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Morphologic and Morphometric Variation of Occipital Condyles in Adult Egyptian Population. Dry Bone and Radiological Study

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Abstract

Background: Successful lateral suboccipital approaches in neurosurgery depend on understanding the anatomy of the paracondylar occipital region and the detailed knowledge about the orientation of the occipital condyles in relation to the foramen magnum and hypoglossal canal. The present study was assigned to demonstrate the morphological and morphometrical variation of these occipital condyles.

Aim of Study:

The present study was assigned to:

- Study the morphologic and morphometric characteristics of the ocs by using Egyptian males and females dry human skulls.
- Clarify the morphometric data of the occipital condyles of adult Egyptian males and females in different five age groups by using multi-detected computed.

Material and Methods: The present study was carried out on 38 skulls (76 occipital condyles) in the Anatomy and Embryology Department, Faculty of Medicine, Cairo University and 150 MDCT images (300 OCs) obtained from the Radiology Department, Faculty of Medicine, Cairo University Hospital.

Results: Several variations were observed in the dry bone, the oval OCs was in 44.7% while the irregular and triangular OCs were in 1.3% of the total studied sample. The posterior condylar foramen was observed bilaterally in 55.2%, unilaterally in 26.3% and totally absent in 18.5%. The sex influence on the distances between the OCs, the hypoglossal canalexternal opening, basion and opisthion in the current work was found to be statistically non-significant. In the radiological images, there was statistically significant difference in the OCL, OCW, ACA, CCH between males and females and among the different age groups of both sexes. The width and thickness of OCs are of ultimate surgical importance to allow the neurosurgeon to know the medial limit and the maximum depth allowed for drilling in transcondylar approaches.

Conclusion: It could be concluded that the sex and age of the patient should be considered while selecting the optimal approach among the lateral suboccipital approaches in patients with certain type and size pathologies ventrolateral to the brainstem to avoid the complications of open cranial surgeries.

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Introduction

HUMAN occipital condyles (OCs) are the bony structures that link the skull with the vertebral column. The OCs partly cover the anterior fringe of foramen magnum and form articulation with the superior articular facets on the lateral masses of the atlas [1].

A condylar fossa is situated just posterior to the OC and may contain a posterior condylar canal for an emissary vein connecting the sigmoid sinus with the sub-occipital venous plexus [2].

The cranio-vertebral region is predisposed to a wide array of traumatic, degenerative, and neoplastic diseases. Frequent surgical interventions of the OCs are required for successful management of these conditions. Hence, a meticulous anatomical knowledge of the OCs is vital. However, the variability in morphometric dimensions that exists amongst different ethnics hinders the standardization of these measurements [3]. The Lateral suboccipital approach is an umbrella term under which trans-condylar, supra-condylar and para-condylar approaches are located. These approaches differ from each other in the degree of bone resection. However, they all allow better visualization of the ventral aspect of the brain stem, easier access to the intra or extradural tumors and better control of the vertebral artery in bleeding [4]. A computed tomography (CT) based morphometric analysis of OCs in an Indian population aimed to create a normative reference database to aid in safe OCs instrumentation [5].

Material and Methods

1- Material:

A- *Dry bone study:*

In the current study, thirty-eight dried adult Egyptian skulls (19 males and 19 females) were obtained from the Anatomy Department, Faculty of Medicine, Cairo University to study the morphologic and morphometric variation of the OCs in relation to sex. The adult skulls which could be correctly identified for sex were included.

B- Computed tomography scan (CT) study:

One hundred fifty archived CT head of adult Egyptian population (75 males and 75 females) were obtained from the Radiology Department, Faculty of Medicine, Cairo University from March 2020 June 2021. These CT scans were further subdivided by the age group into five subgroups; each subgroup includes thirty scans (15 males and 15 females) as follows: Subgroup I (age range from 19 to <30). Subgroup II (age range from 30 to <40). Subgroup III (age range from 40 to <50). Subgroup IV (age range from 50 to <60). Subgroup V (≥60 years old).

Inclusion criteria:

Adult Egyptian patients older than 19 years who have a CT scan of the CCJ for any cause other than an investigation of the CCJ.

Exclusion criteria:

Skeletal immaturity, trauma (fracture at the CCJ or upper cervical spine), neoplastic pathology, congenital malformation or previous surgery.

2- Methods:

A- *Dry bone study:*

I- Morphological study **[6]**:

Each OC was identified on the skull base and examined for the shape and the presence of the posterior condylar foramen.

II- Morphometrical study **[7]**. (Plate 1):

The following parameters were measured to both OCs using digital Vernier caliper with 0.01mm precision and the collected data were recorded in millimeters (mm).

