THE PROXIMAL TIBIA ANTHROPOMETRY IN ADULT NIGERIANS: CORRELATION TO TIBIAL COMPONENTS OF TOTAL KNEE REPLACEMENT AND EQUATIONS FOR ESTIMATION OF ITS DIMENSIONS

O.I. Akinmokun, MBBS, FWACS, FMCOrtho,Orthopaedic Unit, Department of Surgery, College of Medicine, University of Lagos, Idi-Araba, Nigeria, **N.M. Ibeabuchi,** MBBS, MSc, PhD, MPA, Department of Anatomy, College of Medicine, University of Lagos, Idi-Araba, Nigeria, **I.A. Oyebiyi,** MBBS, MWACS, **O.A. Akinde, I.S. Hussein, S.A. Adejumobi and A.S. Ajayi,** Medical Students, College of Medicine, University of Lagos, Idi-Araba, Nigeria

Correspondence to: Dr. O.I. Akinmokun, Orthopaedic Unit, Department of Surgery, College of Medicine, University of Lagos, Idi-Araba, Nigeria. Email: israelakinmokun@gmail.com; oakinmokun@unilag.edu.ng

ABSTRACT

Background: The knee joint is commonly affected by osteoarthritis. Total Knee Replacement (TKR) is usually considered for knee osteoarthritis after failure of conservative management. The total knee prostheses used during this procedure are fashioned from bony dimensions of Westerners.
Objective: This study compared some of the available tibial baseplate with the proximal tibiae dimension of Nigerians. It also provided equations that can be used to estimate dimensions of different parts of proximal tibia.
Design: This was a prospective descriptive study.
Methods: Fifty four matured tibiae, comprising 23 right and 31 left bones were measured. Ten parameters were measured and documented. Dimensions of proximal tibia bones from other regions of the world were retrieved from published articles. The dimensions of tibial baseplates were extracted from product monographs. Analyses were done with Microsoft excel 2010 (Microsoft Corporation, Redmond, Washington, United States) and STATA version 13 (Stata Corp, Texas. USA). Statistical significance was set at $p \leq 0.05$.
Results: There were no significant differences between the left and right tibiae. The average proximal tibia dimension differs from between racial groups. The average aspect ratio calculated was 1.51 ± 0.11. Three of the four implants have sizes that were far larger than the tibiae dimensions, with increment in sizes that were far steep compared to the dimensions of the proximal tibiae. There was a mismatch of aspect ratio of the tibiae and those of the tibial baseplates. Equation to estimate the anteroposterior dimension for each tibia condyle was generated and tested on published values.
Conclusion: This study provided equations that can be used to estimate the anteroposterior dimensions of tibial plateau, the medial and the lateral condyles with the estimated values within ±5mm of the actual value. This can be used as part of pre-operative planning. It also provided data that can be considered in the designing of a suitable tibial baseplate component of total knee prosthesis for Nigerians.

Key words: Total knee replacement, Pre-operative, Planning, Proximal tibia, Tibia bone fixation, Nigerians, Africans, Anthropometry, Knee prosthesis

INTRODUCTION

The knee joint consists of the articulations between the distal femur and both the proximal tibia and the patella (1). This synovial joint, a modified hinge joint,is the largest joint in the lower limb and helps in locomotion and weight bearing (2). The knee joint, like all synovial joints, is prone to degenerative disease. Osteoarthritis is more common in the knee than the hip (3-6). The severe form of knee osteoarthritis is debilitating, with disabling pain and limitation in mobility thereby causing significant reduction in the patient's quality of life. Total Knee Replacement (TKR) is usually considered for moderate to severe knee osteoarthritis with no response to conservative management (7,8). In TKR, metal components are used to replace degenerated parts of the native bone that are removed at surgery. Studies have shown that the dimensions of proximal tibia differ from different populations and geographical locations (9-23).This study aimed to provide dimensions of proximal tibiae in Nigerian population and compare these dimensions with the documented dimensions from other regions of the world. It compared some of the available TKR tibial base plates with the proximal tibiae dimension and provided equations that can be used to estimate dimension of parts of proximal tibia.

