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# The dimensions of the tibial condyles differ in Nigerians

**RS Ajani[1], BA Abiola[2] and SO Ogunlade[3]**

*Departments of Anatomy[1], College of Medicine, University of Ibadan, Department of Neurological Surgery[2], University College Hospital and Department of Surgery[3], College of Medicine, University of Ibadan, Nigeria*

**Abstract**

*Objective*: The tibia is the larger and medially positioned of the two bones of the leg and is involved in knee articulation. Its proximal part consists of the medial and lateral condyles whose superior surface is known as medial and lateral plateau respectively. The knee joint is commonly involved in chronic osteoarthritis which may invariably require knee replacement surgery. This surgical procedure entails excision and replacement of a portion of proximal tibial metaphysis with implants. The available tibial implants consist of excessive number of sizes that may be inappropriate for our population. Thus the need to generate proximal tibial dimensions that may assist in the manufacture of tibial implants appropriate for Nigerians becomes pertinent hence the rationale for the study.

*Materials and method:* One hundred and thirty one adult tibiae (right:44.3% and left:55.7%) obtained from macerated cadavers were used for the study. On the superior surface of each condyle, the anteroposterior length (APL), transverse length (TL) , intercondylar length (ICL) and mediolateral length (MLL)were measured.

*Results:* The mean APL of the right tibial medial condyle was significantly ($p< 0.05$) longer than that of its lateral condyle (44.27±4.10 vs 39.49±3.89 mm). For the left tibia, the mean APL of the medial condyle was also significantly longer (43.55±4.38 vs 39.23±4.02 mm). The mean TL for the right tibial medial and lateral condyle was 30.30±3.42 and 30.84±3.67 mm respectively. The mean TL for the left tibial medial and lateral condyle was 30.16±3.16 and 30.59±3.30 mm respectively. The mean ICL of right tibia was 13.03±1.81 and that of the left tibia was 12.85±1.47 mm. The mean MLL of right tibia was 74.17±6.68 while that of the left tibia was 73.60±6.01mm. The differences in the various parameters between the right and left tibia were insignificant.

*Conclusion*: There is asymmetry between the anteroposterior length of the medial and lateral condyles. When compared with similar studies, the dimensions of the tibial condyles in Nigerians were different from those of other nationals. Thus there exists racial variations in the dimensions of tibial condyles and this has to be considered in the manufacture of tibial implants for knee arthroplasty. Results of this study may thus serve as reference values for Nigerians.

**Keywords**: *Tibial condyle dimensions, tibial implants, Nigerians*

**Abstrait**

*Objectif*: Le tibia est la partie la plus grande et la plus médiane des deux os de la jambe et est impliqué dans l'articulation du genou. Sa partie proximale est constituée des condyles médial et latéral dont la surface supérieure est respectivement appelée plateau médial et latéral. L'articulation du genou est couramment impliquée dans l'arthrose chronique qui peut nécessiter invariablement une chirurgie de remplacement du genou. Cette intervention chirurgicale implique l'excision et le remplacement d'une partie de la métaphyse tibiale proximale par des implants. Les implants tibiauxdisponibles consistent en un nombre excessif de tailles qui peuvent être inappropriées pour notre population. Ainsi, la nécessité de générer des dimensions tibiales proximales pouvant aider à la fabrication d'implants tibiaux appropriés pour les Nigérians devient pertinente, d'où la raison d'être de l'étude.

*Matériel et méthode :* Cent trente et un tibias adultes (droit : 44,3 % et gauche: 55,7%) obtenus à partir de cadavres macérés ont été utilisés pour l'étude. Sur la surface supérieure de chaque condyle, la longueur antéropostérieure (APL), la longueur transversale (TL), la longueur inter-condylaire (ICL) et la longueur médio-latérale (MLL) ont été mesurées.

