MORPHOMETRIC STUDY OF PROXIMAL END OF TIBIA WITH ITS CLINICAL IMPLICATIONS IN NORTH INDIAN POPULATION

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ABSTRACT

BACKGROUND

The knee joint is a complex synovial joint as the surfaces of tibia and femur are not conforming, so the proper interaction between articular surfaces is essential. Hence, the knowledge regarding the morphometry of articular surfaces of tibia is important. Therefore, we aimed our study to measure the dimensions of the upper end of tibia to contribute and guide for designing tibial prosthesis in Indian population.

MATERIALS AND METHODS

In this cross-sectional study, 224 dry tibias were studied in the Department of Anatomy at a medical college in north India, out of which 105 tibias were of right side and 119 were of left side. The measurements: antero-posterior (AP) and transverse diameter (TD) of medial (MTC), lateral (LTC) and total tibial condyles (TTC) were taken by digital vernier calipers and were analysed.

RESULTS

We found that the mean AP and TD diameters of MTC are more than the AP and TD diameter of LTC. The measurements of MTC on both sides were significantly greater than LTC. The measurements of MTC and LTC on both sides were significantly greater in males ($p < 0.05$). In the TTC the AP diameter was more in females on both sides, while the TD was again more in males. The area of MTC and LTC was more in males as compared to females on both sides ($p < 0.05$).

CONCLUSION

Data obtained from the present study will provide a baseline data pertaining to morphometric details of upper end of tibia with reference to unicompartmental and total knee arthroplasty in Indian population.

KEY WORDS

Prosthesis, Unicompartmental Knee Arthroplasty, Morphometry.

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BACKGROUND

The lower limb is primarily adapted for weight bearing and locomotion, therefore more strength and stability is required than upper limb. The knee joint is a complex synovial joint consisting of tibiofemoral and patellofemoral articulations. It functions to control the centre of body mass and posture in daily activities. This necessitates proper interaction between articular surfaces, as the surfaces of tibia and femur are not conforming.^[1] Hence, the knowledge regarding the morphometry of articular surfaces of both the lower end of femur and upper end of tibia is important.

Morphometric measurements of tibia are close to living state, as it resists the erosive forces and keeps its anatomical shape for a longer time.^[2] The tibial plateau presents medial and lateral articular surfaces (Facets) for articulation with the corresponding femoral condyles. The medial articular surface is oval (Long axis antero-posterior) and longer than the lateral articular surface.

The lateral tibial condyle is more circular and overhangs the shaft postero-laterally above a small circular facet for articulation with the fibula. Separating these two condyles is the non-articular intercondylar area, central part of which is raised to form intercondylar eminence having medial and lateral intercondylar tubercles.^[1]

Knee joint is a weight bearing joint and is susceptible to various pathological conditions. Knee osteoarthritis is most common and severe form of deformity related to ageing, genetic factors and mechanical forces, urban lifestyle and environmental changes of modernisation. Hence, the corrective knee surgeries have become frequent and demanding these days. An elaborate anatomical study of this area would help in planning required interventions in various pathological and degenerative conditions.

Most of the morphometric assessments of knee joint are pertaining to western population and there are very few studies on morphometric analysis of both tibial condyles including the non-articular area in Indian subjects. Therefore, we aimed our study to measure the dimensions of the upper end of tibia to contribute and guide for designing tibial prosthesis in north Indian population.

MATERIALS AND METHODS

In this cross-sectional study, 224 dry tibia were studied in the Department of Anatomy, out of which 105 (51 females, 54 males) tibias were of right side and 119 (58 males, 61

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females) were of left side. The measurements {antero-posterior (A-P) and transverse (T-D) diameter of medial tibial condyle (MTC), lateral tibial condyle (LTC) and total tibial condyle (TTC)} were taken by digital vernier calipers (Figure 1). The measurements were repeatedly taken for each bone to ensure the accuracy. The following measurements were taken as follows (Figure 2)-

