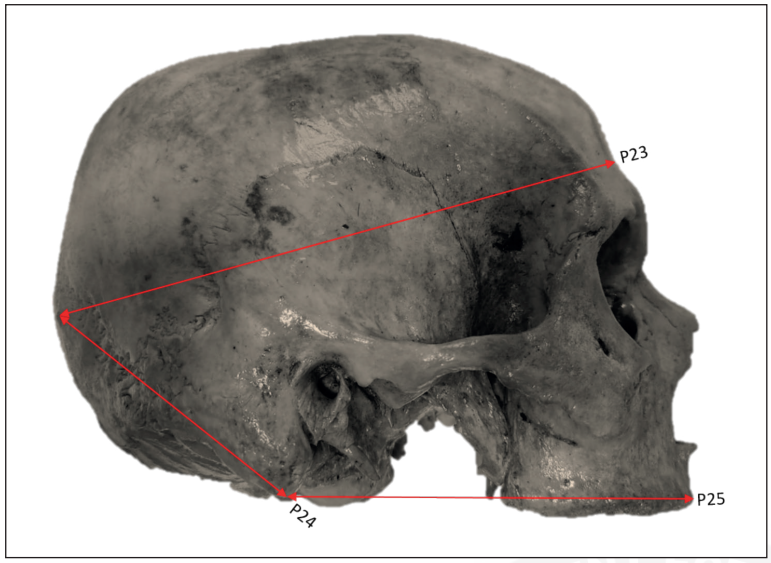

Figure 4: The parameters measured on the lateral aspect of the skull.

DISCUSSION

The anterolateral region of the foramen magnum is one of the skull base's deepest and most anatomically complex areas. The occipital condyle, surrounds the foramen magnum, and limits the surgical appearance of lesions located in the anterior region of the foramen magnum. In that case the partial resection of the occipital condyle can be necessary (4,14). Lateral suboccipital craniotomy and the occipital condyle resection are among the preferred methods because they are safe and effective methods against lesions occurring in the craniovertebral region. However, deterioration in craniocervical instability may occur after partial condylectomy (2). In the posterolateral approach, which is usually preferred in the resection of tumors located intradural in the anterior and anterolateral side of the neuraxis in the foramen magnum region, the posterior arch of the C1 and partial occipital condyle resection (1/3) is applied to widen the visual area (15,16). Therewithal in recent years, direct occipital condyle screw and occipital condyle-C1 transarticular screw techniques have been used for occipitocervical fixation for craniocervical instability (11,17,18). Consequently, a safe operation needs to be know the topographic anatomy of the region including the morphometric features of the occipital condyle and the distances between the occipital condyle and adjacent anatomical structures closely related.

Bayat et al. in their study on the Iranian population in 2014, found the total width of the occipital condyle as 9.31±1.91 mm, the posterior intercondylar distance to be 35.60±8.4 mm, and the anterior intercondylar distance to be 15.39±7.99 mm (19).

As a result of the study conducted by Kalthur et al. on the Indian population in 2014, they found the total length of the occipital condyle as 2.28±0.25 cm, the total width of the occipital condyle 1.05±0.18 cm, the posterior intercondylar distance as 3.9±0.3 cm and the anterior intercondylar distance as 2.1±0.3 cm (20).

Saluja et al. studied the skulls of the Indian population in 2016. As the result of this study, they found the occipital condyle length as 22.75±2.90 mm, the occipital condyle width to 12.97±1.53 mm, the posterior intercondylar distance to 38.9 ± 4.16 mm and the anterior intercondylar distance as 17.81±22.93 mm (21).

As a result of the study conducted by Degno et al. on Ethiopian population skulls in 2019, they determined the occipital condyle length as 25.69±3.44 mm on the right side, 26.96±3.928 mm on the left side, 12.76±1.89 mm on the right side, and 13.04 ± 2.04 mm on the left side (22).

As a result of the study conducted by Anjum et al. in India in 2021, the length of the occipital condyle was found as 22.44±2.01 mm on the right side, 22.62±2.41 mm on the left side in females, 23.5±2.71 mm on the right side, and 23.34±3.06 mm on the left side in males; the occipital condyle width was found as 11.46±1.56 mm on the right side 11.87±1.45 mm on the left side in females, 12.19±1.53 mm on the right side 12.29±1.47 mm on the left side in males; the posterior intercondylar distance was found to be 38.59±4.53 mm in females and 41.27±4.74 mm and in males; the anterior intercondylar distance measured as 18.44±2.96 mm and 17.86±2.45 respectively (23).

