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Anthropologic features of proximal end of the tibia

Dr. Işık Tuncer
Department of Anatomy, Meram Faculty of Medicine, Necmettin Erbakan University, Meram, Konya, Turkey

Abstract
Aim: The aim of this study is to evaluate different morphometric parameters of condylar and inter-condylar surfaces of tibia, by doing so gathering results and analyze them, so it can be formulized for studies in this field for future on Turkish population. The data obtained from this study will also be accessible to be compared with existing data in the literature. The data mentioned above may be useful on treatment and monitoring for knee surgeries, because information obtained from morphometry studies is very crucial on knee deformity cases.
Material and Methods: 36 right and 46 left adult human tibia bones were included in this study. Tibia length, anteroposterior and transverse measurements of superior articular surface of medial and lateral condyle, transverse measurements of superior articular surface of medio-lateral, the height of tuberculum inter-condylare mediale and laterale were measured with calipers with a 0.001 mm sensitivity. Student's - t test was performed to determine significance level of p values (<0.05) and 95 percent confidence level.
Results: When comparing results on right and left, all measurements have been found statistically and significantly correlated (p<0.05). Tibia length was found same in both sides. Antero-posterior measurements were found greater on lateral condyle than medial condyle. Antero-posterior diameter of right medial condyle was found longer than of left one. Antero-posterior diameter of left lateral condyle was found longer than of right one.
Conclusion: This study was conducted with the intention of providing base morphometric data of the proximal end of tibia in Turkish population to be used for arthroplasty purposes. Results gathered from this study are important for technical advancements in surgical procedures in orthopedic practice.

Keywords: Tibia, lateral condyle, medial condyle, morphometry, anatomy

Introduction

Knee replacements surgeries require preciseness. Bone cutting, balancing soft tissues and covering resected bone are needed to be done carefully [1, 2] and it is a routine orthopedic procedure for Asian-Pasific populations. Asian subpopulations generally have smaller stature compared with their Western counterparts [3]. And because of this implant sizes do not match correctly on bones in the Asian population. Tibia parts are more likely to have complications among all knee arthroplasty to compare with femoral parts [4]. So it is important to determine the proper size for the prostheses and to cut the surface of the proximal end of the tibia [5, 6]. There is no enough anthropometric data on proximal end of tibia in Asian populations.

Despite that total knee arthroplasty (TKA) has higher success rate in advanced degenerative or inflammatory diseases of the knee; proximal tibia cut surface is still an issue. Mismatch has two different types: size and rotation mismatches. Many effects on tibial components were reported to be overhang and underhang [6, 7, 9]. Rotational mismatch issues cause patella-femoral in congruence followed by dislocation of the patella and anterior knee pain and polyethylene wear of the tibial-bearing insert [10, 11]. Some morphological studies of the proximal tibia were conducted to represent data for matching correctly [2, 12, 17]. Also sex and race differences of proximal tibia were included [12, 17].

Body weight in man is a factor of extended knee position. Relationship between different weight bearing scenarios and the anteroposterior and medio-lateral dimensions of diaphysis and epiphysis of the tibia is well stated [18, 19]. When treating knee deformities, to have a sense on morphometric traits of upper end of the tibia is crucial. They may be used on treatment and monitoring purposes on total knee replacement surgeries. Precise and repeatable measurement systems aid in definition of tibial deformity and improvement of tibial prostheses design [20].

Like the other parts of the world, TKA usage is getting higher in Turkey. But there is not much data about the proximal tibia of Turkish population. So the requirements for a tibial component were not yet successfully fulfilled. But data about proximal tibia on Turkish population is not completed and this field requires a lot many studies. For these purposes, this study was conducted to obtain data for proximal tibia and compare it with the existing data.

Material Methods

82 adult human tibia bones were used for this study. The study group comprised of 36 right and 46 left bones. This study was approved by Ethical Committee of Meram Faculty of Medicine, Necmettin Erbakan University according to Copenhagen Criteria (2017/217). Measurements were performed by using vernier calipers and measuring tape with the sensitivity of 0.01 mm.

Following metric parameters were noted:

1. Tibia length: The length between the distal most end of malleous medialis and vertex point of tibial plato eminentia inter-condylaris (Fig-1: AB/Table 1, 2, 3).
2. Anteroposterior measurement of superior articular surface of medial condyle: The maksimum distance

between anterior and posterior borders of superior articular surface of medial condyle (Fig-2: CD/ Table 1, 2, 3).

