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ANATOMY

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MORPHOLOGICAL AND MORPHOMETRIC ANALYSIS OF THE  
FORAMEN MAGNUM AND OCCIPITAL CONDYLE IN DRIED ETHIOPIAN  
AND GERMAN SKULLS

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## Abstract

**Introduction:** In anatomy, the foramen magnum (Latin: “great hole”) is a large opening in the occipital bone of the cranium. It is oval and wider behind, with its greatest diameter anteroposteriorly through which the medulla oblongata (an extension of the spinal cord) and other neurovascular structure enters and exits the skull vault. The occipital condyles (OC), an important part of the craniovertebral or craniocervical junction are located anterolaterally on either side of the foramen magnum. The occipital condyles represent the cranial portion of the craniocervical junction

**Objective:** To assess morphological and morphometric variation of the FM and OC in dried Ethiopian and German skull in the university of Gondar.

**Methodology:** Comparative observational based descriptive study design was conducted. The study was conducted on 54 (26 Ethiopian and 28 German) skull of unknown sex in University of Gondar, department of human anatomy from December 30 up to January 30/ 2016. Checklist guided observation and measurement was made for the anteroposterior and transverse diameter as well as shape and area of the foramen magnum and occipital condyle length and width. Simple statistical methods like means, range, standard deviation and percentage was used to analyze the data.

The result was presented in the form of tables, figures and text using frequencies and summary statistics

**Result:** The mean APD and TD of the FM is 35.19mm and 30.17mm respectively and the mean area of the FM is 853.36mm<sup>2</sup>. The foramen magnum shapes were determined as round in 25.9%, oval in 18.5%, egg in 20.4%, triangular in 1.9%, pentagonal in 11.1%, hexagonal in 7.4%, irregular in 13% and rectangular in 1.9%. The mean length of right and left OC is 25.69mm and 26.96mm respectively and the mean width of the right and left OC is 12.76mm and 13.04 respectively.

**Conclusion:** The mean APD, TD and Area of the FM both Ethiopian and German skulls do not show significant difference.

The mean width of OC of Ethiopian and German skull does not show any significant difference whereas the mean length of right and left OC shows significant difference

## Acronyms

APD	Anteroposterior diameter
FM	Foramen magnum
LOCL	Left occipital condyle length
OC	Occipital condyle
OCL	Occipital condyle length
OCW	Occipital condyle
ROCL	Right occipital condyle length
SD	Standard deviation
TD	Transverse diameter

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# 1. Introduction

## 1.1. Background

In anatomy, the foramen magnum (Latin: “great hole”) is a large opening in the occipital bone of the cranium. It is oval and wider behind, with its greatest diameter anteroposteriorly. The anterior border of the foramen magnum is formed by basilar process of the occipital bone, the lateral border by the left and right ex-occipitalis and posterior border is formed by the supraoccipital part of the occipital bone. It is one of the oval or circular apertures in the base of the skull (the foramina), through which the medulla oblongata (an extension of the spinal cord) enters and exits the skull vault. Apart from the transmission of the medulla oblongata and its membranes the foramen magnum transmits the vertebral arteries, the anterior and posterior spinal arteries, the membrane tentoria and alar ligaments. It also transmits the spinal component of the accessory nerve into the cranial fossa [1].

Due to its relatively protected anatomical position, this area of the skull tends to withstand both physical insults and inhumation somewhat more successful than many other areas of the cranium [2].

Many authors have classified foramen magnum depending upon its shapes, such as oval, egg- shaped, round, tetragonal, pentagonal, hexagonal and irregular(see figure one) [3][4]. Variations of the shape of FM have got diagnostic, clinical and radiological importance [1].

The occipital condyles (OC), an important part of the craniovertebral or craniocervical junction which are located anterolaterally on either side of the FM [5]. The occipital condyles represent the cranial portion of the craniocervical junction. Each occipital condyle is oval in outline and oriented obliquely so that its anterior end lies nearer the midline than its posterior end. It is markedly convex anteroposteriorly, less so transversely, and its medial aspect is roughened by ligamentous attachments. The hypoglossal canal, directed laterally and slightly forwards, traverses deep to each condyle [6].