Bernstein et al. in 2021, studied radiological images of the occipital condyle in the USA. As a result of the study, they stated that they found the occipital condyle length as 18.6±1.7 mm and the width of the occipital condyle as 10.5±1.2 mm (24).

Zhou et al. found the occipital condyle length as 22.2±1.7 mm and the width of the occipital condyle as 12.1±1 mm in the Chinese population, in 2016 (25).

Gonzales-Colmenares et al. studied the skull radiographs of the cranial structures in the Colombian population, in 2019. They found the skull width (Eu-Eu) as 159.05±5.78 mm in males, 151.62±7.29 mm in females; the bizygomatic breadth 152.27±5.59 mm (26).

Meyvacı et al. studied the 3-dimensional computerized tomography reconstruction images of the skull belonging to the males in Turkey, in 2021. They stated that they found the skull width (Eu-Eu) as 152.87±6.80 mm and the bizygomatic breadth 139.94±5.17 mm and 141.97±7.27 mm, respectively in males and females (27).

In the current study conducted in Turkey, we found the occipital condyle length 22.91±3.15 mm, the occipital condyle width 10.85±1.25 mm, the distance between anterior ends of the occipital condyle 18.42±5.39 mm, distance between posterior ends of the occipital condyle 37.93±7.44 mm, the width of the skull 91.11±8.99 mm, orbital width 33.69±3.02 mm, the orbital height 33.96 ± 4.01 mm, and the bizygomatic width 92.36±9.25 mm.

In conclusion, when studies conducted among different populations and even studies conducted within the same populations are compared, it can be seen easily that there are morphometric variabilities not only between populations but also in individuals within the same population. If the mean values given in the literature are used for individuals in the same population, it may lead to erroneous results during surgical operations. Therefore, before the surgical operation is performed, it is necessary to know the topography of the region to be operated on, as well as to take into account individual variations. The regression formulas we have developed in terms of person-specific surgical planning will guide surgeons in terms of both occipital condyle resection and screwing to be applied to the occipital condyle region.

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Author Contributions

Data scanning, analysis, article writing: **Serdar Babacan, Rohat Bayat, Mustafa Deniz,** Data scanning: **Serdar Babacan, Rohat Bayat,** Idea, design, data and literature review, resource research, article, writing, analysis, comment: **Serdar Babacan, Rohat Bayat, Mustafa Deniz,** Data analysis: **Serdar Babacan, Rohat Bayat.**

Conflicts of Interest

There is no conflict of interest in our study.

Financial Support

There is no financial support.

Ethical Approval

Ethics Committee approval was obtained for the study from the Harran University Clinical Research Ethics Committee (HRU122/15/22).

Review Process

Extremely peer-reviewed and accepted.

REFERENCES

1. Mahajan D, Agnihotri A, Sheth A, Brar R. An anatomical perspective of human occipital condyles and foramen magnum with neurosurgical correlates. Anatomy 2013;7:29-33.
2. Verma R, Kumar S, Rai AM, Mansoor I, Mehra RD. The anatomical perspective of human occipital condyle in relation to the hypoglossal canal, condylar canal, and jugular foramen and its surgical significance. J Craniovertebr Junction Spine 2016;7(4):243-249.
3. Standring S. Head and neck: Overview and surface anatomy. In: Gleeson M, Tunstall R, editors. Gray's Anatomy. The Anatomical Basis of Clinical Practice. 40th ed. Edinburg: Churchill and Livingston; 2008.41541-6.
4. Avci E, Dagtekin A, Ozturk AH, Kara E, Ozturk NC, Uluc K, Akture E, Baskaya M.Anatomical variations of the foramen magnum, occipital condyle and jugular tubercle. Turk Neurosurg 2011;21:181-90.
5. al-Mefty O, Borba LA, Aoki N, Angtuaco E, Pait TG. The transcondylar approach to extradural nonneoplastic lesions of the craniovertebral junction. J Neurosurg 1996;84(1):1-6.
6. Seyfried DM, Rock JP. The transcondylar approach to the jugular foramen: a comparative anatomic study. Surg Neurol 1994;42(3):265-271.
7. Dowd GC, Zeiller S, Awasthi D. Far lateral transcondylar approach: dimensional anatomy. Neurosurgery 1999;45(1):95-9; discussion 99-100.
8. Ilhan P, Kayhan B, Erturk M, Sengul G. Morphological analysis of occipital condyles and foramen magnum as a guide for lateral surgical approaches. MOJ Anatomy & Physiology 2017;3(6):188-194.
9. Alpyörük Taşer F, Başoğlu H. Condylus occipitalis'lerin morfometrik değerlendirilmesi: "Cerrahi Uygulamalar için bir rehber. Ege Tıp Dergisi 2003;42(2):121-125.
10. Pereira GAM, Lopes PTC, Santos AMPV, Duarte RD, Piva L, Pozzobon A. Morphometric analysis related to the transcondylar approach in dry skulls and computed tomography. Int J Morphol 2012;30(2):399-402.
11. Bosco A, Venugopal P, Shetty AP, Shanmuganathan R, Kanna RM. Morphometric evaluation of occipital condyles: Defining optimal trajectories and safe screw lengths for occipital condyle-based occipitocervical fixation in indian population. Asian Spine J 2018;12(2):214-223.
12. De Oliveira E, Rhoton AL Jr, Peace D. Microsurgical anatomy of the region of the foramen magnum. Surg Neurol 1985;24:293-352.
13. Schneider CA, Rasband WS, Eliceiri KW. NIH Image to ImageJ: 25 years of image analysis. Nat Methods 2012;9(7):671-675.