*Résultats :* La moyenne APL du condyle médial tibial droit était significativement plus longue ($p <0,05$) que celle de son condyle latéral (44,27 ± 4,10 vs 39,49 ± 3,89 mm). Pour le tibia gauche, la moyenne APL du condyle médial était également significativement plus longue (43,55 ± 4,38 vs39,23 ± 4,02 mm). Le TL moyen pour le condyle médial et latéral tibial droit était respectivement de 30,30 ± 3,42 et de 30,84 ± 3,67mm. Le TL moyen pour le condyle médial et latéral tibial gauche était respectivement de 30,16 ± 3,16 et de 30,59 ± 3,30mm. L'ICL moyenne du genou droit était de 13,03 ± 1,81 et celle du genou gauche de 12,85 ±

Correspondence: Dr. R.S. Ajani, Department of Anatomy, College of Medicine, University of Ibadan, Ibadan, Nigeria. E-mail: rsaajani@yahoo.co.uk.

1,47mm. Le MLL moyen du genou droit était de 74,17 ± 6,68 tandis que celui du genou gauche était de 73,60 ± 6,01mm. Les différences dans les divers paramètres entre le tibia droit et gauche étaient insignifiantes.

*Conclusion* : Il existe une asymétrie entre la longueur antéropostérieure des condyles médial et latéral. Quand comparés à des études similaires, les dimensions des condyles tibiaux chez les Nigérians étaient différentes de celles des autresres sortissantsnationaux. Il existe donc des variations raciales dans les dimensions des condyles tibiaux et il faut en tenir compte dans la fabrication d'implants tibiaux pour arthroplastie du genou'. Les résultats de cette étude peuvent donc servir de valeurs de référence pour les Nigérians.

**Mots clés** :*dimensions tibiale de condyle, implants tibial, Nigérians*

## Introduction

The tibia is the larger and the medially positioned of the two bones that constitute the skeletal framework of the leg, while the other being the fibula. It is a long bone consisting of two epiphyses (proximal and distal) and in between them is the diaphysis. It is formed both by intramembranous (the epiphyses) and endochondral (diaphysis) ossification. The proximal epiphysis is the growing end of the bone and consists of the medial and lateral condyles. Both condyles differ in shape and length with the medial being oval and longer while the lateral is circular [1].

The superior surface of each condyle is known as tibial plateau and the two plateaus are separated by the intercondylar eminence and the morphology of the plateaus differs [2]. The plateaus provide attachments for the respective meniscus and the lateral has a more extensive coverage for its meniscus than the medial plateau [3]. The medial meniscus occupies 50-60 % of the medial condyle [4] and is connected to the lateral meniscus by four ligaments [4,5]. The femoral condyles articulate with the respective tibial condyles in the knee joint articulation. The knee joint is the largest and most complex synovial articulation in the body. Its anterior, medial and lateral aspects are superficial; they are not overlaid by muscles but only with skin.

This, coupled with the fact that its stability largely depends on ligaments (which could get torn or ruptured) make it very prone to injury particularly in contact sports. Normally, the surfaces of the femoral and tibial condyles involved in the knee articulation are covered with hyaline cartilage, this with the synovial fluid maintain the integrity of the surfaces. Due to its large surface area and most of it being superficial, the knee joint is very prone to degenerative changes. These arthritic changes may be due to obesity, part of ageing process or trauma however, in most cases the cause is unknown. The initial management of osteoarthritis of the knee include analgesia and physiotherapy maneouvres, these measures only offer symptomatic relief and may not halt the progression of the pathology. When the disability i.e. knee joint movement becomes severely limited coupled with severe pain, the need for surgical intervention may become inevitable. Surgical options for knee joint osteoarthritis include joint replacement which may be either partial or total.

These procedures involve replacement of the proximal tibia and or distal femur with prostheses. The production of these knee implants are by very few manufacturers in very limited number of countries. Also the knee implants are available in very limited sizes and they are not one size-fit-all. The universal fitness of these implants is thus an important issue that requires appropriate consideration and resolution. Studies have shown that proximal tibial dimensions vary along racial and gender line [2,3,6-8]. Since osteoarthritis of the knee also afflicts Nigerians, it thus becomes pertinent to generate proximal tibial dimensions in adult Nigerians that may serve as reference data for the populace. This may assist the manufactures of knee implants to produce those that are appropriate for Nigerians and thus make knee replacement surgery less cumbersome. This was the rationale for this study.