MATERIALS AND METHODS

This was a prospective descriptive study that involved measurements of parts of dry tibiae. Ethical approval was obtained from the Hospitals' Ethics and Research Committee before the commencement of the study (ADM/DCST/HREC/APP/3466). The tibiae were from the Department of Anatomy, College of Medicine, University of Lagos. A total of 54 matured, non-sexed, non-paired tibiae were retrieved after those that were deformed and distorted were excluded. There were 23 right and 31 left bones. Each was allocated an alphanumerical label (R1 to R23; L1 to L31). Measurements were done using digital vernier calipers and osteometric board. Each measurement was done twice, separately by two authors. Measurements with large discrepancies (>5mm) were resolved by re-measuring the affected dimension together. The average of the measured values were obtained and documented. Measurements taken were:

a. *Maximum Tibia Length (MTL)*: The maximum distance from the highest point of the upper part of the tibia (tip of intercondylar eminence) to the lowest point of the tibia (tip of medial malleolus) using osteometric board.
b. *Anterior-Posterior Dimension (APD) of the tibia plateau*: The widest diameter between the anterior and posterior margins of the tibia plateau.
c. *Medio-Lateral Dimension (MLD) of the tibia plateau*: the widest diameter between the medial and lateral margins of the tibia plateau(Figure 1).
d. *Proximal Tibia Length (PTL):* the distance from the tibia plateau to a point 1cm below the tibial tuberosity(24)(Figure 2).
e. *Proximal Tibia Width (PTW)*: the width of the tibia measured at a point 1 cm below the tibial tuberosity (24).
f. *Anterior-Posterior Diameter of Medial Condyle (APDMC):* The maximum anterior-posterior diameter of the medial condyle of tibia(Figure 3).
g. *Transverse Diameter of Medial Condyle (TDMC)*: The maximum diameter from the medial side of the medial condyle to the medial intercondylar tubercle of intercondylar eminence of tibia.
h. *Anterior-Posterior Distance of Lateral Condyle (APDLC)*: The maximum anterior-posterior diameter of the lateral condyle of tibia.
i. *Transverse Diameter of Lateral Condyle (TDLC):* The maximum diameter from the lateral side of the lateral condyle to the lateral intercondylar tubercle of the intercondylar eminence of tibia
j. *Intercondylar Distance (ID)*: The distance between medial and lateral intercondylar eminences.
k. *The aspect ratios of the proximal tibiae were calculated by dividing the Medio*: Lateral Dimension (MLD) of the tibia plateau with Anterior-Posterior Dimension (APD) of the tibia plateau. The results obtained were then compared with results from other populations.

Figure 1

Measurement of the mediolateral diameter

Figure 2
Proximal tibia length measurement

Figure 3
Anterioposterior diameter of the medial condyle

The dimensions of four implants (tibial baseplates) that were used in this study were obtained from the product monographs. Analyses were done with Microsoft excel 2010 (Microsoft Corporation, Redmond, Washington, United States) and STATA version 13 (StataCorp, Texas, USA). Mean and standard deviation were documented. Chi square and regression analysis were done for associations. Statistical significance was set at $p \leq 0.05$.

RESULTS

A total of 54 tibiae (23 right sided and 31 left sided) were measured. Table 1 shows a summary of the results of the measured parameters. There were no significant differences between the dimensions of the left sided and right sided tibial specimens. Table 2 shows a comparison of the measured dimensions with measurements from other populations. The aspect ratio calculated for the measured tibiae ranged from 1.13 to 1.76 with an average of 1.51 ± 0.11. The aspect ratio from other populations were included in Table 2.

Table 1
Measured parameters from the tibiae

Parameter	Right	Left	Average	Minimum	Maximum	P- value
MTL (cm)	40.6 ± 1.9	40.1 ± 2.4	40.3 ± 2.2	33.2	44.1	0.9627
APD (mm)	49.2 ± 3.3	47.8 ± 2.8	48.4 ± 3.1	42.1	54.8	0.252
MLD (mm)	73.5 ± 3.6	72.6 ± 4.2	73.0 ± 3.9	62.1	80.4	0.3268
ID (mm)	11.6 ± 1.8	11.2 ± 1.6	11.4 ± 1.7	8.4	14.8	0.4267
APDMC (mm)	46.9 ± 3.2	45.8 ± 3.1	46.2 ± 3.2	37.4	52.1	0.8028
TDMC (mm)	33.1 ± 3.6	31.6 ± 2.6	32.2 ± 3.1	25.6	39.8	0.2258
APDLC (mm)	43.4 ± 4.1	41.0 ± 2.6	42.0 ± 3.5	36.8	51.5	0.9951
TDLC (mm)	34.2 ± 4.0	30.1 ± 2.7	31.8 ± 3.8	24.4	47.0	0.5579
PTL (mm)	70.7± 6.2	265.3 ± 8.4	67.6 ± 7.9	50.7	87.5	0.9380
PTW (mm)	31. 5 ± 3.1	30.9 ± 2.7	31.2 ± 2.9	24.5	36.9	0.3010

