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Original Article

Anatomy Section

Morphometric analysis of the Proximal End of the Dry Adult Tibia : A Cross-sectional Study from Eastern India

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ABSTRACT

Introduction: The morphometric measurement of the proximal tibia plays an important role in determining the clinical outcome of Total Knee Arthroplasty (TKA), including long-term survivorship and quality of life for patients. However, due to ethnic and geographical variations in these measurements, findings from western countries cannot be directly applied to the Asian population or any other subpopulation.

Aim: To describe the anatomical morphometry of the proximal tibia in the East Indian population and to explore any associations of these measurements with sex and laterality.

Materials and Methods: This cross-sectional study was conducted in the Department of Anatomy, MKCG Medical College, Berhampur, Odisha, India, from August 2020 to August 2022. A total of 200 fully ossified, dry, and processed bones from both sides, which were grossly normal and complete, were obtained from the Department of Anatomy of various medical colleges in Odisha, India. Different measurements of the tibia, such as Mediolateral Length (ML), anteroposterior length of the medial and lateral condyles, circumference, intercondylar region, and tibial tuberosity, were measured using standard procedures and standardised vernier calipers. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 27.0 (IBM Corporation, Armonk, New York, USA). A comparison of means between two groups was conducted using an independent sample t-test, and correlation between two quantitative variables was assessed using Pearson correlation.

Results: Out of the included bones, 114 (57%) were male tibiae, and 116 (58.0%) were right-side tibiae. The ML, anteroposterior length of the lateral and medial condyles, intercondylar area, tibia to tibial tuberosity length, and circumference were measured as 67.91 mm, 39.44 mm, 42.72 mm, 42.73 mm, 33.48 mm, and 19.37 mm, respectively. The ML showed a significant positive correlation (p-value < 0.001) with the anteroposterior length of the lateral tibial plateau, medial tibial plateau, and intercondylar area, with correlation coefficients (r) values of 0.726, 0.762, and 0.747, respectively. All morphometric parameters were comparable between the right and left sides of the tibia. ML, anteroposterior length of the lateral and medial condyles, intercondylar area, circumference, and tibia to tibial tuberosity length were significantly higher in males compared to females.

Conclusion: This study provides a description of the morphometric parameters of the tibia among the Eastern Indian population. Although there was no significant difference in laterality, the parameters of male tibiae were significantly higher compared to females.

Keywords: Cross-sectional anatomy, Knee joint, Total knee arthroplasty

INTRODUCTION

Human skeletal remains can provide valuable information for studying biological variation among human populations, both spatially and temporally. The study of human skeletons not only provides insight into the natural ageing process but also helps in understanding the biological, behavioural, cultural, and environmental factors that influence human lifestyles. This understanding, in turn, contributes to a deeper comprehension of variation at the individual and population levels over time and space, as well as the identification of unknown human characteristics. These variations are typically studied in relation to gender, age, and ethnicity, along with interactions between these variables, to gain a greater understanding of human life [1,2].

The knee is a complex synovial joint with a major function of controlling posture and body mass, and facilitating daily activities such as walking, standing, climbing, running, kicking, jumping, and changing directions [3]. The distal end of the femur and proximal end of the tibia play an important role in transmitting body weight through the tibio-femoral articulation. However, there are many situations in our daily activities where the mediolateral and anteroposterior dimensions of the knee joint are involved. The role of the epiphysis and diaphysis of the tibia is well established in this regard [4-6].

Long-term weight-bearing on the knee joint can lead to various pathological conditions, including inflammatory arthritis, post-traumatic arthritis, and age-related osteoarthritis, which are common [7,8]. Total Knee Arthroplasty (TKA) or Unicompartmental Knee Arthroplasty (UKA) is the most frequently performed intervention to treat these chronic conditions. The basic concept behind TKA is to resect the superior surface of the proximal tibia and replace it with a tibial prosthesis. The success of the surgery/intervention is not only determined by the adequacy of soft tissue balance but also by precise rotational and sagittal alignment, with minimal overhang of the components [7,8].

The success of this procedure largely depends on the selection, accurate sizing, and precise placement of the components. The anteroposterior and mediolateral dimensions of the prosthesis play an important role in maintaining flexion-extension and providing adequate coverage of the resected bone surface, as well as allowing tension-free wound closure [9-11].

