

ANTHROPOMETRY OF THE PROXIMAL TIBIA IN A KENYAN POPULATION AND ITS CORRELATION WITH TOTAL KNEE REPLACEMENT IMPLANTS

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ABSTRACT

Background: No local study has been done to determine the anthropometric features of the proximal tibia, compared it with other studied populations and some of the widely used total knee replacement implants.

Objective: To determine the Medio-Lateral (ML) width of the condyles of the tibia, the anteroposterior (AP) diameter of the condyles, determine the relationship between length of the tibia and the proximal tibia measurements, compare the results with other studied populations and the tibial components of widely used total knee replacement implants.

Methods: The distances were measured using digital vernier calipers on dried tibiae which were grossly not deformed. The dimensions of the tibial components of widely used total knee replacement implants were obtained from respective product monographs.

Results: Average ML width was 69.38mm while average AP diameter was 49.38mm. There was a positive correlation between length of the tibia and the ML and AP dimensions. The dimensions in the Kenyan tibiae were less than those of other populations. Comparison with tibial components of widely used TKR implants showed that most of the implants had dimensions that did not match closely with those of the local tibia specimens.

Conclusion: The dimensions of the proximal tibia in the Kenyan population are different from those of other populations. Dimensions of tibial components of widely used TKR implants did not match closely with dimensions of the local tibia specimens.

Key words: Proximal tibia width, Aspect ratio, Total knee replacement

INTRODUCTION

The dimensions of the proximal tibia have important implications in total knee replacement, which aims to restore the anatomy and alignment of the knee to as near normal as possible. An accurately sized tibial baseplate would cover the resected bony surface and have no mediolateral or anteroposterior overhang or underhang. If it is undersized, the plate would rest on weak cancellous bone, leading to subsidence, loss of alignment, loosening and failure of the component (1). Failure to adequately cover the resected bone can also potentially lead to prolonged bleeding from the cut surface with an attendant risk of postoperative infection. Overhanging has been shown to lead to irritation of the soft tissues around the knee with resultant chronic knee pain (2). These include irritation of the MCL if there's medial overhang (3) and the popliteus tendon when there is posterolateral overhang (4). Though the authors

are not aware of any study that has particularly looked at implant mismatch and revision rates, a study on 17,772 TKRs from the Norwegian Arthroplasty Register showed that some specific implant types had higher revision rates due to pain and aseptic loosening, which were attributed to the design of the specific implants (5). Whilst the presence of implant mismatch in the study was not documented, it may be possible that it could have played a role in the genesis of pain and aseptic loosening.

All of the implants locally used in total knee replacement have been sized and manufactured using dimensions of tibiae from different populations, which may be different from those of the local population. Studies have shown that dimensions of the proximal tibia differ between populations and between genders (6 - 10). Local studies have also shown that the dimensions of the femur from the local population differ from those of other populations (11 - 13). We therefore

postulate that similarly, the dimensions of the proximal tibia in Kenyan specimens would differ from those of other populations, as well as tibial baseplates of widely used total knee replacement implants.

MATERIALS AND METHODS

Dried tibiae were obtained from the Department of Human Anatomy, Egerton University, Njoro, Kenya and the Department of Human Anatomy, Kenyatta University, Nairobi, Kenya. Only specimens which were skeletally mature were used. Specimens that looked grossly deformed, those with previous fracture or surgery and those with post-mortem damage were excluded from the study.

The length of the tibia was measured from the highest point of the intercondylar eminence to the tip of the medial malleolus. The following distances were then measured by use of digital vernier calipers: the Medio-Lateral (M-L) width of the tibial plateau and the widest anteroposterior (A-P) diameter of the plateau. The widest anteroposterior (AP) and mediolateral (ML) dimensions of the lateral and medial condyles were also separately measured using digital vernier calipers. Each dimension was taken three times

by one investigator and the average obtained. The results obtained were compared with those obtained in other studies and also compared with the dimensions of tibial components of widely used total knee replacement implants. The dimensions of the implants were obtained from respective product monographs. Data analysis was done using Numbers® version 4.3.1(Apple Inc.,). For comparisons, a p value of less than 0.005 was taken to be statistically significant.

RESULTS

A total of 52 tibiae free of gross pathology were obtained and used in the study. Of these, 26 were from the right side, while 26 were from the left side. Table 1 shows a summary of the results of the various parameters.

There was no significant difference between the dimensions of the left and right sided tibial specimens. Table 2 shows a comparison of the results with other populations.