Table 2
Proximal tibia parameters and the aspect ratios from different regions of the world

Author	Ethnicity	Specimen type	MTL (cm)	APD (mm)	MLD (mm)	APDMC (mm)	TDMC (mm)	APDLC (mm)	TDLC (mm)	Aspect Ratio
Present	Nigerians	Dry bone	40.3 ± 2.2	48.4 ± 3.1	73.0 ± 3.9	46.2 ± 3.2	32.2 ± 3.1	42.0 ± 3.53	1.8 ± 3.8	1.51
Lakati *et al* (10)	Kenyans	Dry bone	39.8	49.38	69.38	42.06	27.21	37.43	26.78	1.41
Shah *et al* (11)	Indians	3D CT scan live patients		51.2±4.3	73.8 ± 4.7					1.45
Kumar *et al* (12)	Indians	Dry bones		37.2±3.04	67.2±5.89	42.7±4.13	30.8±2.86	37.5±3.98	30.6±3.65	
Erkocak *et al* (12)	Turkish	MRI live patients	43.5±3.4	71.9±4.4						1.65
Karimi *et al* (14)	Iranians	MRI live patients		46.53+4.05	73.36±6.86	50.12±4.88		48.70±5.35		1.58
Loures *et al* (15)	Brazilians	Intraoperative live patients	48.2±5.9	72.4±6.6						1.5
Kwak *et al* (16)	Koreans	CT scan cadavers	47.3±3.8	73.5±5.6						1.55
Bae *et al* (17)	Koreans	Intraoperative live patients		72.7 ± 4.0	48.0± 3.1	39.8±2.9				
Yan *et al* (18)	Chinese	CT Scan		49.87±3.9	73.5±5.6	48.0±3.1		39.8±2.9		1.47
Chaichankul *et al* (20)	Thai	MRI		46.04±4.4	68.8 ±5.8					1.48
Mukhia *et al* (21)	Nepalese	Dry bones		48.38± 1.98	66.72±0.65	46.38±1.98		39.14±0.97		1.37
Servien *et al* (22)	Caucasians	CT scan live patients					50.8±3.3	47.2±3.3		
Hussain *et al* (23)	Malay	CT scan live patients		48.1±4.7	72.6±6.8					1.51

There were significant statistical associations between the MTL and APD ($p = 0.0025$) and between the MTL and MLD ($p = 0.0001$) (Figure 4). Multiple regression analysis was performed($p = 0.0101$)and it generated the equation:

*APD (mm) = 25.7 + 0.062*MTL (mm) – 0.033*MLD (mm)*

There is no statistical relationship between MLD and APD (p= 0.192)

There were significant statistical relationships between MLD and APDMC ($p = 0.0002$) and between MLD and APDLC ($p = 0.0009$) (Figure 5) with each generating equation

APDMC (mm) = 17.6 + 0.39* MLD (mm)
APDLC (mm)= 13.6 + 0.39* MLD (mm)

The MLD and APD of the tibiae measured and the corresponding dimensions of the tibial