1- The distance between the occipital condyle posterior tip and the median point of the anterior margin of foramen magnum (basion) OCPT-B distance (P-B).

2- The distance between the occipital condyle posterior tip and the median point of the posterior margin of foramen magnum (opisthion) OCPT-O distance (P-O).

3- Intercondylar distances: Anterior intercondylar distance (AID) and posterior intercondylar distance (PID).

B- *Radiological study* (Plate 2):

Multiplanar reconstruction (MPR) of the CT images was done by using the RadiAnt DICOM viewer software and the parameters were measured with its caliper tool. Each radiological image was evaluated for the following (4) **[16]**.

a- In axial planes:

1- The occipital condyles length (OCL) as a line along the longitudinal axis of the condyles between their anterior and posterior midpoints.

2- The occipital condyles width (OCW) was measured by a line perpendicular to the midpoint of the longitudinal axis of the OCs.

3- The axial condylar angle (ACA) (in degrees) was the angle between the longitudinal axis of the condyles and the sagittal midline.

b- In coronal planesthe coronal condylar height (CCH) was measured by a line perpendicularly from the hypoglossal canal to the inferior margin of the condyles.

Statistical methods: Data were coded and entered using the statistical package for the Social Sciences (SPSS) version 26 (IBM Corp., Armonk, NY, USA). Data was summarized using mean, standard deviation, minimum and maximum for quantitative variables and frequencies (number of cases) and relative frequencies (percentages) for categorical variables. Comparisons between groups were done using unpaired *t*-test when comparing 2 groups and analysis of variance (ANOVA) with multiple comparisons post hoc test when comparing more than 2 groups. Comparisons between right and left sides within same individuals were done using paired *t*-test **[8]**. *p*-values less than or equal to 0.05 were considered as statistically significant.

Results

A- Dry bone study:

I- *Morphological study:*

1- The shape of the occipital condyles (OCs) (Fig. 1): The shape of OCs was classified into eight types as follows: Oval, kidney-shaped, S-shaped, eight-shaped, triangular, diamond-shaped, two-pointed and irregular. The variability of OCs shape regarding the side and sex was illustrated.

2- The posterior condylar foramen: The posterior condylar foramen was observed in 31 skulls (14 males and 17 females) (81.6%) while it was completely absent in seven skulls (five males and two females) (18.4%). The posterior condylar foramen was found bilaterally in 21 skulls (10 males and 11 females) (55.2%) while unilateral right foramen was observed in seven skulls (three males and four females) (18.5%) and unilateral left foramen was observed in three skulls (one male and two females) (7.8%).

III- *Morphometrical study:*

1- The distance between the posterior tip of occipital condyle and Basion OCPT-B distance (P-B): In males, the mean of (P-B) distance was 27.43±2.1mm and 27.46±2.16mm in the right and left sides respectively, while in females it was 27.18±1.56mm and 26.85±1.75mm in the right and left sides respectively. There was no statistically significant difference in the mean neither between both sexes nor on both sides (p=0.674 in the right side and 0.344 in the left side).

2- The distance between the posterior tip of occipital condyle and Opisthion OCPT-O distance (P-O): The mean of (P-O) in males was found to be 28.93±2.47mm and 28.81±2.67mm in the right and left sides respectively, while in females it was 28.17±2.99mm and 28.41±3.64mm in the right and left sides respectively. The difference in the mean of (P-O) distance between both sexes was statistically non-significant on both sides (p=0.402 in the right side and 0.696 in the left side).

3- Intercondylar distances:

a- Anterior intercondylar distance (AID): The mean of (AID) was found to be 21.84 ±3.89mm in males, while in females it was 20.12±3.03mm. There was no statistically significant difference in the mean neither between both sexes and on both sides (p=0.136).

b- Posterior intercondylar distance (PID: The mean of (PID) in males was 42.20±4.59mm, while in females it was 41.65 ±2.83mm. There was no statistically significant difference in the mean neither between both sexes nor on both sides (p=0.658).

III- *Radiological study:*

1- The occipital condyles length (OCL): The mean of the OCL in males and female was statistically non-significant in both sides. While the difference in the mean of the right OCL between both sexes was statistically significant (p=0.007) as well as in the left OCL with (p=0.034) as illustrated. The mean of the right and left OCL in male age groups (I-V) was measured and recorded. These differences were statistically non-significant (p=0.083). While in female age groups (I-V) was statistically significant (p=0.005). The mean differences of the right and left OCL between males and females in age group I, II, V were statistically non-significant. But in age group III, IV were statistically significant in the right side and non-significant in the left side.

