Research article

A study on topography of tibial plateau and its applications in knee arthroplasty

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(Received: July 2022 Revised: September 2022 Accepted: October 2022)

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ABSTRACT

Introduction and Aim: This investigation was designed for evaluating the tibial plateau in Indian population and compares the data with other populations. The major intention is to observe if significant difference exists in diverse a demographic profile that necessitates production of population specific implants ensuring success in total knee arthroplasty.

Materials and Methods: Morphometry of 200 adult human tibial plateaus were measured in dry bones using a sliding digital caliper and data analysis was done.

Results: The mean anteroposterior dimension of the medial condyle was 38.98 ± 4.46 mm on the left and 38.81 ± 5.05 mm on the right and the lateral condyle was 32.99 ± 4.01mm on the left and 32.42 ± 4.88 mm on the right. The mean transverse dimension of the medial condyle was 24.95 ± 3.22 mm on the left and 24.54 ± 2.69 mm on the right and the lateral condyle was 28.15 ± 4.10 mm on the left and 27.76 ± 3.50 mm on the right. The anteroposterior dimension of the intercondylar area was 44.78 ± 3.87 mm on the left and 44.19 ± 4.51mm on the right.

Conclusion: The data obtained will help in designing tibial prosthetic implants best suited for Indian population. The surgeon can assess how much a given deformity deviates from the normal values. The dimensions of the tibial plateau vary in different populations and most available prosthesis is designed based on Caucasian data. The tibial prosthetic sizing needs to be population specific to avoid a mismatch or mediolateral overhang.

Keywords: Osteoarthritis; tibial plateau; tibial prosthesis; total knee arthroplasty

INTRODUCTION

The knee joint is a complex and compound anatomical structure modified to facilitate locomotion (1). The femoral condyles and the intercondylar fossa articulate with the tibial condyles and the intercondylar eminence to form a hinge joint that efficiently transmits body weight (2). Knee joint is vulnerable to trauma and inflammation. Superficial joint trauma usually responds to medical treatment but deep trauma involving the menisci needs appropriate surgical intervention (3). Unicompartmental knee arthroplasty or a collative knee arthroplasty are the regimen available for treating intractable osteoarthritis (4). Success rates of this regimen depends on the accuracy of the size of prosthesis, its embedding and positioning so as to allow sufficient movement (5). The size of the tibial prosthesis must be accurate for maximum coverage of its resected surface to facilitate the transmission of body weight (6). The anteroposterior measurement of the prosthesis must be accurate to allow adequate flexion and extension and the mediolateral measurement must be accurate to sufficiently envelop the expunged surface and allow an effective closure of the wounds (7). Surgical procedures such as knee arthroplasty, arthrodesis and corrective osteotomies are ever evolving, and the newer procedures are providing better functional outcomes (8).

Several authors have suggested the need to compare the tibial plateau dimensions in different ethnic groups as it is likely that the dimensions will have a demographic difference (9, 10). Most studies are on Caucasians where the knee size is much larger and hence the commonly available prosthetic implants do not complement with the removed surfaces of the bones from Asian patients (11).

In this study, the dimensions of medial and lateral condylar area as well as inter condylar area of the tibia were studied from Indian population. The resulting dimensions obtained will not only define the normal dimensions of the plateau in Indians but it will also help the surgeon in assessing deformities by understanding how much a given clinical case deviates from the normal values. This will help surgical companies design appropriate prosthesis suited for Indian population thus improving surgical outcome in Indian and Asian patients. The article also reviews the dimensions of tibial plateau in different ethnic groups.

MATERIALS AND METHODS

In this observational study, we selected two hundred dry human tibias (100 Left and 100 Right) available in the Department of Anatomy of a Medical College where sex and age of the bones were unknown.

Inclusion/exclusion criteria: Only tibias having intact anatomical features were selected for the study. Bones which were damaged and poor anatomical features were excluded from the study.

Institutional ethical clearance was not taken, since the study material were selected from the collection of bones from Department of Anatomy. All these bones were from the cadavers donated to the department for the purpose of study and research with consent.