Figure 4
Scatter plot of MTL, APD and MLD

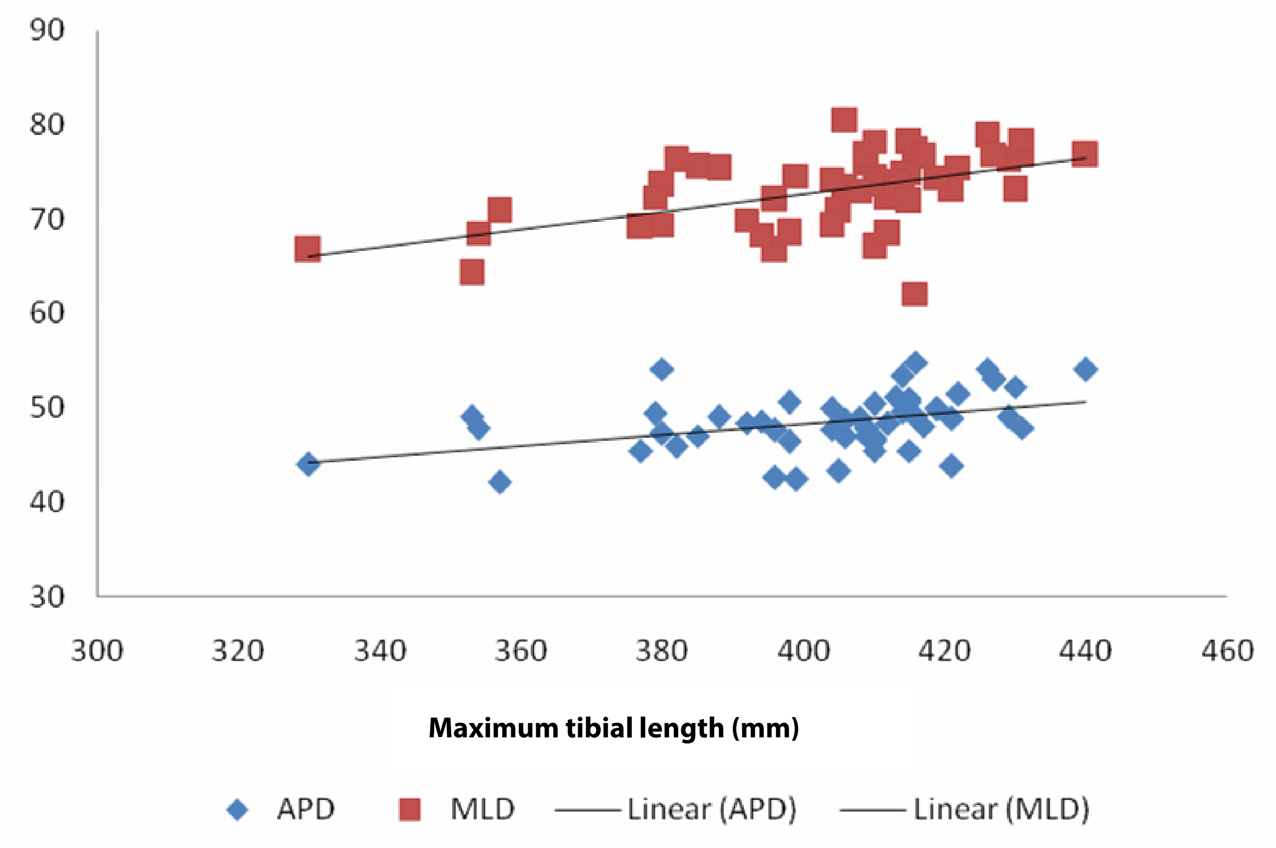
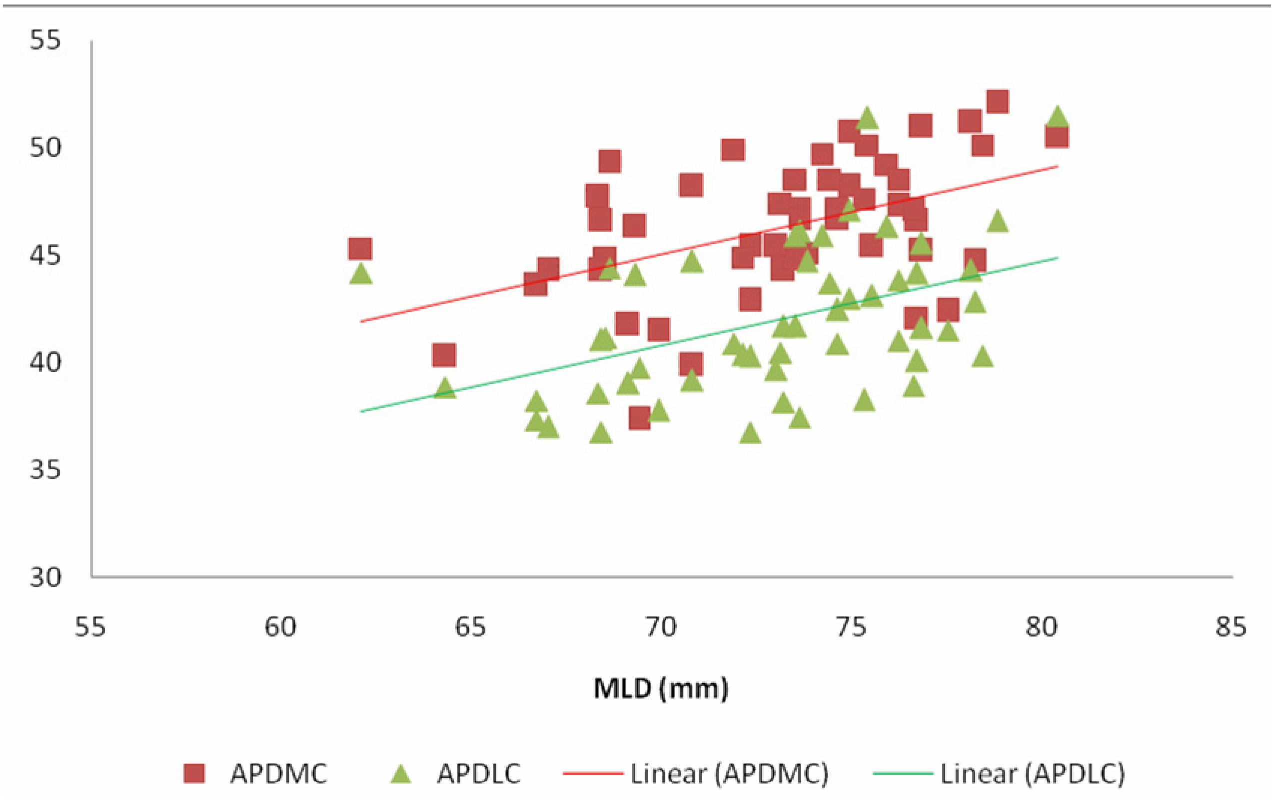


