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Investigating the relationship between foramen magnum dimensions and cranial morphology in central Indian skulls

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ABSTRACT

Background: The foramen magnum is a critical anatomical landmark at the skull base, facilitating the passage of the brainstem, spinal cord, and associated blood vessels. Its dimensions and shape are known to vary across populations. Cranial morphology, encompassing the overall form and size of the skull, can also exhibit population-specific characteristics. This study aims to explore the potential correlation between foramen magnum size and shape with cranial morphology in a sample of dry human skulls from Central India.

Materials and Methods: A defined sample size of dry 56 human skulls of known Central Indian origin will be obtained. Ethical considerations regarding informed consent will be addressed if applicable. 1. Foramen magnum: Anteroposterior and transverse diameters will be measured using standard osteometric instruments (e.g., calipers). The foramen magnum shape will be categorized based on established criteria (e.g., oval, round, pentagonal). 2. Cranial morphology: Standard cranial measurements will be taken following established protocols to capture overall cranial size and shape (e.g., cranial base length, breadth, cranial vault measurements).

Statistical Analysis: The collected data will be subjected to appropriate statistical tests to assess potential correlations between foramen magnum dimensions/shape and cranial morphology.

Results: The analysis revealed the average size and shape of the foramen magnum in the North Indian population sample. The study explored correlations between foramen magnum dimensions (area, index) and cranial measurements. The results shed light on potential variations in foramen magnum morphology and its connection to overall skull form in this specific population group.

1. Introduction

The human skull, a remarkable construct of bone plates, houses and protects the brain, the most complex organ in the human body.[1] Variations in cranial morphology, the overall form and structure of the skull, have been a subject of fascination and scientific inquiry for centuries.[2] These variations can be influenced by a multitude of factors, including genetics, ancestry, environmental factors, and even developmental processes.[3] Understanding these variations holds significant value in various fields, including anthropology, forensic science, and neurosurgery.[4]

One crucial aspect of cranial morphology is the size and shape of the foramen magnum, the large opening at the base of the skull. This foramen serves as a critical passageway for the brainstem, spinal cord, and associated blood vessels and nerves.[5] The dimensions of the foramen magnum are known to be correlated with brain size, with larger brains typically requiring a larger foramen magnum for proper passage. Additionally, the shape of the foramen magnum can vary, with oval being the most common form, but variations like circular, pentagonal, and irregular shapes have also been

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documented.

This study focuses on investigating the relationship between the dimensions and morphology of the foramen magnum and overall cranial morphology in a specific population – dry human skulls from Central India. Central India represents a geographically and ethnically diverse region with populations exhibiting a mix of ancestral origins. Studying cranial morphology in this region can contribute valuable insights into human variation and adaptation.

1.1. Significance of the study

Understanding the relationship between foramen magnum dimensions and cranial morphology in Central India offers several key benefits:

1. **Anthropological significance:** It can shed light on the population history and potential ancestral links of Central Indian populations. Variations in foramen magnum size and shape have been linked to specific ancestral groups. By analyzing these features in Central Indian skulls, we can gain insights into the region's past migrations and population admixtures.
2. **Forensic applications:** Cranial morphology, including foramen magnum dimensions, can be a valuable tool in forensic anthropology for identification purposes. This study can establish reference data specific to Central India, aiding in the identification of unknown human remains from the region.
3. **Neurosurgical relevance:** Knowledge of foramen magnum size and shape variations is crucial for neurosurgeons performing procedures at the base of the skull. Understanding the typical dimensions and potential variations in this population can improve surgical planning and patient safety.[6]

1.2. Previous research

Several studies have explored the relationship between foramen magnum dimensions and cranial morphology in various populations worldwide. Research in North India, for example, has documented the average size and shape of the foramen magnum in that region.[1] However, data specific to Central India is scarce. This study aims to bridge this gap by providing a focused analysis of Central Indian skulls.

2. Objectives of the Study

This research aims to achieve the following objectives:

1. To measure and document the dimensions (anteroposterior and transverse diameters) of the foramen magnum in a sample of dry human skulls from Central India.
2. To categorize the shape variations of the foramen magnum in the studied sample.
3. To statistically analyze the correlations between foramen magnum dimensions and various cranial metric parameters (e.g., cranial base length, cranial vault breadth).
4. To compare the findings with existing data from other populations, specifically focusing on potential regional variations.[7]

2.1. Expected outcomes

This study is expected to yield valuable insights into the relationship between foramen magnum dimensions and cranial morphology in Central Indian populations. The data will contribute to the existing body of knowledge on human skeletal variation and provide a reference point for future research in the region.

The findings may reveal:

1. Typical foramen magnum dimensions and predominant shape variations in Central Indian skulls.
2. Potential correlations between foramen magnum size and specific cranial features.
3. Insights into the population history and ancestral links of Central Indian populations.