3. Transverse measurement of superior articular surface of medial condyle: The maximum distance between medial and lateral borders of superior articular surface of medial condyle (Fig-2: EF/ Table 1, 2, 3).
4. Anteroposterior measurements of superior articular surface of lateral condyle: The maksimum distance between anterior and posterior borders of superior articular surface of lateral condyle (Fig-2: GH / Table 1, 2, 3).
5. Transverse measurement of superior articular surface of lateral condyle: The maximum distance between medial and lateral borders of superior articular surface of lateral condyle (Fig-2: IJ/Table 1, 2, 3).
6. Transverse measurement of superior articular surface of of medio-lateral: The maksimum transverse diameter of superior articular surface of medio-lateral (Fig-3: KL/Table 1, 2, 3).
7. The height of tuberculum inter-condylare mediale: Height between the vertex point of tuberculum inter-condylare mediale (Fig-4: MN / Table 1, 2, 3).
8. The height of tuberculum inter-condylare laterale: Height between the vertex point of tuberculum inter-condylare laterale and its base (Fig-4: OP/ Table 1, 2, 3).
9. Values of this study were entered to SPSS version 13.0 package program and analyzed. Results were shown as mean, maximum, minimum and standard deviation. As for comparison of the parameters, student- t test was applied and spearman test was applied to determine the correlation of parameters. $p<0.05$ value was accepted as significance level.

AB; Tibia length

Fig 1: Anterior view of the left tibiae.

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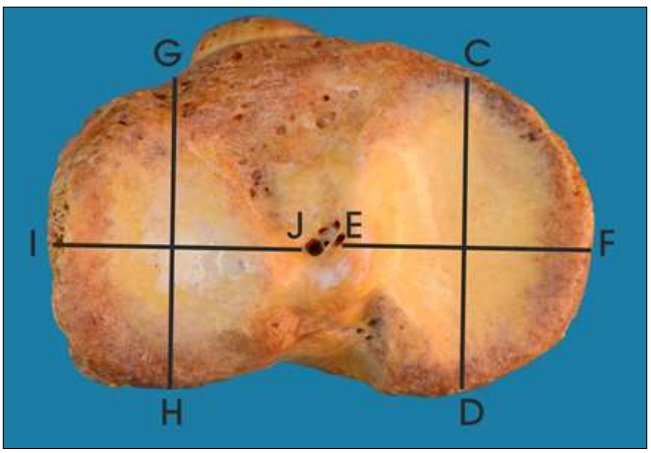


GH-IJ; Anteroposterior-Transvers measurements of superior articular surface of lateral condyle.

Fig 2: CD-EF; Anteroposterior-transvers measurements of superior articular surface of medial condyle.

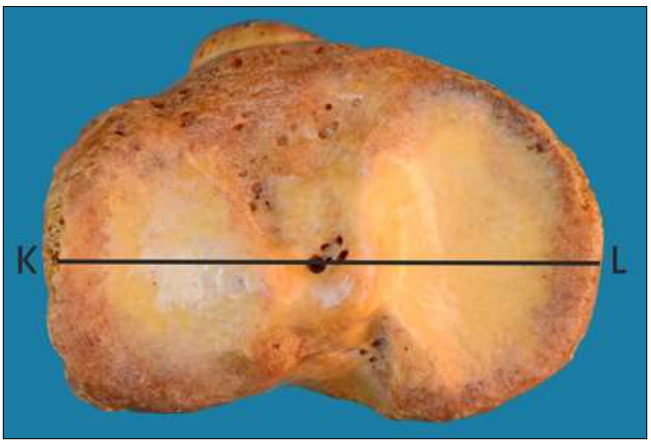
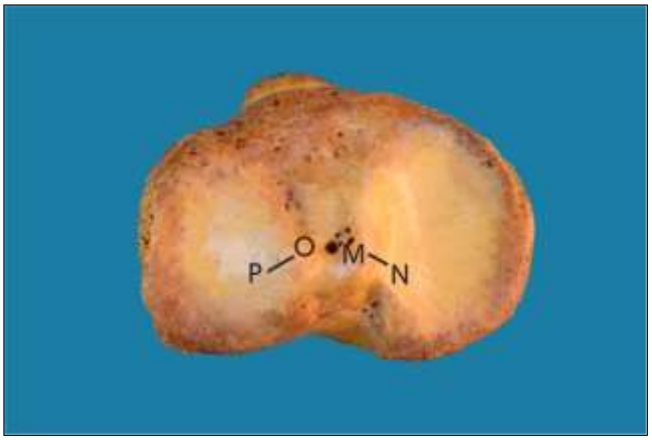


Fig 3: KL; Maximal transverse diameter of superior articular surface.