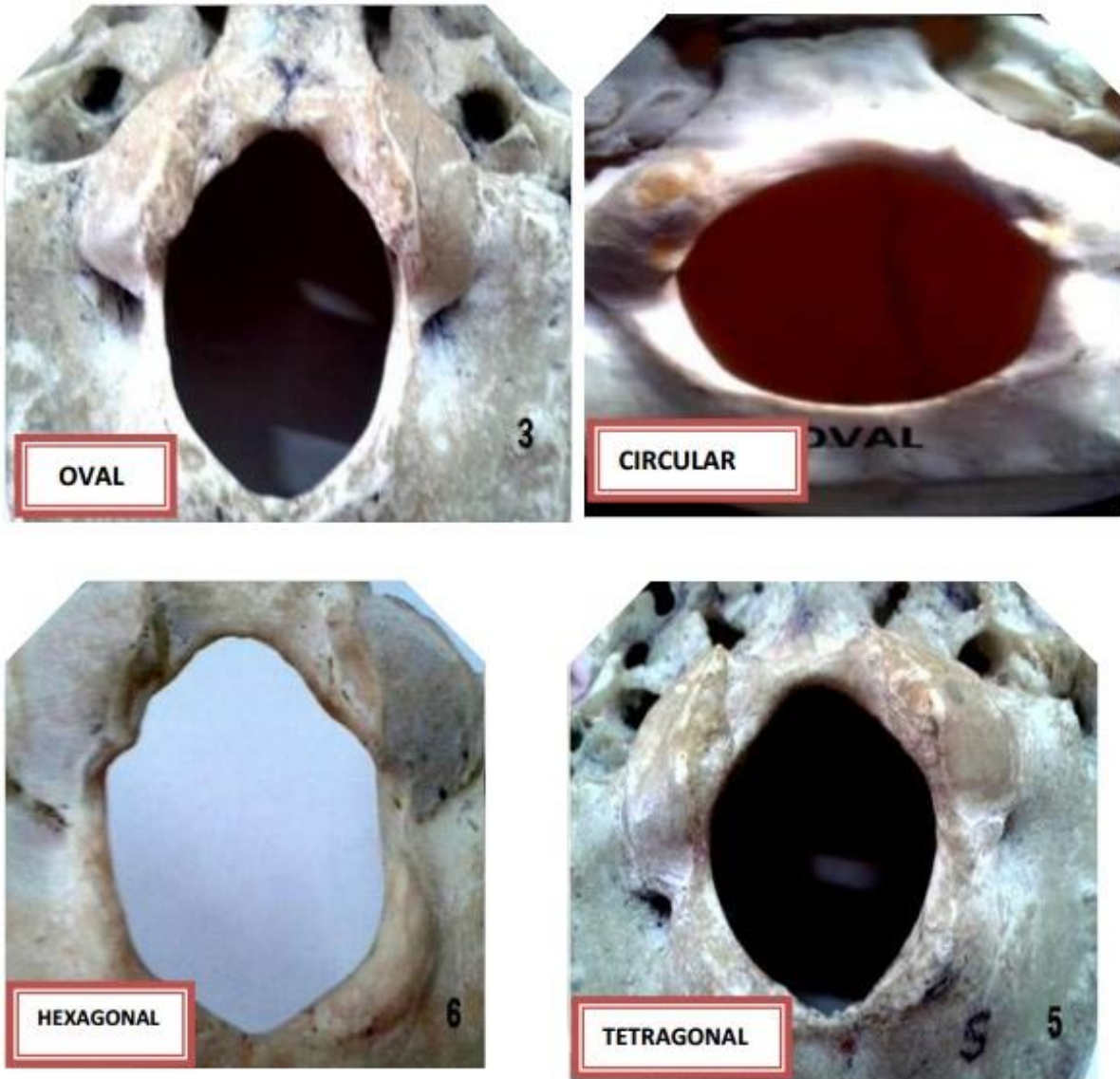


Figure 1: Various shapes of the foramen magnum of the Turkey skull in 2016 (Adopted from [4])

## 1.2. Statement of the Problem

The knowledge of the foramen magnum diameters is needed to determine some malformations such as Arnold Chiari syndrome, which shows expansion of transverse diameter [4]. In a computerized tomographic study of Catalina & Herrera, dimensions of the foramen magnum of the 63 achondroplasia individuals were compared to standards established for non-achondroplasia individuals. The size of the foramen magnum in patients with achondroplasia was small at all ages, particularly in those with serious neurological problems [6].

The dimensions of the FM become clinically as well as surgically important because those vital structures that pass through it may become compressed in cases of FM herniation, FM meningioma's and FM achondroplasia [7]. Foramen magnum stenosis in achondroplasia patients causes respiratory depression and increased sudden infant death rate due to compression of vital centers [8].

The foramen magnum however, shows different morphology in each individual skull, and reportedly, it has different outlines of shapes ranging from round to polygonal or even irregular [7]. Keshav Krishna ,Alka Rashmi Nag , Renu Prasad reported that oval shape is associated with difficult surgical approach to the anterior part of foramen magnum [4].

Traditionally, lesions located anterior to the craniocervical junction have posed a surgical challenge. The space-occupying lesion ventral to the spinal canal at the level of the foramen magnum can be reached using a ventral or dorsal approach. Newly described transcondylar approach requires information regarding the morphometric aspects of the occipital condyle [8]. Wanebo et al. stated that longer FM anteroposterior dimensions permitted greater contralateral surgical exposure for condylar resection [9]. Partial resection of the occipital condyle during transcondylar surgical approaches is an important step for access to the ventral and ventrolateral part of foramen magnum. Therefore, the assessment of morphometry of foramen magnum and occipital condyles is helpful for lateral surgical approaches for reaching lesions in the middle and posterior part of cranial base [8].

### 1.3. Literature review

#### 1.3.1. Anatomy of the Foramen magnum and Occipital condyle

The posterior part of the cranial base is largely formed by the occipital bone. Prominent features are the foramen magnum and associated occipital condyles, jugular foramen, mastoid notch and squamous part of the occipital bone up to the external occipital protuberance and the superior nuchal lines, hypoglossal canals (anterior condylar canals) and condylar canals (posterior condylar canals) [10].