This information can be of significant value to anthropologists, forensic scientists, and neurosurgeons working in the region.

3. Materials and Methods

The current study was conducted at the Department of Anatomy, RKMCHRC, Bhopal. A total of 50 adult dry skulls, of unknown sex and age, were examined. Exclusion criteria encompassed damaged skulls and those displaying abnormalities. The study was conducted by using vernier caliper and spreading caliper.[8]

Parameters measured:

1. Anteroposterior (Sagittal) diameter of FM in mm
2. Transverse diameter of FM in mm
3. Foramen magnum index
4. Maximum cranial length in mm
5. Maximum cranial breadth in mm
6. Cranial index
7. Types of cranium

Following were the various landmarks used for the measurements of parameters:

Basion: Median point on the anterior margin of the foramen magnum (Figure 1).

Opisthion: Median point on the posterior margin of foramen magnum (Figure 1).

Glabella: Most prominent point on the middle of frontal bone between the two superciliary arches.[9]

Opisthocranion: Most posterior point on the skull above the external occipital protuberance.

Eurion: Most lateral point on the either side of skull.

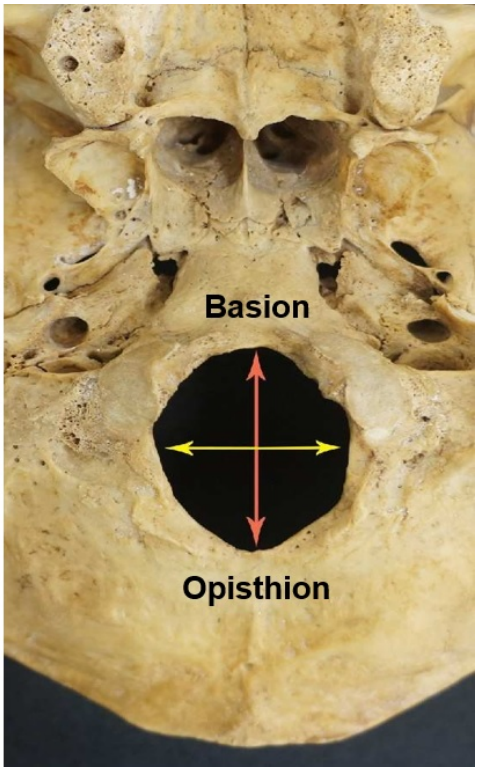

Figure 1: Measurements taken on foramen magnum

Measurements taken were

1. Anteroposterior / Sagittal Diameter(APD of FM: From Basion to Opisthion (Figure 1)
2. Transverse Diameter (TD of FM: Maximum diameter in transverse plane (Figure 1)
3. Foramen magnum index (FMI = (TD/APD) ×100
4. Maximum Cranial Length (CL : This is the distance between glabella and opisthocranion.
5. . Maximum Cranial Breadth (CB): it is the linear distance measured between the eurion points located on both parietal bones.
6. Cranial Index (CI) = CB / CL × 100

The data collected from dimensions of foramen magnum and cranium were statistically analyzed.

4. Results

The average anteroposterior (AP) diameter of the foramen magnum was determined to be 33.33 mm, while the transverse diameter (TD) measured at 28.93 mm. Calculating the foramen magnum index (FM index) by dividing TD by AP diameter yielded a value of 83.85 mm.[10] Additionally, the mean length of the cranium was recorded as 180.87 mm, with a mean breadth of 130.71 mm. The cranial index, obtained by dividing the breadth by the length of the cranium, was found to be 71.34 mm (Table 1).

Table 1: Mean and standard deviation of various parameters

Variables		Mean ± Sd (mm) (N= 50)
Foramen Magnum	Foramen Magnum Anteroposterior/Sagittal Diameter	33.33 ± 2.66
	Foramen Magnum Transverse Diameter	28.93 ± 2.45
	Foramen Magnum Index	83.85 ± 3.26
Cranium	Maximum Cranial Length	180.87 ± 1.55
	Maximum Cranial Breadth	130.71 ± 1.31
	Cranial Index	71.34 ± 3.43

Table 2: Correlation between parameters of foramen magnum and cranium

Variables			Pearson's r	p-value
Foramen magnum Sagittal diameter	-	Cranial Length	0.891	.001
Foramen magnum Transverse diameter	-	Cranial breadth	0.908	.001
Foramen magnum index	-	Cranial index	0.200	0.163

On comparison, a strong positive correlation (r= 0.891) was observed between the sagittal diameter of the foramen magnum and cranial length, demonstrating statistical significance (p-value < 0.05). Similarly, a strong positive correlation (r= 0.908) was identified between the transverse diameter of the foramen magnum and cranial breadth, also exhibiting statistical significance (p-value < 0.05). Conversely, when comparing the indices of the foramen magnum and the cranium, a weak correlation (r = 0.200) was detected, which was not statistically significant (p-value > 0.05) (Table 2).[11]

