Innovations

Proximal Tibia Morphometry in South Indians: Tailoring Knee Prosthesis for Precision

S Dipak Raj[1], Dr Ashwini NS[2], Dr Srinivasa Reddy P[3]

[1] Undergraduate student, Sri Devaraj Urs Medical College, Sri Devaraj Urs Academy of Higher Education & Research, Kolar, India

[2]Professor, Department of Anatomy, Sri Devaraj Urs Medical College, Sri Devaraj Urs Academy of Higher Education & Research, Kolar, India

[3] Professor, Department of Forensic Medicine, Sri Devaraj Urs Medical College, Sri Devaraj Urs Academy of Higher Education & Research, Kolar, India

Corresponding author**: Dr. Srinivasa Reddy.P**

Abstract: *Knee arthroplasty is a common approach for addressing arthritis and knee injuries. The utilization of knee prostheses in this context necessitates tailored sizing based on the population's specific characteristics. This study aims to conduct a morphometric analysis of the tibial plateau to contribute valuable insights to this sizing requirement. The study included 55 human tibia bones (24 left and 31 right). The mediolateral length, anteroposterior diameter, transverse diameter and area of superior articular surface of both tibial condyles along with the anteroposterior length and transverse measurements of the intercondylar were noted with digital vernier calliper. The data was tabulated and analysed. The mean AP diameter of the right medial tibial condyle (39.25 ± 5.07) exceeds that of the left medial condyle (37.6 ± 4.26). The mean transverse measurement of the right tibial condyle (29.04 ± 4.38) is slightly more than the left medial tibial condyle (28.06 ± 3.93). The mean AP diameter of the intercondylar was found to be greater in males (44.49 ± 4.49) than in females (40.99 ± 5.95). These results have been compared with existing studies for comprehensive analysis. This study furnishes crucial data on the upper end of the tibia, aiding in the precise selection of knee prostheses based on observed measurements. Gender-wise and side-specific data enhance the longevity and mobility potential of knee prostheses, thereby enhancing post-knee replacement surgery lifestyles. The study concludes that conventional prostheses designed for caucasians may not be optimal for the South Indian population due to their smaller anatomical measurements. Adherence to these measurements and guidelines can pave the way for designing knee prostheses tailored to the South Indian demographic, ensuring prolonged utilization.*

Key Words: *Tibia, Morphometry, South India, Arthroplasty and Prosthesis*

Introduction:

The knee is the largest synovial joint in the body and functions to control the centre of body mass and posture in the activities of daily living. This requires a large range of movements in three dimensions together with the ability to withstand high forces.

The joint consists of a complex array of bone, soft tissue, muscle and fluid, making it the most sophisticated joint in the human frame. It has three distinct and partially separated compartments which are; two condyloid joints (tibio-femoral joints), one between each condyle of the femur and the corresponding meniscus and condyle of the tibia; and a third between the patella and the femur (patello-femoral joint), that together form a complex hinge joint. This articulation, allows for motion in six degrees of freedom and makes the knee joint inherently unstable and especially susceptible to damage [1].

The knee joint is involved in several degenerative and inflammatory disorders of which the commonest one is osteoarthritis (OA). Osteoarthritis is a chronic degenerative disorder of multi factorial etiology characterized by loss of articular cartilage and periarticular bone remodelling. Studies estimate the prevalence of OA in India to be 22-39% [2] amongst patients with joint disease. Osteoarthritis of the knee is the most common cause of locomotor disability in the elderly. Patients with persistent pain and progressive limitation of daily activities despite medical management may be candidates for surgery in whom, total knee replacement is proven to be safe and cost-effective treatment for alleviating pain and restoring physical function [2].

The introduction of the total condylar prosthesis by Insall and colleagues in 1972, marks the era of modern knee replacement [3]. This prosthesis was the first to replace all three compartments of the knee. Modern total knee arthroplasty consists of resection of the diseased articular surfaces of the knee, followed by resurfacing with metal and polyethylene prosthetic components. For the properly selected patient, the procedure results in significant pain relief, improved function and quality of life [4].