2- The occipital condyles width (OCW): The mean of the OCW in males was statistically non-significant (p=0.090). While in females wasthis difference was statistically significant (p=0.033). While the difference in the mean of the right and left OCW between both sexes was statistically significant as p=0.032 and 0.025 respectively. The mean of the left OCW in the 5 female age groups was statistically significant (p=0.181). The mean differences of the right and left OCW between males and females in age group I, II was statistically significant. While in age group III, IV and group V they were statistically non-significant in both sides.

3- The axial condylar angle (ACA): The mean of the ACA in males was statistically non-significant (p=0.395), while in females was statistically significant.

4- (p<0.001). The difference in the mean of the right and left ACA between both sexes was statistically significant in the right side (p=0.028) and statistically non-significant in the left side (p=0.653). The mean of the right and left ACA in males age groups (I-V) was statistically non-significant. While in female age groups (I-V) was statistically significant. The mean differences of the right and left ACA between males and females in age group I was statistically non-significant. While, in age group II was statistically significant in the right side (p=0.047) and statistically non-significant in the left side (p=0.106). The mean differences of the right and left ACA between males and females in age group III, they were statistically significant in both sides. While in age group IV and V were statistically non-significant in both sides.

5- The coronal condylar height (CCH): The mean of the CCH in males was 10.38±1.35mm (in the right side) and 11.13±3.18mm (in the left side), this difference was statistically significant (p=0.037). The mean of the CCH in females was 9.92±1.11mm (in the right side) and 10.27±1.08mm (in the left side), this difference was statistically significant (p<0.001). The difference in the mean of the right and left CCH between both sexes was statistically significant. The mean of the right and left CCH in male and female age groups (I-V) was These differences were statistically non-significant. The mean differences of the right and left CCH between males and females in age group I, III, IV and V were statistically non-significant. While, in group II were statistically significant in both sides as p=0.007 and 0.042 respectively.

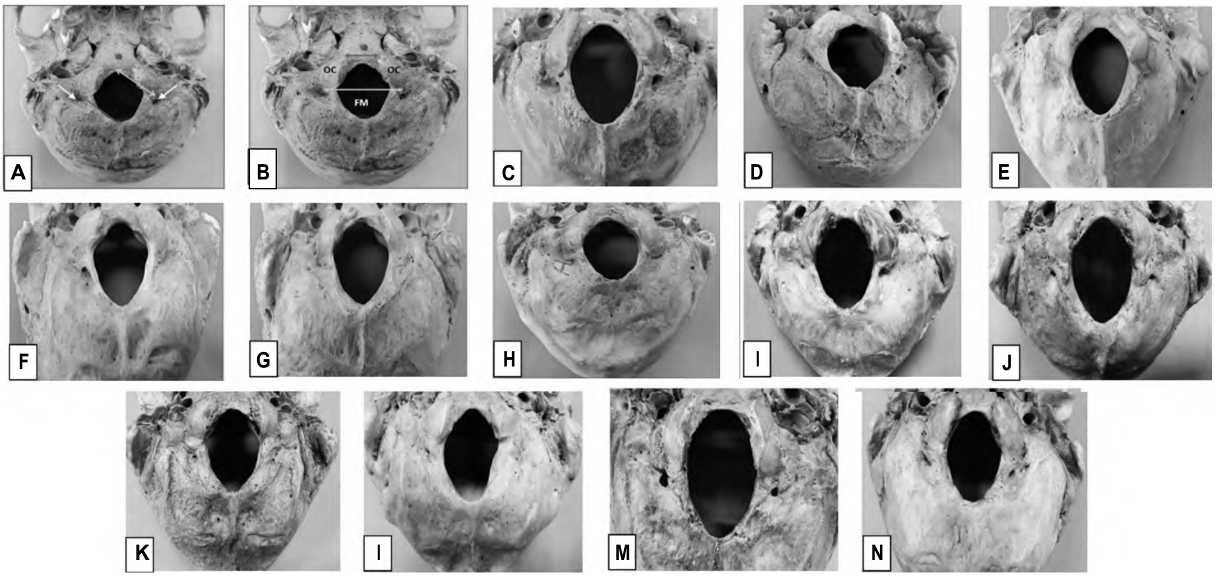

Fig. (1): Aphotograph of a dried human skull base showing: (A): How to measure the (P-O) distance (red arrow). How to measure the (P-B) distance (yellow arrow). The posterior condylar foramina (white arrows) (B): How to measure the AID (red arrow) and PID (yellow arrow). (C): Bilateral oval OCs. (D): Bilateral diamond-shape OCs and bilateral posterior condylar foramina. (E): Bilateral S-shape OCs. (F): Right diamond-shape OC and left irregular one with unilateral posterior condylar foramen. (G): Right oval OC and left S-shape one and bilateral absent posterior condylar foramina. (H): Right S-shape OC and left oval one. (I): Bilateral 8-shape OCs with unilateral posterior condylar foramen. (J): Bilateral kidney-shape OCs. (K): Bilateral S-shape OCs. (L): Right diamond-shape OC and left triangular one with bilateral absent posterior condylar foramina. (M): Right oval OC and left 8-shape one. (N): Right oval OC and left irregular one.