OP; Height of the tuberculum intercondylare laterale.

Fig 4: MN; Height of the tuberculum intercondylare mediale.

Results

82 tibia bones (36 right and 46 left) were used for this study. Results from the statistical comparison of the bones were shown in Table 1, 2, 3. Standard deviation (SD), minimum and maximum values were shown in table 1.

There were no significant difference between measurements according to lateralization ($p>0.05$). Right and left

comparison values of tibial morphometric measurements were shown in table. Excluding AB, DI, GJ, all values were found to be higher on left.

Pearson correlation test was applied to determine significance level of the relation of parameters. Correlation coefficient numbers (r) between tibial measurements were shown in Table 3.

Table 1: Mean, minimum, maximum and standard deviation values of the parameters (mm)

	n	Minimum	Maximum	Mean	SD
AB	82	29,0	41,5	32,62	2,23
CD	82	35,0	53,7	45,2	1,55
EF	82	24	49	30,8	3,42
GH	82	29,7	48,6	40,3	3,85
IJ	82	31,0	49,5	40,3	3,79
KL	82	52,3	81,8	70,0	5,82
MN	82	6	12	9,1	1,30
OP	82	7,1	14	10,4	2,01

Table 2: Mean, standard deviation, P and t values of the bones that were measured on the study according to lateralization

		n	Mean	SD	t	P
AB	Right	36	34,6	2,34	,060	,952
	Left	46	34,6	2,16		
CD	Right	36	38,1	1,42	-,604	,548
	Left	46	35,9	1,66		
EF	Right	36	40,1	4,25	-,342	,733
	Left	46	40,4	3,55		
GH	Right	36	30,6	2,75	-,252	,802
	Left	46	30,8	3,89		
IJ	Right	36	39,8	3,50	-,900	,371
	Left	46	40,6	4,01		
KL	Right	36	69,7	6,62	,155	,670
	Left	46	70,2	5,18		
MN	Right	36	9,2	1,33	,595	,900
	Left	46	9,1	1,29		
OP	Right	36	10,2	1,77	,486	,860
	Left	46	9,6	1,36		

Table 3: Correlation between length of tibia and other parameters of it

TB	AB	CD	EF	GH	IJ	KL	MN	OP
AB	,234							
CD	,187	,164*						
EF	,538**	,146	,503					
GH	,516**	,146	,636**	,828**				
IJ	,173	,133	,410**	,613**	,241*			
KL	,459**	,049	,745**	,345**	,305**	,441**		
MN	,197	-,007	,298**	,324**	,562*	3,18	,525	
OP	,186	,005	196	302	196	,765**	,867	,432*

Discussion

The biggest finding in the study by Erkocak *et al*. was that there was a sex related significant difference on proximal tibial plateau of the population. There was also mismatching of the dimensions in tibial components. Their data showed that male individuals had high AP (antero-posterio plane) and ML (mediolateral plane) and female individuals had higher AR (aspect ratio). Moreover, the samples on their study were more likely to be overhang antero-posteriorly. Also some female individuals were having tibial antero-posterior diameters smaller than the common tibial components.

However Turkish population has a similar type and stature compared with Western people [21, 22], they also have their own anthropometric differences. Some studies covered the morphology of Asian knees and compared them with of Western populations [23, 26]. But no present data were the case on regarding the anthropometry of the proximal tibia among the Turkish population. So this is one of the first studies on this field.

In their study Erkocak *et al*. [21] reported some results. One the results was that female individuals were having significantly smaller dimensions at the simulated resection level of the proximal tibia than male was. This was not something that was unexpected and resembles the previous studies on the field [1, 12, 27, 28]. In the study by Erkocak *et al*. [21] many of the male individuals (77 in 89 of them) were having AP diameter range between 40 and 55 mm, and many of the female individuals had (107 in 138 of them) between 35 and 45 mm.