In total knee arthroplasty (TKA), improper fit between the implant and the bony surface leads to several problems. If components are too small (under hang), the bone–implant interface will be reduced leading to higher contact stresses, increased risk of fracture and accelerated process of loosening. The Swedish Knee Arthroplasty Register (2006) reported this problem as the main reason for TKA revision between 1995 and 2004 [5]. Conversely, if components are too large (overhang), they may impinge on the surrounding capsular tissues and ligaments, causing pain and limiting the range of motion of the joint [6].

This study is to measure the dimensions of proximal tibia in the South Indian population by collecting data dry bones and to obtain the fraction ‘Aspect ratio’. To assess gender distinctions, these dimensions will be compared between male and female specimens. Additionally, a comparative analysis will be conducted, examining morphometric dimensions in relation to other racial groups and current knee arthroplasty systems in India. This study will be highly relevant in designing appropriate sized prosthesis for total knee replacement in Indian population.

Materials and Methods:

The study was done after approval from the Institutional Ethics Committee. The study included measurements on unpaired fully ossified dry adult bones. The study group was composed of 55 adult dry human tibiae, all of which were sourced from the Department of Anatomy and the Department of Forensic Medicine at Sri Devaraj Urs Medical College, Kolar. The study is specific to South Indian population as dry tibiae we have in the department belong to the local population. These tibiae were specifically chosen due to their known sex and side characteristics, ensuring a representative sample. To conduct our measurements and analyses, we employed a digital Vernier calliper with a precision of 0.01 mm.

SEX/SIDE	RIGHT	LEFT	TOTAL
MALE	20	13	33
FEMALE	11	11	22

[Table/Fig-1]: Table depicting the description of the study group (n=55).

2.1 The parameters included were:

1. Mediolateral length: This was defined as the maximum length in the mediolateral dimension
2. Anteroposterior Medial Condyle: The maximum distance from the front to the back of the superior articular surface of the medial condyle.
3. Anteroposterior Lateral Condyle: The maximum distance from the front to the back of the superior articular surface of the lateral condyle.
4. Transverse Medial Condyle: The maximum width of the superior articular surface of the medial condyle.
5. Transverse Lateral Condyle: The maximum width of the superior articular surface of the lateral condyle.
6. Anteroposterior Intercondylar: The maximum distance between the front and back borders of the intercondylar area.
7. Transverse Anterior Intercondylar Area: The portion of the intercondylar area located in front of the intercondylar eminence.
8. Transverse Posterior Intercondylar Area: The portion of the intercondylar area located in back of the intercondylar eminence.
9. Circumference of upper end of tibia: The distance round the superior articular surface of Tibia.
10. Area of medial condyle: The size of the surface of superior articular surface of the medial condyle.
11. Area of lateral condyle: The size of the surface of superior articular surface of the lateral condyle.
12. Total area of the condyle: The sum of values of area of medial condyle and area of lateral condyle
13. Aspect ratio: The ratio which is calculated as the mediolateral dimension divided by the anteroposterior dimension.

Statistical Analysis:

All the data was entered into Excel workbook sheets (Microsoft Office Excel; version 2007, Microsoft ® Corporation, US.) and analysed using SPSS (version 22.0; SPSS Inc., Chicago, IL). The data was analysed as follows. The dimensions were summarized as the mean and standard deviation and compared using paired t-test. A Two-tailed P values less than 0.05 were considered statistically significant and P values less than 0.001 were considered highly significant. Correlation coefficient used for assessing relationships between aspect ratio and anterior posterior of intercondylar area. All the results were expressed in mean ±SD.

