Original article:

A Morphological and morphometric study of foetal and adult, human foramen magnum in relation with age changes, sexual dimorphism and symmetry

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Abstract:

Introduction: Foramen Magnum (FM) is The most important bony foramen at the skull base, and the information regarding this foramen is useful for various skull base surgeries, radiological and forensic investigations, anatomical and anthropological studies. This study is carried out with following aims 1) To study various dimensions of foramen magnum. 2) To study comparative morphometry of the foramen Magnum between foetal, adolescent & adult age. 3) To study symmetry of the foramen Magnum with respect to midline. Also statistical analysis has been carried out to show the age changes and morphology of foramen magnum from foetal to adult age and in male and female sex and to show the symmetry of foramen magnum.

Method: 181 skulls of known sex (age ranging from 13 to 60 and above), and 54 foetal skulls were studied from different medical institutes in Maharashtra, Karnataka, Andhra Pradesh, and Chattisgarh states of India. The skulls were divided into 5 groups as A: foetal age group; B-f: female skulls of age group 13-25 years; B-m: male skulls of age group 13-25 years; C-f: female skulls of age group above 25 years; C-m: male skulls of age group above 25 years.

Observations and results: Foramen Magnum showed statistically significant difference in its morphology as the age advanced from foetal to adolescent and adolescent to adult age. Foramen Magnum showed significant sexual dimorphism within adoloscent group ($p<0.05$) but did not show significant sexual dimorphism within adult group. Further the foramen magnum showed significant asymmetry in foetal age and it becomes more symmetrical with advanced age, however it was longer posteriorly than anteriorly. In some foetal and adult skulls, the FM also showed a significant angle between its anteroposterior diameter and the Y-axis mid sagittal line of the skull.

Conclusion: The dimensions of FM show statistically significant increase from foetal to adult age, the FM shows significant sexual dimorphism within adolescent male and females but not within adult male and females. The FM is significantly asymmetrical in foetal age and becomes more symmetrical as the age advances to adolescent and adult age. The FM is longer posteriorly than anteriorly and sometimes shows an angle between its anteroposterior diameter and Y axis, and this angle can be seen in all the age groups.

Key Words: Foramen Magnum

Introduction

The Foramen Magnum (FM), is the most important bony foramen at the skull base and the knowledge about its various dimensions is necessary for radiologists, for surgeons to perform various skull base surgeries, for forensic experts to differentiate in age groups and sex, for anatomists and anthropologists.

Standard literature quotes the FM to be oval in shape, wider posteriorly than anteriorly. The FM can be used to differentiate between the adult male and female sex in humans, [1,2]. Sexual dimorphism, however, cannot be made out in the foetal or infant age as the skull bones are not completely formed [4]. Among the researchers who have worked on the FM, some have found that the FM shows sexual dimorphism, while some have stated that the FM does not show sexual dimorphism. The morphological variations in FM are significant and it is important to study the symmetry of FM. Therefore the present study was carried out with following objectives;

1) To study various dimensions of the FM by setting different parameters.

2) To compare the morphometric dimensions of the FM between foetal, adolescent & adult age.

3) To study symmetry of the FM with respect to midline in skull groups of same age.

Materials and Method

A total of 235 dry skulls were studied for this purpose which included 181 adult and 54 foetal skulls. Adult skulls were of known age and sex. The skulls studied were categorised into Five groups labelled as A, B-f, B-m, C-f and C-m. A Group included 54 foetal skulls sex differentiation is not possible in this group). Second and third group is of skulls of age between 13 years to 25 years, these groups were labelled as B-f for female skulls which included 26 skulls, and group B-m for male skulls which included 44 skulls . The fourth and fifth group is of skulls above 25 years of age, and these groups were labelled as, C-f for female skulls, which included 34 skulls, and group C-m for male skulls, which included 77 skulls. The dimensions of FM in each skull were measured by using a screw adjustable pair of compass. The measurements on the compass were read by a Vernier Calliper (zero error). The dimensions were measured thrice and the average was taken as the final reading to eliminate personal bias. The base of each skull studied was photographed for reference by using a digital camera. The readings taken were tabulated and processed and analysed statistically. Statistical calculations were done with the help of statistical software. The 'students t test for independent and correlated samples' and one way ANOVA with significance level of 95% or more ($p<0.05$) was considered significant.