The tibial plateau morphology was studied. The dimensions of medial tibial condyle were measured as shown in Fig.1, lateral tibial condyle as shown in Fig.2 and intercondylar area as shown in Fig.3.

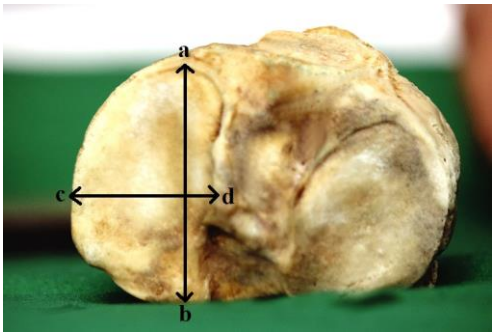

Fig.1: The measurement of medial condylar dimensions

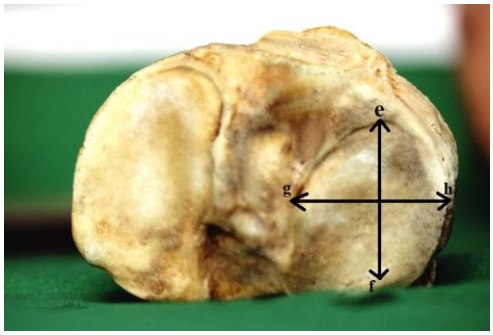

Fig.2: The measurement of lateral condylar dimensions

A sliding digital callipers with an accuracy of 0.01mm was used for the measurements. The measurements were taken in duplicates and the average was calculated. Third measurement was taken in case of a large variation of greater than 0.1 mm existed.

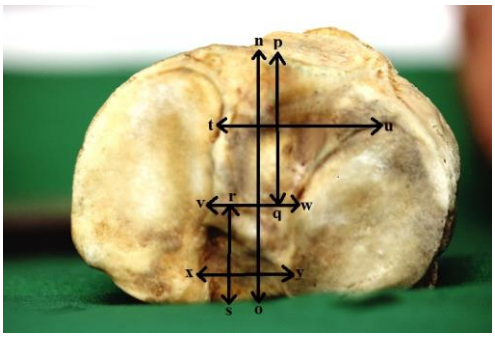

Fig.3: The measurement of intercondylar dimensions

Statistical Package for Social Sciences (SPSS version 20.0) and two tailed Student's t-test ($P < 0.05$) was used for analyzing the statistical variation. The mean and standard deviation of all the dimensions were obtained and analyzed for bilateral statistical significance. The results of the present study were compared with the previously available literature on morphological measurements of tibial plateau in other ethnic groups. The author had no information on the gender, age or any pathology related to the bones and this is a limitation of this study.

RESULTS

Table1 summarizes the descriptive statistics of dimensions of condyles. The mean anteroposterior dimension of the medial condyle was 38.98 ± 4.46 mm on the left and 38.81 ± 5.05 mm on the right and no significant difference was observed bilaterally with P= 0.803 (P>0.05).The mean transverse dimension of the medial condyle was 24.95 ± 3.22 mm on the left and 24.54 ± 2.69 mm on the right and no significant difference was observed bilaterally with P=0.324 (P>0.05). Mean anteroposterior dimension of the lateral condyle was 32.99 ± 4.01mm on the left and 32.42 ± 4.88 mm on the right and no significant difference was observed bilaterally with P=0.359 (P>0.05). The mean transverse dimension of the lateral condyle was 28.15 ± 4.10 mm on the left and 27.76 ± 3.50 mm on the right and no significant difference was observed bilaterally with P=0.482 (P>0.05).

