

Original Article

Quantitative Analysis of The Femoral Condyles: Morphometric Insights For Orthopaedic Surgery

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Abstract

Objective: Accurate morphometric data of the femoral condyles are critical for optimising the design of knee joint implants. This study analysed distal femur morphometry to address existing demographic knowledge gaps.

Methodology: A descriptive cross-sectional study was conducted on 65 adult cadaveric femur specimens. All measurements of the lower end of the femur were taken using a Digital Vernier Caliper. Data were analysed using SPSS version 24, with t-tests comparing the right and left femurs.

Results: The mean bicondylar width was 78.27 mm for the right femur and 77.13 mm for the left femur ($P=0.34$; 95% CI -1.24, 3.52). The mean medial condylar anteroposterior distance was 56.48 mm for the right femur and 57.25 mm for the left femur ($P=0.49$; 95% CI -2.99, 1.45). The lateral condylar anteroposterior distance was 60.04 mm for the right femur and 59.30 mm for the left femur ($P=0.44$; 95% CI -1.20, 2.68).

Conclusion: This study provides data on the morphometry of the femoral condyles. This will facilitate the development of customised knee implants that match the unique anatomical requirements of the Pakistani population.

Keywords: knee joint, knee prosthesis, arthroplasty, osteoarthritis.

Introduction

The femur is also known as the thigh bone. It is the longest and strongest bone in the human body. It comprises the proximal end, shaft, and distal end. Its proximal end has a head and articulates with the acetabulum of the hip bone to form the hip joint. Its distal end has expanded condyles that articulate with the tibia inferiorly and patella anteriorly, forming the knee joint. This specialised joint is classified as a modified-hinge joint. Flexion, extension, and a degree of slight rotation, including locking and unlocking, occur in this joint, thereby facilitating a range of motions essential for locomotion and other activities.¹ The femur serves as a crucial attachment site for many powerful muscles, which are important in facilitating movement, maintaining posture, and ensuring overall body stability.

Precise measurements of the femoral condyles are important in clinical contexts, particularly in orthopaedic surgery, as they play a critical role in the design and development of implants and prosthetic devices. These implants are essential for treating femoral fractures and facilitating successful joint replacement surgeries.² The success of treatment depends on obtaining a perfectly matched prosthesis, which helps prevent complications after surgery.³ Osteoarthritis is a chronic condition that most frequently affects the knee joint. In this condition, the articular cartilage is degenerated by multiple contributing factors.⁴ Total knee arthroplasty is the optimal surgical treatment for patients with severe arthritis is total knee arthroplasty.⁵ The optimal implant size is crucial for preventing soft tissue pressure and postoperative complications.⁶ Common injuries of the lower end of the femur include supracondylar and intercondylar fractures. Fractures of the femoral condyle are often intra-articular and can lead to postoperative complications.⁷ These fractures are difficult to manage and may cause disabilities.⁸ A comprehensive

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Data Availability Statement: The raw and processed morphometric data supporting the findings of this study are openly available in the Mendeley Data repository at V1, doi: 10.17632/rhxjs9gd5m.1, licensed under CC BY 4.0.

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review of the existing literature revealed a significant lack of data regarding the morphometric analysis of the lower end of the femur within the context of the Pakistani population.

The main goal of this research study is to fill the current gap in understanding by conducting a detailed analysis of the morphometry of the femoral condyles that will aid in the safe instrumentation and fixation of bones. Additionally, the study will offer measurements of the characteristics of the lower end of the femur for constructing artificial joint components and implants that will aid in producing prostheses.

Methodology

This descriptive cross-sectional study will be conducted from January 2025 to June 2025 in the Department of Anatomy at the Services Institute of Medical Sciences. The study was conducted after obtaining ethical approval from the IRB of the Services Institute of Medical Sciences (Ref No. IRB/2025/1500/SIMS). The study was conducted on 65 cadaveric femurs (33 right-sided and 32 left-sided) of adult size, irrespective of the sex of the individual. The sample size of 65 femurs was calculated based on a standard deviation of 4.5 mm (medial condylar anteroposterior distance MCAPD),¹⁶ at a 95% confidence level and with a 1.09 mm margin of error. The 65 adult dry femurs were obtained from an existing, de-identified legacy teaching collection within the Department of Anatomy of the Service Institute of Medical Sciences. The IRB granted an explicit waiver of informed consent for their use. The use of these cadaveric materials was fully compliant with institutional and regional ethical regulations regarding human tissue and osteological research. The consecutive sampling technique was used, and unossified, broken femurs were not included in the study. A Digital Vernier Caliper was used to record the bicondylar width (BCW), medial condylar anteroposterior distance (MCAPD), lateral condylar anteroposterior distance (LCAPD), medial condylar transverse distance (MCTD), lateral condylar transverse distance (LCTD), and intercondylar notch width (ICNW) of the distal end of the femur, as shown in Fig 1-3. Data management and descriptive statistics were performed using IBM SPSS Statistics, Version 24 (IBM Corp., Armonk, NY, USA; RRID: SCR_016479). The mean and standard deviation (SD) values were calculated to depict quantitative data. The 95% confidence intervals (CI) for the mean diameters were calculated to estimate the population parameters. An independent t-test was applied to the parameters of the right and left femurs, and a P-value ≤ 0.05 was considered significant.