The morphometric measurements of the proximal tibia play a crucial role in achieving successful outcomes in total knee replacement surgeries. Common morphometric measurements include the medial posterior slope, lateral posterior slope, proximal tibial length, medial condyle area, and lateral condyle area. These measurements not only help in determining knee deformities but also guide therapeutic procedures and monitor outcomes for patients undergoing total knee replacement surgeries [7,12,13].

However, due to ethnic and geographical variations (such as the smaller build and stature of the Asian population compared to the Western population), the measurements from the Western population cannot be directly applied to the Asian population or any other subpopulation. Furthermore, there will be variations within subpopulations. Most commercially available prostheses are best suited for the Western population. Given the large variability in morphometric measurements among different populations worldwide, it is likely that Asian populations, including the Indian population, have a risk of component oversizing in both UKA and TKA [14,15].

There is a lack of studies measuring the morphological parameters of the tibia in the Indian population, particularly in Eastern India. In this context, this study aims to provide valuable data on the average dimensions of the proximal tibia in the East Indian population. This data can serve as guidelines for designing suitable tibial components for total knee prostheses for this population, ultimately improving the quality of life for postoperative patients. Therefore, this study was conducted with the objective of describing the anatomical morphometry of the proximal tibia in the East Indian population and investigating any associations between these measurements and sex and laterality.

MATERIALS AND METHODS

A cross-sectional study was conducted in the Department of Anatomy, Maharaja Krushna Chandra Gajapati Medical College, Berhampur, Odisha, India from August 2020 to August 2022. The study received approval from the Institutional Ethics Committee (IEC) (letter No. 1034/Chairman-IEC, M.K.C.G. Medical College, Brahmapur-4).

Inclusion criteria: Fully ossified tibia bones, irrespective of age, laterality, and gender, were included in the study.

Exclusion criteria: Bones that were not fully ossified, diseased, had defects, or displayed gross abnormalities were excluded from the study.

A total of 200 fully ossified dry tibia bones were collected from five medical colleges in Odisha. All necessary precautions were taken to address ethical issues and adhere to good clinical practices.

The following parameters of proximal tibial morphometry were measured using vernier calipers [Table/Fig-1].

[Table/Fig-1]: Morphometric measurements of proximal tibia.
(a) Mediolateral length; (b) Anteroposterior intercondylar diameter; (c & e) Anteroposterior diameter of medial tibial condyle and lateral tibial condyle; (d & f) Transverse diameter of medial tibial condyle and lateral tibial condyle; (g & i) Anteroposterior diameter of anterior intercondylar area and posterior intercondylar area; (h & j) Transverse diameter of anterior intercondylar area and posterior intercondylar area.

Study Procedure

The following parameters of the proximal end of the tibia were measured by using a Vernier calliper:

1. Mediolateral Length (ML): The longest mediolateral line of the proximal cut tibial surface, parallel and collinear to the surgical epicondylar axis of the femur.
2. Anteroposterior length of the Medial condyle (APM): The length of a perpendicular line drawn through the midpoint of the medial condyle.
3. Anteroposterior length of the Lateral condyle (APL): The length of a perpendicular line drawn through the midpoint of the lateral condyle.
4. Anteroposterior length of the Intercondylar region (API): The maximum distance between the two condyles.
5. Circumference of the upper end (CM): The circumference was measured using a non stretchable thread wrapped around the maximum diameter. The circumferential measurements were obtained using a measuring tape.
6. Length between the upper end and the Tibial Tuberosity (LTT).
7. Aspect ratio: ML divided by the anteroposterior length of the intercondylar region, multiplied by 100.
8. Presence or absence of a groove for the ligamentum patellae.

STATISTICAL ANALYSIS

All categorical variables were expressed in terms of numbers and percentages. All continuous variables were expressed in terms of mean and standard deviation. A comparison of the means between the two groups was performed using an independent sample t-test. The correlation between two quantitative variables was obtained using Pearson's correlation. The normality of the quantitative variables was checked using the Shapiro-Wilk test before applying the statistical tests. A p-value <0.05 was considered statistically significant. The statistical analysis was conducted using SPSS version 27.0 (IBM Corporation, Armonk, New York, USA).

RESULTS

Out of the included bones, 114 (57%) were male tibia bones, and 86 (43%) were female tibia bones. In terms of laterality, 84 (42.0%) were left-side tibia bones, and 116 (58.0%) were right-side tibia bones. The measured morphometric parameters are presented in [Table/Fig-2].

