

The Frequency of Occipital Spurs in Relation to the Cephalic Index: An Anatomorphometric Cone Beam CT Study

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ABSTRACT

Background: The occipital spur (OS) can be described as an abnormal elongation of the external occipital protuberance (EOP). The cephalic index (CI) refers to the ratio of width to length in any skull. **Aim:** The aim of the present study was to evaluate the frequency and types of OS. It also aimed to determine the mean CI and the distribution of skull types using cone beam computed tomography (CBCT). And to determine if there was a relationship between the cephalic index and the presence and types of OS. **Methods:** CBCT scans from 523 patients were included in the study. OSs were classified as type 1 (flat), type 2 (crest), and type 3 (spine). Skull length and width were measured on axial sections and the CI was calculated. Based on the cephalic index (CI), skull types were classified as dolichocephalic ($CI < 75$), mesocephalic ($75 < CI < 80$), brachycephalic ($80 < CI < 85$), and hyperbrachycephalic ($CI > 85$). **Results:** The most common cranial types in the study group were brachycephalic (44.7%), mesocephalic (28.3%), hyperbrachycephalic (21.2%), and dolichocephalic (5.7%). Regarding the presence of OS, 54.3% of the participants had no OS, 23.1% had flat type, 15.3% had crest type, and 7.2% had spin type OS. There was a statistically significant difference ($P < 0.05$) in the frequency of OS according to skull type. **Conclusion:** This study, the first to evaluate CI and OS using CBCT, concludes that brachycephaly is the most common cranial type. OS is more common in mesocephalic and dolichocephalic skulls, at older ages, and in males.

KEYWORDS: Cephalic index, external occipital protuberance, occipital spur

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INTRODUCTION

The external occipital protuberance (EOP) is an anatomical prominence at the center of the outer surface of the squamosal of the occipital bone to which the nuchal ligament and trapezius muscle attach. The occipital spur (OS) can be described as an abnormal elongation of the EOP^[1] and is also known as the occipital knob, occipital bun, chignon, or inion hook, elongated or enlarged EOP.^[2] A functional adaptation due to mechanical stress can be considered.^[3,4] OS is quite common and is classified into three types: i: Type I smooth, ii: Type 2 crest, and iii: Type III spine.^[2,5]

Shahar *et al.*^[3] suggested that mechanical stress is the most important factor in the development of OS. It is hypothesized that this type of bony prominence is more likely to occur in people who perform more

vertical movements, such as basketball/volleyball and mountaineers, due to overuse and overstretching of the trapezius muscle.^[1,6]

The cephalic index (CI) is an important measure of racial and gender discrimination. It varies according to factors, such as heredity, geography, race, and sex. It refers to the ratio of width to length in each skull. An index of less than 75 means that the skull is long and narrow; this is called dolichocephalic and is typical of Aboriginal Australians and indigenous southern Africans. An index

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between 75 and 80 means that the skull is almost oval; this is called mesocephalic and is typical of Europeans and Chinese. A skull with an index above 80 is broad and short and is called brachycephalic; such skulls are common among Mongolians and Andaman Islanders.^[7]

Cone beam computed tomography (CBCT) can provide accurate images with submillimeter resolution in three-dimensional imaging of the complexity of the craniofacial hard tissues with a lower radiation dose compared to medical CT.^[8] With its isotropic cubic voxels and high resolution, CBCT allows accurate measurements in all three planes and oblique sections.^[9]

The aim of the present study was to evaluate the presence, frequency, and types of OS using CBCT. It also aimed to determine the mean CI and the distribution of cranial types. And, of course, to determine whether there was a relationship between the cephalic index and the presence and types of OS. To the best of our knowledge, there is no other study in the literature that evaluates OS and cephalic index together in CBCT scans.