The comparison between the results obtained in the current study and the results in other populations show that the average ML width and AP diameter of the proximal is less in the Kenyan population compared to Turkish, Korean,

Table 1
Lengths and widths of the specimens

	Number	Mean length (cm)	Mean mediolateral (ML) width(mm)	Mean widest anteroposterior (AP) width (mm)	Lateral condyle AP width (mm)	Lateral condyle ML width (mm)	Medial condyle AP width (mm)	Medial condyle ML width (mm)
All specimens	52	39.8	69.38	49.38	37.43	26.78	42.06	27.21
Right tibiae	26	39.5	70.09	49.99	38.17	26.96	42.28	27.13
Left tibiae	26	40.0	68.66	48.77	38.68	26.61	41.83	27.29
p value		0.56	0.36	0.38	0.14	0.79	0.70	0.91

Table 2
A comparison of the dimensions of local tibiae and those of other populations

Author	Specimen type	Ethnicity	Mean ML width (mm)	AP diameter (mm)	Lateral condyle AP width (mm)	Lateral condyle ML width (mm)	Medial condyle AP width (mm)	Medial condyle ML width (mm)
Current study	Dry bone study	Kenyan	69.38	49.38	37.43	26.78	42.06	27.21
Kwak <i>et al</i> (6)	3D CT models cadaveric	Korean	71.9±5.6	45.7±3.8	42.2±3.7		45.9±4.2	
Li <i>et al</i> (7)	3D MRI living patients	Chinese male	77.4±3.3	49.6±2.4				
		Chinese female	69.1±2.8	44.2±2.3				
		Caucasian male	79.4±4.3	49.5±2.9				
		Caucasian female	70.2±2.7	45.2±2.3				
Erkokoc <i>et al</i> (8)	MRI study living patients	Turkish	71.9±4.4	43.5±3.4	42.3±3.3			
Moghtadaei <i>et al</i> (9)	CT scans of live patients	Iranian	74.6±5.9	48.6±4.5	48.9±5.0		50.5±4.39	
Murlimanju <i>et al</i> (9)	Dry bone study	Indian			33.6±3.7	26.1±2.9	39.8±3.8	26.7±2.8

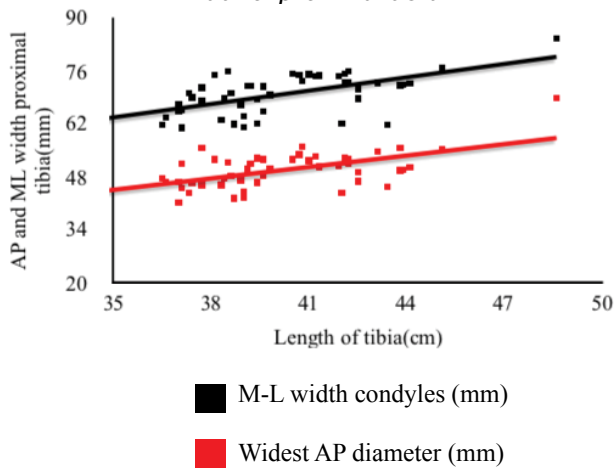
Caucasian and Chinese male populations and closely matched the Chinese female populations.

The results of the current study also show the asymmetric nature of the proximal tibia, with the medial condyle being longer and wider than the lateral condyle. This was also observed in the Korean, Iranian and Indian tibiae. In the current study, the medial condyle AP diameter was longer than that of the lateral condyle by an average of 4.5 mm (p value 0.0000002).

Comparison between the length of the specimens and the AP and ML widths showed a positive correlation, as shown in Figure 1, both having a coefficient of determination (R2 of 0.4).