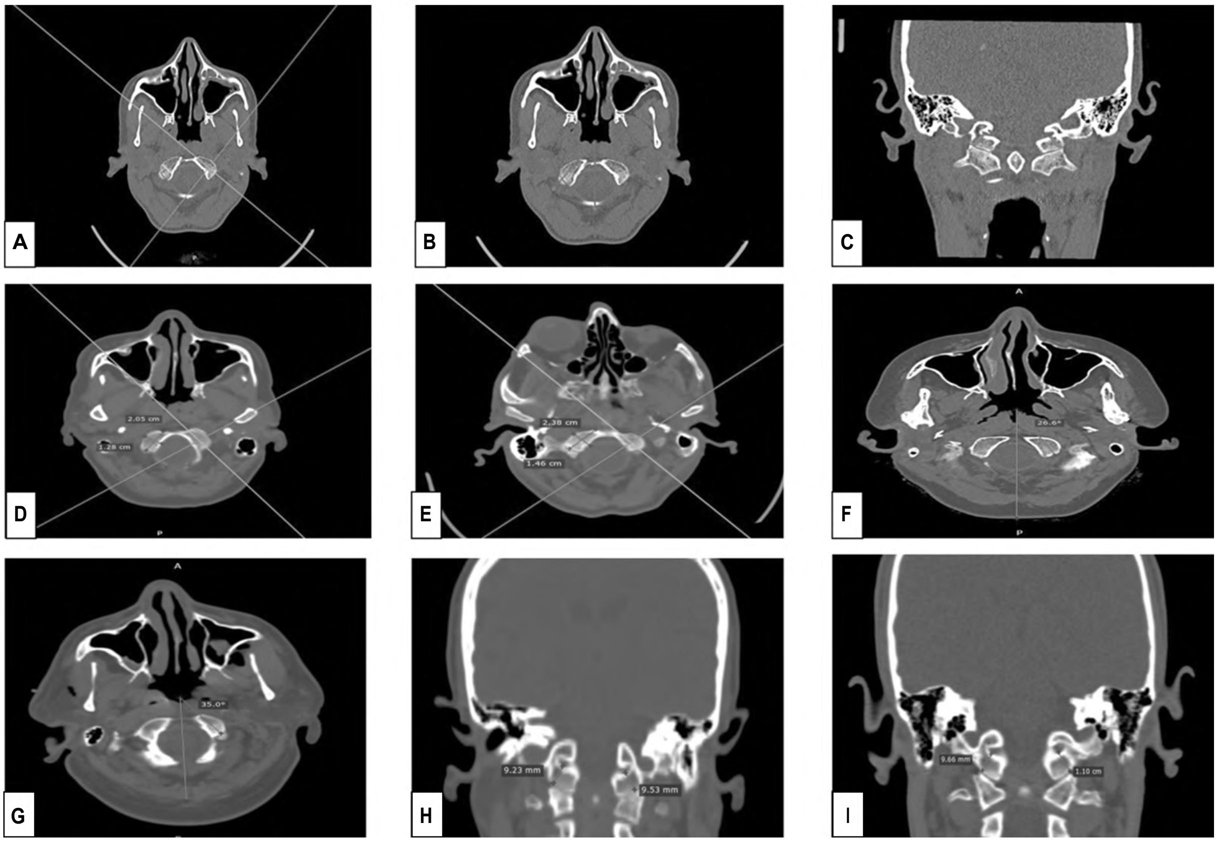

Fig. (2): (A) An axial computed tomography image showing the OCL (the red line) and the OCW (the yellow line). (B): An axial computed tomography image showing how to measure the ACA represented in between the red arrows. (C): A coronal computed tomography image showing the CCH (the red lines). A MDCT image (axial cut) of (D): Female patient aged 33 years showing right OCL and W measurements. (E): 65 years old male patient showing right OCL and OCW measurements. (F): 21 years old female patient showing left ACA measurement. (G): A male patient aged 46 years old showing left ACA measurement. Coronal cut of (H): A female patient aged 50 years old showing right and left CCH measurements. (I): A 25 year old male patient showing right and left CCH measurements.

