# Distal Femur MRI Rotational Anatomy in a Black African Population: A Pilot Study

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**Abstract**

**Background:** Correct distal femoral rotation, which varies across populations, is one important factor in total knee arthroplasty (TKA) surgical success. This descriptive pilot study aims to present the magnetic resonance imaging (MRI) findings in a black population using recognized measures that have been utilized in different populations and to compare these findings with published data. **Materials and methods:** MRI images of 58 knees taken over a 6-month period were retrospectively reviewed to measure the condylar twist angle (CTA), Whiteside-posterior condylar angle (W-PC), and Whiteside-epicondylar angle (W-EP). The correlation between the angles and age and gender was assessed. **Results:** The mean CTA was 4.4° (4.7° in males and 4.2° in females), while the mean W-PC and W-EP were 87.1° (87.2° in males and 87.1° in females) and 86.5° (86.5° in males and 86.4° in females), respectively. There was no correlation between the rotational measurements and the age or gender of the study subjects. **Conclusion:** The mean CTA was 4.4 in this study which differs from published data showing 6° in Indian and 3° in Caucasian populations. A larger study is required to review the distal femoral and proximal tibial anatomy in the black population group to assess whether significant variations exist that may impact the outcomes in TKA using standard implants.

**Keywords**: Condylar twist angle, Posterior condylar axis, Whiteside-epicondylar axis, Whiteside-posterior condylar angle, Knee, Black population

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## Introduction

Total knee arthroplasty (TKA) remains a successful orthopedic procedure in alleviating pain resulting from degenerative joint damage with the average global incidence of the procedure being 136/100,000 according to the Organisation for Economic Co-operation and Development (OECD) data (1). Over the years, the procedure has been refined and the surgical implants have been improved to reproduce more closely the native knee anatomy and kinematics. These improvements and innovations have been made taking into account finer details of a wider range of native knee anatomy. The rotational alignment of the knee with a focus on different population groups has been studied in an attempt to define variations that may influence the best implant choice for individuals (2-4). The rotational profile of the distal femur is of particular significance as it has a major influence on the patella tracking, which is considered an important factor in TKA survivorship and patient satisfaction as reported by Matz et al. (5). The early failures in TKA were deemed to be due to femoral

malrotation in turn leading to patella maltracking with some studies quoting tracking problems as being behind up to 50% of TKA failures (5, 6). These findings underscore the importance of closely approximating the native patella tracking when performing TKA. Related to this, Akagi et al. also showed a greater need for intraoperative soft tissue releases when maltracking was present (7). Most TKA systems use a 3° external rotation cut to ensure satisfactory patella tracking and ligament balancing. A deviation from the expected 3° external rotation in native knees has been demonstrated in various population groups; however, there is no information on the rotational profile in black African knees. This pilot study seeks to assess the distal femur rotational profile in a black African population using magnetic resonance imaging (MRI) and to compare the findings with other published data on this aspect of knee morphology. This will lay the foundation for a comprehensive study assessing further distal femur and proximal tibia morphology using MRI and to relate it to existing implants in the market.

**Materials and Methods**

Ethics approval was applied for and obtained from the Institutional Scientific Ethics Review Committee (2023/ISERC-349V1) for this retrospective cross-sectional pilot study carried out at the Aga Khan University Hospital, Nairobi, Kenya. A census was taken of all MRI scans of the knee joint in adult black Kenyan patients aged between 18 and 79 years taken over a 6-month period between June 2023 and December 2023. The MRI scans were taken to assess knee pain, including trauma, where no fractures were identified on the X-ray. Patients with a history of fracture, previous surgery, or malignancy involving the knee were excluded. Fifty-eight consecutive MRI scans of the knee joint were eligible for use in the study.

The patient variables selected for the study were age and gender. The MRI images were obtained and analyzed using the enterprise picture archiving computer system program with the following parameters measured:

- The condylar twist angle (CTA)
- The Whiteside-epicondylar angle (W-EP)
- The Whiteside-posterior condylar angle (W-PC)

The rotational measurements were performed on the axial MRI images of the knee using the slice with both epicondyles most prominent in the proton density fat-saturated sequence. The anatomical transepicondylar axis was determined by drawing a line through the most prominent point of the medial and lateral epicondyles. The posterior condyle line was drawn tangent to the posterior aspect of both medial and lateral femoral condyles and was also used as a reference for measuring the rotation. The angle made between these two drawn lines was the CTA (see Figure 1). The Whiteside line was determined on the axial MRI slice with the trochlear groove most prominent and was a line connecting the most posterior (lowest) point of the groove and the most anterior (highest) point of the trochlear notch. W-EP and W-PC were measured in all the knees (see Figure 1) as both measures were rotational measurements used intraoperatively in TKA.