14. Shamkuwar S, Mokhasi V. Morphometry and morphology of occipital condyle related to the transcondylar approach in dry skulls. Int J Anat Res 2018;6:5830-5834.
15. Aras Y, Kırış T. Foramen magnum meningiomları. Türk Nöroşirürji Dergisi 2011;21(2):158-161.
16. Batay F, Yakupoğlu H, Ulus A, Deda H. Foramen magnum tümörlerinde cerrahi strateji. Türk Nöroşirürji Dergisi 2005;15(1):69-75.
17. La Marca F, Zubay G, Morrison T, Karahalios D. Cadaveric study for placement of occipital condyle screws: Technique and effects on surrounding anatomic structures. J Neurosurg Spine 2008;9:347-353.
18. Gonzalez LF, Klopfenstein JD, Crawford NR, Dickman CA, Sonntag VK. Use of dual transarticular screws to fixate simultaneous occipitoatlantal and atlantoaxial dislocations. J Neurosurg Spine 2005;3:318-323.
19. Bayat P, Bagheri M, Ghanbari A, Raoofi A. Characterization of occipital condyle and comparison of its dimensions with head and foramen magnum circumferences in dry skulls of Iran. Int J Morphol 2014;32(2):444-448.
20. Kalthur SG, Padmashali S, Gupta C, Dsouza AS. Anatomic study of the occipital condyle and its surgical implications in transcondylar approach. J Craniovertebr Junction Spine 2014;5(2):71-77.
21. Saluja S, Das SS, Vasudeva N. Morphometric analysis of the occipital condyle and its surgical importance. J Clin Diagn Res 2016;10(11):AC01-AC04.
22. Degno S, Abrha M, Asmare Y, Muche A. Anatomical variation in morphometry and morphology of the foramen magnum and occipital condyle in dried adult skulls. J Craniofac Surg 2019;30(1):256-259.
23. Anjum A, Pandurangam G, Garapati S, Bandarupalli N, Rabbani H, Divya P. Morphology and morphometric study of occipital condyles. Int J Anat Res 2021;9:7905-7911.
24. Bernstein DN, Ikpeze TC, Foxx K, Omar A, Mesfin A. Anatomical parameters for occipital condyle screws: An analysis of 500 condyles using CT scans. Global Spine J 2022;12(7):1475-1480.
25. Zhou J, Espinoza Orías AA, Kang X, He J, Zhang Z, Inoue N, An HS. CT-based morphometric analysis of the occipital condyle: Focus on occipital condyle screw insertion. J Neurosurg Spine 2016;25(5):572-579.
26. González-Colmenares G, Sanabria Medina C, Rojas-Sánchez MP, León K, Malpud A. Sex estimation from skull base radiographs in a contemporary Colombian population. J Forensic Leg Med 2019;62:77-81.
27. Meyvacı SS, Hızal M, Ankaralı H. Examination of craniofacial parameters in Turkish males with golden ratio in piriform aperture size. J Surg Med 2021;5(3):289-293.