## Materials and method

One hundred and thirty one (131) bones with a right to left ratio of 58:73 were used for the study. These bones were products of macerated cadavers used for gross anatomy dissection by undergraduate students spanning several years. All the cadavers were unclaimed Nigerians (as the corpses of non-Nigerians would have been collected for burial). They were soureed from facilities located in south west Nigeria. The post -dissected cadavers were macerated serially and the bones obtained were warehoused in the Bone store of the Anatomy Department of the College of Medicine, University of Ibadan, Nigeria. Only bones with intact features and without any evidence of previous fractures, deformities or arthritic changes were recruited for the study. No documentation as to the age and gender of the tibae. Bones that had pathological features or erosion of the proximal end were excluded from the study.

By means of a digital caliper graduated in millimetres, the following measurements on the superior surface of each of the condyle were taken (i) anteroposterior length (APL) represented by

arrows 'a' and 'd' in figure 1, (ii) the transverse length (TL) at approximately midpoint along the transverse plane represented by the arrows 'b' and 'c' and (iii) the intercondylar length (ICL) arrow 'e'. The APL was measured from the most anterior end to the most posterior end of each condyle.

While the TL was measured from the respective tubercle of the intercondylar eminence to the corresponding medial or lateral plateau at the midpoint. Measurement of each tibia was done twice independently by the authors. Having noticed the closeness of the obtained values; the average value was accepted and recorded as the result for each parameter and for each of the tibiae. The summation of the transverse lengths of the condyles and the intercondylar length of each side constituted the mediolateral length (MLL) for the respective side (i.e. MLL = b+c + e). The obtained data was analyzed with SPSS version 21 and expressed as means plus standard deviation with level of significance set at $P < 0.05$.

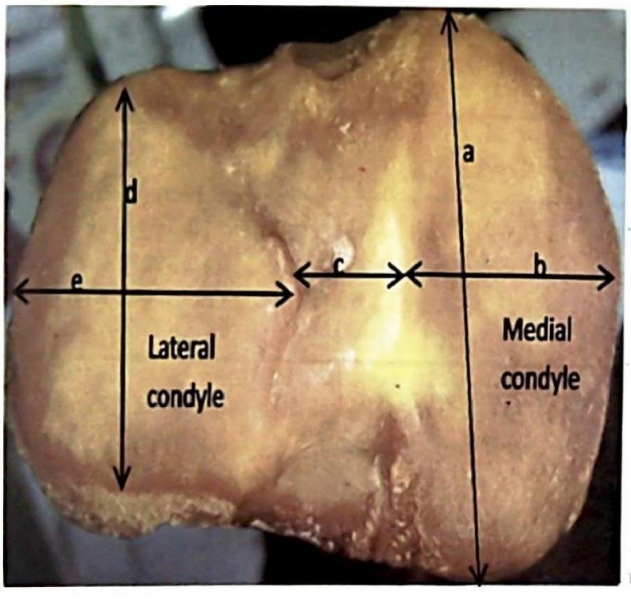


*Fig. 1 Left Tibia (superior surface) shhowing arrows: a-anteroposterior (AP) lenght of the medial condyle; b-transverse length (TL) of the medial condyle; e-intercondylar distance (ICL); d- anteroposterior length of the lateral condyle and c-transverse length (TL) of the lateral condyle*

## Results

A total of 131adult tibiae with the right constituting 44.3% (58) and the left being 55.7 % (73) were used for the study. The mean APL of the medial condyle of the right tibia (44.27±4.10 mm) was significantly longer than that of the lateral condyle (39.49±3.89 mm) (p 0.01) However, there was no significant difference between the mean transverse lengths of both condyles of the right tibia (30.30±3.42 vs30.84±3.67 mm). The mean APL of the left tibial medial condyle was significantly longer than that of its lateral condyle (43.55±4.38 vs 39.23±4.02 mm; p= 0.01). The mean transverse lengths of both condyles of the left tibia were not significantly different (30.16±3.16 vs30.59±3.30 mm). The median APL of each of the condyle of both tibiae was closer to the respective maximum APL than the minimum APL (Table 1). For the transverse length, the median value was midway between the respective minimum and maximum values for all the four condyles (Table 1). The right tibia median ICL was midway between the minimum and maximum values (13.11 vs9.53; 17.98 mm). For the left tibia the median ICL was closer to the maximum value (13.06 vs 15.38; 9.24 mm). For all the measured parameters, their mean values were very close to the respective median value (Table 1).