Table 1: Descriptive statistics of condylar dimensions bilaterally and their significance

Dimension measured	Side	Number	Mean	Standard Deviation	P value
Anteroposterior dimension of medial condyle	Left	100	38.98	4.46	0.803
	Right	100	38.81	5.05	
Transverse dimension of medial condyle	Left	100	24.95	3.22	0.324
	Right	100	24.54	2.69	
Anteroposterior dimension of lateral condyle	Left	100	32.99	4.01	0.359
	Right	100	32.42	4.88	
Transverse dimension of lateral condyle	Left	100	28.15	4.10	0.482
	Right	100	27.76	3.50	

Table 2: The descriptive statistics of intercondylar area bilaterally and their significance

Dimension measured	Side	Number	Mean	Standard deviation	P value
Anteroposterior dimension of intercondylar area	Left	100	44.78	3.87	0.313
	Right	100	44.19	4.51	
Anteroposterior dimension of anterior intercondylar area	Left	100	31.56	5.41	0.617
	Right	100	31.89	3.58	
Anteroposterior dimension of posterior intercondylar area	Left	100	11.36	1.81	0.022
	Right	100	10.78	1.71	
Transverse dimension of anterior intercondylar area	Left	100	23.12	2.97	0.016
	Right	100	21.96	3.66	
Transverse dimension at intercondylar eminence	Left	100	8.85	1.93	0.232
	Right	100	8.53	1.85	
Transverse dimension of posterior intercondylar area	Left	100	12.87	2.21	0.000
	Right	100	11.47	2.12	

Mean anteroposterior diameter of medial condyle was more than the mean anteroposterior bilateral dimension of lateral condyle. Lateral condyle had a higher dimension than the mean transverse dimension of medial condyle bilaterally. The mean anteroposterior dimensions of condyles were more the mean transverse dimensions bilaterally and all these observations are consistent with the shape of the condyles. The descriptive statistics of intercondylar area bilaterally is summarized in Table 2.

The anteroposterior dimension of the intercondylar area was 44.78 ± 3.87 mm on the left and 44.19 ± 4.51mm on the right with a P value of 0.313 (>0.05) which is statistically insignificant. The anteroposterior dimension of the anterior intercondylar area was 31.56 ± 5.41mm on the left and 31.89 ± 3.58 mm on the right with a P value of 0.617 (>0.05) which is statistically insignificant. The anteroposterior dimension of posterior intercondylar area was 11.36 ± 1.81mm on the left and 10.78 ± 1.71mm on the right with a statistical significance of P=0.022(<0.05). The transverse dimension of anterior intercondylar area was 23.12 ± 2.97 mm on the left and 21.96 ± 3.66mm on the right with a statistical significance of P=0.016 (<0.05). The transverse dimension at the intercondylar eminence was 8.85 ± 1.93mm on the left and 8.53 ± 1.85mm on the right with a P value of 0.232 (>0.05) which is statically insignificant. The transverse dimension of posterior intercondylar area was 12.87 ± 2.21 mm on the left and 11.47 ± 2.12 mm on the right with a statistical significance of P=0.000 (<0.05).

DISCUSSION

Total knee arthroplasty is the recommended surgery for relieving chronic pain in osteoarthritis (12). Today, the growing concern is the increasing burden of osteoarthritis due to increased life expectancy which has resulted in a global surge in Total Knee Arthroplasty procedures (13). The success of arthroplasty primarily depends on the accuracy of the prosthesis size (5). The prosthesis should adequately cover the resected surface to facilitate the transmission of body weight (6) and allow sufficient flexion and extension and a tension free wound closure (7).

Most prosthetic implants are designed based on data provided by studies involving predominantly white Western male patients (14 - 16). Therefore, it is essential to study the dimensions of tibial and femoral condyles in diverse demographic profiles with an objective to note if such a significant demographic difference exists which necessitates the production of population specific tibial prosthesis (17). The dimensions of the tibial plateau in Indian, Japanese and Caucasians are summarized in Table 3.

The studies in Caucasians, Japanese, Chinese, Turkish, Danish, French and Korean ethnic groups are reviewed (10, 17 -19). The studies reveal statistically significant differences in condylar dimensions between different sexes and ethnicities.