Figure 5
Scatter plot of MLD, APDMC and APDLC



baseplates available were plotted on a scatter plot (Figure 6). Though all the trend lines in the plot showed positive slopes, the trend lines of the tibial baseplates had steep slopes compared to the trendline of the tibial bones with gentle positive slope. Three of the four baseplates studied had larger sizes that would not fit the tibiae studied.

The aspect ratios of the tibiae were plotted against the aspect ratios of the tibial baseplates (Figure 7). The trend line of the tibiae showed a

Figure 6

The tibial baseplates and the dimensions of the tibiae

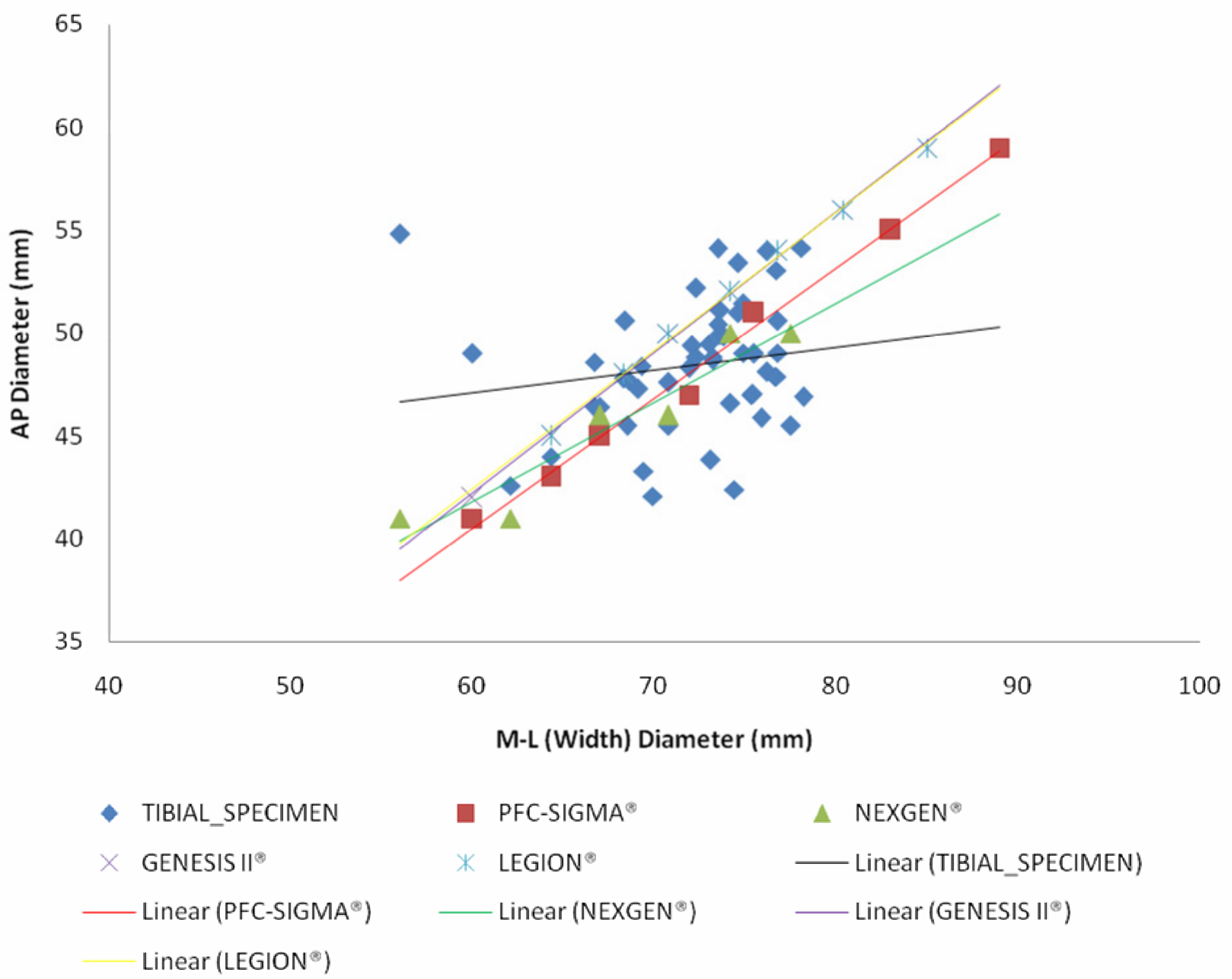
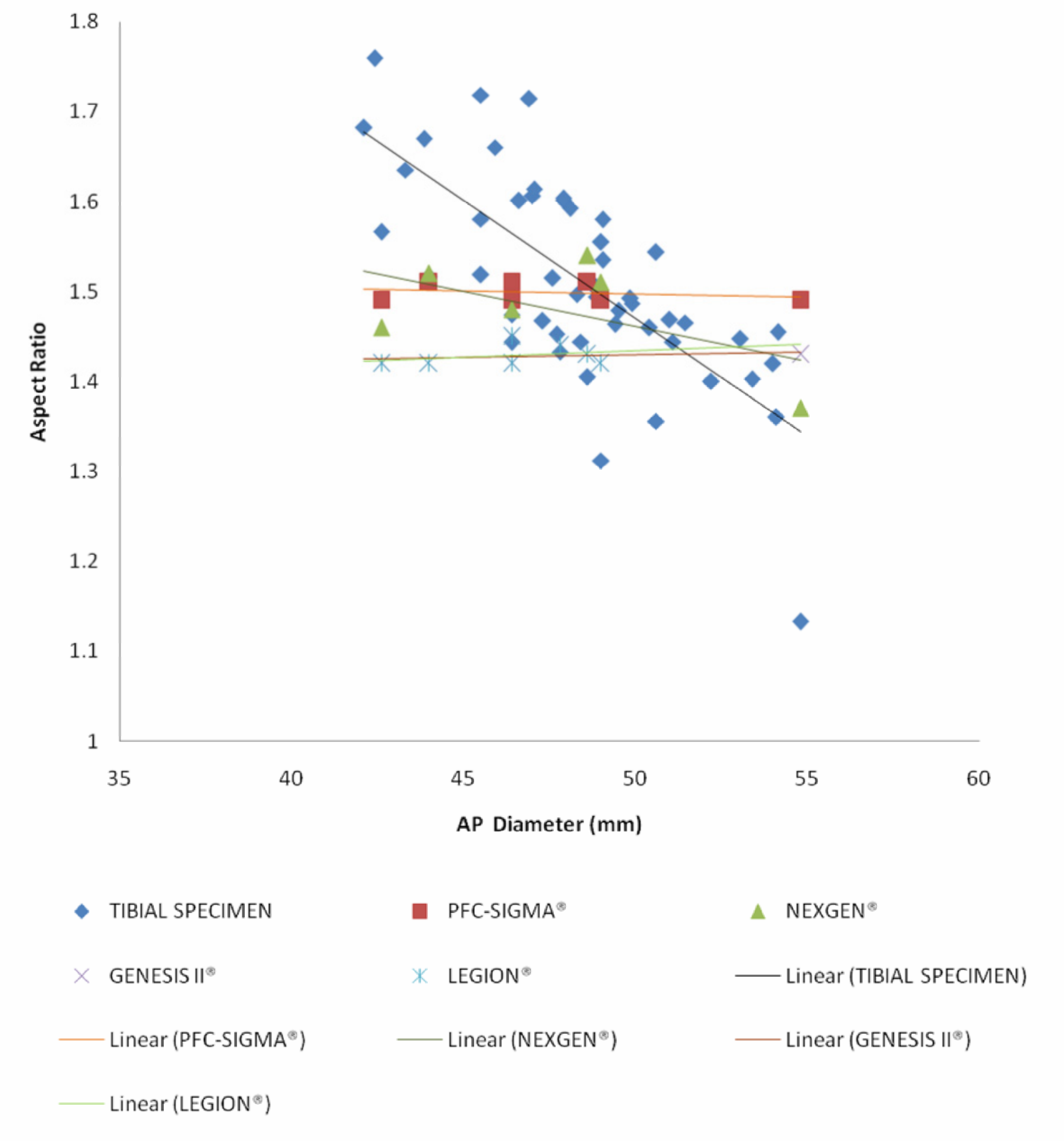


