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Morphological analysis of the distal femur: a radiological study

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Abstract

Objectives: The morphology of the femur in both proximal and distal parts has been the subject of various studies. The dimensions of the distal femur are important in prosthesis and implant design, especially for knee joints in cases such as total knee arthroplasty. This study aims to enrich the limited literature on distal femur morphology by using computed tomography images of 100 dry femur bones obtained from the human skeleton.

Methods: Computed tomography sections were evaluated for the distal parts of 100 dry human femur bones and parameters such as mediolateral length, anteroposterior width, and medial and lateral condyle widths were measured. Measurement data were presented as means and standard deviations.

Results: As a result of the measurements, the mean mediolateral length was 76.1 mm and the mean anteroposterior width was 59.9 mm. The femoral aspect ratio was 1.27.

Conclusion: Understanding the variations in distal femur morphology will reduce the risk of bone-size mismatch in total knee replacement designs.

Keywords: computed tomography; distal femur; morphology; total knee arthroplasty

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Introduction

The femur is the largest bone in the human body, and its morphology in both the proximal and distal parts has been the subject of various studies.[1,2] Studies of femur morphology can be performed using techniques based on data from radiography, computed tomography (CT) , and magnetic resonance imaging (MRI). CT data can be obtained in both two-dimensional and three-dimensional formats.[3–5]

The dimensions of the distal femur are important in prosthesis and implant design, especially for knee joints in cases such as total knee arthroplasty.[6,7] For the design of the knee implant, implant geometry and size are important factors affecting the durability of the prosthesis. Optimizing the size of the implant coating surface area between the bone and the implant component may help prolong the life of prostheses as it reduces stress around the bone and wear on the tibial insert.[8] Distal femur morphology varies greatly and components are produced in a limited range of sizes and morphologies, primarily for economic reasons. Surgeons often have to compromise when choosing the size of a component, which can disrupt rotation and the stability of soft tissues. It has been reported that the components are too large for 66% to 76% of patients undergoing total knee arthroplasty.[9]

This study aims to enrich the limited literature on distal femur morphology by using CT images obtained from 100 dry femur bones from human skeletons.

Materials and Methods

The data source of our study comprised the records of 100 dry adult femur bones for which CT images had been performed in a different study. Bones with pathologies such as fractures, tumors, abnormal deformities, or previous surgeries as well as avascular necrosis, hip dysplasia, or slipped capital femoral epiphysis related to the femoral head were excluded from the study. All female and male bones that did not meet any of the exclusion criteria and exhibited no bone pathologies were included in the study. The results of

CT images (including 3D reconstructions of the femurs) were reviewed to obtain data on morphometric properties. All scans had been performed at a cross-sectional thickness of 0.6 mm (256-slice multidetector scanner; Siemens, Erlangen, Germany). All measurements were made by the author who has more than 10 years of orthopedic experience. The measurements were repeated 2 times and the arithmetic average of the 2 values was used.

Parameters noted in the CT records and their definitions are as follows (**Figure 1**):

- **Mediolateral length (ML-L):** The distance between the lateral epicondyle and the most prominent point of the medial epicondyle.
- **Anteroposterior width (AP-W):** The distance between the most anterior cortex point and the line connecting the most posterior point of the lateral and medial condylar.
- **Medial anteroposterior width (MAP-W):** The distance between the most anterior and posterior point of the medial condyle.
- **Lateral anteroposterior width (LAP-W):** The distance between the most anterior and posterior point of the lateral condyle.
- **Medial condyle width (MC-W):** The distance between the most medial point and the most lateral point of the medial condyle.
- **Lateral condyle width (LC-W):** The distance between the most medial point and the most lateral point of the lateral condyle.
- **Intercondylar notch width (IN-W):** Width of the intercondylar notch.
- **Femoral aspect ratio (ML-L/AP-W):** The ratio of mediolateral length to anteroposterior width.

Results

As a result of the measurements, the mean mediolateral length was 76.1 mm and the mean anteroposterior width was 59.9 mm. The femoral aspect ratio was 1.27. All measurements of distal femur morphology are shown in **Table 1**.

Table 1
Morphometric parameters of the distal femur.

Parameters	Mean±SD
ML-L (mediolateral length)	76.1±6.2
AP-W (anteroposterior width)	59.9±5.4
MAP-W (medial anteroposterior width)	65.2±5.4
LAP-W (lateral anteroposterior width)	67.8±5.2
MC-W (medial condyle width)	27.3±3.1
LC-W (lateral condyle width)	25.8±2.9
IN-W (intercondylar notch width)	23.8±3.0
ML-L/AP-W (femoral aspect ratio)	1.27±0.1