Results:

The morphometric measurements of the proximal end of the tibia are summarized in [Table/Fig-2]

PARAMETERS	SIDE	MALE (MEAN±SD)	COMBINED MALE (MEAN±SD)	SIDE	FEMALE (MEAN±SD)	COMBINED FEMALE (MEAN±SD)
Mediolateral length	Right	65.56±4.84	65.53±4.82	Right	63.7±6	62.62±5.78
	Left	65.48±4.98		Left	61.53±5.61	
AP diameter of medial tibial condyle	Right	40.54±4.55	39.59±4.72	Right	36.91±5.33	36.94±4.48
	Left	38.13±4.78		Left	36.97±3.69	
AP diameter of lateral tibial condyle	Right	34.98±2.72	33.92±3.45	Right	32.81±3.78	32.25±3.52
	Left	32.29±3.91		Left	31.69±3.32	
AP diameter of intercondylar	Right	44.68±5.27	44.49±4.49	Right	40.09±7.64	40.99±5.95
	Left	44.19±3.1		Left	41.89±3.78	
Transverse diameter of medial tibial condyle	Right	29±2.92	29.1±3.43	Right	29.12±6.43	27.88±5.10
	Left	29.26±4.23		Left	26.64±3.16	
Transverse diameter of lateral tibial condyle	Right	27.63±2.5	27.76±2.78	Right	26.8±4.03	26.44±3.24
	Left	27.96±3.25		Left	26.09±2.34	
Transverse diameter of anterior intercondylar	Right	34.22±3.9	34±3.83	Right	31.46±5.36	30.94±4.66
	Left	33.65±3.86		Left	30.41±4.05	
Transverse diameter of posterior intercondylar	Right	15.7±1.97	15.76±1.69	Right	14.59±1.82	15.1±1.54
	Left	15.87±1.20		Left	15.6±1.05	
Circumference of upper end of tibia (cm)	Right	19.26±1.53	19.26±1.38	Right	18.7±1.63	18.39±1.45
	Left	19.26±1.15		Left	18.08±1.24	

[Table/Fig-2]: Table depicting the Mean of all parameters of right, left and total tibia with the Gender (n=55)

In this study the Aspect ratio of tibia was as the ratio of Mediolateral length and the AP diameter of intercondylar.

Aspect ratio	Sex	N	Mean ± Std. Deviation	p-Value	t- value
	Female	22	1.58± 0.5	0 .154	1.074
	Male	33	1.48±0.16		

[Table/Fig-3]: Comparison showing measurements of aspect ratio

The difference of value for right and left side were statistically insignificant (p > 0.05). A negative correlation was seen between AR and APIC which was statistically significant, There is a negative correlation. This means that as one variable increases in value, the second variable decreases in value.

.

Side	***N***	Correlation coefficient	***p***
Right	31	-0.14	< 0.05
Left	24	-0.00	< 0.05
Total	55	-0.06	< 0.05

[Table/Fig-4]: Correlation between AP diameter of intercondylar area and aspect ratio

In the study by Gupta, et al there was statistical significant relation between right and left AP diameter of medial condyle, transverse diameter of lateral condyle and area of the lateral condyle as P value was 0.045, 0.001 and 0.046. However, there was no significant relation with other parameters of right and left side as P > 0.05. Whereas in our study there was no significant relation with parameters of right and left side as P > 0.05.

In our study, the area covered by medial tibial condyle is 38.37% and by lateral tibial condyle is 40.87% out of total condylar area in the right side. The area covered by medial tibial condyle is 37.21% and by lateral tibial condyle is 37.5% out of total condylar area in the left side.

Discussion:

The obtained morphometric measurements of the tibial condyles and intercondylar areas contribute valuable insights into the anatomical variations within the South Indian population. Data attained in the present study would presumably give a base for designing the optimal tibial element for unilateral and total knee arthroplasty for the South Indian population.

