ANTHROPOMETRY OF THE DISTAL FEMUR IN A KENYAN POPULATION AND ITS CORRELATION WITH TOTAL KNEE REPLACEMENT IMPLANTS

K.C. Lakati, FCS Orth (ECSA), Department of Human Anatomy, Egerton University, Njoro, Kenya, **B.M. Ndeleva,** MMed (Mak), FCS Orth (ECSA), Department of Surgery and Orthopaedics, Kenyatta University, Nairobi, Kenya, **C.K. Kibet,** Medical Student, **S.M. Odhiambo,** Medical Student, and **V.B. Sokobe,** Medical Student, Egerton University, Njoro, Kenya

Correspondence to: Dr. K.C. Lakati, P.O. Box 15711-20100, Nakuru, Kenya. Email: klakati@yahoo.com

ABSTRACT

Background: No local study has been done to determine the anthropometric features of the distal femur, compared it with other studied populations and some of the total knee replacement implants available.
Objective: To determine the Medio-Lateral (ML) width of the condyles of the femur, the anteroposterior (AP) diameter of the condyles and the intercondylar notch width, determine the relationship between length of the femur and the distal femur measurements, compare the results with other studied populations and the femoral components of widely used total knee replacement implants.
Methods: The distances were measured using digital vernier calipers on dried femora which w ere grossly not deformed. The dimensions of the femoral components of widely used total knee replacement implants were obtained from respective product monographs.
Results: A total of 62 grossly normal femora were used in the study, 29 from the right side, and 33 from the left side. Average femoral length was 46.12cm, average medio-lateral width of condyles was 68.44mm, with average anteroposterior width of the lateral condyle being 61.20mm, while that of the medial condyle was 58.01mm.There was no significant difference between the dimensions of the left and right sided femora. There was a positive correlation between length of the femur and the mediol-lateral and anteroposterior widths of the condyles. There was no correlation between length of femur and the intercondylar notch width. The distal femur dimensions were greater than those reported in studies on Indian, Chinese and Malay populations, but lesser than the dimensions reported in studies on Greek femora. Comparison with femoral components of eight total knee replacement implants showed that three of the components had dimensions that closely matched those of the femora.
Conclusion: The dimensions of the distal femur of the adult Kenyan differs from other ethnic populations. Of the implants sampled, most had dimensions that did not closely match those of the femora studied. Local clinical studies are needed to determine the clinical significance of the mismatch on the outcome of total knee replacement.

Key words: Anthropomentry, Width of condyles, Aspect ratio, Total knee replacement

INTRODUCTION

The anatomy of the distal femur has important implications in total knee replacement, which aims to restore the morphology of the distal femur to as near normal as possible. An accurate femoral component size helps to create a balanced flexion-extension gap. A correct fit in the mediolateral direction ensures proper patellar tracking and also ensures that the component rests on strong cortical bone. It also affords easy closure of the soft tissues. An accurate fit in the anteroposterior plane ensures proper tension of the extensor mechanism. Overhang in the mediolateral plane can potentially lead to post-operative soft tissue irritation and clinically significant post-operative knee pain, as reported by Mahoney *et al* (1).

Previous studies have shown that the dimensions of the distal femur vary between populations, and between genders (2-4). Most of the total knee replacement implants have been modeled on the anthropometry of Caucasian femora, and therefore could potentially have a mismatch when implanted in other populations.

Studies of the anthropometric features of the proximal femur and the anterior femoral curve in femora from a Kenyan population have found these features to be different from those of other populations. These studies also documented a mismatch between the femora and locally available implants (5,6). We postulated that similarly, the features of the distal femur in a Kenyan population would differ from those of other populations as well as available TKR implants.

MATERIALS AND METHODS

Dried femora were obtained from the Department of Human Anatomy, Egerton University, Njoro and the Department of Human Anatomy, Kenyatta University, Nairobi, Kenya. Only femora from skeletally mature individuals were used. Age and sex of the source cadaver were not available. Femora that looked grossly deformed, those with previous fracture and postmortem damage were excluded from the study.