The Antero-Posterior Diameter (abbreviated as APD, line C-B in photograph 3) and Transverse Diameter (Abbreviated as TD, line D-E in photograph 3) of the FM in each skull were measured. In this study the terms APD and TD are used instead of Longest and Shortest Diameter respectively, as it was observed in 11 skulls out of 235 skulls studied (4.6%), that the TD is larger than the APD (Photograph 3), therefore, using these terms would give a more precise idea about in which way the FM is actually larger in diameter. To know the symmetry of FM, X-axis and Y-axis were marked on the norma occipitalis. The Pharyngeal Tubercle (PT) is situated almost on the centre of basi-occiput and it was used as a landmark point for the junction of X and Y axis (point 'G' in photoghraph 3). The X-axis extends normally up to the posterior border of mandibular fossa in the adult skull. The Y-axis extends anteriorly from the middle of the vomerovaginal canal, posteriorly up to the external occipital crest which is an elevated vertical ridge behind the posterior margin of foramen Magnum, it passes normally from the middle of foramen Magnum (where it is made out by placing a thread of calibre 0.01mm congruently upon the entire Y-axis) (photograph 1,2,3). The shortest distance of each FM, from its anterior end to the PT was measured (line B-G in photograph 3). The shortest distance of X-axis from TD was measured, which required three measurements, as follows;

- First, the shortest distance of TD to PT is measured (Line A-G, photograph 3).
- shortest distance of the farthest point on TD on left and right side respectively from the X axis is measured. (Line D-F on left side ,and Line E-H on right side respectively). These measurements were taken to observe the symmetry of the FM with respect to X-axis (Photograph 3)

The shortest distance of X-axis from APD is already measured as the shortest distance between anterior margin of foramen Magnum & Pharyngeal tubercle (line B-G in photograph 3)

As observed in most of the FM, the APD coincides with the Y axis and there is no angle formed in them. However, in some cases where it does not coincide with the Y axis, (49 skulls in this study) an angle is made by the APD with

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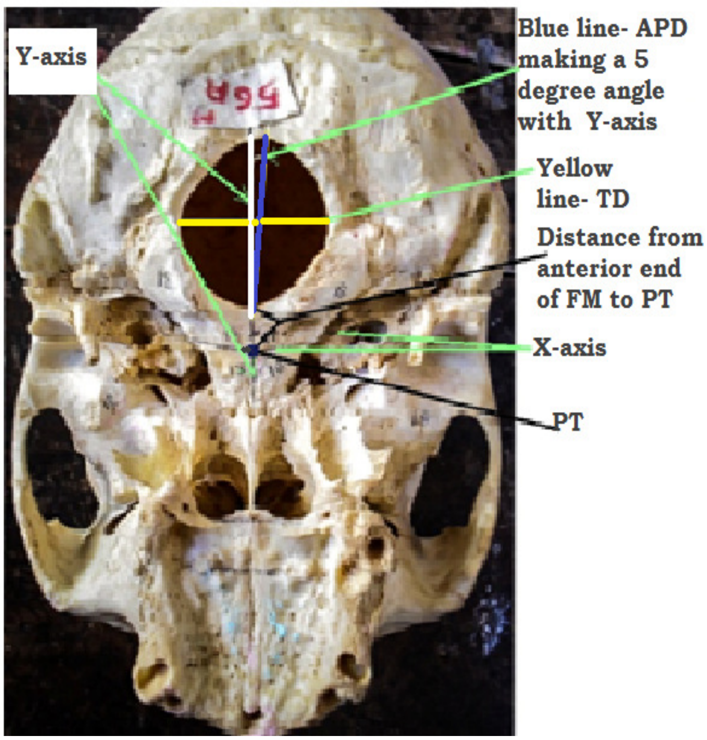
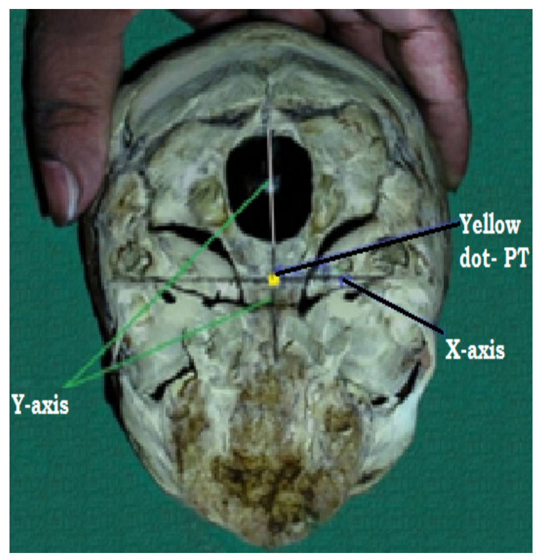
the Y axis in the FM (Photograph 1), such angles formed in the FM were measured in this study with the help of a semicircle protractor against a thread of calibre 0.5 mm placed congruently on the Y axis, with the base line of the protractor lying congruently on the Y axis and the centre of the protractor on the point of union of Y axis and the APD.