The ML dimensions of the tibial component may be focused on a length of 65-75 mm for female and 75-85 mm for male, because 90% of knees are in this range. As a result, a tibial component with a size variation in the ML length of 65-85 mm and in the AP length of 35-55 mm is suitable for the majority of the Turkish population. Comparing our result data with the previously data on the field it may be seen that AP and ML lengths were smaller than the values of Western population [27]. And also the study showed that tibial plateau was larger than the lateral tibial plateau in the Turkish population and sex difference had no effect on it. This shows that asymmetric shape of the proximal tibial surface at the simulated resection level and it is also is consistent with previous studies on this field [1, 27]. But the symmetric or asymmetric tibial components usage in the previous studies does not match. There are studies that suggest using first and others suggest using the latter one [1, 32]. But after all, many studies use symmetric design for tibial components.

To successfully match tibial component and proximal tibial cut surface is the most important part in total knee arthroplasty (TKA) [33]. Many morphological studies of the proximal tibia were conducted to gather data on proper matching [6, 12, 17, 28] and usage of computer simulations were also an approach [14, 16, 17].

Uehara [12] performed some measurements on proximal tibial cut surface and the anteroposterior dimension was measured at the center of the tibia, since the proximal tibia had an asymmetrical shape [5, 6]. Also anatomical morphology of the knee changes by sex and race [12, 17, 28]. In their study Myatake *et al*. performed measurements on Japanese male and female during TKA and they compared the results with those of TKA systems available in Japan.

In their study Westrich *et al*. stated that the proximal tibial surface should be taken as asymmetric (34). Kwak *et al*. [1] have measured the anteroposterior dimensions of the medial and lateral condyles of the proximal tibia (MAP, LAP) at defined points also with their distance from the central point (C), on the resected proximal tibial surface (CM&CL).

In the same way as the previous studies, the medial tibial condyle was longer anteroposteriorly than the lateral condyle, indicating asymmetry of the proximal tibia [13, 27].

By comparing the ML (mediolateral) and AP (anteroposterior) dimensions of the proximal tibia with the conventional tibial prostheses, Kwak ve ark [1] reported that the prostheses that fit the smaller AP dimensions of the proximal tibia were undersized in the medio-lateral

dimension, and the prostheses that fit the larger AP dimensions of the proximal tibia were oversized in the mediolateral dimension. Among the different implant designs reviewed, Duracon was the one that most closely, however it was not the best match of the proximal tibia morphometric data for Koreans, especially on the female individuals.

A statistical comparison of measurements between Danish and study by Gandi *et al*. [18] in the Indian population reported that the transverse measurements of intercondylar area at anterior and middle parts were more in Danish population (35 mm and 11 mm) but that at posterior end the values were very close (16 mm). Recognizing the importance of anatomical description of the intercondylar area for the precise identification of skeletal structures and soft tissue insertions in radiographs, Jacobsen [35] emphasized that the shape of posterior contours of the tuberculum mediale and laterale may be used for the identification of the posterior contours of the two tibial condyles and the posterior contour of the condylus lateralis tibiae may be identified by tracing the posterior curved part of the tuberculum laterale. In his study, the latter contour was found to be the most helpful as a landmark for to measure the "drawer sign" in the knee joint by the radiological method of Kennedy and Fowler [36]. The design of prostheses, considering the sex difference, was also a case in Chinese population according to Cheng *et al*. [23]. Geoffrey [6] stated that asymmetric smaller lateral condylar surface has better outcome compared to the symmetrically constructed prostheses. As the metric parameters of medial and lateral plateau symmetrically have differences with reference to each other, it can make it difficult the medial uni-compartmental knee arthroplasty because of unrequired mediolateral overhanging in the attempts of optimal anteroposterior coverage of articular surface [37]. However, the morphometric analysis of the proximal articular surface of tibia made in this study may prove to be beneficial in designing appropriate knee prostheses for uni-compartmental and total knee arthroplasty in Turkish population.

The results of this study provide anthropometric data of the proximal tibia in the Turkish population. These data may be used as a guideline to design a tibial component suitable for Turkish patients. Female individuals of this population tend to have a tibial component having an AP diameter of<38 mm. These values are smaller than the currently available smallest tibial prosthetic sizes. We think that studies like these may help to advancements in arthroplasty technology and so that well designed individual-specific prosthetic components will help to minimize and/or totally eliminate mismatch cases in the future.

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