The length of the femur was measured from the highest point of the femoral head to the distal part of the medial condyle. The following distances were then measured on the distal femur by use of digital vernier calipers: the Medio-Lateral (M-L) width of the femoral condyles, widest Antero-Posterior (A-P) diameter of the medial and lateral femoral condyles and the width of the intercondylar notch as shown in Figures 1 and 2. For uniformity, for each of the parameters, one investigator did the measurements in all the specimens.

The aspect ratios of the femora were calculated by dividing the mediolateral (M-L) width with the anteroposterior (A-P) diameter of the lateral condyle. The results obtained were then compared with results from other studied populations and the sizes of the femoral components of some widely used total knee replacement implants. The dimensions of the implants were obtained from the respective product monographs. Data analysis was done using Numbers® version 4.1.1(Apple Inc,.).

Figure 1
Measurement of AP diameter lateral condyle

Figure 2
Measurement of M-L width

RESULTS

A total of 62 femora free of any gross pathology and deformity were obtained and used in the study. Of these, 29 were from the right side, while 33 were from the left side. Table 1 shows a summary of the results.

Table 1
Summary of the dimensions of the femur specimens

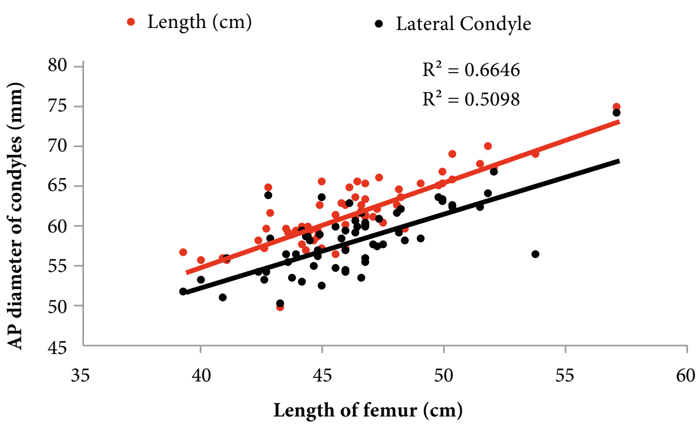
	Number	Mean femur length (cm)	Mean mediolateral width (mm) (ML Width)	Mean anteroposterior (AP) diameter medial condyle (mm)	Mean anteroposterior(AP) diameter lateral condyle (mm)	Mean width intercondylar notch (mm)	Mean aspect ratio (ML/AP Lateral condyle)
All specimens	62	46.12	68.44	58.01	61.20	23.04	1.12
Right femora	29	46.13	68.39	57.98	61.36	23.00	1.11
Left femora	33	46.12	68.49	58.05	61.08	23.06	1.12

Table 2 shows a comparison between the results of the current study and studies of other populations.

Table 2
Comparison with other populations

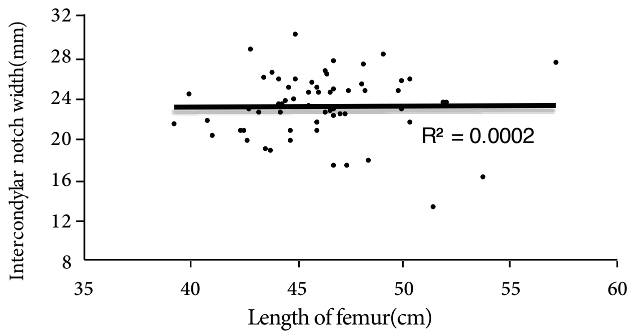
Author	Ethnicity	Mediolateral (ML) Width of condyles (mm)	AP diameter lateral condyle (mm)
Current study	Kenyan	68.4±5.19	61.2±4.17
Terzidis *et al* (4)	Greek	83.9±6.3	58.5±4.0
Shah *et al* (7)	Indian	68.3±3.9	62.7±4.8
Moghtadaei *et al* (8)	Iranian	67.06±6.3	60.82±3.9
Ewe *et al* (9)	Malay	65.46±6.23	59.88±5.37
Ewe *et al* (9)	Indian	65.33±4.56	61.50±5.62
Ewe *et al* (9)	Chinese	64.68±4.47	59.45±4.33
Kwak *et al* (10)	Korean	70.2±5.5	43.9±3.8
Thilak *et al* (12)	Indian	78.55±4.76 (Male) 66.88±4.72 (Female)	66.91±3.31 (Male) 59.38±4.07(Female)