Distance AB & AC is measured which represents distance between point of intersection of AP & transverse Diameter to farthest point on anterior margin & posterior margin of foramen Magnum respectively.

Similarly distance AD & AE is also measured which represents distance between point of intersection of AP & transverse Diameter to farthest point on Left & Right margin of Foramen Magnum respectively.



Photograph 1: (Skull No. 81) Showing Angle of APD with Y-axis, Distance from PT The Y-axis, X-axis, PT, APD and TD.



Photograph 2: (Skull No. 228) foetal skull showing the Y-axis, PT and the X-axis.

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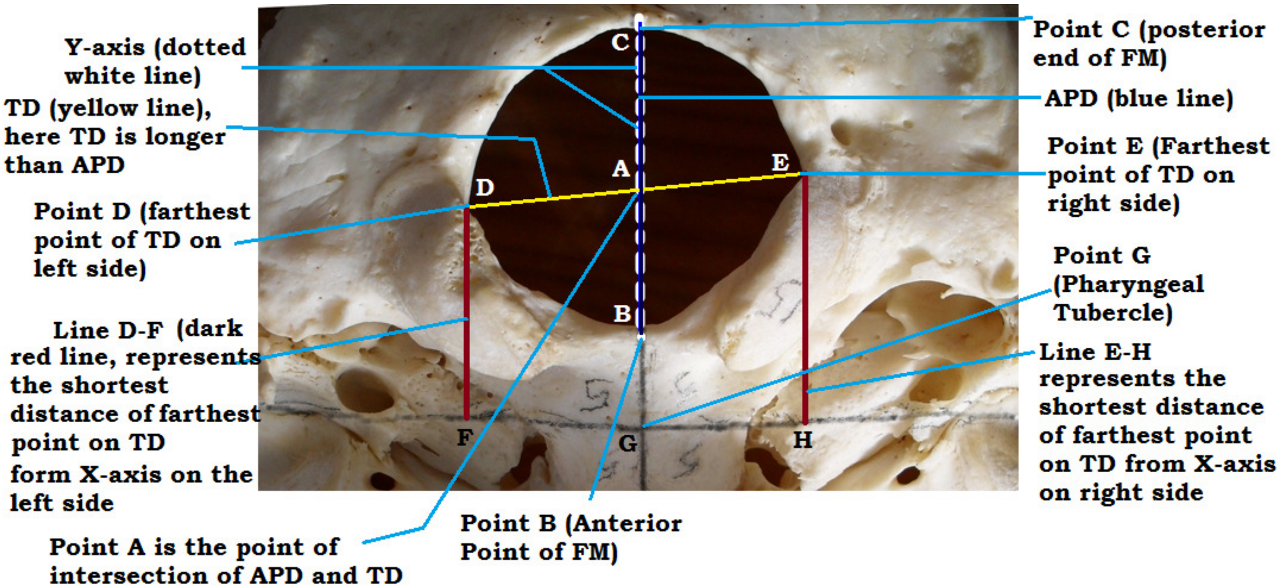

Photograph 3: Shows the X-axis and Y-axis. Y-axis continues imaginarily through the FM. Point A is the intersecting point of APD and TD. Here the APD coincides with the Y-axis. Point F and H are shortest distance of the farthest point on TD on left and right side respectively from X-axis. Various other points have been explained on the digram. ***This Photograph also shows that, in this perticular skull (skull No. 5), the TD is longer than APD.***

Observations and Results:

Part 1: The morphological and morphometric dimensions of FM were observed and measured in part 1. Table 1 below, shows the mean, maximum and minimum range, and standard deviation of dimensions of foramen magnum, which were measured in this study.

Table 1.

APD (Line C-B)	A	B-f	B-m	C-f	C-m	**TD (Line D-E)**	A	B-f	B-m	C-f	C-m
Mean	1.295	3.361	3.448	3.49	3.515	Mean	1.095	2.833	2.937	2.89	2.938
Minimum	0.4	2.813	2.9	2.965	2.64	Minimum	0.321	2.5	2.4	2.4	2.4
Maximum	2.725	3.785	3.84	3.921	4.088	Maximum	1.9	3.242	3.476	3.6	3.785
SD	0.462	0.252	0.243	0.2369	0.2699	SD	0.3246	0.2148	0.2458	0.2516	0.2225
Distance from PT (Line B-G)	A	B-f	B-m	C-f	C-m	**TD-PT (Line A-G)**	A	B-f	B-m	C-f	C-m
Mean	0.722	1.154	1.174	1.154	1.155	Mean	1.299	2.632	2.705	2.673	2.659
Minimum	0.2	0.855	0.9	0.886	0.8	Minimum	0.371	2.213	2.213	2.257	1.849