Figure 1

Relationship between length of tibia and AP and ML width of proximal tibia

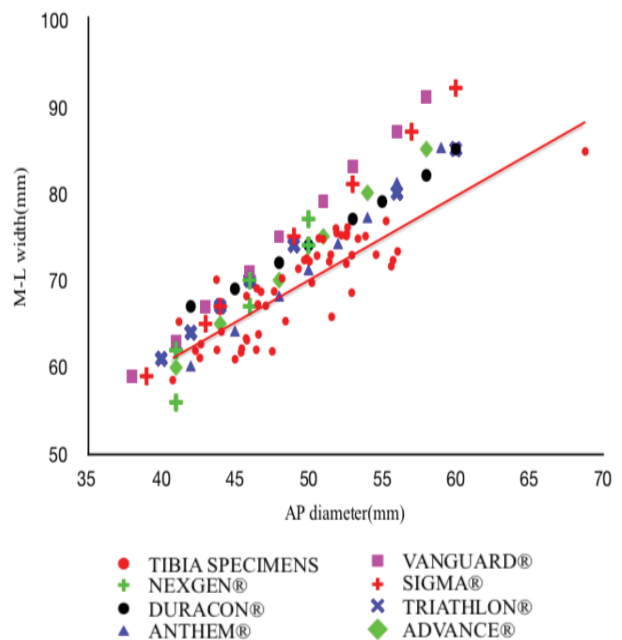


The ML width and AP diameters of the tibiae were then plotted on a scatter graph with the corresponding dimensions of tibial baseplates of widely used total knee replacement implants. These were, the Anthem® (Smith-Nephew Inc., Memphis, TN), Duracon® and Triathlon® (Stryker Orthopaedics, Mahwah, NJ), Vanguard® and Nextgen® (Zimmer-Biomet, Warsaw, IN), Sigma PFC® (DePuy-Synthes, Warsaw, IN) and the Advance® (Wright-Medical, Arlington, TN).

The scatter graph (Figure 2) shows the relationship between the dimensions of the tibial specimens and the various implants. From the scatter plot, it can be seen that not all the implants had dimensions that closely matched those of the tibia specimens, especially as the size increased.

Figure 2

Comparison between dimensions of the tibiae and the tibial baseplates of various implants



The Duracon® and the Triathlon® (Stryker), the Anthem® (Smith-Nephew) and the Advance® (Wright-Medical) tibial components had dimensions that closely matched those of the specimens through the sizes. The rest of the implants were oversized in the mediolateral dimension as the AP size increased. It is also noted that generally for all the implants, there was a close match with the tibial dimensions in the small sized components. It is also noted that all the implants sampled had much larger sizes, with AP diameters more than 56mm. Only 2 (3.5%) of the tibia specimens had AP sizes greater than 56mm. The average aspect ratio (ML/AP) of the tibial specimens was 1.46. The implants sampled had aspect ratios as shown in Table 3.

Table 3

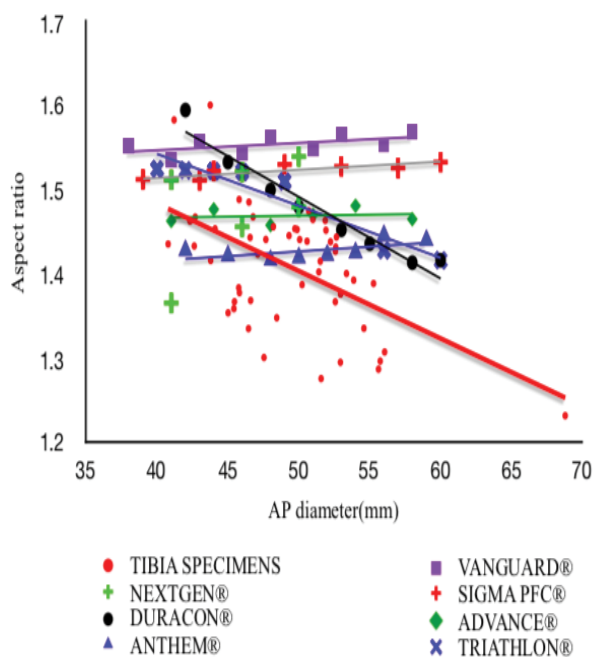
Aspect ratios of the specimens and various implants

Specimen/implant	Average aspect ratio
Tibial specimens	1.41
Anthem® (Smith-Nephew)	1.43
Duracon® (Stryker)	1.48
Vanguard® (Zimmer-Biomet)	1.55
Sigma PFC® (DePuy-Synthes)	1.52
Advance® (Wright-Medical)	1.47
Triathlon® (Stryker)	1.49
Nextgen® (Zimmer-Biomet)	1.48

A plot of the aspect ratios of the specimens against the AP diameter showed a gradual reduction of the aspect ratio as the AP diameter increased, i.e, the shape of the proximal tibia became less oval as the size increased. Of the implants sampled, only the Duracon® and the Triathlon® matched this reduction in aspect ratio as the size increased. Most of the other implants maintained their aspect ratio with increase in size, while the Nextgen® had an increase in its aspect ratio with increase in size. This is shown in Figure 3.