MATERIALS AND METHOD

Study design

This study was conducted at the Department of Oral and Maxillofacial Radiology. The study was approved by the local ethics committee (decision date/number: 2022/88). Five researchers conducted the study and two researchers performed the radiological assessments. The principal investigator, who has 20 years of experience in maxillofacial radiology and CBCT, trained the researcher to perform the assessments and measurements. The first 20 radiographs were jointly assessed under the guidance of the principal investigator, and the researcher was calibrated. Intraobserver agreement was also tested. The study retrospectively evaluated 526 large FOV CBCT scans from 2022 at the Department of Oral and Maxillofacial Radiology. The selected scans were apparently healthy, with no visible spinal or cranial deformities. During analysis, images from three patients were excluded from the study because the desired anatomical points were not fully included in the study area. As a result, 523 CBCT scans were included in the study.

Imaging procedures

Imaging was performed using the same parameters for all scans. The cone beam images were taken with a NewTom VGi evo (Cefla, Imola, Italy, 110 kV, 15.3 mAs, slice thickness: 0.3, field of view: 240 × 190 mm) with the Frankfurt horizontal plane parallel to the ground.

Evaluation of cephalic index

The raw images were divided into 0.5-mm-thick axial slices in the secondary reconstruction process to obtain the study data. The glabella, which is the most prominent point in the midline between the superciliary arches, the opisthocranium, which is the most prominent point in the posterior part of the head on the occipital bone, and the eurions, which are the most prominent points in the lateral direction on both parietal bones, were determined from the data. Secondary reconstruction was performed so that the plane passing through these points was parallel to the horizontal plane. Skull length and breadth were then measured on axial sections. The cephalic index was calculated as follows [Figure 1]:

Skull length = maximum length between glabella and opisthocranium.

Skull breadth = maximum breadth between eurions.

Cephalic index = (skull breadth/skull length) × 100.

Based on the cephalic index (CI), skull types were classified as dolichocephalic (CI < 75), mesocephalic (75 < CI < 80), brachycephalic (80 < CI < 85), and hyperbrachycephalic (CI > 85) [Figure 2].^[10]

Evaluation of occipital spur

The presence and types of OS were assessed in a 1-mm-thick sagittal section through the center of the head. First, the presence of OS was assessed. If OS was present, its type was determined. OS were classified as type 1 (flat), type 2 (crest), and type 3 (spine) as previously reported in the literature [Figure 3].

Statistical analyses

IBM SPSS Statistics 20 package (Armonk, NY: IBM Corp.) was used for statistical analysis. The Chi-squared test was used to determine the distribution and statistical analysis of the frequency and types of OS according to sex, age group, and cephalic index. Independent samples *t* test was used to compare cranial measurements in males and females. The homogeneity of data was assessed by Levene's test. The one-way ANOVA test was used to compare cranial measurements between age groups. A *P* value < 0.05 was considered statistically significant.

G*Power analysis was used to determine the sample size. The minimum sample size for the ANOVA test, which was used to compare measurements between age groups was 252 (effect size: 0.25, power: 0.95, number of groups: 3). The minimum sample size for the independent samples *t* test used to compare measurements between genders was 105 for each group (effect size: 0.5, power: 0.95).

RESULTS

The demographic and descriptive characteristics of the study group are shown in Table 1. Accordingly, CBCT scans of 209 male and 314 female patients were included in the study. Their mean age was 24.17 ± 12.91 years (min: 6, max: 76). The distribution of age groups is also shown in Table 1. According to this, the majority of the study group consisted of people under 20 years of age. The mean cephalic index for the entire study group was 81.62 ± 4.11 . The most common cephalic types in the study group were brachycephaly (44.7%), mesocephaly (28.3%), hyperbrachycephaly (21.2%), and dolichocephaly (5.7%). Regarding the presence of OS, 54.3% of the participants had no OS, 23.1% had flat type, 15.3% had crest type, and 7.2% had spin type OS.