Maximum	1.42	1.434	1.675	1.415	1.658
SD	0.2169	0.178	0.1687	0.1363	0.1783

Maximum	2.154	3.066	3.188	3.254	3.32
SD	0.3265	0.2308	0.2291	0.2282	0.4077

APD to Farthest Point on TD, Right (Line A-E)	A	B-f	B-m	C-f	C-m
Mean	0.551	1.413	1.468	1.454	1.458
Minimum	0.164	1.2	1.224	1.1	1.19
Maximum	1.1	1.612	1.711	1.9	1.695
SD	0.1779	0.122	0.1249	0.1442	0.1186

APD to Farthest Point on TD, Left (Line A-D)	A	B-f	B-m	C-f	C-m
Mean	0.544	1.42	1.469	1.439	1.466
Minimum	0.157	1.237	1.165	1.215	1.21
Maximum	0.827	1.64	1.787	1.725	1.737
SD	0.1552	0.1105	0.1485	0.1348	0.1074

TD to Farthest Point on APD Anterior (Line A-B)	A	B-f	B-m	C-f	C-m
Mean	0.571	1.492	1.512	1.5	1.516
Minimum	0.171	1.148	1.124	1.134	1.079
Maximum	0.914	1.86	1.944	1.868	2.08
SD	0.1866	0.1878	0.1891	0.1716	0.1676

TD to Farthest point on APD posterior (Line A-C)	A	B-f	B-m	C-f	C-m
Mean	0.725	1.905	1.959	1.942	1.999
Minimum	0.229	1.629	1.156	1.357	1.378
Maximum	1.811	2.29	3.119	2.3	2.494
SD	0.3439	0.215	0.3016	0.2359	0.2212

X-axis to Farthest Point on TD, Right (Line E-H)	A	B-f	B-m	C-f	C-m
Mean	1.308	2.514	2.54	2.563	2.594
Minimum	0.359	2.099	1.998	2.055	1.695
Maximum	2.174	3.045	3.318	3.287	3.241
SD	0.3222	0.2666	0.3124	0.2976	0.3107

X-axis to Farthest Point on TD, Left (Line D-F)	A	B-f	B-m	C-f	C-m
Mean	1.33	2.53	2.579	2.55	2.58
Minimum	0.378	2.156	1.912	1.91	1.91
Maximum	2.123	3	3.055	3.078	3.355
SD	0.3334	0.2346	0.3011	0.2722	0.2601

Angle of APD with Y-axis	A	B-f	B-m	C-f	C-m
Mean	1.759	0.788	0.45	0.509	0.429
Minimum	0	0	0	0	0
Maximum	7.8	4.5	5	4	5.2
SD	1.9559	1.5822	1.2633	1.3313	1.2267

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In part 1 of the observations, it was seen the observed measurements of the parameters of morphometric dimensions and symmetry of the FM, gradually increase form foetal to adolescent and adult group and they also show difference within male and female groups.

Part 2: This part of the observations shows the comparison between the dimensions of different groups. The tables 2.1 to 2.6 show comparison of one group with the other group to observe the age changes. The tables 2.7 and 2.8 show comparison between male and female to observe sexual dimorphism. The dimensions compared in this part are, APD, TD, PT and TD-PT, as these represent the morphometric dimensions of the FM. The tables below show the results of the comparisons.

Mean of the Parameters	A group	B-m group	p
APD (Line C-B)	1.295	3.448	**<0.01**
TD (Line D -E)	1.095	2.937	**<0.01**
PT (Line B-G)	0.722	1.174	**<0.01**
TD-PT (Line A-G)	1.299	2.705	**<0.01**

Mean of the Parameters	A group	B-f group	p
APD (Line C-B)	1.295	3.361	**<0.01**
TD (Line D -E)	1.095	2.833	**<0.01**
PT (Line B-G)	0.722	1.154	**<0.01**
TD-PT (Line A-G)	1.299	2.632	**<0.01**

Mean of the Parameters	A group	C-f group	p
APD (Line C-B)	1.295	3.49	**<0.01**
TD (Line D -E)	1.095	2.89	**<0.01**
PT (Line B-G)	0.722	1.154	**<0.01**
TD-PT (Line A-G)	1.299	2.673	**<0.01**