Figure 3
Relationship between femur length and AP diameter of condyles



There was a strong positive correlation between the length of the femur and the AP diameter of the medial and lateral condyles, with a coefficient of determination (R^2) of 0.5 and 0.7 respectively, as shown in Figure 3.There was no correlation between the length of the femur and the width of the intercondylar notch, as shown in Figure 4, with a coefficient of determination (R^2) value of 0.0002.

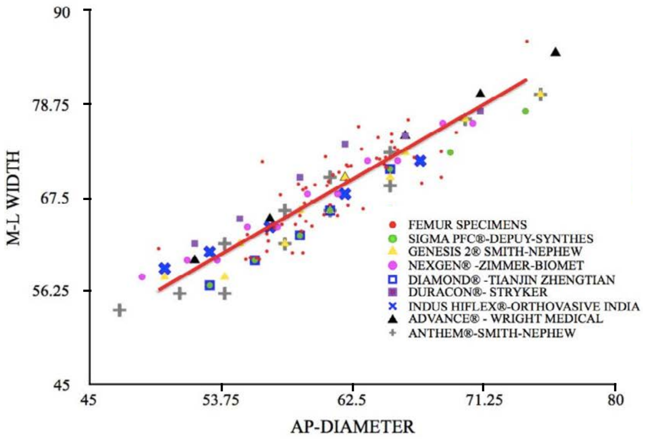
Figure 4
Relationship between length of femur and width of the intercondylar notch



The AP diameter and ML width of the femoral condyles were then plotted on a scatter graph with the corresponding measurements of femoral components of widely used total knee replacement implants. These were, the Genesis II® and Anthem® (Smith and Nephew Inc., Memphis, TN), Sigma PFC® (DePuy-Synthes), Nextgen® (Zimmer-Biomet, Warsaw, IN), Duracon® (Stryker Orthopaedics, Mahwah, NJ), Indus HiFlex®(Orthovasive, India), Diamond®knee (Irene,TianJin ZhengTian Medical Instrument Co., Ltd,Beijing,China) and the Advance®knee (Wright Medical,Arlington,TN). Figure 5 shows the relationship between the dimensions of the femur specimens and the various total knee implants.

Figure 5

Comparison between dimensions of the femora and femoral components of various implants



The slope of the graph shows that generally, the dimensions of the femur specimens approximated the dimensions of the various implants. However, it would appear that of the implants above, the Nexgen® (Zimmer-Biomet.Warsaw,IN), the GenesisII® and Anthem ®(Smith-Nephew, Inc., Memphis, TN) closely match the sizes of the femora studied, without significant overhang or underhang irrespective of the size of the component. It is of note that these implants offer a wide range of sizes of the components in increments of between 1-4mm. The Advance® knee (Wright Medical, Arlington, TN), whose trend line closely matches that of the specimens has very few sizes, with increments of 5mm between sizes. Consequently, for some of the femora, this would potentially lead to underhang or overhang if a smaller or bigger component is used. The Duracon® knee (Stryker Orthopaedics, Mahwah, NJ) would tend to have a significant mediolateral overhang especially with the small to the medium sized components. Others like the Sigma PFC®(DePuy-Synthes) and the Diamond® knee (Irene, TianJin ZhengTian Medical Instrument Co., Beijing, China) would have mediolateral underhang through the range of the sizes of femoral components. The Indus Hiflex®Knee (Orthovasive, India)would tend to have a mediolateral overhang in the small sizes and underhang in the larger sizes. The Indus Hiflex®Knee(Orthovasive, India) and the Diamond® knee(Irene, TianJin ZhengTian Medical Instrument Co.,Beijing, China), with their maximum AP lengths of 67mm and 65mm respectively, and M-L widths of 72mm and 71mm respectively, would not be adequately sized for some of the larger sized femora.