Figure 3

Relationship between aspect ratio and AP diameter of specimens and tibial components and implants



DISCUSSION

The current study has elucidated proximal tibial anthropometry in adult Kenyan tibiae. The average ML width of the tibial plateau was 69.71mm while the widest AP diameter was 47.69mm. There was no significant difference in the dimensions between the right and left sides. These dimensions were lower compared to those of Turkish, Korean, Iranian, Caucasian and Chinese males (6-9), but slightly higher than those of Chinese females (7). Whilst different methods of measurement were used in the various studies, even when the same method of measurement is used, ethnic variations have been documented (7). The differences are most likely due to ethnic differences between the various populations just as studies of other bones have shown a difference between Kenyan population and other populations. For instance, previous studies on Kenyan femora have revealed

differences in their dimensions when compared to other ethnic groups (11-13).

Comparison between the dimensions of the medial and lateral condyles showed that the medial condyle was longer and wider than the lateral condyle. The medial condyle had a longer AP dimension than the lateral one by an average of 4.5mm. The medial condyle also had a wider ML width than the lateral condyle by an average of 1.2mm. This asymmetry in the tibial plateau has been reported in other populations as well (6,9,10).

There was a positive correlation between the length of the specimens and the AP and ML widths, with the stronger correlation being with the AP dimension. This has also been reported in studies on Korean specimens (6). It can thus be inferred that a tall individual would most likely require larger sized tibial baseplates during total knee replacement.

In total knee replacement, the tibial baseplate should cover as much of the resected surface as possible, and rest on good quality cortical bone. An overhanging component can potentially lead to postoperative soft tissue irritation and chronic knee pain, while an undersized component would leave part of the resected bone surface bare, potentially leading to prolonged bleeding and potential post-operative infection, and in the long-term, subsidence of the component. It has been reported that complications after TKR seem to involve the tibial more than the femoral component (14). Whilst the exact reason for this has not yet been elucidated, it is possible that mismatch between the component and the proximal tibia could be a contributing factor. While there are only finite sizes of components available, the dimensions of the proximal tibia vary as alluded to. Many studies have shown that the proximal tibia is asymmetric, with the medial plateau being wider and longer than the lateral one (6,9,10). This has also been shown in the current study. It may thus be postulated that for the local population, asymmetric components would be more suitable. However, most of the widely available total knee implants have symmetric tibial baseplates. This means that a component that fits optimally medially would have an overhang in the lateral aspect, especially in the posterolateral aspect which is poorly visualized at surgery, potentially causing irritation of the popliteus tendon (4). Conversely, asymmetric component that fits well in the lateral aspect would have an underhang on the medial aspect. Overhang of more than 4mm in the medial aspect has been shown to cause significant impingement on the medial collateral ligament

(3). This asymmetry has led to the development of asymmetric/anatomical components, which have a smaller sized lateral plateau. Some studies have shown these components to offer better coverage of the resected tibial surface without significant overhang and malrotation (15,16). However, other studies have failed to show any difference in coverage when they are compared with the symmetric components (17).

The tibial specimens in the study showed a progressive decline in the aspect ratio as the AP size increased. This means that the shape of the proximal tibia became less oval as the size increased. It would therefore be ideal that the components would have the same change in shape. This reduction in aspect ratio was only closely mimicked by two implants of those sampled, i.e the Duracon® and the Triathlon®. The other implants maintained their aspect ratios as the size increased, while the Nextgen® had an increase in its aspect ratio as the size increased.

It is significant to note that, in the current study, more than 95% of the specimens had AP diameters less than 56mm, while the sampled implants had AP sizes all the way up to 60mm. Consequently, these larger sized implants may not find much use in the local population. This would be important especially in stocking of hospital inventories and design of implants for the local population.

There are unfortunately, no local clinical studies that have documented the outcomes in situations where there is component mismatch during a total knee replacement. Whilst there are certainly other factors that determine the outcome after TKR, it is possible that symptoms due to mismatch between the components and the resected bone could be a contributing factor to the higher rates of dissatisfaction in patients who undergo a total knee replacement compared to those who undergo a total hip replacement. Studies have shown that the rates of dissatisfaction after TKR can be as high as 19% (18). It has been shown that some of these dissatisfied patients choose to seek legal redress in the face of worsening symptoms (19).

CONCLUSION

The dimensions of the proximal tibia from a Kenyan population differ from those from other population. Comparison with tibial components of widely used TKR implants showed that most of the implants had dimensions that did not match closely with those of the local tibia specimens.

RECOMMENDATIONS

The difference in the dimensions of the proximal tibia in different populations should be considered when designing and manufacturing implants for total knee replacement. Studies should be done to determine the clinical significance of the mismatch between the dimensions of the proximal tibia in a Kenyan population and the commonly used implants.

Conflict of interest

The authors declare no conflict of interest. No funding was received for the study.

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