Mean of the Parameters	A group	C-m group	p
APD (Line C-B)	1.295	3.515	**<0.01**
TD (Line D -E)	1.095	2.938	**<0.01**
PT (Line B-G)	0.722	1.155	**<0.01**
TD-PT (Line A-G)	1.299	2.659	**<0.01**

Mean of the Parameters	B-m group	C-m group	p
APD (Line C-B)	3.448	3.515	>0.05
TD (Line D -E)	2.937	2.938	>0.05
PT (Line B-G)	1.174	1.155	>0.05
TD-PT (Line A-G)	2.705	2.659	>0.05

Mean of the Parameters	B-f group	C-f group	p
APD (Line C-B)	3.361	3.49	**<0.05**
TD (Line D -E)	2.833	2.89	>0.05
PT (Line B-G)	1.154	1.154	>0.05
TD-PT (Line A-G)	2.632	2.673	>0.05

Mean of the Parameters	B-f group	B-m group	p
APD (Line C-B)	3.361	3.45	**<0.05**
TD (Line D -E)	2.833	2.937	**<0.05**
PT (Line B-G)	1.154	1.174	>0.05
TD-PT (Line A-G)	2.632	2.705	**<0.05**

Mean of the Parameters	C-f group	C-m group	p
APD (Line C-B)	3.49	3.515	>0.05
TD (Line D -E)	2.89	2.938	>0.05
PT (Line B-G)	1.154	1.155	>0.05
TD-PT (Line A-G)	2.673	2.659	>0.05

1. In part 2, highly significant increase in the measurements of all the parameters of morphometric dimensions of FM was observed from foetal to adolescent (B-m & B-f) & adult age group (C-m & C-f). (Table 2.1, 2.2, 2.3 and 2.4).
2. The adult male group (C-m) did not show significant increase in the measurement of any parameter of

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morphometric dimension of FM over adolescent group (B-m) (Table 2.5). However, the adult female group (C-f) showed statistically significant increase in the APD over adolescent female group (B-f) (Table 2.6), the other parameters of morphometric dimensions did not show significant increase between C-f and B-f group.

3. The adolescent male group (B-m) showed statistically significant increase in the APD, TD, and TD-PT (line A-G, photograph 3), over adolescent female group (B-f), indicating sexual dimorphism between adolescent male and female (Table 2.7).
4. The adult male however did not show any significant increase in the measurements of any parameter of morphometric dimensions over adult female, indicating absence of sexual dimorphism in adult male and female (Table 2.8).

Part 3: Next part of observation is to study the symmetry of FM. For this purpose only the measurements of parameters of symmetry are compared. Here the parameters of left side are compared with right side and anterior side compared with posterior side within the same group. The compared parameters are as shown below in table 3.1 to 3.3; (refer photograph 3)

Table 3.1

Groups	APD to farthest point on TD, Right (Line A-E) (Mean)	APD to farthest point on TD, Left (Line A-D) (Mean)	p
A Group	0.551	0.544	**<0.05**
B Group Female	1.413	1.42	>0.05
B Group Male	1.468	1.469	>0.05
C Group Female	1.454	1.439	>0.05
C Group Male	1.458	1.466	>0.05

Table 3.2

Groups	X-axis to farthest point on TD, Right (Line E-H) (Mean)	X-axis to farthest point on TD, Left (Line D-F) (Mean)	p
A Group	1.308	1.33	**<0.05**
B Group Female	2.514	2.53	>0.05
B Group Male	2.54	2.579	>0.05
C Group Female	2.563	2.55	>0.05
C Group Male	2.594	2.58	>0.05

Table 3.3

Groups	TD to farthest point on APD, Anterior (Line A-B) (mean)	TD to farthest point on APD, Posterior (Line A-C) (mean)	p
A Group	0.571	0.725	**<0.05**
B Group Female	1.492	1.905	**<0.05**
B Group Male	1.512	1.959	**<0.05**
C Group Female	1.5	1.942	**<0.05**
C Group Male	1.516	1.999	**<0.05**

1. In part 3, all the measurements of the parameters of symmetry of FM showed highly significant asymmetry in the foetal age group (A group) (Table 3.1, 3.2, and 3.3).
2. The measurement of Line AE & Line AD (i.e. APD to farthest point on TD, Right versus Left) and Line EH & DF (i.e. X-axis to farthest point on TD, Right versus Left) did not show any

significant asymmetry in adolescent groups (B-m and B-f) and in adult groups (C-m and C-f). However, the measurement of Line AB & AC (i.e. TD to farthest point on APD, Anterior versus Posterior) showed highly significant asymmetry in all age groups (i.e foetal, adolescent and adult). Here the measurement of the posterior side of FM (Line AB) was significantly higher (statistically) than the anterior side (Line AC) (Table 3.3).

