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ORIGINAL RESEARCH

Morphometric variations of the patella in eastern Indian population: insights for implant design and forensic identification

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ABSTRACT

Background: The patella, the largest sesamoid bone in the human body, is pivotal in personal identification due to its resilience against post-mortem alterations. Despite lacking distinct features for sex or racial determination, its morphometric dimensions are essential for anthropological studies and clinical applications, particularly in knee surgeries and implant design. **Methods:** This study analyzed 95 patellae from the Eastern Indian population using magnetic resonance imaging (MRI). Exclusion criteria included patellae with deformities, fractures, previous surgeries, or other pathological conditions. Measurements focused on patellar height, width, thickness, and the dimensions of the medial and lateral articular facets. Data were statistically analyzed to identify significant morphometric variations and classify patellae based on articular facet morphology. **Results:** The mean dimensions observed were 38.07 mm in height, 38.58 mm in width, and 18.29 mm in thickness. The medial articular facet averaged 17.4 mm, while the lateral facet averaged 22.4 mm. Type B patellae, characterized by a smaller medial facet compared to the lateral facet, were predominant. Comparative analysis revealed significant differences in patellar dimensions between the Eastern Indian population and other ethnic groups, highlighting the necessity for population-specific implant designs. **Conclusion:** The study provides comprehensive morphometric data on the patellae of the Eastern Indian population, offering valuable insights for the design of patellar implants and enhancing the accuracy of forensic identification processes. These findings underscore the importance of considering ethnic variations in clinical practices and anthropological research.

Keywords: Patella, Morphometry, Anthropological Study, Clinical Application, Forensic Science, Patellar Implant

INTRODUCTION

The patella, commonly known as the kneecap, is the largest sesamoid bone in the human body, embedded within the tendon of the quadriceps femoris and situated anterior to the femoral condyles. Structurally, the patella exhibits a flat, distally tapered shape with a proximally curved surface, comprising distinct anterior and posterior facets, three borders, and a distal apex. The anterior convex surface is overlaid by a prepatellar bursa and an extension of the quadriceps tendon, while the posterior surface features an articular area divided by a vertical ridge that aligns with the intercondylar groove of the femur [1].

Despite the patella's limited utility in determining sex or racial characteristics due to its relatively uniform morphology across populations, it remains a critical element for personal identification, particularly in forensic contexts, owing to its resistance to post-mortem degradation and trauma [2]. Moreover, the precise dimensions and morphological variations of the patella are indispensable in clinical settings, especially in the realm of knee arthroplasty and patellar implant design. Accurate anthropometric data ensure the appropriate sizing and fitting of implants, thereby minimizing postoperative complications such as implant misalignment, reduced range of motion, and knee instability [3].

Historically, Wiberg's classification system [4] has been pivotal in categorizing patellae based on the morphology of the articular facets. This system delineates three primary types: Type I, where the medial and lateral articular facets (MAF and LAF) are equal and concave; Type II, characterized by a flat or slightly convex MAF that is smaller than the LAF;

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and Type III, where the MAF is convex and significantly smaller than the LAF. Subsequent studies, including those by Koyuncu et al. [5], have further refined these classifications, emphasizing the variability of patellar morphology across different populations.

The present study is the first of its kind to conduct a comprehensive morphometric analysis of patellae within the Eastern Indian population. By meticulously measuring various dimensions of the patella and classifying them based on articular facet morphology, this research aims to fill the existing gap in anthropological and clinical data for this demographic. The findings are anticipated to inform the design of population-specific patellar implants and enhance the precision of forensic identification methodologies.

MATERIALS AND METHODS

Sample Selection

A total of 95 patellae were included in this study, derived from MRI scans conducted at the Institute of Medical Sciences, Banaras Hindu University (IMS BHU), Varanasi, India. The sample comprised 86 male and 9 female individuals. Patellae exhibiting any form of deformity, malalignment, bipartite structure, fractures (both old and new), previous infections, surgical interventions, or tumors in the vicinity of the knee joint were excluded to ensure the integrity of the morphometric analysis.

