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RESEARCH ARTICLE

Quantitative Assessment of Tibial Condylar Dimensions in Human Dry Bones

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ABSTRACT

Background: The proximal tibia serves an important function in weight transmission and contributes significantly to the stability of the knee joint. Precise morphometric data of tibial condyles are essential for designing knee prostheses and improving outcomes of arthroplasty procedures. Variations in condylar dimensions across populations necessitate region-specific anatomical data.

Objective: To perform a quantitative assessment of tibial condylar dimensions in human dry bones and evaluate side-wise differences.

Methods: This cross-sectional study included 50 adult dry tibiae (25 right and 25 left) collected from the anatomy and forensic department. Measurements such as anteroposterior (AP) and transverse diameters of both condyles, along with total condylar dimensions, were obtained using a digital Vernier caliper. Statistical analysis included calculation of mean, standard deviation, and p-values to assess side differences.

Results: The medial condyle AP diameter averaged 39.40 ± 4.58 mm (right) and 41.29 ± 4.69 mm (left), showing no statistically significant difference. However, the lateral condyle AP diameter was significantly greater on the left (38.62 ± 3.23 mm) compared to the right (35.98 ± 3.86 mm) ($p < 0.01$). Total condylar AP diameter also demonstrated a significant side difference ($p < 0.01$), while transverse diameters and total condylar area did not show statistically significant variation.

Conclusion: The study provides valuable morphometric data on tibial condyles, highlighting significant side differences in certain parameters. These findings are clinically relevant for the design of knee prostheses and can help improve surgical outcomes in knee arthroplasty.

Keywords: Tibia, condyle, Morphometry, Knee joint, Arthroplasty, Dry bones.

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Introduction

The tibia is a major long bone of the lower limb that plays a fundamental role in supporting body weight and facilitating locomotion. Structurally, it consists of a shaft (diaphysis), expanded proximal and distal ends (epiphyses), and intervening metaphyseal regions. Owing to its subcutaneous position, a large portion of the tibial surface is easily palpable. Functionally, it is considered a preaxial bone and is essential for efficient transmission of forces across the lower extremity.

The proximal extremity of the tibia is comparatively broadened and is characterized by the presence of medial and lateral condyles. These articular surfaces interact with the femoral condyles to constitute the knee joint, which is a modified hinge-type synovial joint. The two condyles are separated by the intercondylar region, where the intercondylar eminence is formed by medial and lateral tubercles. Morphologically, the medial condyle is typically larger and more oval, whereas the lateral condyle is relatively smaller and tends to be more circular in shape [1]. Previous studies have also demonstrated structural differences between the medial and lateral tibial plateaus [2].

The articulation between femoral and tibial condyles is complemented by the presence of menisci, which enhance

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joint congruity and stability, making the knee a complex synovial articulation. The upper end of the tibia plays a key role in transferring loads from the femur to the foot and is therefore crucial for routine functional activities [3].

As a primary weight-bearing bone, the tibia contributes significantly to maintaining posture and enabling a wide range of movements at the knee joint. The knee itself is a highly integrated structure comprising bones, cartilage, ligaments, tendons, and surrounding musculature, all of which collectively ensure stability and mobility.

Clinically, disorders of the knee joint are frequently encountered, particularly in individuals above the age of 40 years. Such conditions may compromise daily activities including walking, stair climbing, standing, and squatting. The underlying causes may include trauma, repetitive stress, or degenerative diseases such as osteoarthritis.

In advanced cases involving deformity, injury, or degenerative changes, surgical interventions such as unicompartmental or total knee arthroplasty are often indicated. Successful surgical outcomes depend largely on precise anatomical knowledge of the proximal tibia. Detailed morphometric data are essential for designing appropriately fitting prosthetic components, which in turn help minimize complications such as implant loosening, ligament imbalance, restricted joint movement, and postoperative instability [4–6]. Prostheses tailored according to the anatomical dimensions of the femur and tibia are associated with improved functional recovery and reduced complication rates following surgery [7–8].

The present study aims to contribute to the existing anatomical database by providing accurate morphometric measurements of the proximal tibia. Such data are valuable not only for orthopedic applications but also for anatomical and forensic investigations.

Aim and Objectives

To determine the Quantitative Assessment of Tibial Condylar Dimensions in Human Dry Bones.

Materials and Methods

A cross-sectional observational study was carried out on 50 adult dry human tibiae, comprising 25 right-sided and 25 left-sided specimens. These bones were obtained from the anatomy department and the forensic museum of the institution. The age and sex of the specimens were not documented.

Exclusion Criteria

Specimens showing visible deformities, pathological changes, or damage due to preservation or handling were excluded from the study.