In a study by Mahfouz *et al.,* which was conducted using adult knees from the normal persons (860 Caucasian, 80 East Asian and 80 African American: n=1000) significant difference was observed between the sexes and ethnicities. Male parameters were higher than female in all the ethnic groups. African American females had a smaller dimension of tibial mediolateral area, deeper patellar groove, and increased dimension of anteroposterior tibia compared to Caucasian females. African American males had larger femoral anteroposterior dimension, mediolateral tibia diameter and anteroposterior tibial diameter in comparison to Asian males. The authors concluded that further clinical studies are necessary to substantiate the need for sex and ethnic specific prosthetic design. In a study by Kim *et al.,* in Caucasian, East Asian and Black Populations, the white patients had significantly larger femoral anteroposterior dimensions (P<0.001) and a smaller femoral aspect ratio (P=0.001) compared to East Asian patients. Further, aspect ratio was enhanced in case of whites than the black patients (P=0.005) (17).

Table 3: The condylar dimensions in Indian, Caucasian, and Japanese ethnic groups

Author	Ethnicity	Dimension	Side	Sex	Mean ± S.D.
Swathi Gandhi and others	North Indian	AP of medial condyle	Right	Male	48.45±4.14
				Female	42.39±4.19
			Left	Male	47.73±4.37
				Female	42.36±4.65
		Transverse of medial condyle	Right	Male	30.18±2.83
				Female	27.25±3.05
			Left	Male	29.38±3.14
				Female	26.96±2.18
		AP of lateral condyle	Right	Male	40.86±3.79
				Female	36.78±3.03
			Left	Male	40.69±4.13
				Female	37.30±3.81
		Transverse of lateral condyle	Right	Male	28.62±3.10
				Female	26.14±2.51
			Left	Male	28.82±3.12
				Female	26.00±3.06
Dai and Bischoff	Caucasian	AP of medial condyle	Right	Male	54.35±2.99
				Female	47.95±2.36
		AP of lateral condyle	Right	Male	48.62±2.95
				Female	42.63±2.31
Dai and Bischoff	Japanese	AP of medial condyle	Right	Male	52.43±2.31
				Female	46.32±2.09
		AP of lateral condyle	Right	Male	47.26±2.13
				Female	41.44±2.20

There are also studies done using CT scan, MRI and digital models of tibia. Cheng *et al.,* conducted a study using 3D CT measurements in normal knees (n = 172; 78 female and 94 male knees). In this study only the medial tibial condyle and the medial femoral condyles were studied with an objective of providing recommendations for developing the knee prostheses for unicondylar area ideal for the population from China. The measurements were compared with the commonly available prosthesis and it was observed that there was significant overhang and mismatch and the dimensions were much less than that of the Caucasians indicating the need for more of such ethnic studies (19). Zhang *et al.,* compared the tibial plateau and femoral condyles of Han and Mongolian Chinese ethnic groups. The study used Mimics medical imaging program to study 37 knees. Length of the femoral and tibial mediolateral, medial and lateral condyle anteroposterior length and aspect ratio were analyzed. The authors observed that the parameters were higher in males than females in Han Chinese and the aspect ratio of Han Chinese was higher than Mongolian Chinese. The authors concluded that the effects of sex and nationality on the size of tibial plateau and femoral condyles were significant (P<0.05) (20).

Küçükdurmaz *et al.,* compared the sizes of the tibial plateau from MRIs in a virtual scale of 260 patients with dimensions of available prosthesis for Uni-compartmental Knee Arthroplasty. Tibial plateau dimensions of Turkish knees were closer to the Oxford and Zuk prostheses dimensions compared to that of Accuris and Mitus. The study concluded that the tibial prosthesis designed according to the measurements of Asian and Western populations do not perfectly match the requirements of Turkish population (10). Surendran *et al.,* analyzed the dimensions of the medial tibial condyles resected from 50 male and 50 female Korean cadavers by using 3D CT. The measurements were compared with that of conventionally available tibial prosthesis. Significant mediolateral overhang was observed for several dimensions and some of the designs such as DePuy and Smith and Nephew showed mediolateral under sizing. The study provides baseline for scheming appropriate tibial prosthesis for Korean ethnic group and encourages similar studies in other ethnic groups. Servien *et al.,* studied thirty-seven knees (31 females and 6 males) performed with unicompartmental knee arthroplasty postoperatively using computed tomography. The measurements were done at the resection level. The study concluded that the shape of the lateral plateau was very different from the medial tibial plateau and this dissimilarity may lead to mediolateral overhang in cases of medial unicompartmental knee arthroplasty (21).