The average aspect ratio (ML/AP) of the femur specimens was 1.12.The various implants had different aspect ratios as shown in Table 3.

Table 3

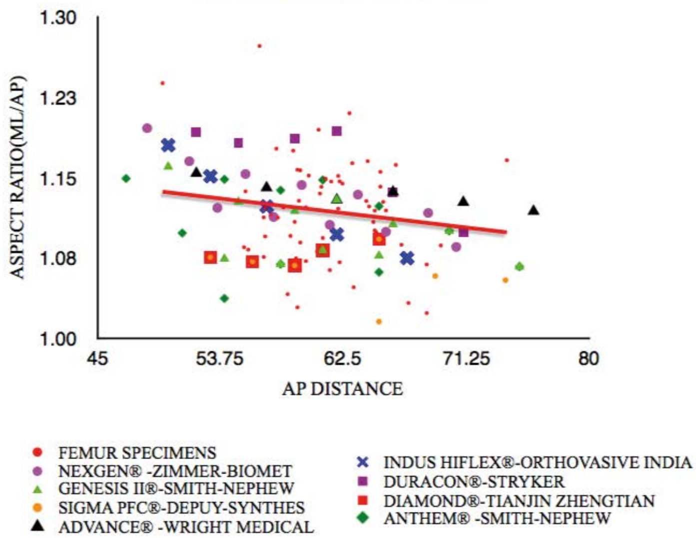
Aspect ratios of the specimens and implants

Specimen/Implant	Average aspect ratio
Femur specimens	1.12
Sigma PFC®-DePuy-Synthes	1.06
Genesis II®-Smith-Nephew	1.10
Nexgen® -Zimmer-Biomet	1.13
Diamond®-TianJin ZhengTian Medical Instrument Co., Ltd	1.08
Duracon®-Stryker	1.16
Indus Hiflex®-Orthovasive,India	1.13
Advance®- Wright Medical	1.13
Anthem®-Smith-Nephew	1.10

It was noted that the implants whose dimensions closely approximated those of the femur specimens also had aspect ratios closer to that of the specimens. These were the Genesis II® and Anthem®(Smith-Nephew), Nexgen®(Zimmer-Biomet), Indus Hiflex®(Orthovasive, India) and the Advance®(Wright Medical).

Figure 6

Relationship between aspect ratio and sizes of knee implants and femur specimens



The aspect ratio of the femur specimens was higher in the smaller knee sizes with the shorter AP diameters and gradually decreased with increase in the AP diameter. The same decrease was noted in the knee implants sampled as shown in Figure 6.

DISCUSSION

The current study has elucidated the morphometry of the distal femur in adult Kenyan femora. The average mediolateral (ML) width of the condyles was found to be 68.44mm, while the average anteroposterior (AP) diameter of the lateral condyle was 61.20mm, without any significant difference between the right and left sides. This is similar to a study on Greek femora by Terzidis *et al* (4) which found no significant difference in the dimensions between left and right sided femora. Though the femora used in the current study were not paired, the similar dimensions between the two sides could be because the femora were obtained from the same cadavers which then suggests that in an individual, the dimensions of the distal femur are generally similar between the right and left sides.

Our findings are similar to those found by Shah *et al* (7) in a CT-based study on Indian femora and those obtained by Moghtadaei *et al* (8) in their study on Iranian femora. Shah *et al* (7) found a mean ML width of 68.3mm and a mean AP diameter of the lateral condyle of 62.7mm while Moghtadaei *et al* (8) found a mean ML width of 67.06mm and a mean AP diameter of lateral condyle of 60.82mm. A study by Terzidis *et al* (4)on Greek femora showed a higher ML width of 83.9mm, but a lower AP diameter of lateral condyle of 58.5mm. Ewe *et al* (9), however found lower ML widths and AP diameters in a study on Malay, Chinese and Indian femora.The reduction in the aspect ratio with increase in AP length of the lateral condyle is consistent with the results obtained by Hitt *et al* (3) in a study on American femora, which showed a higher aspect ratio in smaller knees and a lower one for larger knees.