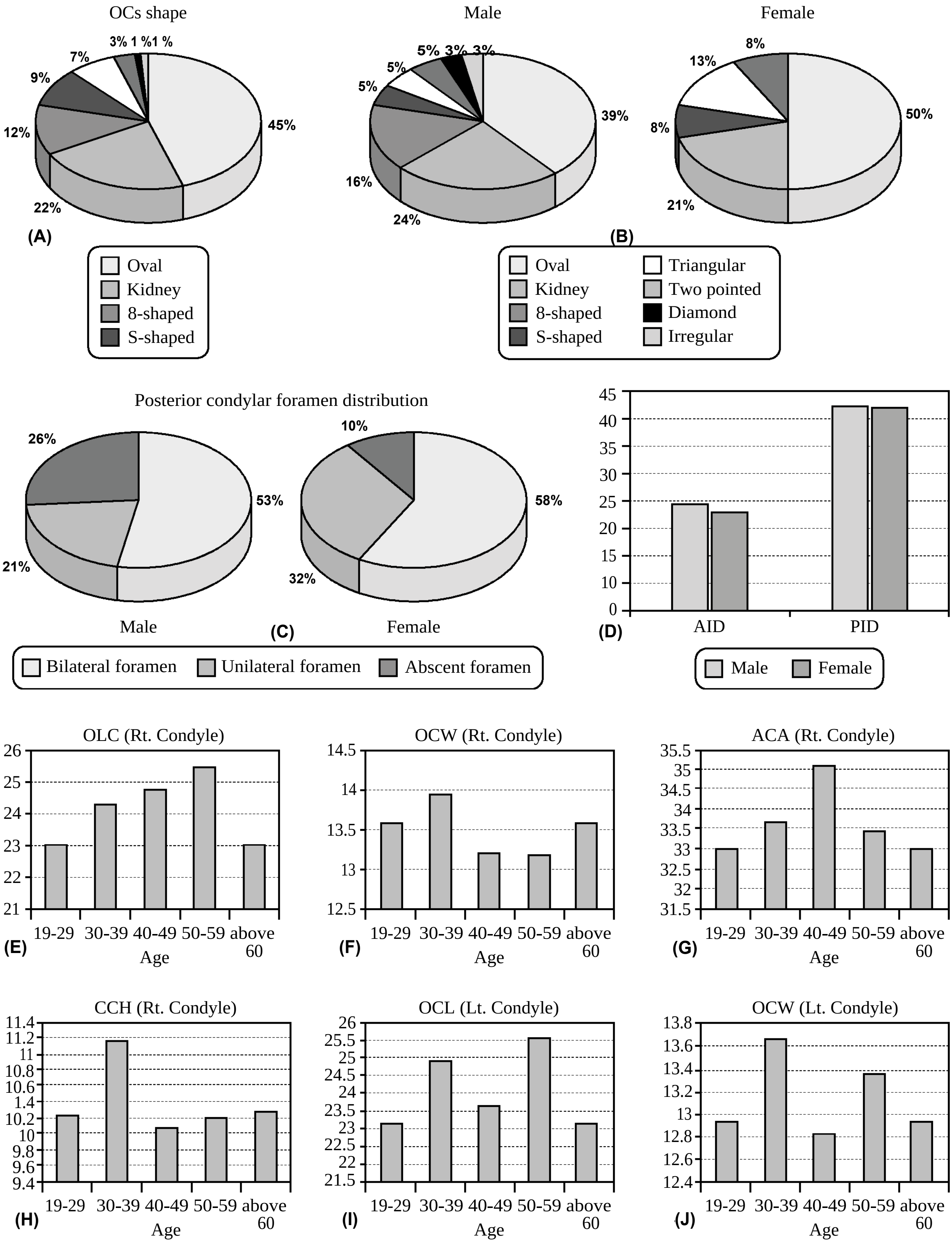

Fig. (3): (A): Pie chart showing OCs shape variability in dry bone regardlesssex.(B): Pie chart showing OCs shape variability regarding sex. (C): Pie chart showing the distribution of PCF in dry bone and their sex differences.Bar chart showing. (D): The mean of AID and PID in both sexes in dry bone. (E): The age influence on the OCL of the right OCs in male CT scans. (F): The age influence on the OCW of the right OCs in male CT scans. (G): The age influence on the ACA of the right OCs in male CT scans. (H): The age influence on the CCH of the right OCs in male CT scans. (I): The age influence on the OCL of the left OCs in male CT scans.(J): The age influence on the OCW of the left OCs in male CT scans.