Imaging and Measurements

All patellar measurements were obtained using a 1.5 Tesla MRI scanner at IMS BHU, employing multi-slice T1-weighted, non-fat-saturated conventional spin-echo sequences (TR = 500 ms, TE = 16 ms, slice thickness = 3 mm, intersection gap = 1 mm). Imaging was performed in both sagittal and axial planes with a flexible surface coil positioned anterior to the patella to minimize image distortion.

Standardized positioning protocols were meticulously followed to ensure consistency across all MRI scans. Each patella was imaged in the maximal dimension planes, and measurements were conducted by a single experienced researcher using digital calipers (Absolute DIGIMATI, IMS BHU). The following parameters were measured:

1. **Longitudinal Length (Height):** Measured on the sagittal image from the distal apex to the proximal base.
2. **Mediolateral Width (Width):** Measured on the axial image at the widest point of the bony margin.
3. **Thickness:** Assessed perpendicular to the longitudinal axis of the patella.
4. **Medial Articular Facet Width (MAF):** Distance from the central ridge to the medial border on the axial plane.
5. **Lateral Articular Facet Width (LAF):** Distance from the central ridge to the lateral border on the axial plane.

The thickness of the articular cartilage was incorporated into the overall patellar thickness measurement, and the bony margin was used as the reference point for width measurements to maintain consistency.

Statistical Analysis

Data were analyzed using descriptive statistics to calculate mean values and standard deviations for all measured parameters. Comparative analyses were performed to identify significant differences between the right and left patellae and between the Eastern Indian population and other ethnic groups reported in the literature. Classification of patellae based on Wiberg's types was conducted to determine the prevalence of each morphometric category within the sample.

RESULTS

A total of 95 patellae were meticulously analyzed in this study. The demographic distribution included 86 male and 9 female subjects. The following mean dimensions were observed:

- **Mean Height:** 38.07 mm (± SD)
- **Mean Width:** 38.58 mm (± SD)
- **Mean Thickness:** 18.29 mm (± SD)
- **Mean Medial Articular Facet Width (MAF):** 17.4 mm (± SD)
- **Mean Lateral Articular Facet Width (LAF):** 22.4 mm (± SD)

TABLE 1: MEAN DIMENSIONS OF PATELLAE IN THE EASTERN INDIAN POPULATION

Parameter	Mean (mm)	Standard Deviation (mm)
Height	38.07	± **2.15**
Width	38.58	± **1.98**
Thickness	18.29	± **0.85**
Medial Articular Facet	17.4	± **1.10**
Lateral Articular Facet	22.4	± **1.25**

TABLE 2: COMPARISON OF PATELLAR DIMENSIONS WITH OTHER POPULATIONS

Population	Mean Width (mm)	Mean MAF (mm)	Mean LAF (mm)
Eastern Indian	38.58	17.4	22.4
Chinese	41.0	19.0	25.1

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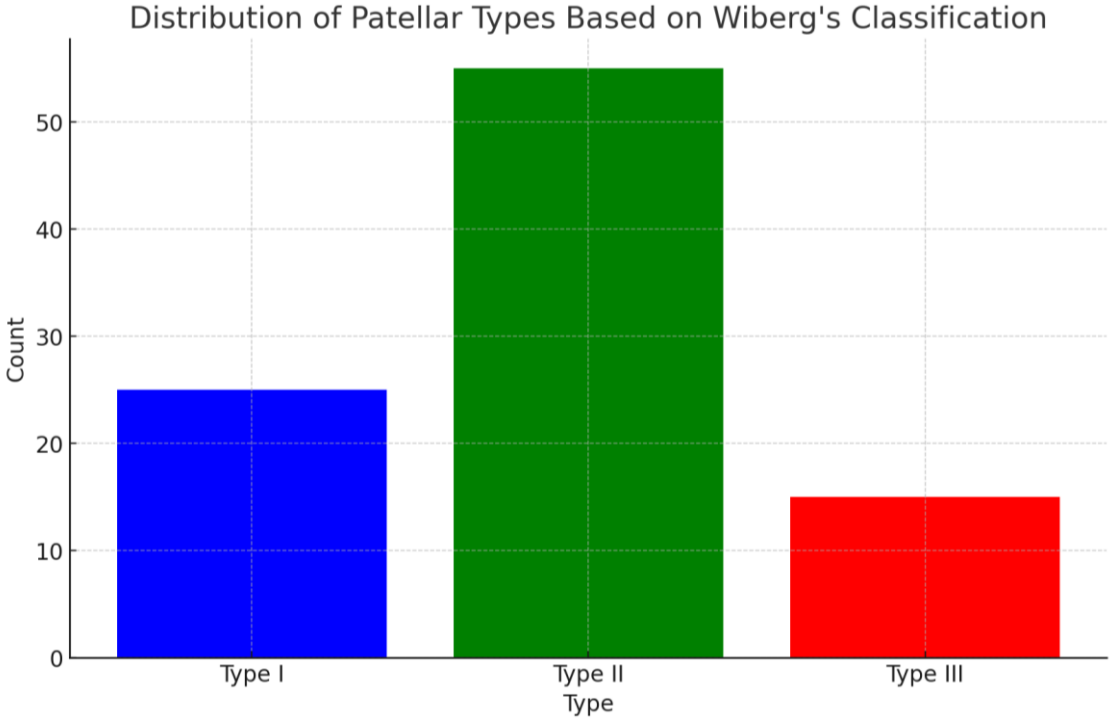
Korean	40.5	18.4	23.3
Western	40.6	18.8	25.3