In this study Angle of APD with Y axis was seen in 49 cases out of 235 skulls studied (total 20.9 %). The details of group wise appearance of such skulls given ahead; group A- 21 skulls out of 54 (38.8%), group B-f- 6 skulls out of 26 (23.07%), group B-m- 6 skulls out of 44 (13.6%), group C-f- 5 skulls out of 34 (14.7%), group C-m- 11 skulls out of 77 (14.2%). It was thus observed that, the angle of APD with Y axis is seen in all the age groups.

Further, in most of the FM, it was observed that the APD was longer than TD, however in 11 skulls (out of 235; total 4.6%) it was observed that TD was longer than APD (Photograph 3). Given ahead is the group wise listing of such skulls seen out of the number of skulls studied, group A – 6 skulls out of 54 (11.1%), group B-f – 0 skulls out of 26, group B-m – 2 skulls out of 44 (4.5%), group C-f – 1 skull out of 34 (2.9%), group C-m – 2 skulls out of 77 (2.6%). It was thus seen that such skulls are found in all age groups.

Discussion:

The FM has been a subject of interest for many researchers, who studied the morphology, morphometry and sexual dimorphism in FM. While most of them have found sexual dimorphism in FM, [10,15,17] some concluded that the FM does not show sexual dimorphism [12,16,18]. In this study, various morphological and morphometric dimensions of FM are studied to observe the age changes, sexual dimorphism, and symmetry of FM. The measurement of Antero-posterior and transverse diameter in the present study is compared below with other researchers;

Table 4

Authors		Antero-Posterior diameter		Transverse diameter	
		Female	Male	Female	Male
Suazo G. I. C. et al. (2009) [4]		3.56 ±0.25	3.65 ±0.26	2.95 ±0.19	3.06 ±0.25
Philipp Gruber et al. (2009) [5]		3.58 ±0.35	3.71 ±0.27	3.1 ±0.28	3.24 ±0.24
Manoel, C. et al (2009) [6]		3.51 ±0.33	3.57 ±0.29	2.94 ±0.23	3.03 ±0.20
Emel Avci (2010) [7]		3.45		2.9	
P. Chethan et al. (2011) [8]		3.1 ±0.24 mm		2.52 ±0.24 mm	
Radhakrishna S. K. et al (2012) [9]		3.17 ±0.21	3.40 ±0.24	2.66 ±0.16	2.86 ±0.19
F. Burdan et al. (2012) [10] (CT)		3.55 ±2.60	3.71 ±3.07	3.09 ±2.78	3.298 ±2.71
Damiani, D. et al (2012) [11] (MRI)		3.48 ±2.19		2.87 ±2.73	
Loyal P et al. (2013) [12]		3.4	4.0	2.8	3.8
Shanthi C. H, S. Lokanadham (2013) [13]		3.38 ±0.38	3.71 ±0.33	3.04 ±0.30	3.20 ±0.31
S. K. Jain et al. (2013) [14]		3.29 ±0.3	3.69 ±0.2	2.95 ±0.28	3.15 ±0.27
Tanuj Kanchan et al. (2013) [15]		3.36 ±2.63	3.45 ±2.77	2.67 ±2.36	2.74 ±2.09
Roma Patel, C. D. Mehta (2014) [16]		3.37		2.83	
Muralidhar P Shepur et al (2014) [17]		3.31 ±0.27	3.34 ±0.26	2.73 ±0.2	2.85 ±0.22
Present Study	A Group (foetal)	1.29 ±0.46		1.09 ±0.33	
	B-m and B-f Group (Age 13-25)	3.36 ±0.24	3.45 ±0.25	2.83 ±0.25	2.94 ±0.22
	C-m and C-f Group (Age 26-60 and above)	3.49 ±0.27	3.52 ±0.24	2.89 ±0.22	2.94 ±0.25

Present study was performed by grouping the skulls into foetal, adolescent male, adolescent female, adult male and adult female group. The skulls of foetal group were not differentiated into male and female sex and however it was observed that the measurements of the foetal parameters were significantly less than that of the adolescent and adult measurements. No data could be found of the study of FM on human foetal skulls. Also, no data could be found on the study of symmetry of FM. In case of adolescent female skulls (B-f group) in this study the mean of the measurements of APD is near to the to the findings of Muralidhar P. Shepur et al [17], Shanthi C. H. et al [13], Tanuj Kanchan et al [15] and Roma Patel et al [16], and the mean of measurements of TD is near to the findings of Loyal P. et al [12] , Muralidhar P. Shepur et al [17], (Table 4)