Table 2 shows the distribution of findings by gender. When the cephalic index measurements were analyzed according to gender, while skull width and skull length measurements were statistically higher in males ($P < 0.001$), there was no statistically significant difference in the cephalic index ratio between females and males ($P > 0.05$). There was also no statistically significant difference in the distribution of cephalic types between the genders ($P > 0.05$). There was a statistically significant difference between the sexes in the presence of OS ($P < 0.001$). In fact, OS was more common in

males and the most common type in both sexes was the flat type.

The distribution of findings by age group is shown in Table 3. It shows that cranial breadth and length increased in parallel with increase in age groups. However, while this increase was statistically significant for cranial length ($P < 0.005$), it was only numerically significant for cranial width ($P > 0.05$). There was no statistically significant difference in the distribution of cephalic index and skull type between age groups ($P > 0.05$). However, there was a significant difference in the presence of OS between age groups ($P < 0.001$). In fact, the presence of OS increased with increase in age group. The prevalence of OS was 33.7% in patients under 20 years of age, 53.4% in patients between 20 and 30 years of age, and 65.7% in patients over 30 years of age.

When we analyzed the frequency of OS according to skull type, we found a statistically significant difference ($P < 0.05$). Namely, the distribution of OS frequency according to skull type was mesocephalic (53.4%),

Table 1: Demographic and descriptive characteristics of the study group

Age	24.17±12.91 (Min: 6, max: 76)
Age group	<20: 270 (51.6%)
	21–30: 148 (28.3%)
	>30: 105 (20.1%)
Gender	Male: 209 (40%)
	Female: 314 (60%)
Cephalic index measurements	Glabella–opisthocranium: 173.36±7.92 mm
	Eurion–eurion: 141.27±5.74 mm
	Cephalic index: 81.62±4.11
Skull type	Dolichocephalic: 30 (5.7%)
	Mesocephalic: 148 (28.3%)
	Brachycephalic: 234 (44.7%)
	Hyperbrachycephalic: 111 (21.2%)
Occipital spur	None: 284 (54.3%)
	Type 1 flat type: 121 (23.1%)
	Type 2 crest type: 80 (15.3%)
	Type 3 spin type: 38 (7.2%)

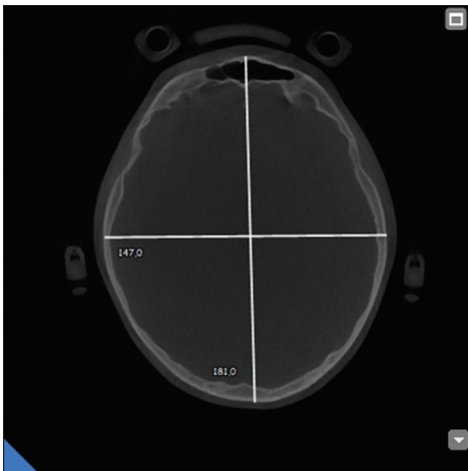


Figure 1: Measurement of skull length and breadth on axial sections

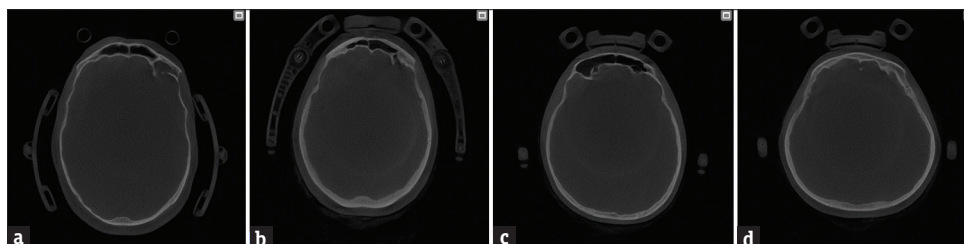


Figure 2:(a-d) Skull types. (a) Dolichocephalic (CI < 75), (b) Mesocephalic (75 < CI < 80), (c) Brachycephalic (80 < CI < 85), (d) Hyperbrachycephalic (CI > 85)