#### 1.3.2. Dimension of the Foramen magnum

A study conducted on dry human skull in Indian in 2015 show that the average APD of the foramen magnum was 33.4mm (range 26.7-39.8mm) and the TD was 28.5mm (range 24.7-37.5) [1]. Similar Study conducted in Indian population of 150 skulls in 2014 show that the mean APD of the foramen magnum was found to be 35.30mm and the mean TD was 29.49mm [9]. Another Study conducted in South Gujarat (Indian) in 2014 showed that the mean APD of the foramen magnum was 33.7mm (range 26-40.2mm) and the TD was 28.29mm (range 21.5-33.5mm) [6]. Another study done in Indian in 2010 shows that the mean anteroposterior and the transverse diameter of the FM was recorded as 34.5 mm and 29 mm, respectively [11].

Comparative study conducted in a Greek population in 2013 show that the average TD and APD were found to be  $30.31 \pm 2.79$  and  $35.53 \pm 3.06$  mm, respectively [5]. Similar Study conducted in southern Nigerian population in 2012 showed that the mean APD and TD of the foramen magnum was  $36.11 \pm 0.24$ mm and  $29.65 \pm 0.24$ mm respectively [12].

Additionally, study done on Brazilian dry skull show that the FM had a mean APD of 34.23 mm, with a standard deviation (SD) of 2.54 mm, and the mean transverse TD was 28.62 mm, with the SD of 2.83 mm. The maximum value for the APD and TD was 39.72 mm and 36.01 mm, respectively, and the minimum value was 26.90 mm for the APD and 22.67 mm for the TD [13]. Similarly Study conducted in Anusandhan University,

India in 2015 showed that mean APD of foramen magnum in 150 skulls was found to be 35.30 mm, ranging from 27-43 mm with a standard deviation of 2.709. The mean TD of foramen magnum in 150 skulls was 29.49 mm. ranging from 24-35 mm. with a standard deviation of 2.572 [8].

### **1.3.3. Shape of the Foramen magnum**

A study conducted on the dry skull in India in 2015 showed that the most common shape of the foramen magnum was two semicircles (25.9 %), whereas the most unusual was the irregular (0.7 %). Other shapes were seen in the following frequencies: pear - 22.4 %; egg - 21 %; oval -14.7 %; rhomboid - 14 %, and round - 1.4 % [8]. Similar study in the same area but at different time also shows that the FM was observed to have a round shape in 29.5%, tetragonal in 18.03%, oval in 31.14%, irregular in 11.47%, hexagonal in 8.9% and pentagonal in 1.63% of the cases [1].

Another study done on the Brazilian dry skull show that the most common shape for the FM was oval [13]. Similar study conducted in south Indian of dry skull of total 100 (55 male and 45 female) shows the following distribution as follows oval-53.24%, round-24.64%, tetragonal-16.88%, egg-2.36%, pentagonal-1.29%, hexagonal-1.29%. ) [14]. Another study done in Indian shows that the various shape of FM were observed as follows: round shape in 22.6%, egg shape in 18.9%, tetragonal in 18.9%, oval in 15.1%, irregular in 15.1%, hexagonal in 5.6% and pentagonal in 3.8% of the cases [15]. (See fig 2)