1. **Antero-posterior Diameter of Medial Tibial Condyle:** The distance between the most anterior points (postero-medial to the attachment of anterior horn of medial meniscus) to most posterior point as straight line.
2. **Transverse Diameter of Medial Tibial Condyle:** The distance measured by a straight line perpendicular to antero-posterior diameter from medial tubercle to medial margin of medial condyle.
3. **Antero-posterior Diameter of Lateral Tibial Condyle:** It is measured from most anterior point (lateral to the attachment of anterior horn of lateral meniscus) to most posterior point as straight line.
4. **Transverse Diameter of Lateral Tibial Condyle:** It is measured by a straight line perpendicular to antero-posterior diameter from lateral tubercle to lateral margin of lateral condyle.
5. **Antero-posterior Diameter of Total Tibial Condyle:** It is measured by a straight line passing exactly in the middle of medial and lateral tubercle of intercondylar eminence from most anterior to most posterior point.
6. **Transverse Diameter of Total Tibial Condyle:** It is measured by a straight line perpendicular to antero-posterior diameter from medial margin of medial condyle to lateral margin of lateral condyle.
7. **Measurements of Intercondylar Area:**
 - A. **Antero-Posterior (AP)**
 - I. Anterior- The maximum distance between most anterior points of intercondylar area to a line joining intercondylar eminence.
 - II. Posterior- The maximum distance between a line joining intercondylar eminence and posterior border.
 - B. **Transverse Diameter (TD)**
 - I. Anterior- It is measured by a straight line perpendicular to antero-posterior diameter at the anterior end.
 - II. Middle- Straight line between medial and lateral tubercle.
 - III. Posterior- It is measured by a straight line perpendicular to antero-posterior diameter at the posterior end.
8. **Area of each Condyle was measured using the following Formula:**
Area of condyle= AP × TD of condyle
 - a. Area of medial tibial condyle.
 - b. Area of lateral tibial condyle.
 - c. Area of total tibial condyle.

All measurements were taken with the help of vernier calipers and have been statistically analysed. The percentage has been calculated of medial and lateral condylar area out of total tibial condylar area. The data was then statistically analysed using SPSS-22.0 software, to hold comparisons between tibia of right and left side and also between medial and lateral tibial condyles of the same side in both sexes. Unpaired student t-test was used to comment upon the statistical significance.

Ethics

The study has been done on dry tibia. There was no involvement of patient and animal.

RESULTS

In the present study, the various parameters of medial and lateral tibial condyle have been measured. The measurements (mean AP and mean TD) of MTC were more than the LTC on both sides, thus the MTC was larger than the LTC on both sides (Table 1). The diameters (mean AP and mean TD) of MTC were significantly greater on right side, while on left side the diameters of LTC were significantly greater (Table 2). The measurements of both sides, MTC and LTC were significantly greater in males. But in the total tibial condyle the mean AP diameter was significantly more in females on both sides, while the mean TD was more in males (Table 2). The mean AP diameter of intercondylar area at the anterior end was significantly more on right side and at posterior end was significantly more on left side in both sexes. The mean TD of intercondylar area at the anterior end was more on left side in both sexes. The mean TD of intercondylar area at the posterior end is more on right side in both sexes, whereas in the middle the diameters were almost equal on both sides. The mean AP of intercondylar area is more in females at anterior end on both sides. The mean AP of intercondylar area was more in females at posterior end on right side and on left side more in males. The mean TD of intercondylar area was more in males at anterior, middle and posterior ends (Table 3).

The area covered by MTC on left side in males and females was 41.97% and 34.66% respectively out of total condylar area. The mean area on left side was more in males. The area covered by LTC on left side in males and females was 41.15% and 35.51% respectively out of total condylar area. The mean area of both MTC and LTC was more in males as compared to females on left side. The area covered by MTC on right side in males and females was 51.73% and 41.01% respectively out of total condylar area on the right side. The area covered by LTC on right side in males and females is 40.83% and 34.66% respectively out of total condylar area on the left side. The area of both MTC and LTC is more in males as compared to females on the right side (Table 4).