The following morphometric parameters were recorded using a digital Vernier caliper:

Anteroposterior (AP) dimension of the medial tibial condyle

The AP dimension was recorded as the linear distance between the anterior-most and posterior-most limits of the medial condyle, identified with reference to the attachment of the anterior horn of the medial meniscus.

Transverse dimenssion of the medial tibial condyle

The transverse measurement was taken at a right angle to the AP axis, extending from the medial tubercle to the outer boundary of the medial condyle.

Anteroposterior (AP) dimension of the lateral tibial condyle

The AP length of the lateral condyle was assessed by noting the distance between its anterior and posterior extremities, located relative to the attachment of the anterior horn of the lateral meniscus.

Transverse dimension of the lateral tibial condyle

The transverse dimension was obtained perpendicular to the AP orientation, extending from the lateral tubercle to the lateral edge of the condyle.

Anteroposterior dimension of the total tibial condyle (TTC-AP)

This measurement was taken along a line passing through the midpoint of the intercondylar eminence, between the medial and lateral tubercles, covering the anterior to posterior extent.

Transverse dimension of the total tibial condyle (TTC-TD)

The transverse extent was measured at a right angle to the above reference line, extending between the medial and lateral margins of the condyles at the level of the medial tubercle.

Area of the condyle

Calculated using the formula: Area = AP diameter × Transverse diameter

The total condylar area represents the combined surface area of the medial and lateral condyles, including the intercondylar region.

All measurements were systematically recorded, tabulated, and subjected to statistical analysis.

1.Ap diameter of medial condyle
2.Ap diameter of lateral condyle
3.Ap diameter of inter condyle
4. Transverse diameter of medial condyle
5.Transverse diameter of lateral condyle
6.Total transverse diameter of upper end of tibia

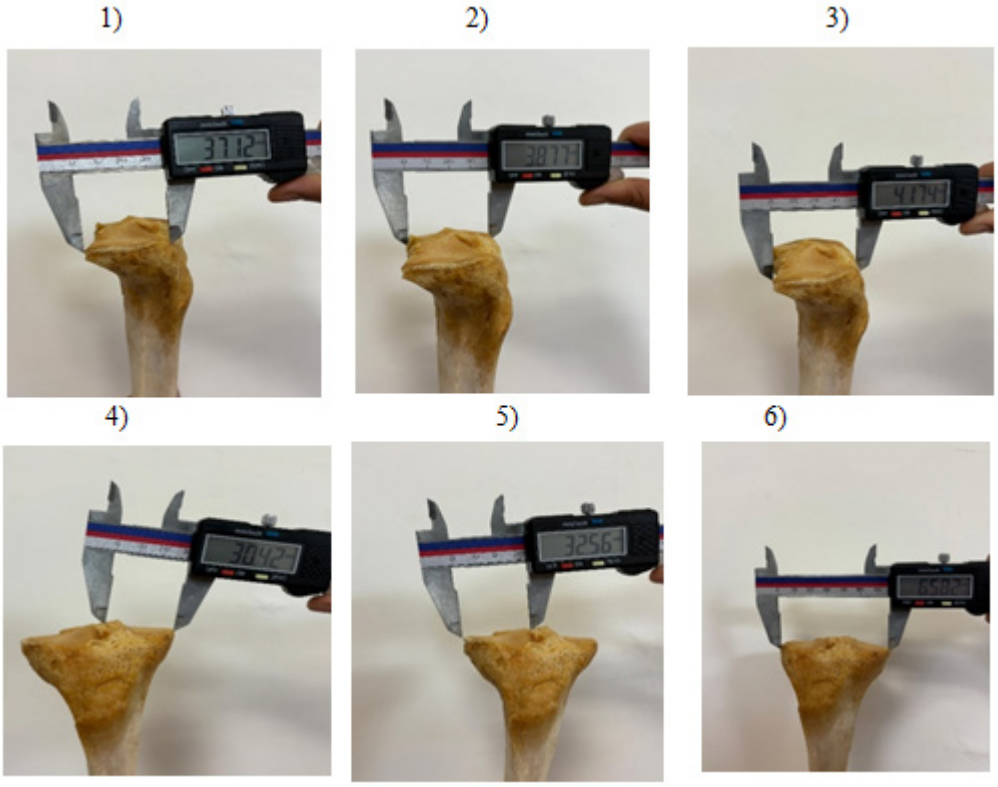

Figure 1: Morphometric Measurement of Proximal Tibia

Results

Morphometric evaluation of the proximal tibia was performed using a digital Vernier caliper. The parameters assessed included anteroposterior (AP) and transverse diameters of both medial and lateral condyles, along with total condylar measurements.