*Comparison between the right and left tibiae*

The mean APL of the right tibial medial condyle was marginally and insignificantly higher than that of the left tibia (44.27±4.10 vs 43.55±4.38 mm). While the lateral condyles of both right and left tibiae had very similar mean APL (39.49±3.89vs39.23±4.02mm). The mean TL of the medial condyle of the right and left tibia respectively was almost same (30.30±3.42 vs30.16±3.16 mm). Similar results were obtained for the mean transverse length of the lateral condyle (30.84±3.67 vs30.59±3.30 mm) (Table 2).

## Discussion

The results of this direct measurement study showed the existence of asymmetry between the anteroposterior length (APL) of the tibial condyles with the medial condyle being significantly longer. This significant asymmetry is in agreement with similar measurements amongst the Turkish population [6], Koreans [7], Japanese population [8], French [2] and South Indians [3]. The mean APL for the adult Turkish population was 50.1±4.1 mm for the medial condyle and 42.3±3.3 mm for the lateral condyle. Although these were higher than those of this study, the asymmetry was statistically significant.

The fact that the Turkish evaluation was a magnetic resonance imaging (MRI) study may not offer complete explanation for the higher values as there might be some degree of genetic input as a result of racial differences. In this Turkish study, it was observed that none of the available tibial implant design exhibited a perfect conformity to the proximal tibial morphology with regards to shape and size. Thus the need to have knee implants that meet the

**Table 1:** Values of the Parameters measured

| Parameter (mm) | Right Tibia N=58 | | Left Tibia N=73 | |
|---|---|---|---|---|
| | Medial condyle | Lateralcondyle | Medialcondyle | Lateralcondyle |
| Mean APL | 44.27±4.10 | 39.49±3.89 | 43.55±4.38 | 39.23±4.02 |
| Minimum APL | 31.73 | 26.26 | 29.66 | 28.88 |
| Maximum APL | 52.93 | 47.15 | 54.16 | 47.02 |
| Median APL | 44.02 | 39.77 | 43.57 | 39.68 |
| Mean TL | 30.30±3.42 | 30.84±3.67 | 30.16±3.16 | 30.59±3.30 |
| Minimum TL | 22.99 | 20.91 | 21.53 | 22.68 |
| Maximum TL | 38.52 | 38.87 | 39.60 | 38.57 |
| Median TL | 30.74 | 31.40 | 30.52 | 30.73 |
| Mean ICL | 13.03±1.81 | | 12.85±1.47 | |
| Minimum ICL | 9.53 | | 9.24 | |
| Maximum ICL | 17.98 | | 15.38 | |
| Median ICL | 13.11 | | 13.06 | |
| Mean MLL | 74.17±6.68 | | 73.60±6.01 | |
| Minimum MLL | 58.42 | | 56.82 | |
| Maximum MLL | 86.69 | | 87.16 | |

*APL Anteroposterior length, TL transverse length, ICL Intercondylar length MLL Mediolateral length.*

**Table 2** Comparison of mean values of the measured parameters between right and left tibia.

| Parameter (mm) | Medialcondyle | | P-value | Lateralcondyle | | P-value |
|---|---|---|---|---|---|---|
| | Right | Left | | Right | Left | |
| Mean APL | 44.27±4.10 | 43.55±4.38 | 0.17 | 39.49±3.89 | 39.23±4.02 | 0.36 |
| Mean TL | 30.30±3.42 | 30.16±3.16 | 0.41 | 30.84±3.67 | 30.59±3.30 | 0.34 |
| Mean ICL | 13.03±1.81 | (Right tibia) | | 12.85±1.47 | (Left tibia ) | 0.26 |
| Mean MLL | 74.17±6.68 | (Right tibia) | | 73.60±6.01 | (Left tibia) | 0.30 |