The current study showed a positive correlation between the length of the femur and the AP diameter of the condyles of the femur. This observation was also made by Kwak *et al* (10) in a study of the Korean femora, who found a positive correlation between the height of the subject and the AP width of the condyles. It can thus be inferred that the taller the individual, the longer the femur, the longer the diameter of the condyles, and consequently he/she would need a larger sized femoral component.

The width of the intercondylar notch in the current study was higher than that obtained by Shelbourne *et al* (11) in a radiographic study,who reported a width of 17.1mm for men and 14.7mm for women. The current study showed no correlation between femoral length and the width of the notch. Shelbourne *et al* (11) also found no correlation between width of the notch and height of the individual.

In total knee replacement, an accurately sized femoral component should cover the resected bone surfaces adequately, rest on good quality cortical bone and ensures proper patella tracking and extensor apparatus function. A comparison of the specimens and the femoral components of some total knee replacement implants show that for some of the implants, there may be a mediolateral mismatch, either as an overhang or underhang of the component, though the trend lines of the femora and the components generally closely matched. Hitt *et al* (3), in a study on 337 total knee replacements in both males and females found that, considered together, the femoral measurements closely approximated those of the implants they considered. However, stratification to male and female groups revealed considerable mediolateral mismatch, especially with the large implant sizes on females. The prostheses that closely matched the femora in the current study through the range of sizes were the Nexgen®(Zimmer-Biomet), Genesis II® and the Anthem®(Smith-Nephew). These particular implants offer a wide range of sizes of components in increments of between 1-4mm. Because we used dried cadaveric femora whose source cadaver could not be identified, it was not possible to determine specific gender and implant mismatch.

The clinical significance of a mismatch is as follows: intraoperatively, an overhanging component may cause difficulty in soft tissue closure and later it can potentially cause soft tissue irritation and chronic post-operative knee pain, as reported by Mahoney *et al* (1).Thilak *et al* (12) also reported poor knee scores postoperatively in patients who had a femoral component mismatch. An undersized femoral component would potentially not cover some parts of the resected bone. This can lead to prolonged bleeding from the cut bone surfaces and potentially a postoperative infection. An undersized component, especially in the AP plane can also potentially result in flexion instability (13). While some studies have shown better patient reported outcomes with specific implant types with anatomic features that closely match the distal femoral anthropometry, (14,15), others have failed to show any difference between traditional implants and better fitting, gender-specific implants with little or no overhang (16).

The problem of mismatch between the femoral components and the femur is not uncommon. Mahoney *et al* (1) reported an overhang of more than 3mm in 40% of men and 60% of women undergoing a total knee replacement, while Thilak *et al* (12) reported an overhang in 20 out of 150 of patients (13.3%) undergoing a total knee replacement. In a Pakistani study, Sultan *et al* (17) found a mean anteroposterior (AP) overhang of 4.7mm between the femoral components and the distal femur. The clinical effect of this overhang was, however, not reported, as there was no follow-up of the patients reported in that study.

There are unfortunately no local clinical studies that have been done to document component mismatch and its effect on postoperative outcomes. While there are other factors that can play a role, it is possible that the effects of component mismatch could be a contributing factor to the generally higher dissatisfaction among patients who undergo a total knee replacement. A study on 1703 total knee replacements by Bourne *et al* (18) showed that 19% of patients were dissatisfied, with only 72-86% satisfied with pain relief. It would therefore be prudent to conduct local clinical studies on the occurrence of component mismatch and the long-term effects, if any, on the clinical outcomes.

CONCLUSION

The current study has elucidated the dimensions of the distal femur in adult Kenyan femora. These dimensions are different from those of other ethnic populations. Comparison with femoral components of total knee implants showed that some designs had dimensions that closely matched those of the femora sourced from a Kenyan population, while others had a mediolateral mismatch.

We recommend that local studies be conducted on the clinical significance of the component mismatch.

CONFLICT OF INTEREST

No funding was received from any implant manufacturer for the study.

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