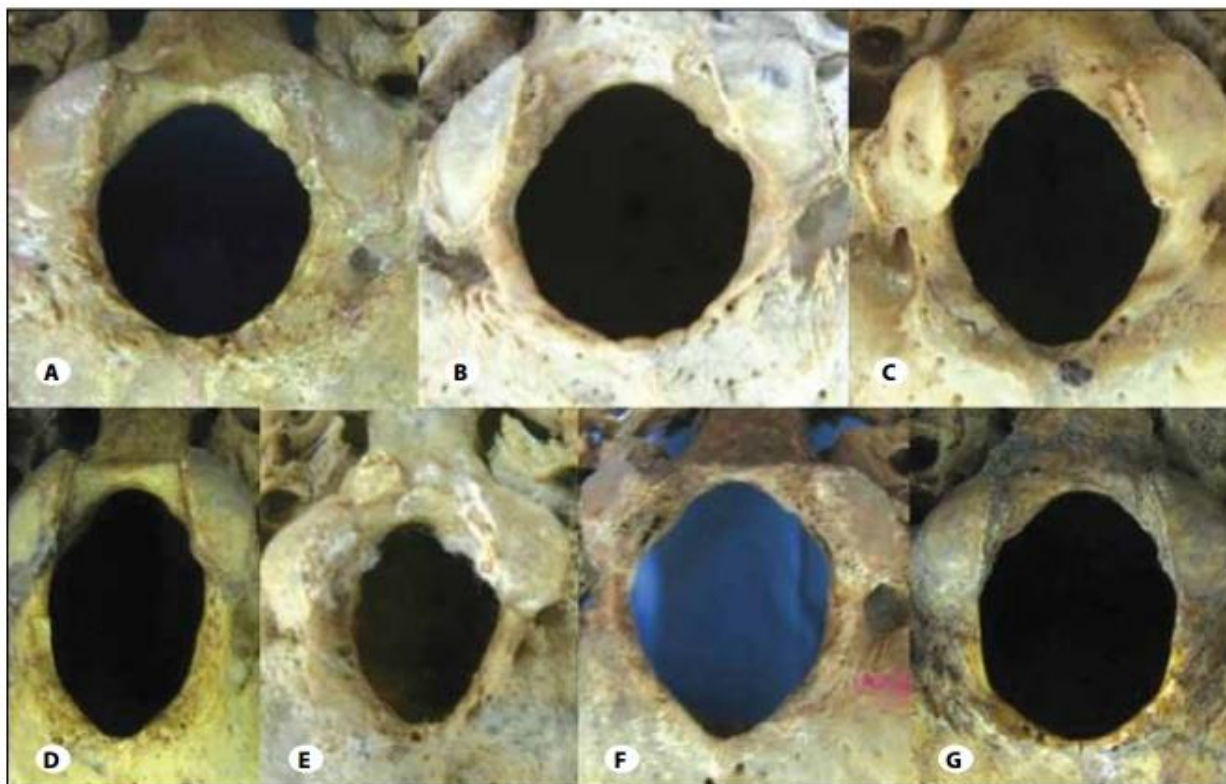


Figure 2: Morphological variants of the shapes of foramen magnum of the human skull in turkey in 2012 (A- round shape; B- egg shape; C- tetragonal; D- oval; E- irregular; F- hexagonal and G- pentagonal shape). (Adopted from [17])

#### 1.3.4. Area of the Foramen magnum

Riyaz.et.al calculated the surface area of Foramen by using formula stated bellow.  $AREA = \pi \times \{(h \times w)/4\}$  where, h=anteroposterior diameter, w=transverse diameter and  $\pi = 22/7$ . Similarly study conducted in Indian in 2015 show that the mean surface area of the foramen magnum was  $747.92\text{mm}^2$  [1]. Similar study conducted at different time in South Gujarat(Indian) in 2014 showed that the mean surface area of foramen magnum was  $755.37\text{mm}$  [6]. Another study conducted in Indian in 2016 reveal that the mean surface area is  $747.67\text{mm}^2 (\pm 108.60)$ , [16]

### 1.3.5. Dimension of the occipital condyle

Occipital condyle is one of the prominent features of the posterior part of the cranial base. Anteriorly it overlaps foramen magnum and project down to articulate with the superior articular facets on the lateral masses of the atlas[11]. Even though it is prominent feature many research report that there is great variation in length and width between right and left as well as from person to person.

Study conducted in Mersin University (Turkey) on dry human skull show that the mean length of ROCL and LOCL is 23.7mm and 24mm respectively. Similarly the mean width of right and left OC is 12.2mm and 12.4mm respectively. The OC was classified according to its length as <20 mm (short), 20-26 mm (moderate), or >26 mm (long) [16]. In this study, the incidences of short, moderate and long OC were found to be 5%, 62%, and 33%, respectively. It was observed that the morphology of the two condyles were rarely symmetrical [11].

Another study conducted in the Anusandhan University, India in 2015 showed that the mean length of the right occipital condyle was 22.45 mm, ranging from 15-29 mm. Similarly, they found that the mean length of the left occipital condyle was 22.65 mm, ranging from 15-30 mm. The mean length of the total 300 occipital condyles was 22.55 mm, ranging from 15-30 mm. In this study, it was observed that, 30 occipital condyles were of short type (10%), and 263 condyles were of moderate type (87.67%) and 7 condyles were of long type (2.33%). the mean width of right occipital condyle was 12.55 mm. Similarly, the mean width of left occipital condyle was found to be 12.92 mm. The mean width of total 300 occipital condyles was 12.73 mm [1].

Comparable study conducted in a Greek population on dry human skull in 2013 showed that the mean OCW, OCW and OCL were found to be  $13.09 \pm 1.99$ ,  $5.71 \pm 1.61$  and  $25.60 \pm 2.91$  mm on the right, and  $13.01 \pm 1.98$ ,  $6.25 \pm 1.76$  and  $25.60 \pm 2.70$  mm on the left side, respectively. Similarly Twenty OC (7 %) were short, 217 moderate (75.9 %) and 49 long (17.1 %) [5].

Another Study conducted in the Indian among eastern population in 2015 shows that the maximum value of the right and left width of OC is 1.8cm and the minimum value is



0.9cm. Similarly the maximum value of length of the right and left OC is 3cm and 3.1cm respectively and the minimum value of 1.8cm and 1.9cm respectively. The mean length of LOC and ROC is nearly  $2.44 \pm 0.25$ cm and mean width of LOC and ROC is nearly  $1.34 \pm 0.20$ cm [17]. Another Study conducted in Istanbul University (Turkey) reveal that the width of the OC was measured to be 11.3 (8.5-14.2) mm on the right side and 11.4 (8.0-14.5) mm on the left side. The length of OC was found to be 23.1 (12.1-31.2) mm on the right side and 22.9 (16.0-31.9) mm on the left [18].