FIGURE 1: DISTRIBUTION OF PATELLAR TYPES BASED ON WIBERG'S CLASSIFICATION



The analysis revealed that the mean width of patellae in the Eastern Indian population (38.58 mm) was significantly lower compared to the widths reported in studies and, which recorded mean widths of 44.1 mm and 45.1 mm, respectively. Additionally, the medial articular facet in this study (17.4 mm) was smaller than those documented in Chinese (19.0 mm), Korean (18.4 mm), and Western (18.8 mm) populations. Similarly, the lateral articular facet width (22.4 mm) was less than the values observed in Chinese (25.1 mm), Korean (23.3 mm), and Western (25.3 mm) groups.

DISCUSSION

The present study offers a comprehensive morphometric analysis of the patellae within the Eastern Indian population, revealing significant variations in patellar dimensions compared to other ethnic groups. The observed mean height, width, and thickness of the patellae were slightly lower than those reported in studies conducted on Chinese, Korean, and Western populations [6,7,8], These discrepancies may be attributed to genetic, environmental, and lifestyle factors inherent to different populations, as well as potential variations in measurement techniques and sample sizes across studies.

The predominance of Type B patellae in this study aligns with the findings of Fucentese et al. [9], indicating a common morphological trend where the medial articular facet is smaller than the lateral facet. This classification has practical implications in clinical settings, particularly in the design and selection of patellar implants. Implants designed based on population-specific morphometric data are likely to achieve better anatomical conformity, reducing the risk of postoperative complications such as implant malalignment and knee instability [10,11].

Furthermore, the lack of significant differences between the right and left patellae suggests a bilateral symmetry in patellar morphology within the Eastern Indian population, which is consistent with previous studies [12]. This symmetry is advantageous for forensic applications, where unilateral measurements can reliably represent bilateral patellar dimensions.

The study's findings also hold substantial value for forensic science. Accurate morphometric data enhance the ability to perform personal identification and sex determination with higher precision, especially in cases where other skeletal markers are compromised. Although the patella is not a primary marker for sex determination, its robust nature and resistance to post-mortem changes make it a valuable supplementary tool in forensic investigations [13].

Clinically, the insights derived from this study can inform orthopedic practices, particularly in knee arthroplasty and reconstructive surgeries. Customized patellar implants, tailored to the specific morphometric characteristics of the Eastern Indian population, can improve surgical outcomes and patient satisfaction by ensuring better implant fit and functionality [14].

However, the study is not without limitations. The sample size, particularly the disproportionate

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representation of males over females, may influence the generalizability of the results. Future research should aim for a more balanced gender distribution and consider a larger, more diverse sample to validate and expand upon these findings. Additionally, incorporating three-dimensional imaging techniques could provide more detailed insights into patellar morphology.

CONCLUSION

This study presents essential morphometric data on patellae within the Eastern Indian population, highlighting significant variations in patellar dimensions compared to other ethnic groups. The findings have profound implications for the design of population-specific patellar implants and enhance the precision of forensic identification processes. By addressing the unique anatomical characteristics of this demographic, the research contributes to improved clinical outcomes and supports anthropological and forensic endeavors.

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