Figure 7
Aspect ratios of the tibiae and tibial baseplates



steep negative slope. The Nexgen® tibial baseplate has a gentle negative slope, while the other three prostheses were without any gradient.

DISCUSSION

This study has provided dimensions of proximal tibiae in adult Nigerians. The average MLD was 73.5 mm and the APD was 49.2mm. These values were similar to the values documented by Ugochukwu *et al* (25) among Nigerians. The dimensions of the MLD and APD were also similar to the values documented in the Brazilians (15), Koreans (16), Chinese (18) and Malay (23). It is however larger than the values for Kenyans (10), Thai (20) and Nepalese (21). This further laid credence to different studies that documented variations in bone dimensions around the world. It is pertinent for implants manufacturers to obtain, analyze and utilize data from various parts of the world when implants are being manufactured particularly for a certain region. Moreover, the asymmetry of the proximal tibia condyles, which had been documented by various researchers, was further confirmed by this study. The difference of the average of the APD of both condyles (APDMC and APDLC) in this study was 3.5 mm and the difference was statistically significant ($p = 0.0001$). Most of the tibial baseplates available for use in our environment are symmetrical. In other regions, there are asymmetric and anatomic tibial baseplates. The asymmetric baseplates were made to mimic the asymmetry nature of the proximal tibia. The asymmetrical baseplate has an advantage of better rotational alignment when compared with the symmetrical baseplates (26). Though, both Wernecke *et al* (27) and Miyatake *et al* (28) reported better tibial surface coverage for asymmetric plates when compared with the more common symmetrical plates, some studies however, debunked the advantage and reported neither design has an advantage on tibial surface coverage (13,29). Interestingly, Incavo *et al* (30) reported that symmetrical base plates actually provided better tibial surface coverage than the asymmetrical ones. The asymmetric baseplate has, therefore,not shown clear cut advantages over the symmetrical ones in TKR procedures though the proximal tibial is asymmetrical in shape. The anatomic tibial base plate, however, has shown better advantages, in rotational alignment and coverage, than both symmetrical and asymmetrical baseplates (31,32). Anatomical baseplates are not yet very common, and this study has provided data that can be utilized once anatomic tibial base plates are considered for our region.

Due to the significant difference in the length of the medial and lateral condyles, the anteroposterior dimension seems to be more relevant than the mediolateral one in TKR (33). In pre-operative planning; the mediolateral dimensions can be easily measured. The mediolateral length of the tibia plateau and for either medial or lateral condyle can be measured clinically and/or from true anteroposterior radiograph respectively. The anteroposterior diameter can only be measured from a true lateral radiograph, but overlapping of the condyles on the lateral view usually makes measuring dimension for each condyle difficult. This study generated equations that can be used to estimate the anteroposterior diameters, of the tibial plateau and of each condyle. (APDMC and APDLC) from MLD, which can be measured clinically:

Anteroposterior diameter of tibial plateau (APD) = 25.7 + 0.062*MTL – 0.03*MLD (all measurements in 'mm')

The estimated value should be within ±5mm of the actual AP diameter of the proximal tibia.