The mean of measurements of APD of adolescent male skulls of (B-m group) is close to findings of Tanuj Kanchan et al [15] and Radhakrishna S. K. et al [9], whereas the mean of measurement of TD is close to the findings of Emel Avci et al [7], Damiani D. et al [11]. and Muralidhar P. Shepur et al [17]. Further, in case of adult female skulls (C-f group) the mean of measurements of APD is near to the findings of Manoel C. et al [6] and the mean of measurements of TD is close to the findings of Manoel C. et al [6], Suazo G. I. C. et al [4] and S. K. Jain et al [14]. In case of adult male the mean of measurements of APD is near to the findings of Manoel C. et al [6] and Tanuj Kanchan et al [15], whereas the mean of measurements of TD is near to the findings of Manoel C. et al [6] and Radhakrishna S. K. et al [9].

In the present study sexual dimorphism was observed between adolescent male and female skulls (groups B-m and B-f) in the parameters of APD and TD and TD-PT of FM, which is similar to the findings of Radhakrishna S. K. et al [9], F. Burdan et al [10] (study on CT images), S. K. Jain et al [14], Shanthi C. H. et al [13] and Suazo G. I. C. et al [4]. In the present study however, it was observed that the sexual dimorphism was absent between adult male and female skulls (group C-m and C-f) which is similar to the findings of Tanuj Kanchan et al [15] Loyal P. et al [12], Philipp Gruber et al [5] and Damiani D. et al [11]. Furthermore, Manoel C. et al [6] and Muralidhar P. Shepur et al [17] stated that the FM shows statistically significant asymmetry only in case of TD and not in case of APD.

Embryology:

In this study it was observed that the posterior part of occipital bone lies anterior to the squamous part of occipital bone which itself is separated from the rest of the occipital bone. Even the two lateral parts are separated from the basilar part at the occipital condyles, dividing the occipital condyles into anterior one-third and posterior two-third. The site of their union remains patent forming the hypoglossal canal later in life. This finding was similar to the standard literature [1,2,3]. This might be the reason for the FM to show high amount of variability and asymmetry in foetal age as observed in this study. As the age grows these parts of occipital bone fuse and thus the FM shows less asymmetry.

Conclusion:

As the observation and results of this study were grouped in three parts the findings of this study are concluded in three parts as under;

1. The morphometric and morphological dimensions FM were measured in the first part, and it was concluded that the dimensions of FM change significantly from foetal to adolescent and adult age.
2. In the second part, the following things were concluded;
   a. The FM shows highly significant increase in morphometric parameters of ‘APD, TD, distance from PT and distance from TD to PT’ from foetal to adolescent age and from foetal to adult age.
   b. When the FM of adolescent female is compared to adult female the FM shows significant age changes (in this study, the parameter of APD)
   c. When the FM of adolescent male is compared to adult male, no age change is observed.

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d. When the FM of adolescent male is compared to adolescent female (for sexual dimorphism), the adolescent male shows statistically significant sexual dimorphism over adolescent female. (in this study APD, TD, and distance from TD to PT)

e. When the FM of adult male is compared with adult female (for sexual dimorphism), the FM does not show significant sexual dimorphism.

3. In the third part, following things were concluded;

a. The FM was divided into right and left side with respect to APD and taking the point of intersection of APD and TD as centre. It was concluded that when the left side of FM is compared with the right side, in the foetal age, the FM shows statistically significant asymmetry, however, the asymmetry in the right and left half of FM becomes insignificant in adolescent and adult age.

b. The FM was divided into anterior and posterior parts with respect to TD and taking the point of intersection of APD and TD as centre. By comparing the anterior and posterior part of FM it was concluded that the FM is longer posteriorly than anteriorly in all the age groups i.e. Foetal, adolescent and adult.

c. Further, the distance of the lateral ends of FM from the X-axis was measured on either side to observe the tilt in FM, and it was concluded that FM shows a statistically significant right side tilt in Foetal age only, and the tilt in FM becomes insignificant in adolescent and adult age.

Conflicts of interest: None.