*APL Anteroposterior length, TL transverse length, ICL Intercondylar length*

**Table 3:** Comparison of the results with those of other studies

| Study | Right | | | | | Left | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | TL | | AP | | MLL | TL | | AP | | MLL |
| | MC | LC | MC | LC | | MC | LC | MC | LC | |
| Gupta *et al* [17] (N=50) (cm) | 2.70 ±0.24 | 2.66 ±0.24 | 4.55 ±0.29 | 4.08 ±0.27 | 6.77 ± 0.31 | 2.76 ±0.27 | 2.92 ±0.32 | 4.36 ±0.47 | 4.06 ±0.40 | 6.88 ± 0.65 |
| Ivan [18] (cm) | | | 4.08 ±0.42 | 3.67 ±0.41 | 6.62 ± 0.51 | | | 4.13 ±0.42 | 3.54 ±0.39 | 6.66 ± 0.56 |
| Srivastava *et al* [9] (N150)(cm) | 2.97 | 2.92 | 3.86 | 3.64 | | 2.75 | 2.97 | 3.99 | 3.69 | |
| This Study (mm) | 30.30 ±3.42 | 30.84 ±3.67 | 44.27 ±4.10 | 39.49 ±3.89 | 74.17 ±6.68 | 30.16 ±3.16 | 30.59 ±3.30 | 43.55 ±4.38 | 39.23 ±4.02 | 73.60 ±6.01 |

*APL Anteroposterior length, TL transverse length, MML mediolateral length, MC medial condyle, LC lateral condyle*

need of the Turks was suggested. The mean APL values for the adult Korean population were 48.5± 3.7 mm and 43.5 ± 2.9 mm respectively for the medial and lateral condyle. The Korean study entailed computerized tomographic scanning of the proximal tibiae in cadavers and it was observed that the results obtained were lower than the size of commercially available knee implants.

This observation according to the authors could lead to mediolateral overhang of the implant if used in knee arthroplasty. They therefore concluded that the results of the study could assist implant manufacturers in the design and production of knee implants that best suit the Korean populace. Results of another computerized tomographic study of adult French citizens who had unicompartmental knee arthroplasty (UKA) by Servien et al [2] put the mean APL of the medial and lateral plateau of the tibia at 50.8± 3.3 mm and 47.2 ± 3.3 mm respectively. This French study compared the tibial plateau dimensions with available UKA implants from nine different manufacturers and noted that none of these implants had an asymmetric tibial compartment. The implication of this observation according to them was that the available UKA implants would result either in mediolateral overhang or reduced anteroposterior coverage.

The reduced anteroposterior coverage may result in the load being transmitted to cancellous bone as opposed to cortical bone, this might lead to tibial implant collapse. Srivastava et al [9] measured parameters similar to those of our study in 150 cadaveric tibiae of north Indian extraction and reported the mean APL of the right medial condyle to be 38.63 mm and that of lateral condyle 36.47 mm. The respective mean APL values for the left were 39.94 and 36.94 mm . Similar cadaveric study of south Indian subjects reported a mean APL of 40.6 ±3,9 mm for the right medial condyle and 34.8 ±3.7 mm for the right lateral condyle while the results for the left were 39.2 ±3.6 mm and 32.6 ±3.4 mm respectively. These results showed some degree of asymmetry between the right and the left tibia and the medial and lateral plateaus; with the pattern of asymmetry being similar to that of the present study. Our study and those of the Indians (north and south) have certain features in common namely cadaveric and being direct measurement; yet our results were higher than those of the Indians. This observation gives credence to the assertion that racial differences affect the morphology of the tibia as a bone and the condylar plateaus in particular. Cheng *et al* [10] noted that the smaller sized tibial implants being used for Chinese had under sized mediolateral length while the larger size implants were oversized.