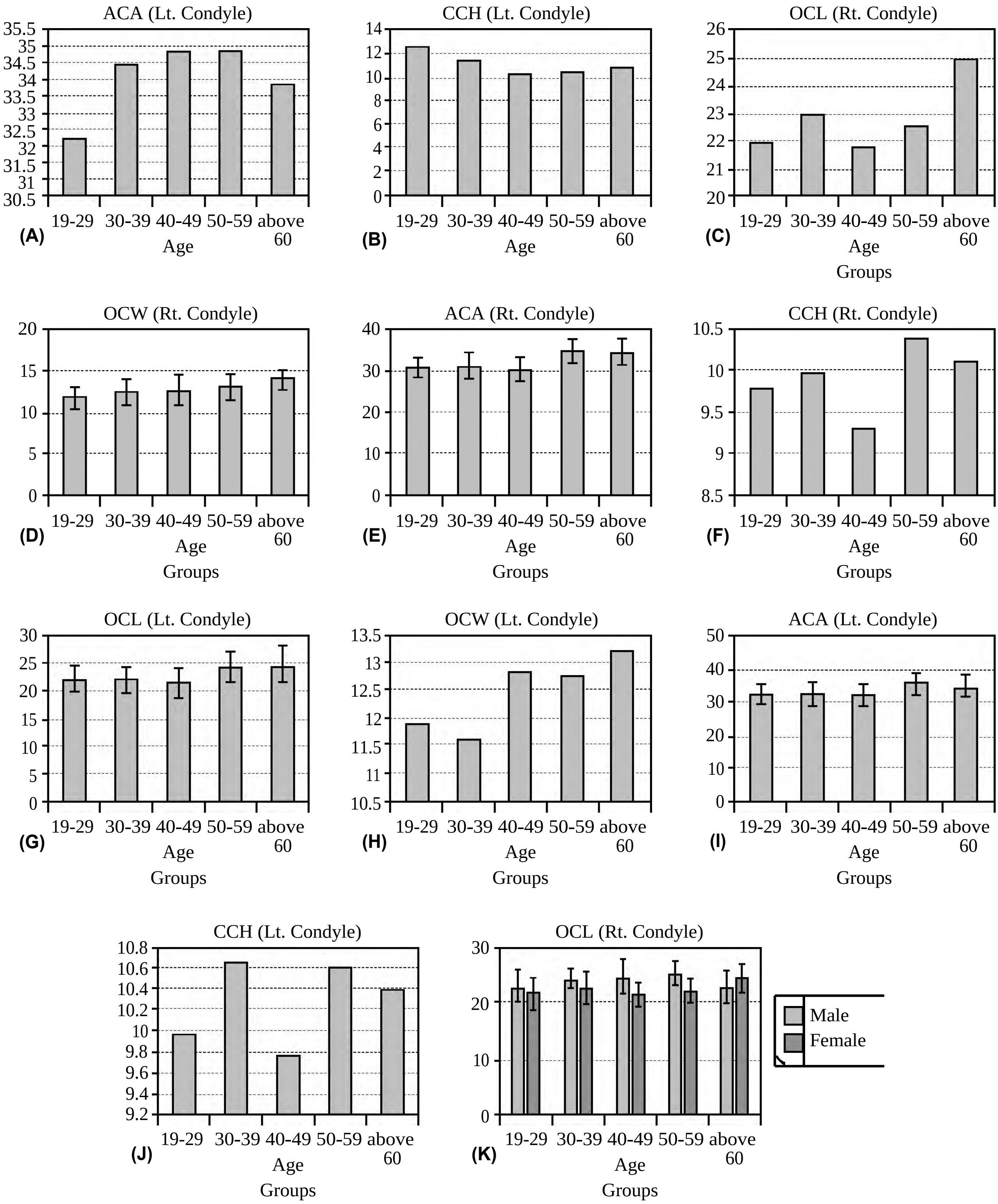

Fig. (4): Bar chart showing (A): The age influence on the ACA of the left OCs in male CT scans. (B): The age influence on the CCH of the left OCs in male CT dcans. (C): The age influence on the OCL of the right OCs in female CT scans. (D): The age influence on the OCW of the right OCs in female CT scans. (E): The age influence on the ACA of the right OCs in female CT scans. (F): The age influence on the CCH of the right OCs in female CT scans. (G): The age influence on the OCL of the left OCs in female CT scans. (H): The age influence on the OCW of the left OCs in female CT scans. (I): The age influence on the ACA of the left OCs in female CT scans. (J): The age influence on the CCH of the left OCs in female CT scans. (K): The sex influence on the OCL of the right OCs in the five age groups of CT scans.