#### 1.4. Justification of the Study

Variation of the shape and dimension of foramen magnum has immense importance because of its effects on the vital structures which passes through it can be compressed and jeopardized. The morphometric and morphological variation of foramen magnum and occipital condyle bring out further research and description of the anatomy in this area to raise awareness in students and health professionals

The progress in the neuroimaging techniques to diagnose craniovertebral abnormalities accurately has increased interest for craniovertebral surgery. Such surgeries are a challenging task for the neurosurgeons, because of the close relation of vascular and neural structures to the foramen magnum. Advances in skull base surgeries such as 'far lateral transcondylar approach' have improved the better and wider access of surgical exposure leading to successful surgeries [3]. To perform such surgeries, Comprehensive anatomical knowledge and prior analysis of the morphometric and morphologic analysis of the foramen magnum and occipital condyle is essential for safe surgical procedure related to this important anatomical region. Given the clinical significance of this anatomical area no osteometric studies of the foramen magnum and occipital condyle have been published so far in Ethiopia.

Hence, the present study of the morphometric and morphological analysis of the foramen magnum and occipital condyles is carried out. It is hopeful that the data will be valuable particularly for anatomist as anatomist is the first person to consider variation of foramen magnum and occipital condyle during teaching and learning process. The study is also valuable for neurosurgeons, radiologists and orthopaedicians particularly in preoperative decision making process and for planning of better operative procedures.

## **2. Objective**

### **2.1. General Objective**

To assess morphological and morphometric variation of the foramen magnum and occipital condyle in dried Ethiopian and German skull in university of Gondar

### **2.2. Specific Objective**

- To determine morphometry of the foramen magnum
- To determine morphology of the foramen magnum
- To determine morphometry of the occipital condyle
- To compare morphology and morphometry of the foramen magnum and right and left side of the occipital condyle of the Ethiopian and German skull

### **3. Methodology**

#### **3.1. Study Design**

Comparative observational based descriptive study design was conducted to assess morphological and morphometric variation of the foramen magnum and occipital condyle among Ethiopian and German dried skull.

#### **3.2. Study Area and Period**

The study was conducted at dissection hall of the department of human anatomy, University of Gondar, North West of Addis Ababa. Gondar University is one of the known medical Universities in Ethiopia which is 738 KM from Addis Ababa. Gondar University was established in 1952. The study was conducted from July 1, 2016 to January 30, 2017

#### **3.3. Study Population**

All dried human skulls prepared for teaching purpose which has no any abnormality in university of Gondar was included in the study.

#### **3.4. Inclusion criteria**

All undamaged skulls and devoid of deformity in the occipital bone was included in the study.

#### **3.5. Exclusion criteria**

The damaged, fractured, eroded with degenerative changes or deformed skull and those having evidence of pathological abnormalities was excluded.

#### **3.6 Sample size and sampling method**

Since there were scarcity of dried skull all available skulls which is devoid of deformity was used. Purposive sampling technique was employed to select skull for observation.

### 3.7. Variable of the study

#### 3.7.1. Dependent variable

- ❖ APD of FM and OC in mm
- ❖ TD of FM and OC in mm
- ❖ Area of FM in mm<sup>2</sup>
- ❖ Shape of FM

#### 3.7.2. Independent variable

- ❖ Race
- ❖ Body side

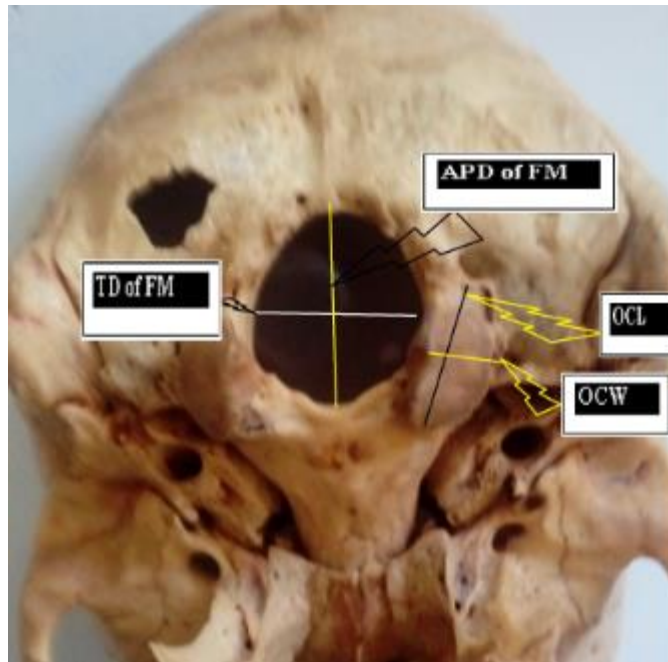
### 3.8. Data collection Procedure and Tools

All the measurements were recorded using digital Vernier caliper. Measurements was done using the following bony landmarks on the skull-

- ❖ Basion
- ❖ Opisthion
- ❖ Anterior tip of right and left occipital condyle
- ❖ Posterior tip of right and left occipital condyle

#### **Parameters will be recorded as follows:**

- ❖ Anteroposterior diameter of the foramen magnum
- ❖ Transverse diameter of the foramen magnum
- ❖ The length of the occipital condyle (right and left)
- ❖ The width of the occipital condyle (right and left)
- ❖ Area of FM was calculated using formula  $\text{Area} = \frac{h \times w}{4}$



**Figure 3:** Shows how APD, TD, OCL, and OCW were measured in this study

## Material

- ❖ Digital Vernier caliper
- ❖ Sony digital camera (16.1 mega pixels)
- ❖ Data collection form (checklist)

### 3.9. Operational definition

**Dried human skull:** a properly macerated and well dried natural human skull

**Antero posterior diameter of Foramen Magnum:** Maximum length between anterior and posterior margins of the foramen magnum as measured from basion to opisthion along the mid-sagittal plane.