It was reported earlier that the parameters differ in medial and lateral compartments of upper end of tibia. This study was done to report the morphometry, compare the parameters statistically and comment upon sexual dimorphism.

Condyles	Side	N	Mean	Std. Deviation	P value
M.C (A-P)	LT	118	39.194	4.02	<0.001
	RT	104	36.384	2.69	
M.C (T-D)	LT	118	26.012	1.81	<0.001
	RT	104	27.063	2.06	
L.C (A-P)	LT	118	35.574	3.71	<0.001
	RT	104	33.195	2.32	
L.C (T-D)	LT	118	25.654	2.51	0.02
	RT	104	24.667	3.58	
T.T.C (A-P)	LT	118	42.885	4.38	0.001
	RT	104	40.960	4.24	
T.T.C (T-D)	LT	118	63.884	5.32	0.88
	RT	104	63.386	4.23	

Table 1. Showing the Mean Diameters of Upper End of Right and Left Tibia and their Comparison using Student-t Test

Condyles	Diameters	Side and Sex	Mean + S.D.	P-value
Lateral	Antero-posterior	Male (101) Right	38.85+2.75	<0.001
		Female (109)	35.16+3.04	
		Male (101) Left	39.26+3.56	<0.001
		Female (109)	36.28+3.05	
	Transverse	Male (101) Right	27.43+2.08	<0.001
		Female (109)	25.75+3.82	
		Male (101) Left	28.08+2.19	<0.001
		Female (109)	26.14+3.14	
Medial	Antero-posterior	Male (101) Right	45.36+3.18	<0.001
		Female (109)	40.18+2.05	
		Male (101) Left	44.18+4.25	<0.001
		Female (109)	41.75+4.14	
	Transverse	Male (101) Right	29.86+2.05	<0.001
		Female (109)	26.54+2.86	
		Male (101) Left	28.24+2.89	<0.001
		Female (109)	26.96+2.25	
Total Tibial	Antero-posterior	Male (101) Right	38.48+4.25	<0.001
		Female (109)	42.75+4.14	
		Male (101) Left	41.43+4.25	<0.001
		Female (109)	44.25+4.14	
	Transverse	Male (101) Right	63.46+3.05	<0.001
		Female (109)	59.56+ 2.75	
		Male (101) Left	64.24+2.89	<0.001
		Female (109)	60.16+2.25	

Table 2. Showing the Mean Diameters of Upper End of Right and Left Tibia in both Sexes and their Comparison

Inter-condylar Area	Diameters	Side and Sex	Mean + S.D	P-value
Antero-Posterior	Anterior end	Male Right	22.18+1.85	<0.001
		Female	24.06+2.18	
		Male Left	20.25+5.14	<0.001
		Female	23.75+4.16	
	Posterior end	Male Right	16.23+2.06	<0.001
		Female	18.87+2.82	
		Male	21.18+2.49	0.055

		Left Female	20.48+2.74	
Transverse	Anterior end	Male Right Female	26.76+3.18	<0.001
		Male Left Female	24.18+2.19	
		Male Right Female	27.45+4.18	<0.001
		Male Left Female	24.61+2.86	
	Middle	Male Right Female	9.25+2.08	<0.001
		Male Left Female	8.21+1.84	
		Male Right Female	9.26+1.05	<0.001
		Male Left Female	8.14+1.06	
	Posterior end	Male Right Female	11.24+1.16	<0.001
		Male Left Female	9.74+1.24	
		Male Right Female	10.25+1.22	<0.001
		Male Left Female	9.19+ 1.02	

Table 3. Showing the Antero-Posterior and Transverse Diameters of Intercondylar Area in Right and Left Tibia in both Sexes and their Comparison using Student-t Test