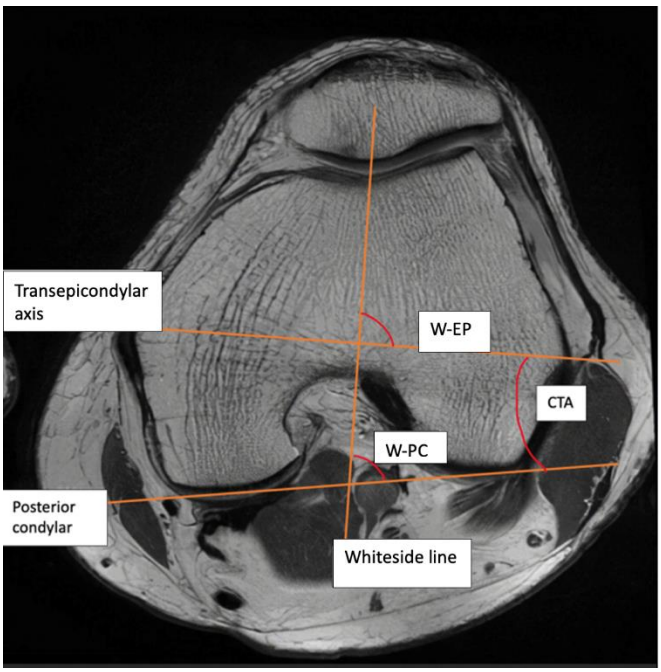


Figure 1. Rotational measurements used in the study. CTA; Condylar twist angle, W-EP; Whiteside-epicondylar angle, W-PC; Whiteside- posterior condylar angle WPC.

All the images were taken using a 1.5T scanner from GE (California, US) and analyzed by one radiologist with an interest in musculoskeletal work.

## Results

The MRI scans of 58 knees were analyzed. There were 27 females and 31 males with a mean age of 42.5 years and an age range of 18–79 years. The mean CTA measured was 4.4° with a range of 0.5°–8.3°. The mean CTA was 4.2° in females and 4.7° in males. The mean W-PC was 87.1° (range, 84.4°–90°). The mean W-PC was 87.1° in females and 87.2° in males. The mean W-EP was 86.5° (range, 81°–89.9°) in males and 86.4° in females. Table 1 provides a summary of the results.

Table 1. Summary of the results

| | **Male, n=31** | **Female, n=27** | **Mean** |
|---|---|---|---|
| Age | 45 years | 37 years | 42.5 years |
| CTA | 4.7° | 4.2° | 4.4° |
| W-PC | 87.2° | 87.1° | 87.1° |
| W-EP | 86.2° | 86.4° | 86.5° |

CTA, condylar twist angle; W-EP, Whiteside-epicondylar angle; W-PC, Whiteside-posterior condylar angle.

For establishing associations between numeric and categorical variables such as age and gender, the Wilcoxon rank-sum test was used. The overall median CTA was 4.7°, with an interquartile range of 3.1°. There was no difference between the median condylar angles in degrees between females (4.40° [2.35–5.95]) and males (5.10° [3.65–6.45]), p = 0.5. The overall median Whiteside-epicondylar axis was 87°, with an interquartile range of 3.5°. There was no difference in the median Whiteside-epicondylar axis between females (86.50° [84.65–88.60]) and males (87.00° [85.10–88.25]), p > 0.9. The overall median Whiteside-posterior condylar axis was 87.4°, with an interquartile range of 2.4. There was no difference in the median Whiteside-posterior condylar axis between females (87.40° [85.55–88.60]) and males (87.00° [86.00–88.35]), p > 0.9.

A Shapiro–Wilk normality test was performed on the collected variables such as age, CTA, W-PC, and W-EP revealing that only age was normally distributed (p = 0.125, p = 0.01792, p = 0.0115, p = 0.02012, respectively). Non-parametric testing was therefore used.