**Width or Transverse Diameter of Foramen Magnum:** Maximum width between the lateral margins of the foramen magnum as measured from perpendicular to the mid-sagittal plan

**Length of occipital condyle:** the maximum length from its anterior tip to posterior tip

**Width of occipital condyle:** maximum distance measured at the right angles to the line joining its anterior and posterior tip.

**Area:** FM volume at its craniovertebral opening which is computed as  $\text{Area} = \frac{1}{4} \times \{(h \times w)\}$

### 3.10. Data Quality Control, Management and Analysis

The quality of data was assured by properly designed checklist and result obtained was compared and the figure was captured. The measurement was taken using a precisely calibrated standard sliding Vernier caliper.

### 3.11. Data processing and analysis

The collected data was checked for completeness, accuracy and clarity before analysis. The data was entered into SPSS version 20 for analysis. Descriptive and summary statistics was carried out. Simple statistical methods (mean, range, standard deviation and percentage) with tabular value were used to analyze and present the data.

### 3.12. Ethical Considerations

Ethical clearance was obtained from University of Gondar Research and Publication Office, ethical review committee.

### 3.13. Dissemination and Utilization of Results

The finding of this study will be disseminated through publication for scientific community, presentation on annual scientific meetings and conferences.

A copy of the study will be offered to Department of Human Anatomy, College of Medicine and Health Sciences, University of Gondar and to all relevant institutions.

## 4. Result

A total number of fifty four (54) 26 Ethiopian and 28 German dried human skulls of unknown sex were studied. The statistical analysis was carried out and the results have been tabulated and represented in the form of table and figure.

### 4.1. Morphometry of the foramen magnum

#### 4.1.1. Anteroposterior and transverse diameter of foramen magnum

As it is presented in the table one, the mean APD of the foramen magnum was found to be 35.19mm ranging from 26-42mm with standard deviation of 2.699 whereas, the mean TD of the foramen magnum was found to be 30.17mm ranging from 25-36mm with standard deviation of 2.44. Although the mean APD and TD of Ethiopian skull seems to exceed German skull Comparison between the two skulls shows there is no statistically significant difference in APD and TD ( $p=0.845$  for APD and  $p= 0.601$  for TD).

**Table 1:** APD and TD of the foramen magnum of Ethiopian and German skull in University of Gondar in 2016

Race	Anteroposterior diameter (APD)				Transverse diameter (TD)			
	Minimum	Maximum	Mean	SD	minimum	Maximum	Mean	SD
Overall (N= 54)	26	42	35.19	2.699	25	36	30.17	2.44
Ethiopian FM (N=)	31	42	35.81	2.514	20	35	30.38	2.21
German FM(N=)	26	39	34.61	2.78	26	36	29.96	2.659

#### 4.1.2. Area of the foramen magnum

Surface area of the Foramen Magnum was calculated by using formula stated bellow.

$Area = \pi \times \{(hxw)/4\}$  where  $h$ =anteroposterior diameter and  $w$ =transverse diameter and  $\pi=3.14$



As shown in the table below the present study reveals that the mean surface area of FM was found to be 853.36mm<sup>2</sup> ranging from 531-1099mm<sup>2</sup>. However significant difference among Ethiopian and German skull was not detected (p=0.370)

**Table 2:** Area of the foramen magnum of Ethiopian and German skull in University of Gondar in 2016

Race	Area of the FM in mm <sup>2</sup>			
	Minimum	Maximum	Mean	SD
Overall( N=54)	531	1099	853.36	109.011
Ethiopian(N=26)	667	1099	855.5	100.914
German(N=28)	531	1041	816.65	114.646

## 4.2. Morphology of the foramen magnum

### 4.2.1. Shape of the foramen magnum

As shown in the tale 3 and figure 4, the most common shape of the foramen magnum was found to be round (22.2%), whereas the most unusual was the triangular and rectangular each accounting for (3.7 %). Other shapes were seen in the following frequencies: hexagonal -7.4 %; pentagonal -11.1 %; oval – 18.5 %; irregular-13% and egg- 1.4 % (See figure 1). Comparisons of the shape between Ethiopian and German skull shows there is no statistical significant difference (p=0.737).

**Table 3:** Shapes of the foramen magnum of Ethiopian and German skull in University of Gondar in 2016.

shape of FM	Frequency	Percentage (%)	Cumulative Percent (%)
Hexagonal	4	7.4	7.4
Rectangular	2	3.7	9.3
Pentagonal	6	11.1	20.4
Round	12	22.2	46.3
Oval	10	18.5	64.8
Irregular	7	13.0	77.8
Egg	11	20.4	98.1
Triangular	2	3.7	100.0
Total	54	100.0	



Figure 4: Picture taken from Ethiopian and German skull in University of Gondar in 2016 showing various shapes of foramen magnum of (A- oval, B-hexagonal, C-irregular, D-egg, E- triangular, F-round, G- pentagonal, H-rectangular) B, D and F are being Ethiopian skull and those left are German skull.