Fig 1-3 Measurements of lower end of femur (A = Bicondylar width, B = Lateral condyle transverse distance, C = Medial condyle transverse distance, D = Intercondylar notch width, E = Medial condylar antero-posterior distance, F = Lateral condylar antero-posterior distance.)

Results

The detailed data with statistical evaluation are compiled in Table 1. The measurements of the right and left femurs are displayed separately.

Bicondylar width (BCW), medial condylar anteroposterior distance (MCAPD), lateral condylar anteroposterior distance (LCAPD), medial condylar transverse distance (MCTD), lateral condylar transverse distance (LCTD), and intercondylar notch width (ICNW) of the distal end of the femur.

Table 1: Measurements of lower end of femur

Parameters	Right femur Mean $\pm$ SD (mm)	Left femur Mean $\pm$ SD (mm)	95% Confidence interval (CI)	P value
BCW	78.27 $\pm$ 5.67	77.13 $\pm$ 3.89	(-1.24, 3.52)	0.34
MCAPD	56.48 $\pm$ 4.82	57.25 $\pm$ 4.19	(-2.99, 1.45)	0.49
LCAPD	60.04 $\pm$ 4.41	59.30 $\pm$ 3.44	(-1.20, 2.68)	0.44
MCTD	28.52 $\pm$ 4.82	27.43 $\pm$ 4.19	(-1.13, 3.31)	0.33
LCTD	31.44 $\pm$ 4.41	32.10 $\pm$ 3.44	(-2.60, 1.28)	0.50
ICNW	20.58 $\pm$ 5.67	21.74 $\pm$ 3.89	(-3.54, 1.22)	0.33
Femur length	475.99 $\pm$ 11.72	473.97 $\pm$ 19.62	(-6.12, 10.16)	0.62

Discussion

Knee joint stability relies on the shape of the femoral condyles. As knee arthroplasty becomes increasingly prevalent in the treatment of degenerative knee diseases, it is essential to understand the anatomical characteristics of the bone surface area resected during total knee arthroplasty. This knowledge helps create prosthetics that fit perfectly and function optimally. Numerous researchers have investigated only the bicondylar width for knee prosthesis design.⁹

There are notable variations in the morphometric measurements of the lower end of the femur among different populations worldwide. In the present study, the bicondylar width (BCW) was 78.27 mm for the right femur and 77.13 mm for the left femur, which is close to the study conducted in India,¹⁰ showing BCW of 74.53 mm but lower than the Greek,¹¹ population showing BCW of 84.1 mm for the right femur and 83.7 mm for the left femur. Existing studies and commercially available prostheses are largely based on the Western population. However, smaller knee sizes were observed in the Pakistani population. In the present study, the mean MCAPD was 56.48 mm, which is higher than that in the Thai population,¹² showing MCAPD 44.27 mm and lower than that in the Mongolian population,¹³ i.e., 60.4 mm.

The size and shape of the intercondylar notch, which separates the medial and lateral condyles, influence the placement of the femoral component and patellar tracking. A narrow or irregular notch can complicate the placement of the femoral prosthesis, leading to instability or compromised knee function.¹⁴ In the present study, the ICNW was 20.58 mm for the right femur and 21.74 mm for the left femur, which is near the study done in the Indian population 20.4 mm for the right femur but higher than that for the left femur, i.e., 18.7 mm.¹⁵ The ICNW noted in our study is near the measurements noted by Janani SV and Ramachandran K,¹⁶ i.e., 21.5 mm for the right femur and 21.6 mm for the left femur.

In the present study, the LCAPD noted for the right femur was 60.04 mm and for the left femur 59.30 mm, with similar results noted by Bhaskar et al. 55.4 mm.¹⁵ In our study, the MCTD noted for the right and left femur was 28.52 mm and 27.43 mm, respectively, which is near the measurements noted by Bhimalli et al. (25.4 mm for the right femur and 27.3 mm for the left femur).¹⁷ The LCTD noted for the right femur was 31.44 mm, and for the left femur, it was 32.10 mm in the present study. These measurements are higher than those reported by Singh et al.,¹⁸ (28.53 mm on the right side and 28.63 mm on the left side). The femur lengths of the right and left femurs were 475.99 mm and 473.97 mm, respectively, in the present study. These measurements are higher than those reported by Babacan et al.,¹⁹ (400.27 mm in the Turkish population).

Differences in body measurements among diverse populations can be attributed to various factors, including genetics, environment, occupation, and societal influences, which collectively impact body build and stature. In our study, no significant side-to-side differences were found for any parameter ($p > 0.05$). Our results align with those of Bhimalli et al., who conducted a similar study on the Indian population.¹⁷ In the absence of statistically significant side-to-side differences, the contralateral healthy side can be reliably used for preoperative templating in total knee reconstruction. The current study has certain limitations, including a small sample size and unknown sex of the bones. Therefore, we were unable to conduct a gender-based analysis, which is medically significant.

Conclusions

This study will contribute valuable insights by providing morphometric data on femoral condyles, which will inform the design and manufacture of implants tailored to the anatomical characteristics of the Pakistani population. With the evolution of knee arthroplasty techniques, the approach of studying individual femoral anatomy with advanced imaging and surgical technologies will improve the longevity of knee prostheses.

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Contributions:

SSR WI SA ST - Conception, Design

SSR WI MAR MRA - Acquisition, Analysis, Interpretation

SSR WI MAR MRA - Drafting

SSR WI SA ST - Critical Review

All authors approved the final version to be published & agreed to be accountable for all aspects of the work.

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