Medial Condyle

The average anteroposterior dimension of the medial condyle measured 39.40 ± 4.58 mm on the right and 41.29 ± 4.69 mm on the left. Statistical analysis indicated that this variation between sides was not significant ($p > 0.05$).

A comparison of transverse diameters showed similar values on the right (28.90 ± 3.72 mm) and left (29.31 ± 3.19 mm), and the difference was not statistically significant.

Lateral Condyle

The anteroposterior diameter of the lateral condyle measured 35.98 ± 3.86 mm on the right and 38.62 ± 3.23 mm on the left. Analysis showed a statistically significant difference ($p < 0.01$), with greater values observed on the left side.

Similar transverse values were noted on the right (27.15 ± 3.26 mm) and left (27.21 ± 3.18 mm), with statistical analysis showing no significant variation between them.

Total Tibial Condyle (TTC)

The total tibial condyle AP dimension averaged 40.43 ± 3.69 mm on the right and 43.85 ± 3.79 mm on the left, and this side-to-side difference was statistically significant ($p < 0.01$).

A comparison of total transverse dimensions showed values of 64.77 ± 4.04 mm on the right and 63.38 ± 4.39 mm on the left, and this variation was not statistically significant ($p > 0.05$).

Total Condylar Area

The mean total condylar area was marginally greater on the left side (2788.97 ± 377.92 mm^2) than on the right (2630.63 ± 379.33 mm^2); however, this difference did not reach statistical significance.

Discussion

Previous research has indicated that indirect imaging-

Table 1: Analysis for the Anteroposterior (AP) and Transverse Diameters of the Medial Condyle of Right and Left Tibia

Measurement	*Right Medial (Mean ± SD)*	*Left Medial (Mean ± SD)*	*p-value*	*Significance*
AP Diameter	39.40 ± 4.58	41.29 ± 4.69	0.1614	Not Significant
Transverse Diameter	28.90 ± 3.72	29.31 ±3.19	0.7151	Not Significant

Table 2: Analysis for the Anteroposterior (AP) and Transverse Diameters of the Lateral Condyle of Right and Left Tibia

Measurement	*Right Lateral (Mean ± SD)*	*Left Lateral (Mean ± SD)*	*p-value*	*Significance*
AP Diameter	35.98 ± 3.86	38.62 ± 3.23	0.0048	Significant ($p < 0.01$)
Transverse diameter	27.15 ± 3.26	27.21± 3.18	0.9379	Not Significant

Table 3: Analysis for the Anteroposterior (AP) and Transverse Diameters of the Total Tibial Condyle (TTC) for the Right and Left Tibia

Measurement	*Right Lateral (Mean ± SD)*	*Left Lateral (Mean ± SD)*	*p-value*	*Significance*
TTC-AP Diameter	40.43 ± 3.69	43.85 ±3.79	0.0027	Highly Significant ($p < 0.01$)
TTC-Transverse Diameter	64.77 ± 4.04	63.38 ± 4.39	0.2502	Not Significant

Table 4: Analysis of Total Condylar Area (TTC) of Right and Left Tibia

Measurement	*Right Lateral (Mean ± SD)*	*Left Lateral (Mean ± SD)*	*p-value*	*Significance*
Total Condylar Area (TTC)	2630.63±379.33	2788.97±377.92	0.1540	Not Significant

based techniques such as computed tomography (CT) and magnetic resonance imaging (MRI) may have certain limitations in accurately assessing bony dimensions, despite advancements in imaging resolution and correction methods [9,10]. In contrast, direct measurement on dry bone specimens provides more precise and reliable morphometric data. Such accuracy is particularly important when these measurements are utilized for designing prosthetic components used in knee joint replacement procedures. Improved anatomical matching of prostheses contributes to better long-term functional outcomes and reduces the likelihood of postoperative complications [11].

The findings of the present study are generally consistent with earlier reports, although minor variations can be attributed to differences in study populations and methodologies.

The present study demonstrated that the mean AP diameter of the medial condyle was 39.40 ± 4.58 mm on the right side and 41.29 ± 4.69 mm on the left side, indicating a slightly larger dimension on the left. A similar trend was observed in the study conducted by Sinha B et al. (2018), where the AP diameter was reported to be greater on the left side (45.2 ± 2.6 mm) compared to the right (43.4 ± 2.1 mm) [12].

With respect to the transverse diameter, the present study recorded values of 28.90 ± 3.72 mm on the right and 29.31 ± 3.19 mm on the left. Comparable observations were noted by Sinha B et al. (2018), who reported slightly higher transverse measurements on the left (28.6 ± 1.4 mm) than on the right (28.5 ± 1.2 mm). Although the differences are minimal, both studies suggest a marginal predominance of the left side in medial condylar dimensions.