### 4.3. Morphometry of the occipital condyle

#### 4.3.1. Length and width of the occipital condyle

The present study indicates that the mean length of right occipital condyle was found to be 25.69mm, ranging from 19-33mm with a standard deviation of 3.447. Similarly, the mean length of left occipital condyle was 26.96mm, ranging from 19-40 mm with a standard deviation of 3.928. The mean length of total 108 occipital condyles was 26.325mm, ranging from 19-40mm. It was found that the length of OC is greater on the left side than on the right side, with 'p' value being 0.001 ( $p=0.001$ ). On the other hand it was found that the mean width of right occipital condyle was 12.76 mm, ranging from

10-21mm and with a standard deviation of 1.893. Similarly, the mean width of left occipital condyle was 13.04mm, ranging from 10-24mm with a standard deviation of 2.046. The mean width of total 108 occipital condyles was 12.9mm, ranging from 10-24mm. Comparisons between the right and left width of OC does not show statistical significance difference (p=0.36))

**Table 4:** Overall length and width of the occipital condyle of Ethiopian and German skull in University of Gondar in 2016

Dimension of OC	N	Minimum	Maximum	Mean	Std. Deviation
ROCL	54	19	33	25.69	3.447
ROCW	54	10	21	12.76	1.893
LOCL	54	19	40	26.96	3.928
LOCW	54	10	24	13.04	2.046

**Table 5:** length and width of the occipital condyle among Ethiopian and German skull in University of Gondar in 2016

Dimension of OC	Race	N	Mean	Std. Deviation	Std. Error Mean
ROCL	Ethiopian	26	25.65	3.644	.715
	German	28	25.71	3.321	.628
ROCW	Ethiopian	26	12.92	2.261	.443
	German	28	12.61	1.499	.283
LOCL	Ethiopian	26	26.92	3.762	.738
	German	28	27.00	4.146	.783
LOCW	Ethiopian	26	12.88	1.395	.274
	German	28	13.18	2.525	.477

As shown in the table 6 occipital condyle can be classified in to short, moderate and long type based on their length. In this study, it was observed that, 2 occipital condyles were of short type (1.85%) which is <20mm, and 55 condyles were of moderate type (50.9%) which is 20-26mm and 51 condyles were of long type (47.2%) which is >26mm.

**Table 6:** Percentage of occipital condyles of different types of Ethiopian and German skull in University of Gondar in 2016

Type of OC	Number of OC	Percentage
Type 1- short(<20mm)	2	1.852%
Type 2- moderate (20-26mm)	55	50.92%
Type 3- long(>26mm)	51	47.222%

## 5. Discussion

The morphologic and morphometric analysis of the foramen magnum and occipital condyle was studied in 54 dried human skulls.

### Morphometry and morphology of the foramen magnum and occipital condyle

Foramen magnum is a transition zone between the spine and the skull. Morphometric analysis of the foramen magnum helps in planning of surgical intervention involving the base of the skull. A total of 54 Ethiopian and German skulls were analyzed for their APD, TD, shape and area.

In this study the mean APD of the FM is 35.19mm and the mean TD of FM is 30.17mm. Similar study conducted in Indian Population of 150 skulls in 2014 shows that the mean APD of foramen magnum was found to be 35.30mm and the mean TD was 29.49mm [1]. our finding was also comparable with study conducted in Greek population in 2013 [5]. Riyaz and Siddiqui found in a morphometric study of 62 dry skulls, the average anteroposterior and transverse diameter of the foramen magnum was 33.4mm and 28.5mm respectively [1]. Similarly Mushed et al reported that the mean APD and TD of the foramen magnum were 35.3mm and 29.49mm respectively [7]. Mustafa et al studied Anatomical variation of the FM, OC and jugular tubercle of Turkey skull and they have reported that the mean APD and TD were 34.5mm and 29mm respectively [13].

Hence, the result of the present study is similar to the above mentioned studies. From the above data, it can be stated that the anteroposterior diameter is generally larger than transverse diameter

The shape and morphological variations of the foramen magnum are important in neurological interpretation. In an ovoid type of the foramen magnum, the ability of the surgeon to adequately expose the anterior portion of the foramen magnum might be difficult [4]. There are various types of foramen magnum based on its shape. It can be oval, egg, round, tetragonal, pentagonal, hexagonal and irregular shape. In the present study round shaped foramen magnum were found more frequently which accounts for 25.9%, which was similar to the results obtained in study conducted in south Indian

population in 2012 which accounts for 24.64%. Our finding was also comparable with study conducted in Indian in 2015.