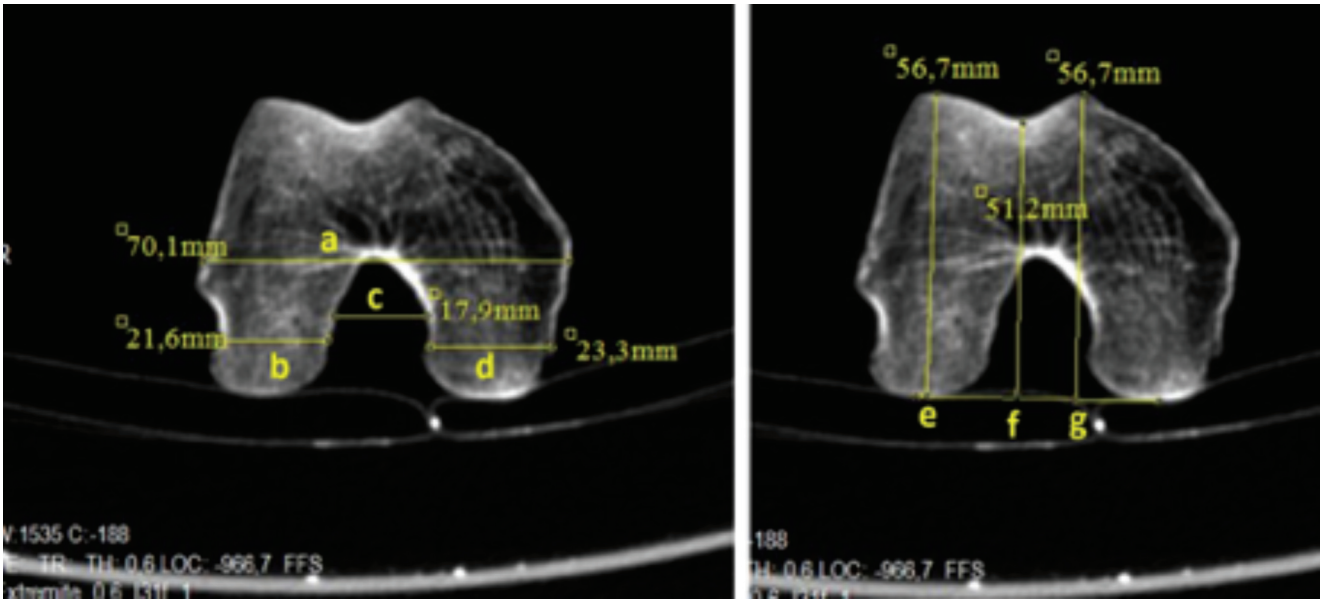

Figure 1. Measurements on CT axial section. The measurements in the figure represent the results in one case. **a**: mediolateral length, **b**: lateral anteroposterior width, **c**: intercondylar notch width, **d**: medial condyle width, **e**: lateral anteroposterior width, **f**: anteroposterior width, **g**: medial anteroposterior width.

Discussion

The morphometric parameters of the distal femur are frequently used in various applications such as gender determination, racial and ethnic identification, and determination of baseline data for the design of knee prostheses.[1,6] Our study has aimed to enrich the limited literature on distal femur morphology by analyzing CT data obtained for dry bones.

The present study showed that, the mediolateral length of the distal femur was 76.1 mm and the anteroposterior width was 59.9 mm. It was observed that the mediolateral length of the femur was greater than the anteroposterior width, and the ML-L/AP-W ratio was 1.27. This ratio was determined by Phombut et al.[10] to be 1.26, showing close similarity to our study.

With improvements in quality of life, changes in lifestyle habits, and increasing life expectancy, the incidence and detection rates of knee diseases are increasing every year. Total knee arthroplasty has made great progress in the general context of the development of orthopedic science in recent years with its wide range of indications and has come to the fore as an important treatment method to improve knee function and quality of life in patients with osteoarthritis, rheumatoid arthritis, and severe knee arthrosis. However, 20% of patients undergoing total knee arthroplasty still report dissatisfaction after surgery.[11] Postoperative outcomes after total knee arthroplasty are closely related to knee prosthesis design and prosthesis placement level. For this reason, it is very important that the intraoperatively applied prosthesis fit the patient's knee geometry. Initial designs for total knee arthroplasty included only one-dimensional femoral components, but knowledge of knee anatomy and prosthetic design have improved significantly over the years.[12] With the increase in studies indicating the differences in distal femur and proximal tibia morphology, manufacturers have introduced implants of different sizes on a wider scale.[2,13–17] Incompatibility between the prosthesis and the osteotomy surface leads to chronic knee pain, instability, and decreased range of motion and may ultimately affect the normal function of the joint.[18] An overly large femoral component causes soft tissue compression, which in turn causes painful irritation of the knee tendons and ligaments, while a small femoral component causes increased blood loss through the exposed spongiosa bone. Mueller et al.[19] reported an increase in midflexion instability in small-sized femurs and attributed this to a decrease in posterior offset. We think that anatomical studies evaluating distal femur morphology in different race, gender, and age groups should be emphasized in light of the danger of incompatibility of total knee prosthesis designs with bone morphology.

The study had some limitations. First, the study material was dry bone, and dry bone that has lost its vitality and water content may change in volume. Second, we did not have access to data such as the genders, ethnicities, or ages of the skeletons from which these bones originated, and the effects of those variables on femur morphology are well known. In spite of these limitations, however, we think that the measurements we have made based on CT images represent safer results compared to other radiographic measurements, and we anticipate that our study will contribute to the literature when evaluated together with other similar studies.

Conflict of Interest

The author declare no conflict of interest.

Ethics Approval

Since the study was conducted from our dry bone CT archive, it does not need ethics committee approval.

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