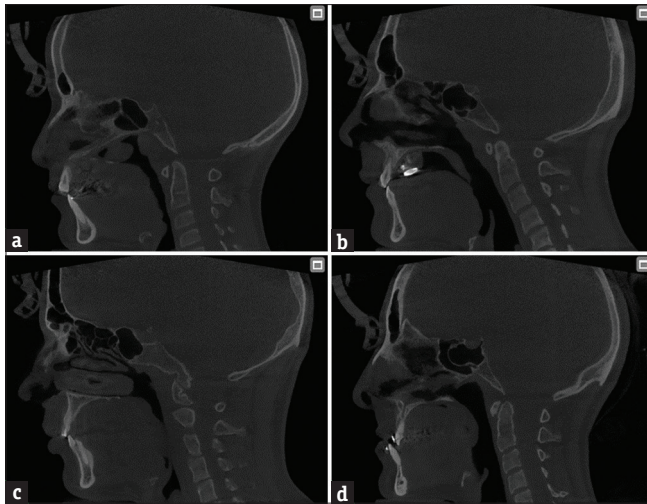


Figure 3: (a-d) Evaluation of occipital spurs. (a) None, (b) Type 1 (flat), (c) Type 2 (crest), (d) Type 3 (spine)

dolichocephalic (50%), brachycephalic (45.3%), and hyperbrachycephalic (35.1%) [Table 4]. However, when we detailed the type of OS, there was no statistically significant difference in the distribution of OS type between skull types ($P > 0.05$) [Table 5].

DISCUSSION

The craniofacial skeleton is one of the most complex and difficult parts of the human body to analyze. Many methods, such as anthropometry, stereophotogrammetry, cephalometry, ultrasound, computed tomography, and magnetic resonance imaging, can be used to assess the craniofacial structure. Head breadth and length became the key measurements in 1943 when the Swiss anatomist Anders Retzius defined the cephalic index, which describes the proportional nature of head

Table 2: Distribution of findings depending on gender

	Male (n=209)	Female (n=314)	P ^a
Age	25.93±14.82	23.0±11.34	0.011*
Cephalic index measurements			P ^a
Glabella–opisthocranium (Skull length)	177.44±7.76 mm	170.64±6.78 mm	0.000**
Eurion–eurion (Skull breadth)	143.92±5.62 mm	139.48±5.09 mm	0.000**
Cephalic index	81.25±4.06	81.85±4.13	0.099
Skull type			P ^a
Dolichocephalic	12 (5.7%)	18 (5.7%)	0.334
Mesocephalic	63 (30.1%)	85 (27.1%)	
Brachycephalic	98 (46.9%)	136 (43.3%)	
Hyperbrachycephalic	36 (17.2%)	75 (23.9%)	
Occipital spur			P ^b
None	83 (39.7%)	201 (64.0%)	0.000**
Type 1 (flat type)	63 (30.1%)	58 (18.5%)	
Type 2 (crest type)	38 (18.2%)	42 (13.4%)	
Type 3 (spin type)	25 (12.0%)	13 (4.1%)	

^aIndependent sample *t*-test, ^bChi-square test. * $P < 0.05$, ** $P < 0.001$

Table 3: Distribution of findings depending on age groups

	Age groups			P
	<20 (n=270)	21–30 (n=148)	>30 (n=105)	
Cephalic index measurements				P ^a
Glabella–opisthocranium (Skull length)	172.30±7.95 mm	173.82±8.08 mm	175.43±7.17 mm	0.002*
Eurion–eurion (Skull breadth)	140.94±5.59 mm	141.43±5.96 mm	141.90±5.82 mm	0.322
Cephalic index	81.93±4.12	81.50±4.15	80.98±3.98	0.127
Skull type				P ^b
Dolichocephalic	14 (5.2%)	10 (6.8%)	6 (5.7%)	0.590
Mesocephalic	70 (25.9%)	44 (29.7%)	34 (32.4%)	
Brachiocephalic	120 (44.4%)	66 (44.6%)	48 (45.7%)	
Hyperbrachycephalic	66 (24.4%)	28 (18.9%)	17 (16.2%)	
Occipital spur				P ^b
None	179 (66.3%)	69 (46.6%)	36 (34.3%)	0.000**
Type 1 (flat type)	44 (16.3%)	37 (25.0%)	40 (38.1%)	
Type 2 (crest type)	32 (11.9%)	29 (19.6%)	19 (18.1%)	
Type 3 (spin type)	15 (5.6%)	13 (8.8%)	10 (9.5%)	