Bibliography:

1. Susan Standring, Neil R Borley, Patricia Collins, Alan R Corssman, Michael A Gatzoulis, Jeremiah C. Healy, David Johnson, Vishy, Mahadeved, Richard LM Newell, Caroline B., Wigley. Gray's Anatomy, The Anatomical Basis of Clinical Practice. 40th Edition (15th Anniversary Edition) Churchill Livingstone 2008. International Edition ISBN 978-0-8089-2371-8.
2. Asim Kumar Dutta, Essentials of Human Osteology, 2nd edition ISBN –: 81-86793-62-63 (pg. 93, 146, 155)
3. Keith L. Moore, T. V. N Persaud; The Developing Human: Clinically Oriented Embryology 8th Edition. ISBN: 1416037055, ISBN-13: 9781416037057
4. M. Samii, W. Draf, J. Lang; Surgery of the Skull Base An Interdisciplinary Approach, With a Chapter on Anatomy by J. Lang. 1 st edition, Springer-Verlag, e-ISBN-13: 978-3-642-73061-0.
5. Suazo, G. I. C.; Russo, P. P.; Zavando, M. D. A.; & Smith, R. L. Sexual dimorphism in the foramen magnum dimensions. Int. J. Morphol., (2009), 27(1):21-23,.
6. Philipp Gruber, Maciej Henneberg, Thomas Boni, and Frank J. Ruhli. Variability of Human Foramen Magnum Size. The Anatomical Record (2009) 292:1713–1719.
7. Manoel, C., Prado FB., Caria PHF, and Groppo FC.; Morphometric analysis of the foramen magnum in human skulls of brazilian individuals: its relation to gender; Braz. J. Morphol. Sci., (2009), vol. 26, no. 2, p. 104-108.
8. Emel Avci , Ahmet Dagtekin, A. Hakan Ozturk, Engin Kara, Nail Can Ozturk, Kutluay Uluc, Erinc Akture, Mustafa K. Baskaya. Anatomical variations of the Foramen Magnum, Occipital Condyle and Jugular Tubercle. Turkish Neurosurgery (2011), Vol: 21, No: 2, 181-190
9. P. Chethan, K.G. Prakash, B.V. Murlımanju, K.U. Prashanth, Latha V. Prabhu, Vasudha V. Saralaya, Ashwin Krıshnamurthy, M.S. Somesh, C. Ganesh Kumar. Morphological Analysis and Morphometry of the Foramen Magnum: An Anatomical Investigation. Turkish Neurosurgery (2012), Vol: 22, No: 4, 416-419.

10. Radhakrishna S.K., Shivarama C.H., Ramakrishna A., Bhagya B.; Morphometric Analysis Of Foramen Magnum For Sex Determination In South Indian Population; Nitte University Journal of Health Science NUJHS March (2012), Vol. 2, No.1, ISSN 2249-7110.
11. F. Burdan, J. Szumiło, J. Walocha, L. Klepacz, B. Madej, W. Dworzański, R. Klepacz, A. Dworzańska, E. Czekajska-Chehab, A. Drop; Morphology of the foramen magnum in young Eastern European adults, Folia Morphol., (2012), Vol. 71, No. 4.
12. Damiani, D., Borelli NS., Melo, HJF., Lima, RS. and Nobeschi, L. Morphometry and spatial correlation of the foramen magnum and spinal cord through the magnetic resonance in normal young adults – anatomical and clinical aspects. J. Morphol. Sci., (2012), vol. 29, no. 2, p. 87-90
13. Loyal P, Ongeti K, Pulei A, Mandela P, Ogeng'o J.; Gender Related Patterns In The Shape And Dimensions Of The Foramen Magnum In An Adult Kenyan Population; Anatomy Journal of Africa (2013), 2 (2): 138 – 141.
14. Shanthi CH, S.Lokanadham; Morphometric Study on Foramen Magnum of Human Skulls; Medicine Science (2013); 2(4):792-8
15. SK Jain, Alok Kumar Choudhary, Pankaj Mishra. "Morphometric evaluation of foramen magnum for sex determination in a documented north Indian sample". Journal of Evolution of Medical and Dental Sciences (2013); Vol. 2, Issue 42, October 21; Page: 8093-8098.
16. Tanuj Kanchan, Anadi Gupta, and Kewal Krishan; Craniometric Analysis of Foramen Magnum for Estimation of Sex. International Journal of Medical, Health, Pharmaceutical and Biomedical Engineering (2013) Vol:7 No:7.
17. Roma Patel, C. D.Mehta; Morphometric study of Foramen Magnum at the base of human skull in South Gujarat, IOSR Journal of Dental and Medical Sciences (IOSR-JDMS) e-ISSN: 2279-0853, p-ISSN: 2279-0861. Volume 13, Issue 6 Ver. IV (2014), PP 23-25
18. Muralidhar P Shepur, Magi M, Nanjundappa B, Pavan P Havaldar, Premalatha Gogi, Shaik Hussain Saheb. Morphometric Analysis of Foramen Magnum. Int J Anat Res (2014); 2(1):249-55.