Authors	Race	Diameters(mm)	Side	Sex	Mean±S.D(n)	p-value
Servien et al.	French	Anteroposterior	-	-	50.8±3.3(37)	-
Uehara et al.	Japanese	Anteroposterior	-	-	48.3 ± 5.4(100)	-
S.Gandhi et al	North Indians	Anteroposterior	Right	Male	48.45±4.14(25)	<0.001*
				Female	42.39±4.19(25)	
			Left	Male	47.73±4.37(25)	<0.001*
				Female	42.36±4.65(25)	
		Transverse	Right	Male	30.18±2.83(25)	<0.001*
				Female	27.25±3.05(25)	
			Left	Male	29.38±3.14(25)	0.003
				Female	26.96±2.18(25)	
Current study	South Indians	Anteroposterior	Right	Male	40.54±4.55(55)	0.951
				Female	36.91±5.33(55)	
			Left	Male	38.13±4.78(55)	
				Female	36.97±3.69(55)	
		Transverse	Right	Male	29±2.92(55)	0.259
				Female	29.12±6.43(55)	
			Left	Male	29.26±4.23(55)	
				Female	26.64±3.16(55)	

[Table/Fig-5]: Comparison of measurements of medial condyle.

Before only servien et al., had measured anteroposterior measures of medial and lateral side condyle in the French population and set up it to be 50.8+3.3mm and 47.2+3.3mm [7]; and the study still was independent of sex and side. A study done by Uehara et al. who studied 100 tibias in the Japanese population showed that mean medial anterior posterior was 48.3 ± 5.4 mm and mediolateral length was 74.3 ± 6.6 mm. [8]

Vasanti et al conducted a study in 100 dry human tibia and noted that antero-posterior measurement of superior surface of medial condyle of tibia was 45.489±0.52 mm and 47.67±1.39 mm on right and left sides respectively, the measurement being significantly greater on the left tibia, [$p<0.05$] [9]

However in our study the mean mediolateral length in males was found to be 65.53±4.82mm and females was 62.62±5.78mm. The anteroposterior measures of medial and lateral side condyle of males was 39.59±4.72mm and 33.92±3.45mm respectively.

Kwak et al. conducted research on the upper end of the tibia to assist in total knee arthroplasty in Korea.[10] Similarly, Cheng et al. undertook similar studies in China. [11] Gandhi et al. established that the right side of the tibia exhibits greater anteroposterior length and transverse diameter of the superior articular surface of the medial condyle. [12]

Likewise, Kwak et al., had measured anteroposterior dimension of intercondylar area in the Korean population but irrespective of side and coitus. Their values were set up to be 47.3+3.8mm, while our study revealed 44.49±4.49mm in males and 40.99±5.95mm in females.

Srivastava et al. found that the area covered by medial tibial condyle is 38.56% and by lateral tibial condyle is 35.97% out of total condylar area in right side. The area covered by medial tibial condyle is 37.32% and by lateral tibial condyle is 35.65% out of total condylar area in the left side. [13] The study by Gupta et al. quoted the values are 38.87% and 34.4% for medial and lateral tibial condyle in right side and 38.89% and 38.25% on left side. [14]

In our study, the area covered by medial tibial condyle is 38.37% and by lateral tibial condyle is 40.87% out of total condylar area in the right side. The area covered by medial tibial condyle is 37.21% and by lateral tibial condyle is 37.5% out of total condylar area in the left side.

Due to the asymmetrical differences in the metric parameters between the medial and lateral plateau, there is a potential challenge in medial unicompartmental knee arthroplasty. This challenge arises from unnecessary mediolateral overhang when striving for optimal anteroposterior coverage of the articular surface. The morphometric analysis conducted in this study on the proximal articular surface of the tibia is anticipated to offer valuable insights. These insights could contribute to the design of suitable knee prostheses for both unicompartmental and total knee arthroplasty, specifically tailored for the South Indian population.

Conclusion:

This study presents crucial morphometric data of the upper end of the tibia through direct observation, offering valuable insights for selecting appropriately sized knee prostheses. Gender-specific data, including right and left sides, enhances prosthesis longevity and patient mobility following knee replacement surgery. The smaller anatomical profile of Indians, as compared to other populations, underscores the necessity for population-specific prosthesis sizing. Additionally, the decrease in the tibial aspect ratio with increased AP length informs prosthesis manufacturing guidelines, ultimately contributing to their long-term success. This research particularly benefits females by facilitating the design of gender-specific prostheses.