Parameters	Mean±SD	Median (IQR)
ML in mm	67.91±5.76	69.43 (63.66-71.81)
APL in mm	39.44±4.32	39.95 (35.75-42.78)
APM in mm	42.72±4.63	43.62 (39.40-46.60)
API in mm	42.73±4.60	43.77 (39.79-45.74)
LTT in mm	33.48±5.52	33.46 (29.89-37.04)
Circumference (CT) in cm	19.37±1.78	19.19 (17.98- 20.94)
Aspect ratio	1.73±0.14	1.72 (1.65-1.80)

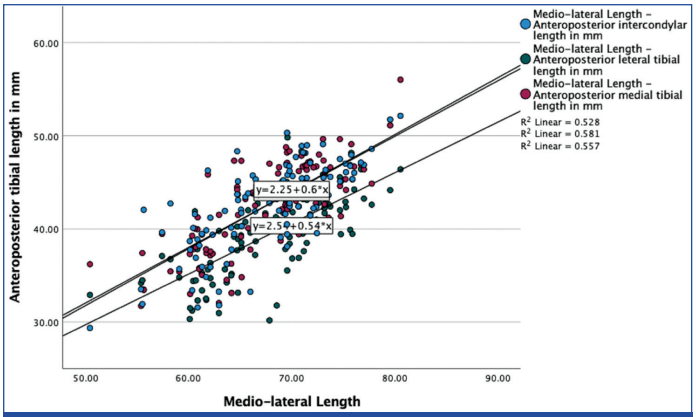
[Table/Fig-2]: Morphometric parameters of the included bones (N=200).
ML:Mediolateral length; APL: Anteroposterior length of the Lateral condyle; APM: Anteroposterior length of the Medial condyle; API: Anteroposterior length of the Intercondylar region; LTT: Length between the upper end and Tibial Tuberosity

The mediolateral length showed a significant positive correlation (p-value <0.001) with the anteroposterior length of the lateral tibial plateau, medial tibial plateau, and intercondylar area, with correlation coefficients (r) values of 0.726, 0.762, and 0.747, respectively [Table/Fig-3]. The groove for the ligamentum patellae was present in 132 (66%) of the tibia bone samples.

All parameters were significantly higher (p-value <0.05) among males compared to females, except for the aspect ratio (p-value = 0.409) [Table/Fig-4]. No significant association between any of the morphometric parameters and the laterality of the bone was observed (p-value >0.05) [Table/Fig-5].

DISCUSSION

There is well-known evidence that significant variation exists in the anthropometric measurements of the tibia among different populations worldwide [15]. Asians, including Indians, are generally smaller in stature compared to Caucasians, who tend to be taller and more robust. This difference in size is reflected in the knee dimensions, with Asians having smaller knees compared to the



[Table/Fig-3]: Correlation between mediolateral length of tibia with various antero-posterior length of tibia.

Morphometric measurement	Male (Mean±SD)	Female (Mean±SD)	p-value*
ML (mm)	69.95±4.76	65.17±5.90	<0.001
APL (mm)	40.84±3.74	37.58±4.36	<0.001
APM (mm)	44.48±3.80	40.34±4.59	<0.001
API (mm)	44.71±3.45	40.06±4.63	<0.001
Circumference (cm)	19.94±1.81	18.61±1.38	<0.001
Aspect ratio	1.72±0.14	1.74±0.13	0.409
LTT (mm)	34.84±5.21	31.64±5.43	0.002

[Table/Fig-4]: Comparison of various morphometric measurement with respect to sex (N=200).
*Independent sample t-test was used to calculate the p-value
ML: Mediolateral length; APL: Anteroposterior length of the Lateral condyle; APM:Anteroposterior length of the Medial condyle; API: Anteroposterior length of the Intercondylar region; LTT: Length between the upper end and Tibial Tuberosity

Morphometric measurement	Left (Mean±SD)	Right (Mean±SD)	p-value*
ML (mm)	67.37±5.65	68.30±5.86	0.408
APL (mm)	39.44±4.09	39.44±4.50	0.999
APM (mm)	42.34±4.78	42.98±4.52	0.477
API (mm)	42.83±4.77	42.64±4.51	0.837
Circumference (cm)	19.18±1.68	19.50±1.82	0.339
Aspect ratio	1.71±0.11	1.74±0.15	0.289
LTT (mm)	33.79±4.96	33.24±5.91	0.608

[Table/Fig-5]: Comparison of morphometric measurement with respect to side of the bone.
*Independent sample t-test was used to calculate the p-value
ML: Mediolateral length; APL: Anteroposterior length of the Lateral condyle; APM: Anteroposterior length of the Medial condyle; API: Anteroposterior length of the Intercondylar region; LTT: Length between the upper end and Tibial Tuberosity

Western population [16,17]. This discrepancy poses a challenge in finding suitable knee prostheses for Indian patients, as there is a risk of implanting an oversized prosthesis during surgical procedures like UKA and TKA [18]. Implanting an oversized prosthesis can lead to compatibility issues with the resected bones [14].