^aOne-way ANOVA, ^bChi-square test. * $P < 0.005$, ** $P < 0.001$

Table 4: Distribution of occipital spur presence depending on the cephalic type

	Skull type				Total	P ^a
	Dolichocephalic	Mesocephalic	Brachiocephalic	Hyperbrachycephalic		
No occipital spur	15 (50%)	69 (46.6%)	128 (54.4%)	72 (64.9%)	284	0.033*
Occipital spur	15 (50%)	79 (53.4%)	106 (45.3%)	39 (35.1%)	239	
Total	30 (100%)	148 (100%)	234 (100%)	111 (100%)		

*Chi-square test, *P<0.05

Table 5: Distribution of occipital spur types depending on the cephalic type

	Skull type				P ^a
	Dolichocephalic	Mesocephalic	Brachiocephalic	Hyperbrachycephalic	
None	15 (50.0%)	69 (46.6%)	128 (54.7%)	72 (64.9%)	0.271
Type 1 (flat type)	7 (23.3%)	40 (27.0%)	53 (22.6%)	21 (18.9%)	
Type 2 (crest type)	4 (13.3%)	27 (18.2%)	35 (6.7%)	14 (15.0%)	
Type 3 (spin type)	4 (13.3%)	12 (8.1%)	18 (7.7%)	4 (3.6%)	

*Chi-square test

measurements.^[11] CI is an important parameter often used to study racial differences. It has also been reported that the CI is a marker of brain volume, which indirectly indicates cranial capacity and mental ability.^[12]

Khatun^[10] carried out cranial index screening in the Tharu community, the indigenous Nepalese community, using Hrdlicka's method, i.e. direct measurement of the head of individuals using a caliper and scale. He found the mean CI to be 75.99 and found that the most common head types in their community were dolichocephaly, mesocephaly, brachycephaly, and hyperbrachycephaly. Muralidhar *et al.*^[13] also analyzed cranial indices in 200 patients by direct measurement of the heads of patients in India and found that the most common cranial type was dolichocephaly. In this study, we found the mean CI to be 81.62 and the most common cranial type in our study group was brachycephaly. There are also studies where brachycephaly is the most common type.^[14] Of course, this situation may vary depending on the population studied. For example, dolichocephaly is the most common head type in Aboriginal Australians and indigenous southern Africans; mesocephaly is common in European and Chinese races; and brachycephaly is common in Mongolians and Andaman Islanders. Researchers who have found high rates of brachycephaly have referred to the tendency of the brain to grow more laterally, and it has been noted that changes in head size and shape can be influenced by many conditions such as climate, diet, and posture. Of course, more research is needed to pinpoint these factors.

In recent years, with the introduction of modern imaging techniques and three-dimensional images, the use of radiological imaging in anthropometric studies has increased. This allows a reduction in cost, time,

and the possibility of retrospective analysis. Computed tomography (CT) allows complete visualization of the entire craniofacial region. Reconstructions of CT slices provide a lifelike view of the face and skull for measurement.^[7] CBCT also allows the precise three-dimensional reproduction of anatomical structures.^[15]

Khanduri *et al.*^[7] performed cranial index measurements on CT scans of 1000 individuals aged 6–95 years and found a mean CI of 76.67 and reported that the most common cranial type was dolichocephaly. They emphasized that CT allows three-dimensional assessment of craniofacial structures. Koizumi *et al.*^[16] reported that brachycephaly was the most common type in Japanese children with normal brain development in their studies performed with CT. In our country, cranial anthropometric parameters were evaluated in a retrospective study conducted by Ekizoglu *et al.*^[17] on cranial CT scans of 400 patients. Like us, they used GL-Op points to measure skull length and Eu–Eu points to measure skull breadth. However, they performed measurements on 3D reconstructed images and we performed measurements on direct axial sections. Our skull breadth and skull length measurements were similar, but they did not look at the CI ratio.