Table 5: Comparison of measurement of the medial condyle with previous study

Authors.	*Antero-posterior diameter (mm) Mean ± S.D*		*Transverse Diameter (mm) Mean ± S.D.*	
	RIGHT	*LEFT*	*RT*	*LEFT*
Sinha B et al (2018) [12]	43.4 ± 2.1	45.2 ± 2.6	28.5 ± 1.2	28.6 ± 1.4
PRESENT STUDY	39.40 ± 4.58	41.29 ± 4.69	28.90 ± 3.72	29.31 ±3.19

Table 6: Comparison of measurement of lateral condyle

Authors.	*Antero-posterior diameter (mm) Mean ± S.D*		*Transverse Diameter (mm) Mean ± S.D.*	
	RIGHT	*LEFT*	*RIGHT*	*LEFT*
Bhadoria P et al (2018)[13]	38.85 ± 2.75	39.26 ± 3.56	27.43 ± 2.08	28.08 ± 2.19
PRESENT STUDY	39.40 ± 4.58	41.29 ± 4.69	28.90 ± 3.72	29.31 ±3.19

Table 7: Comparison of measurement of TTC-AP and TTC-TD of right and left tibia

Authors.	*Antero-posterior diameter (mm) Mean ± S.D (TTC-AP)*		*Transverse Diameter (mm) Mean ± S.D. (TTC-TD)*	
	RIGHT	*LEFT*	*RIGHT*	*LEFT*
Gandhi et.al[14]	47.19 ± 2.93	49.11 ± 3.97	-	-
PRESENT STUDY	40.43 ± 3.69	43.85 ±3.79	-	-
Gupta et al[3]	-	-	67.7 ± 0.31	68.8 ± 0.65
Present study			64.77 ± 4.04	63.38 ± 4.39

In the present analysis, the AP diameter of the lateral condyle measured 35.98 ± 3.86 mm on the right and 38.62 ± 3.23 mm on the left, demonstrating a clear increase on the left side. This observation is in agreement with the findings of Bhadoria P et al. (2018), who also reported higher AP values on the left (39.26 ± 3.56 mm) compared to the right (38.85 ± 2.75 mm) [13].

The transverse diameter in the current study showed values of 27.15 ± 3.26 mm on the right and 27.21 ± 3.18 mm on the left, which are slightly higher than those reported in the comparative study. Despite minor differences in magnitude, both studies indicate a consistent pattern of marginally greater dimensions on the left side.

The study by Gandhi et al. [14], conducted on 100 adult dry tibiae, reported mean AP measurements of the intercondylar region as 47.19 ± 2.93 mm on the right and 49.11 ± 3.97 mm on the left. In comparison, the present study recorded TTC-AP values of 40.43 ± 3.69 mm on the right and 43.85 ± 3.79 mm on the left, showing a similar trend though with comparatively lower values.

Similarly, Gupta et al. [3] reported transverse diameters of 67.7 ± 0.31 mm on the right and 68.8 ± 0.65 mm on the left in a South Indian population. In contrast, the current study observed TTC-TD values of 64.77 ± 4.04 mm on the right and 63.38 ± 4.39 mm on the left. Unlike Gupta et al., the present findings indicate a slightly higher transverse measurement on the right side.

Srivastava et al. [15], in their study on 150 dry tibiae, reported the mean TTC area as 2988.73 mm² on the right and 2951.44 mm² on the left. In the present study, the corresponding values were 2630.63 mm² on the right and 2788.97 mm² on the left. Although the absolute values differ, both studies demonstrate a tendency toward a slightly larger condylar area on the left side.

Table 8: Comparison of measurement of area of total tibial condyle (TTC)

Authors.	*TTC-AREA*	
	RIGHT	*LEFT*
Srivastava et al. [15]	2988.73	2951.44
PRESENT STUDY	2630.63mm	2788.97mm

Overall, the observations from the present study align with previously published data, supporting the presence of side-wise variations in tibial condylar dimensions. Such differences may be influenced by population-specific anatomical characteristics. The morphometric data obtained through direct measurement provide a reliable foundation for improving the design and fitting of knee prostheses, thereby enhancing surgical outcomes and minimizing complications associated with joint replacement procedures.

Conclusion

The present study offers detailed morphometric insights into the proximal tibia, which are of significant value in orthopedic practice, particularly in knee arthroplasty. A clear understanding of these anatomical dimensions assists in the development of accurately fitting prosthetic components, thereby enhancing surgical precision. Such improvements can contribute to reduced postoperative complications, better joint function, and overall improvement in patient mobility and quality of life.

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