A study by Servien E et al., reported a higher anteroposterior length of the medial condyle (50.2±3.4 mm) compared to the lateral condyle (47.3±3.4 mm) [19]. In this current study, similar results were found with a higher anteroposterior length for the medial condyle compared to the lateral condyle, and this difference was statistically significant [19]. There are some methodological differences in measuring tibial dimensions between the current study and Servien E et al., in their study, they used computed tomography scans of a healthy French population to obtain anatomical data, while the current study used a direct method on cadaveric samples. The authors believe that the direct method is more accurate compared to the indirect method.

The current study reported a mean ML length of the tibia to be 67.91±5.76 mm, with the left-side tibia length being 67.37±5.65 mm and the right-side being 68.30±5.86 mm. A study by Chaichankul C et al., reported a total mean ML length of 68.8±5.8 mm in the Thai population, with males having a mean of 74.44±3.44 mm and females having a mean of 64.95±3.45 mm [20]. Another study among the Korean population by Bae DK and Park JY showed a mean ML length of 72.7±4.0 mm [21]. Kwak DS et al., also conducted a study among the Korean population, demonstrating a mean ML length of 73.5±5.6 mm and a mean anteroposterior length of 47.3 mm [22]. Surendran S et al., showed that the ML length of the medial condyle alone was 24.8±2.5 mm [14]. Servien E et al., reported the ML of the medial condyle to be 28.8±2.5 mm and the lateral condyle to be 29.3±2.4 mm [19]. The mean ML length obtained in the current study was comparable to those of the other studies.

The aspect ratio provides a better understanding of the shape of the tibia. A 100% aspect ratio indicates a semi-circular shape for the prosthesis, while less than 100% indicates an oblong shape [14]. In the present study, the aspect ratio was measured to be 1.73, which was consistent with findings from other studies in the Asian population [14,22-24]. Surendran S et al., showed a negative correlation between the aspect ratio of the medial condyle and the anteroposterior dimension, but no correlation was found between the tibial prosthesis and the condylar aspect ratio [14]. Chaichankul C et al., also reported a negative correlation between tibial AP length and tibial aspect ratio [20]. Servien E et al., calculated the aspect ratio for the medial and lateral tibial plateaus separately and reported measurements of 1.8 cm and 1.6 cm, respectively, which were similar to the findings of the current study [19]. Uehara K et al., demonstrated that the aspect ratio decreases with an increase in ML length, indicating a longer AP direction in smaller knees [25].

Srivastava A et al., conducted a study measuring tibial condyles among the North Indian population [26]. They reported a mean anteroposterior diameter of 36.47 mm and 38.63 mm for the lateral and medial tibial condyles of the right tibia, respectively. For the left side, the measurements were 36.94 mm and 39.94 mm, respectively. The current study's findings were similar to this study. Similarly, the mean transverse diameter reported by Srivastava A et al., was 29.2 mm and 29.7 mm for the lateral and medial tibial condyles of the right tibia, while for the left side, the measurements were 29.7 mm and 27.5 mm, respectively. This information may be useful for managing implants for patients from Northern and Eastern India.

The results of this study will provide recommendations for creating suitable tibial prosthetic components for unicompartmental and TKA surgeries in the Eastern Indian population. Anatomists, anthropologists, medical students, and researchers will also benefit from this morphometric analysis.

Limitation(s)

One limitation of the study was its geographical restriction to one state in India, so the generalisability of the study to the entire Indian population should be interpreted cautiously.

CONCLUSION(S)

The current study analysed the morphometric data of proximal tibial dimensions among the East Indian population and used statistical methods to identify associations with different variables. The results obtained in this study may be helpful for clinicians in developing guidelines or standard operating procedures for implants in patients undergoing TKA, UKA, or meniscal implants. The results may also be of great importance to anthropologists, forensic anthropologists, clinical anatomists, and physical anthropologists. Authors believe that the measurements obtained in this study will be valuable in developing tibial knee prostheses specifically for the Eastern Indian population.

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