A Spearman rank correlation coefficient was performed to establish any relationship between the numeric variables. There was no statistically significant correlation between age and CTA (r=0.16), age and Whiteside-posterior condylar axis (r=−0.13), age and Whiteside-epicondylar axis (r=−0.012), and between the two axes (r=0.15). There were weak correlations between the CTA and Whiteside-posterior condylar axis (r=−0.14) and between the CTA and Whiteside-epicondylar axis (r=−0.32).

For establishing associations between numeric and categorical variables such as age and gender, the Wilcoxon rank-sum test was used and no associations were found between any of the variables. This means that for our dataset there was no statistical difference in the distal femur rotational profile with age or gender.

## Discussion

Total knee replacement designs have progressively aimed at reproducing knee biomechanics by the study of anatomical and mechanical axes and using cuts in the jigs reflecting this understanding. The importance of the distal femur rotation has been demonstrated in studies over the years, especially the effect on patella tracking. This is particularly important in knee replacement surgery where surgeons seek to restore near-normal kinematics after resurfacing the chondral surfaces. Most prosthesis designs adopt 3° of external rotation both for the patella tracking and the presumed recreation of the flexion gap after making a perpendicular proximal tibia cut. Several studies reviewing the external rotation of the distal femur have shown variations ranging from an average of 2.6° to 5.9° in different racial groups. Jones et al. demonstrated a mean value of 5.9°, while Griffin et al. found the mean angle to be 3.1° with a tendency to increase in older age (3, 8). Halai et al. assessed a predominantly Caucasian population and measured 3° external rotation in men and 5° in women using the posterior condylar angle (PCA) (9). In their study, Pun et al. measured the mean PCA to be 4.67° and the mean W-EP to be 92.7° in an Indian population on MRI (10). Lu et al. found the CTA to be 10.2° in a Chinese population in a computed tomography (CT) scan study (11). Boisgard et al. found a CTA of 2.65° in a CT study

of arthritic knees in a French population (12), while Jang et al. found the average to be 2.4° in a large CT study of mixed population (13).

In this study, the CTA, W-EP, and W-PC were used to measure the distal femur rotational anatomy. The mean CTA was 4.5° as measured from the posterior condylar axis and the transepicondylar axis. The W-EP was 86.4° and the W-PC was 87.1°.

These results and the published literature on distal femur rotation may lend weight to the argument for using gap balancing techniques with less reliance on absolute rotational figures dialed into the instruments (14). Chao et al. showed that using multiple rotation measures helped improve implant positioning, but this was still dependent on using pre-existing jigs and implants with set external rotation (15). Chalmers et al. showed that there was little correlation between individual rotational profiles (ranging from 3° internal to 7° external rotations), suggesting that less reliance should be placed on the assumed rotation profile of the limb and using a fixed 3° external rotation had the possibility of leading to significant maltracking (16). Beckmann et al. also made the argument for individualized TKA solutions bearing in mind the published patient anatomical variations (17). The results of this study suggest that the 3° external rotation commonly used in TKA may not be representative of black African distal femur rotation profiles and may indicate the need for jigs that allow adjustment to at least 4° of external rotation for a closer approximation.

One of the shortcomings in this study may be the use of MRI scanning to measure bone anatomy. CT scanning would have been more accurate for bone anatomy, but in the assessment of normal morphology, an MRI scan allows consideration of the cartilage which does not wear evenly and has an influence on the rotational assessments (18). Additionally, MRI is ubiquitously used in assessing knee anatomy and has no radiation load. A strength of the study is the use of multiple measures, i.e., CTA, W-EP, and W-PC, as determinants of distal femoral rotation, acknowledging the fact that surgeons use more than one measure intraoperatively when determining distal femur rotation. Another strength of the study is the fact that one radiologist performed all the measurements in a standardized fashion. To our knowledge, these rotational anatomy data have not been published in a living black African population.

## Conclusion

This pilot study found that the average distal femur rotation was 4.4, which suggests that in a black population there may be a deviation from the 3° commonly used in surgical jigs. There is a need for larger research studies to assess the specific anatomic differences demonstrated and whether they translate to poorer outcomes when using the standard implants and instrumentation.

## Author contributions

MA led in conceptualization, methodology and in writing of the original draft, PL led in data curation and IC led in formal analysis. All authors equally contributed to project administration, validation and in reviewing & editing of the original draft.

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