Discussion

In the current study on dry bone, the most common shape of the OC in all specimens (76OCs) was oval in 34 OCs (44.7%), while the rare shapes were the triangular and irregular in one OC (1.3%) for each. These findings were relatively in agreement with ozer [6] who studied the Turkish population and reported that 59.67% of the OCs was oval while the rare shape was the two-pointed in 0.32%. Moreover, Kalthur [1] studied the Indian population reported that the most common shapes were the oval and 8-shape OCs in 22.5% for each while the rare shape was diamond-shape OCs in 1.4%. However, the previous authors didn't compare between both sexes.

In the present work, the commonest shape of the right OCs (38 OCs in total) was oval in 18 OCs (47.4%) while the rare shapes were the two-pointed and diamond in two OCs for each. On the contrary, Natsis [9] studied the Greek population and found that the most common shape of both right and left OCs was the S shape in 33.1% and 28.3% respectively while the rare shape on both sides was the diamond shape in 2.9% and 5.8% of the studied OCs respectively. The shape of occipital condyle may affect the amount of condylectomy. Among the different shapes of the occipital condyles, the triangular, deformed and kidney shape occipital condyles may require a more extensive condylectomy to reach the lesions ventral or ventrolateral to the brain stem [10].

Regarding the distribution of the posterior condylar foramen, in this work the posterior condylar foramen was bilaterally present in 21 skulls (55.2%), unilateral right foramen in seven skulls (18.5%), unilateral left foramen in three skulls (7.8%) and bilateral absent foramina in seven skulls (18.5%). In Indian population the posterior condylar foramen was present bilaterally in 20%, on the right side only in 32%, on the left side only in 8% and totally absent foramina in 40% [11]. On the other hand, Barut [12]. Studied the Turkish population and reported thatthe posterior condylar foramen was present bilaterally in 55.4%, unilateral right foramen in 19.6%, unilateral left foramen in 5.4% and totally absent foramina in 19.6%. However, all the previously mentioned authors didn't compare between both sexes.

In the present study, the mean OCPT-B distanceon the right side was 27.31 and 27.16mm on the left side. Ozer [6] studied the Turkish population and reported that the OCPT-B distance on the right side was 29.4mm while on the left side it was 29.5mm. There was no statistically significant difference in the mean of OCPT-B distancebetween both sides in both of the present study and Ozer's study while the OCPT-B distances were significantly greater on the right side in his study on the Indians [3].

On the contrary, the sex difference in the current study was 28.93mm and 28.17mm on the right side while the left side measurements were 28.81mm and 28.41mm in male and female skulls respectively. Kalthur [1] studied the sex differences in Indian population and found that the mean OCPT-O distance on the right side was 27.8mm and 28.2mm while on the left side the measurements were 28mm and 29.3mm in male and female skulls respectively. The OCPT-O distance is an important anatomical factor for posterolateral approaches as the larger this distance is, the more the clarity of the surgical field [10].

The mean of the anterior intercondylar distance in the current study was 2 1 mm while in the Kenyan population studied by Cheruiyot [13] asit was 19.66mm and in Indians it was 17.8mm [3]. In the current study the sex difference of AID, in males, the mean AID was 21.84mm and 21.17mm while in females it was 20.12mm and 20.05mm [14]. The current study was in agreement with the study performed by Lyrtzis [14] about the non-significant statistical difference in the mean of AID between both sexes.

The mean of PID in the present study was 41.92mm while in Cheruiyot [13] study on Kenyan populationit was 38.52mm. In addition, the mean PID in the Turkish population was 43.1mm while in Greeks and Indian it was 51.61 and 38.91mm [3,9]. In the current study the sex difference regarding the PID measurements, and the results were 38mm, 43.36mm and 42.2mm in males while in females the measurements were 39mm, 41.23mm and 41.65mm [14].

The mean OCL difference between males and females was statistically significant with $p<0.0001$ in agreement with the Chinese sample in males was 23.16mm and in females was 20.85mm [7]. On the other hand, the mean OCL of the right OCs in the current work was 23.49mm while that of the left OCs was 23.57mm. In accordance with the studies on Americans [15]. And Chinese [16] population who studied the and right and left OCL, and they found that the mean length of the right OCs was 22.2 and 22.37 respectively while that of the left ones was 22.5mm and 22.05mm respectively.

In the current study reported that there was statistically significant difference between the different age groups among females only. However no statistically significant difference between the different age groups was recorded [5].