The types of the foramen magnum based on their shapes were compared with the previous studies and tabulated in the table below

**Table 7:** Types of the foramen magnum based on the shape in comparison with previous studies

Shape of FM	Study (Authors)				
	Sahoo et al (2015)	Riyaz et al (2015)	Radhakrishna et al (2012)	Inceleme et al (2012)	Present study
Oval	14.7%	31.4%	53.24%	15.1%	18.5%
Egg	21%	-	2.36%	18.9%	20.4%
Round	14%	29.5%	24.64%	22.6%	25.9%
Triangular	-	-	-	-	1.9%
Pentagonal	-	1.63%	1.29%	3.8%	11.1%
Hexagonal	-	8.9%	1.29%	5.6%	7.4%
Irregular	0.7%	11.47%	-	-	13%
Rectangular	14%	-	-	-	1.9%

Riyaz.et.al calculated the surface area of the Foramen by using formula,  $Area = \frac{\pi \times \{(h \times w)/4\}}$  and they found that the mean surface area of foramen magnum was 747.92mm<sup>2</sup>[1]. Similarly Patel et al reported that the mean surface area of the FM was 755.67 mm<sup>2</sup> [9]. Our study has revealed that the mean surface area of the foramen magnum was 853.36mm<sup>2</sup> which is greater than the above result. The possible reason for difference between the results could be sex, age, race and geographical variation.

The OC is the major factor when neurosurgeon evaluates the amount of bone removal. The most important question when performing this procedure is how much of the OC should be removed.

Therefore, the OCL should be measured preoperatively, in order to determine the exact area of resection, paying extra attention when the OC is short [5]. In our study, we found short OC in 1.85 % of the skulls. This result is away from the results obtained by Riyaz et al, Kondil et al and Natsis et al who observed short OC in 10%, 5% and 7% respectively. Similarly present study reveal moderate OC in 50.9% of the skull which is away from the result obtained by Kondil et al, Riyaz et al and Natsis et al who observed moderate OC in 62%, 87.67% and 75.9% respectively. On the other hand our study shows that 47.22% of OC is long type which is away from the results obtained by Natsis et al, Riyaz et al Kondil et al which is 17.1%, 2.3% and 33% respectively. The possible reason for the differences between the results could be due to age, gender, racial and geographic variations in the cranial morphometry of different studied populations and small number of sample in our study.

In the present study, as depicted in tables below, the mean length of ROC and LOC is 25.69mm and 26.96mm respectively showing significant difference between two sides. This measured length is comparable to what was found by Natsis et al who reported the length as 25.6mm in both right and left OC, but far-away from the result obtained by Riyaz et al who reported the length as 22.45mm on the right and 22.65mm on the left. The possible reason for the difference between the results could be due to age, gender, racial and geographic variations. Similarly present study reveals that the mean width of ROC and LOC is 12.76mm and 13.04mm respectively. This value is comparable to result found by Riyaz et al who reported mean width as 12.55mm on the right and 12.92mm on the left, but away from result obtained by Sahinoglu et al, who reported the width as 11.3mm on the right and 11.4mm on the left.



**Table 8:** comparison of length and width of occipital condyle with previous study

Authors	Body side			
	Mean ROCL in mm	Mean ROCW in mm	Mean LOCL in mm	Mean LOCW in mm
Kondil et al (2010)	23.7	12.2	24	12.4
Riyaz et al(2015)	22.45	12.55	22.65	12.92
Natsis et al (2013)	25.6	13.09	25.6	13.01
Sahinoglu et al (1999)	23.1	11.3	22.9	11.4
Present study	25.69	12.76	26.96	13.04

## 6. Limitation of the study

This study has the limitation of the unknown age and sex of the subjects, which could be a factor that affects the morphology and morphometry of the FM and occipital condyle region.

It was impossible to collect adequate number of skull since there was scarcity of skull

## 7. Conclusion

In the present study it can be concluded that the mean APD, TD and Area of FM both Ethiopian and German skulls do not showed significant difference

The mean length and width of ROC of Ethiopian skull exceed the German skull whereas, the mean length of LOC of German skull exceed Ethiopian skull despite absence of statistically significant difference.

The mean width of OC of Ethiopian and German skull does not show any significant difference whereas the mean length of right and left OC shows significant difference

Round shaped foramen magnum were found more frequently whereas triangular and rectangular shapes were found less frequently.

## **8. Recommendations**

### **For researcher**

To have a better understanding of the morphometry and morphology of FM and OC further research should be done considering sex and age as well as comparing results of CT measurements with anatomical measurements.

To conclude for the general population, it will be good to conduct a research using large number of skull

### **For Anatomist and physician of multiple disciplines**

The detailed morphometric and morphological information on foramen magnum and occipital condyle provided in this result could be a base line for Anatomist and physicians of multiple disciplines such as orthopedics, neurology, ENT, radiology, neurosurgery.

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## 10. Annex

### Annex I: Declaration

I the undersigned MSc student declare that this thesis is my original work in partial fulfillment of the degree of master in Human Anatomy. I also declare that it has never been presented in this or any other university and that all resources and materials used in this thesis has been acknowledged

Name of the student Sisay Degno

Date.....signature.....

This thesis has been submitted with our approval as university advisors

Name of the advisor 1. Mueez Abraham

Name of the advisor 2.Yared Asmare

**Annex II:** Data collection format

date of data collection.....

Skull no.....

S. No	Parameters
1	APD
2	TD
3	ROCL
4	ROCW
5	LOCL
6	LOCW
7	Area
8	Shape
9	Race