For example, Lakati *et al* (10) documented average MTL = 39.8cm (398mm); average MLD = 69.38mm

Estimated tibial AP diameter = 25.7 + 0.062 (398) – 0.03 (69.38) = 48.3mm (which is within ±5mm of the documented value of 49.38mm by Lakati *et al* (10))

Ugochukwu *et al* (25)documented average MTL = 40.5cm (405mm) and MLD = 74.13mm

Estimated tibia AP diameter = 25.7 + 0.062 (405) – 0.03 (74.13) = 48.59mm (which is within ±5mm of the documented value of 50.1mm by Ugochukwu *et al* (25)).

Moreover, the AP diameter of the medial (APDMC) and lateral (APDLC) condyles can also be estimated from the equations:

APDMC = 17.6 + 0.39 (MLD)

APDLC = 13.6 + 0.39 (MLD)

Examples would be from the average of measured values in published articles:

Lakati *et al* (10) (from Kenya) documented the MLD = 69.38mm

APDMC = 17.6 + 0.39(69.38) = 44.65 mm (average measured value =42.06mm)

APDLC = 13.6 + 0.39(69.38) = 40.66 mm (average measured value =37.43mm). Values from other racial groups are also estimated and tabulated in Table 3.

Table 3
Values from other racial groups

Authors	Ethnicity / Racial groups	Documented values MLD (mm)	Documented values APDMC (mm)	Estimated value from APDMC (mm) = 17.6 + 0.39*MLD	Documented values APDLC (mm)	Estimated value from APDLC (mm) = 13.6 + 0.39*MLD
Lakati *et al* (10)	Kenyans	69.38	42.06	44.65	37.43	40.66
Kumar *et al* (12)	Indians	67.2	42.7	43.81	37.5	39.81
Yan *et al* (18)	Chinese	73.5	48.0	46.26	39.8	42.26
Mukhia *et al* (21)	Nepalese	66.72	46.38	43.62	39.14	39.62
Bae *et al* (17)	Koreans	72.7	48.0	45.95	39.8	41.95

The estimated values were all within ±5mm of the measured value. The equations can be used as part of pre-operative planning to estimate the AP length of the condyles and to envisage the type of tibia baseplates that may be used during the procedure. These equations had shown that though the dimensions of the bones in different geographical areas may differ, there is a relationship between each of the parts of the bone. It has shown that the dimension of a part can be estimated from a known dimension of another part. The examples also have shown that these equations can be useful in different geographical regions.

The MLD and APD of the tibiae measured from this study and the corresponding dimensions of the four tibial baseplates were plotted. The plot revealed a gentle positive slope for the tibial specimens and steep positive slopes for all the tibial baseplates (Figure 1). This implies that the increment in dimensions of the tibial baseplates from a lower size to the next available size was larger (both in APD and MLD dimensions) than the natural increment observed in the different tibial dimensions measured. The nexgen® trend line has the closest to that of the tibial specimens. Its' tibial baseplates dimension has a constant APD for a step increment in MLD (i.e size 1 and 2 has same APD, 41mm but different MLD 56mm and 62mm respectively). The divergence at the extreme ends of the trend lines that represented the tibial specimens and those of the prostheses indicated the likelihood of a mismatch at the extremes of sizes. Three of the four implants had implants sizes that were far bigger than the sizes of proximal tibia in Nigerians.

The aspect ratio of the tibia specimen measured plotted against the aspect ratio of the tibial baseplates showed mismatched trends. The aspect ratio of the tibial specimen decreased as the AP diameter increased but all but one tibial baseplate maintained no gradient, which represented constant aspect ratio. There can be a possibility of mismatch tibial baseplates in larger sizes. It is therefore, important that implants' manufacturers consider data and input from other regions of the world to modify their implants to fit specific regions for which the implants is being manufactured for, as TKR is a procedure that is performed globally.

CONCLUSION

This study provided equations that can be used to estimate the anteroposterior diameters of tibial plateau, the medial and the lateral condyles with the estimated values within ±5mm of the actual value. This can be used as part of pre-operative planning. It also provided data that can be considered in the designing of a suitable tibial component of total knee prosthesis for Nigerians.

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