Knee femoral components (n = 47 osteoarthritic Indians-21 male and 26 female) were assessed using CT scan. The participants were categorized into 3 groups based on anteroposterior diameter (>59 mm, 55-59 mm, >55 mm). It was observed that 86.8% Indian men have femoral components effectively restored by possible designs and 60.4% women (P<0.001) possessed smaller femoral anteroposterior

diameters. In a given anteroposterior size, splaying in mediolateral dimension (>10mm) was acclaimed in all the three cohorts. This short study representing the Indian population can be utilized to fabricate inventories of prosthesis suitable for Asian patients with reduced anthropometric measurements in comparison with populations from West (7). In a study by Gupta et al. (26 left and 24 right; n = 50) medial tibial condyle covered 38.87% area of adult tibia and 34.4% was contributed by lateral condyle on right side. On left side, 38.89% area was constituted by medial condyle and lateral condylar area was 38.25% of total area of plateau (22).

There are studies that suggest a need to design gender specific knee prosthesis for better surgical outcome. Yang *et al.*, compared the dimensions of anterior component flange with anterior femoral condyle using intraoperative data from 962 patients (1227 knees). Intersex comparison for anterior lateral/anterior medial condylar height was analyzed and lateral/medial anterior femoral offset and over-/under stuffing aspects were compared. A significant gender difference was observed in anterior lateral condylar height ($p < 0.05$) and its-suitable fit rate ($p < 0.01$). The study concluded that significant gender differences exist in knee anterior lateral condyles and the anterior flange component has not been precisely of fabricated to reproduce normal trochlear anatomy with an evidence level 2 (23). In a study by Gandhi *et al.*, in 100 adult human tibias in north Indian ethnic group the bones were classified according to both side and sex. The study involved 50 male and 50 female tibias. The statistical analysis revealed significant difference in condylar dimensions between males and females with male dimensions being significantly higher than female with a P value of <0.05(24). Dai and Bischoff conducted a study using digital models of 347 tibias, covering both multiple ethnicities and genders. Here virtual total knee arthroplasty was performed and the study concluded that the clinically pertinent differences in the proximal tibial structure at the level of surgical removals can be attributed to differences in universal proximal tibial size rather than the ethnicity or gender.

Hovinga and Learner studied tibial width, torsion and variations in mechanical knee alignment between Caucasian and Japanese populations. Healthy young adult knee joints were studied in 47 Caucasian and 23 Japanese subjects using coronal magnetic resonance imaging. Subjects from Japan had a significantly enhanced varus alignment than Caucasians and women displayed a more valgus alignment than men. There were significant differences in tibial torsion wherein Japanese exhibiting lower torsion of the tibia compared to Caucasians. The study gives a novel insight into geometrical differences in the knee joint between Caucasians and Japanese (25).

CONCLUSION

The present study achieves the desired objective of providing the data on dimensions of tibial plateau in Indian ethnic group. This will help in designing tibial prosthetic implants that are best suited for Indian population, reducing the chance of mismatch, under sizing and overhanging linking the implant and the resected surface. The data helps the surgeon to assess as to how much a given deformity deviates from the normal values in Indian population. This will help in better planning of total and single-compartmental knee arthroplasty. The dimensions of the tibial plateau vary among various ethnic groups and most of the available literature involves the Caucasians where the knee size is much larger. The tibial prosthetic implant sizing needs to be population specific to avoid a mismatch or mediolateral overhang. The dimensions of the tibia at surgical resection level are not calculated in this study and are a limitation of the study. The authors wish to conduct research at resection levels of femur and tibia in future for better designing of prosthesis.

ACKNOWLEDGEMENT

Authors are grateful to the statistician who helped to analyze the data of this study.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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