In the current study, the mean of OCW was 13.49mm and 13.14mm in males while in females it was 12.92mm and 12.46mm on the right and left sides with statistically significant difference between both sexes on both sides with p-values = 0.032 and 0.025 respectively. These results were discordant with the mean of the OCW in males was 9.8mm and 9.6mm while in females these measurements were 9mm and 9.5mm on the right and left sides in Indians as it showed statistically non-significant difference between males and females (p=0.156) [7].

On the contrary, the mean OCW of the right OCs in the current work was 12.92mm while that of the left OCs was 12.46mm. Zhou [16]. Studied the Americans and Chinese right and left OCW respectively, they found that the mean width of the right OCs was 11.2mm and 12.08mm respectively while that of the left ones was 11.2mm and 12.16mm respectively. The current study reported that there was statistically significant difference between both side and this was discordant with the previous authors [15,16].

The age influence on the mean OCW and reported that that there was no statistically significant difference between the different age groups [5]. While the present work suggested the reverse in the female age groups in the right OCs only. The width of OCs is of ultimate surgical importance because the neurosurgeon should know how much medially the condyle can be respected and the adequate width to accommodate a 3.5mm average width screw as described in the original technique [7]. Based on the present work, the mean of ACA was 33.62° and 34.02° in males while in females it was 32.45° and 33.73° on the right and left sides respectively. The mean ACA in Indians was 31.1° in males and 30.7° in females without side specification [5]. Concerning the side related measurements, the mean of the right ACA of the Americans was 33.1° and that of the left OCs was 32.5° while the present study found that the mean on the right side was 33.03° and that on the left side was 33.87° [17].

Regarding the coronal condylar height (CCH), the mean of CCH was 10.38mm and 11.13mm in males while in females it was 9.92mm and 10.27mm of the right and left OCs respectively with statistically significant difference between males and females in both sides (p-values=0.024 and 0.029) respectively. These results agreed with Srivastava [7] studies on the Indians as the male measurements were 9.7mm and 9mm while in females these measurements were equal on both sides (8.6mm) respectively with statistically significant difference between both sexes (p-value= 0.012).

Conclusion:

It could be concluded that the sex and age of the patient should be considered while selecting the optimal approach among the lateral suboccipital approaches in patients with certain type and size pathologies ventrolateral to the brainstem to avoid the complications of open cranial surgeries.

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التنوع الشكلى والقياسى فى اللقم القذالية فى المصريين البالغين
دراسة على العظم الجاف والأشعة

مقدمة: تعتمد الأساليب الناجحة فى جراحة الأعصاب على فهم تشريح المنطقة القذالية المجاورة للقمة والمعرفة التفصيلية حول اتجاه اللقم القذالى فيما يتعلق بالثقبة العظمية والقناة تحت اللسان. تم تخصيص الدراسة الحالية لإثبات الاختلاف المورفولوجى والمورفو مترى لهذه اللقمات القذالية.

المواد والطرق: أجريت الدراسة الحالية على ٣٨ جمجمة (٧٦ قناة قذالية) بقسم التشريح والأجنة بكلية الطب جامعة القاهرة و ١٥٠ صورة MDCT (300 OCs) تم الحصول عليها من قسم الأشعة بكلية الطب بالقاهرة، مستشفى الجامعة.

النتائج: لوحظت عدة اختلافات فى العظم الجاف، فكانت أشكال اللقم البيضاوية ٤٤.٧٪ فى بينما كانت الأشكال غير المنتظمة والمثلثة ١.٣٪ فى من إجمالى العينة المدروسة. تمت ملاحظة الثقبة اللقمية الخلفية بشكل ثنائى فى ٥٥.٢٪، من جانب واحد فى ٢٦.٣٪ وغائبة تماماً فى ١٨.٥٪. تم العثور على أن اختلاف النوع فى العمل الحالى ليس له دلالة إحصائية فى الفتحة الخارجية لقناة تحت اللسان، والسرداب، والفتحة فى الصور الإشعاعية، بينما كان هناك فرق ذو دلالة إحصائية فى OCL وOCW وACA وCCH بين الذكور والإناث وبين الفئات العمرية المختلفة لكلا الجنسين. يعد عرض وسماكة اللقم القذالية ذات أهمية جراحية قصوى للسماح لجراح الأعصاب بمعرفة الحد العمق الأقصى المسموح به للجفر فى منطقة اللقمتين.

الخلاصة: يمكن الاستنتاج أنه يجب مراعاة جنس وعمر المريض عند اختيار النهج الأمثل من بين الأساليب الجانبية تحت القوقعة فى المرضى الذين يعانون من أمراض معينة من النوع والحجم البطنى الجانبى لجذع الدما غ لتجنب مضاعفات العمليات الجراحية القحفية المفتوحة.