References:

1. *Standring S, Ellis H, Johnson D, Healy J, Williams A. Pelvic Girdle and Lower Limb. In: Newell R, editor. Gray's Anatomy. 39 ed. London: Elsevier Churchill Livingstone;* ***(2005).*** *p. 1399.*
2. *Chopra A, Patil J, Billempelly V, Relwani J, Tandle HS. Prevalence of rheumatic diseases in a rural population in western India: a WHO-ILAR COPCORD Study. J Assoc Physicians India.* ***(2001)*** *Feb;49:240–6. 24.*
3. *Insall JN. Surgical techniques and instrumentation in total knee art hroplasty.In: Insall JN, Windsor RE, Scott WN, editors. Surgery of the Knee. 2nd ed. NewYork: Churchill Livingstone;* ***(1993).*** *p. 739*
4. *Lavernia CJ, Guzman JF, Gachupin-Garcia A. Cost effectiveness and quality of life in knee arthroplasty. Clin. Orthop. Relat. Res.* ***(1997)*** *Dec;(345):134–9.*

5. *Department of Orthopedics, Lund University Hospital. Swedish Knee Arthroplasty Register, Annual report – 2006.* ***(2006).***
6. *Fitzpatrick C, FitzPatrick D, Lee J, Auger D0. Statistical design of unicompartmental tibial implants and comparison with current devices. Knee (**2007**);14(2):138–144*
7. *Servien E, Saffarini M, Lustig S, Chomel S, Neyret P. Lateral versus medial tibial plateau: morphometric analysis and adaptability with current tibial component design. Knee Surgery, Sports Traumatology, Arthroscopy. **(2008)**;16 (12):1141-5.*
8. *Uehara K, Kadoya Y, Kobayashi A, Ohashi H, Yamano Y. Anthropometry of the proximal tibia to design a total knee prosthesis for the Japanese population. J Arthroplasty. (**2002**) Dec;17(8):102832.*
9. *Vasanthi A, Rao BN. Study of condylar parameters of tibiae an analysis pertaining to North Costal Andhra Pradesh population. IOSR. (**2017**);16(8):4-9*
10. *Kwak DS, Surendran S, Pengatteeri YH, Park SE, Choi KN, Gopinathan P, et al. Morphometry of the proximal tibia to design the tibial component of total knee arthroplasty for the Korean population. The Knee. **(2007);**14 (4):295-300.*
11. *Cheng FB, Ji XF, Lai Y, Feng JC, Zheng WX, Sun YF, et al. Three dimensional morphometry of the knee to design the total knee arthroplasty for Chinese population. Knee. **(2009**);16:341-47.*
12. *Gandhi S, Singla RK, Kullar JS, Suri RK, Mehta V. Morphometric analysis of upper end of tibia. Journal of clinical and diagnostic research: JCDR. **(2014**);8(8):AC10.*
13. *Srivastava A, Yadav A, Thomas RJ, Gupta N. Morphometric Study of Tibial Condylar area in the North Indian population. J Med Sci Clin Res (**2015**);2:515-9.*
14. *Gupta C, Kumar J, Kalthur SG, D«SQ»souza AS. A morphometric study of the proximal end of the tibia in South Indian population with its clinical implications. Saudi J Sports Med **(2015**);15:166-9*
15. *Nadia Ahmad,Deepa Singh, Aksh Dubey, S. L. Jethani,Morphometric Analysis of Proximal End of the Tibia. Natl J Clin Anat (**2019**);8:82–86*
16. *Insall JN, Clarke HD. Historic development, classification and characteristics of knee prosthesis. In: Fitz W, Scott RD, Scott WN, eds. Unicompartmental Total Knee Arthroplasty. Insall and Scott Surgery of the Knee. 4th ed. Vol. 2. Philadelphia*
17. *Zanasi S. Innovations in total knee replacement: new trends in operative treatment and changes in peri-operative management. Eur Orthop Traumatol. (**2011**); 2: 21–31.*
18. *Joshy S, Datta A, Perera A, Thomas B, Gogi N, Kumar Singh B. Ethnic differences in preoperative function of patients undergoing total knee arthroplasty. Int Orthop. (**2006)** Oct;30(5):426–8.*