Yang *et al* [11] also made similar observation that the smaller tibial implants exhibited mediolateral undersizing while the larger ones had overhang . Quite a number of studies have demonstrated that most of the available tibial component designs do not fit adequately with the anthropometric parameters of different ethnic groups [10-14].This has stimulated studies that tend to generate anthropometric parameters of the tibia that may serve as baseline data in the manufacture of tibial implants that meet the specifications of different ethnic groups.

Attached to the surface of each plateau is a fibrocartilaginous structure known as the meniscus. Each meniscus is peripherally situated and has two tips known as the anterior and posterior horn. The distance between the anterior and posterior horns may thus reflect the anteroposterior length of the respective condyle. In a study by Koyuncu *et al* [15], in which the distance between the anterior and posterior horn of each meniscus was measured in 105 cadaveric human fetuses grouped into first trimester, second trimester, third trimester and term. It was observed that the mean distance between the anterior and posterior horns of the medial meniscus was significantly greater than that of the lateral meniscus in all the four developmental periods and in fact the respective values for the medial meniscus were about twice that of the lateral meniscus. From the foregoing, it may thus be concluded that the longitudinal growth of the medial condyle occurs at a faster rate than that of the lateral condyle. This differential growth rate though about twice during the foetal period is sustained till adulthood with reduction in the gap as evidenced by the mean APL values of our study.

The above explains why the mean APL of the medial condyle was longer than that of the lateral condyle in all the cited studies including the present study. Unlike the APL, the mean TL values were very similar for both condyles and for both sides. This is in concordance with the results of similar studies (Table 3). However, the mean TL still varies along racial and ethnic lines.

Yue *et al* [16] reported the mean mediolateral length (MML) of the tibial condyle in Chinese male and female as 75.2 ±3.6 and 66.2±2.1 mm respectively. The same study reported 78.7 ±5.4 and 69.0±4.2 mm as the MLL for American male and female respectively. Our results are similar to those of the Chinese male but lower than that of the

American male. This may be due to the fact that the Americans on the average have greater body status than Nigerians. The mean MLL for the Turkish population was 71.9±4.4 mm which is similar to that of the present study.

None of the studies reviewed measured the intercondylar length (ICL). Our study showed that the mean ICL of the right tibia was marginally and insignificantly longer than that of the left tibia. Our study was thus the first to document the tibia intercondylar distance.

Comparing all the measured parameters of the right tibia with the respective tibial counterpart, we did not observe any significant difference rather they were similar (Table 2).

This observation was also noted in similar studies that were compared with the present one as stated in Table 3. This may be the basis why available tibial implants are not side specific. The results of this study thus further reinforces the non-side specific manufacture of the available tibial implants.

We also noted that the mean APLs were closer to their respective maximum values while for the transverse length, they were midway between their respective minimum and maximum values. For the mediolateral length, the mean value was also closer to the respective maximum value. For all the assessed parameters, the mean and respective median values were very similar. Thus from these two observed relationships between the mean and the range (minimum and maximum) on one hand and the mean and median on the other hand; it may thus be deduced that the obtained values were fairly representative of the study population. Thus the data generated by this study may be a template for the production of tibial implants that will be suitable for adult Nigerians scheduled for knee replacement surgeries.

Knee osteoarthritis is the commonest osteoarthritis of large joint [19], and as such a good knowledge of the tibial condylar measurement in our environment will be beneficial to both clinician and the industry involved in knee arthroplasty.

## Conclusion

The tibia, and by extension the knee, has variable anatomy and geometry that is irrespective of gender and race. This should be strongly considered in the design and manufacture of the tibia implant for knee arthroplasty.

The clinical relevance of this study is that anatomic design of tibial implant that takes the proximal tibial parameters of Nigerians into consideration will allow for increased rotational alignment of the tibia and better coverage of the tibia. This will reduce soft tissue entrapment and collapse of the implant; both of these will increase postoperative restoration of function to the osteoarthritic knee. Data from this study may thus serve as a guideline in the design of tibial implant suitable for the Nigerian population. To the best of our knowledge, this is the first that will document the dimensions of the tibial condyles in Nigerians.

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