5. Discussion

This study explores the morphology of the foramen magnum and its relationship to overall cranial morphology in a specific population. The foramen magnum, a crucial opening at the skull base, connects the brain and spinal cord. Its size and shape hold evolutionary significance and understanding its variations is vital in various fields.[12]

5.1. Key points about the foramen magnum

1. The foramen magnum acts as a critical passage between the skull and spine, providing access to vital

Table 3: Comparison of anteroposterior diameter of FM, Transverse diameter of FM and FM Index of present study with previous studies

Author	Anteroposterior Diameter of FM (mm)	Transverse Diameter of FM (mm)	Foramen Magnum Index
Sharma et al [1] (2019)	34.44	30.46	88.44
Bharti et al [5] (2021)	Males: 30 Females: 29	Males: 26.1 Females: 25.03	Males: 87.33 Females: 85.54
Chandekar et al [3] (2017)	Males: 36.23 Females: 31.5	Males: 29.06 Females: 27.41	Males: 80.19 Females: 87.01
Singh et al [2] (2019)	33.57	27.49	82.09
Present study	33.33	28.93	83.85

structures like the brain, spinal cord, and nerves.
2. Its morphology exhibits variability, reflecting adaptations throughout human evolution.
3. Fetal development involves the foramen magnum as a key point of ossification within the cartilaginous skull base.
4. A comprehensive understanding of its anatomy is crucial for diagnosing and treating disorders affecting the craniovertebral junction, the area where the skull meets the spine.

5.2. Cranial anatomy and anthropometry

1. The human skull consists of 22 bones, forming the head skeleton. With the inclusion of the hyoid bone and ear ossicles, the total count reaches 29.
2. Two main cranial divisions exist: the neurocranium, encasing the brain, and the splanchnocranium (viscerocranium), surrounding the oral and nasal cavities.
3. The neurocranium comprises eight bones, while the splanchnocranium consists of fourteen, all categorized as flat or irregular bones..
4. Immobile joints called sutures connect these bones, excluding the mandible.
5. Cranial anthropometry, the study of cranial measurements, is increasingly important for anatomists, anthropologists, and plastic surgeons, allowing for detailed analysis of skull variations. [13]**?**

5.3. Study findings and comparisons

1. This research measured the foramen magnum index, a measure of its relative size and shape. The average index in this study (83.85) differed from previous reports, highlighting population variations.
2. Similar observations were made with the cranial index, a measure of overall head shape. The average value (71.34) contrasted with other studies, again emphasizing cranial diversity. [14]

5.4. Overall significance

This study contributes to the understanding of foramen magnum morphology and its connection to cranial morphology within a specific population. The observed variations underline the importance of considering population-specific data for accurate assessments in various medical fields.

6. Conclusion

This section of your paper discusses the key findings and their broader significance. Here's a breakdown of the points you provided and how you can expand on them: [15]

6.1. Morphometric analysis and existing literature

1. Highlight similarities: While your measurements differ slightly from previous studies, emphasize that these differences fall within the expected range of variation across populations. You can mention specific studies that showed similar findings.
2. Statistical significance: Explain the importance of statistically significant parameters (except indices). This indicates a strong, non-random connection between cranial size and foramen magnum size.

6.2. Expansion

1. You can present a table or graph summarizing the correlations between cranial parameters and foramen magnum dimensions.
2. Briefly explain how statistical tests like Pearson's correlation coefficient were used to determine significance. [16]

6.3. Implications for medical fields

1. Neurosurgery: Larger foramen magnum might suggest a larger brainstem or spinal cord, which can be crucial information for neurosurgeons planning procedures at the cranial base.
2. Orthopaedic surgery: Understanding cranial and foramen magnum size variations can be relevant for surgeons operating on the craniovertebral junction for

conditions like Chiari malformation.
3. Radiology: Reference data on foramen magnum size can aid radiologists in interpreting scans and identifying potential abnormalities.
4. Forensic science: Cranial and foramen magnum measurements can be used for identification purposes in forensic anthropology, especially when dealing with skeletal remains.
5. Anatomy & anthropology: The study contributes to the understanding of human skeletal variation and potential evolutionary adaptations related to brain size and cranial morphology.

6.4. Overall impact

1. Emphasize how this research provides valuable information for various medical professionals, potentially improving surgical planning, diagnosis, and overall patient care.

6.5. Additional considerations

1. You can discuss limitations of the study, such as sample size or population specificity.
2. Briefly mention future research directions, such as investigating the impact of sex or age on the observed correlations.

By elaborating on these points, you can create a compelling discussion section that highlights the importance of your research findings and their potential applications in different medical fields.

7. Sources of Funding

None.

8. Conflict of Interest

None.

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