In our literature search, we found only one study that evaluated head types using CBCT. Ludwigs *et al.*^[15] performed skull measurements using CBCT scans of 90 patients. However, they imported the DICOM data into software to create a virtual model of the skull and measured the 3D model. Unlike them, we measured directly on axial slices made parallel to the points of interest in the secondary reconstruction. In fact, CBCT allows real measurements in all planes, even in oblique planes, thanks to its isotropic, cubic voxels.^[9] They

showed four skull subtypes, calculated a mean shape, and identified brachiocephalic and dolichocephalic phenotypes for males and females. Their study was not designed to look at OS anyway. Therefore, there is no other study in the literature that evaluates the presence of OS with cephalic index on CBCT sections. This study will be the first to do so.

In general, the cranial measurements in the studies were larger in males. The results of our study also showed that males had larger skull sizes than females. This is of course due to sexual dimorphism. However, when the CI ratio was taken into account, there was no statistically significant difference between males and females.

It has recently been noted that the incidence of prolonged EOP or OS in young people has increased due to the increased use of electronic devices and associated postural disorders. In forensic studies, EOP has been found to be a landmark that can be used to estimate gender.^[18] Zhang and Schepartz^[18] reported that EOP was more pronounced in European males. In this study, there was also a statistically significant difference in the frequency of OS in males and females. In fact, OS or elongated EOP was more common in males and flat-type OS was the most common in both sexes.

In a study conducted in our country in 2022, Gunacar *et al.*^[5] found OS in 52% of people over 18 years of age and 47.5% of people under 18 years of age. They concluded that there was no significant difference in the frequency, type, and size of OS according to age groups and gender. In the present study, we found that the frequency of OS was 45.7%. Similarly, in the present study, the frequency of OS was found to be higher in older age groups. In another study conducted in our country, Gülekon and Turgut^[19] in their study on both skulls and radiological images in 2003 stated that the most common type of EOP in women was type 1 (flat) and in men was type 3 (spin) and the frequency of type 2 was similar in both genders. In this study, we also found that the frequency of OS was higher in men, and the most common type in both sexes was the flat type (type 1).

In the present study, the frequency of OS was higher in mesocephals and dolichocephals than in brachycephals and hyperbrachycephals. We can probably say that the increase in head length may cause more tension in the nuchal ligaments and muscles. This can lead to spur formation in the EOP region. As there is no other study in the literature where OS and SI were evaluated together, the discussion could not be extended in this direction. However, we can say that as this is the first study in this area, it may be a pioneer for future studies.

Of course, this study has some limitations. As the CBCT scans were analyzed retrospectively, data on the clinical status and lifestyle of the patients could not be obtained. In this respect, there is a need for further studies and long-term follow-up of OS. However, an advantage of this study is that it was conducted in a large group of patients.

CONCLUSION

This study has two aspects. Firstly, the cephalic index and skull types were analyzed, and secondly, the frequency and types of OS were analyzed. At the same time, the frequency of OS according to the cephalic index was also evaluated on CBCT. As a result, our conclusions are: brachycephaly is the most common cranial type in our study group, similar to other studies conducted in our population; OS is more common in mesocephalic and dolichocephalic heads, at older ages and in males. We believe that the data from our study will also be useful to anatomists, anthropologists, archaeologists, forensic scientists, neurologists, and maxillofacial surgeons.

Ethical approval

The study was approved by the Ethics Committee of the Faculty of Dentistry of Atatürk University (decision date/number: 2022/88).

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Conflicts of interest

There are no conflicts of interest.

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