Area of Condyles	Side + Sex	Mean Value + S. D	Area (%)	P-value
Lateral	Male Right Female	1045.65+150.5	40.83	<0.001
	Male Left Female	901.25+140.5	34.66	
	Male Right Female	1101.42+153.7	41.15	<0.001
	Male Left Female	946.21+ 143.8	35.51	
Medial	Male Right Female	1324.16+ 164.8	51.73	<0.001
	Male Left Female	1066.35+ 151.4	41.01	
	Male Right Female	1203.45+ 160.9	41.97	<0.001
	Male Left Female	1083.68+ 158.1	34.66	
Total Tibial	Male Right Female	2559.12+ 301.6		0.361
	Male Left Female	2599.34+332.7		
	Male Right Female	2675.39+353.8		0.832
	Male Left Female	2664.63+377.9		

Table 4. Showing the Area of Medial, Lateral and Total Tibial Condyle of Right and Left Tibia in both Sexes and their Comparison using Student-t Test

DISCUSSION

There are very few morphometric studies, which provide the complete information about all the dimensions of upper end of tibia in both sexes. Earlier work by Kwang et al (2007) reported antero-posterior and medio-lateral (ML) diameter of proximal tibial surface in Korean population and this was irrespective of side and gender. Their average dimensions were found to be 73.5 ± 5.6 and 47.3 ± 3.8 mm respectively. They also documented that the measured values were smaller than the symmetric commercially available TKA implants.^[3]

Servien et al (2008) measured antero-posterior diameters of medial and lateral condyle in French population and found it to be 50.8 ± 3.3 mm and 47.2 ± 3.3 mm respectively. The study however was independent of sex and side.^[4]

Later Cheng et al (2009) measured the antero-posterior (AP) and widest dimension (WD) of medial tibial condyle and compared the measurements with the similar dimensions of five tibial unicondylar knee prostheses conventionally used in China.^[5]

Gupta et al (2015) had done the morphometric study of the proximal end of the tibia in South Indian population. In their study, the parameters of the tibial articular areas measured were similar to our study, but they had neither measured the dimensions of non-articular area nor commented upon the sexual dimorphism. In the present study, we have measured the AP and TD of both medial and lateral tibial condyle in both the sexes and we have concluded that the diameters of MTC and LTC were greater in males on both sides.^[6]

Gupta et al also reported that the area covered by medial tibial condyle is 38.87% and by lateral tibial condyle is 34.4% out of total condylar area on the right side. The area covered by medial tibial condyle is 38.89% and by lateral tibial condyle is 38.25% out of total condylar area on the left side. While in our study we calculated the area of both MTC and LTC and reported that it is more in males as compared to females on both right and left side.

Srivastava et al (2014) reported that the area covered by MTC is 38.56% and by LTC is 35.97% out of total condylar area on right side. The area covered by MTC is 37.32% and by LTC is 35.65% out of total condylar area on the left side. While in our study after calculating and comparing the mean area, we came to the conclusion that the area of both MTC and LTC is more in males as compared to females on both sides.^[7]

Gandhi et al 2014 reported that both antero-posterior and transverse diameters were greater in medial condyle than in lateral condyle on both sides and sexes. In our study we had similar findings as well, but we had also measured the area of both tibial condyles and found that the area of MTC and LTC is more in males as compared to females on right side.^[8]

Seema et al (2012) measured the weight, length, mid-shaft circumference and the widths at the upper and the lower end of the tibia. We used the similar parameters to do the sex differentiation, though we have not quantified the parameters.^[9]

CONCLUSION

The present study demonstrates the accurate complete comparative measurements of all the parameters of both the medial and lateral tibial condyles. Data obtained from the present study will provide guidelines for designing appropriate tibial prosthetic component of unicompartmental and complete knee arthroplasty in Indian population. This will also provide morphometric information to anatomists, anthropologist and medical students.

In clinical practice, surgeons do not favour implants with insufficient tibial coverage as a small or large sized prosthesis can lead to the possibility of tibial implant collapse.^[4,5] The failure of unicompartmental knee arthroplasty (UKA) is most frequently associated with implant loosening. These days total and unicompartmental joint replacements have become the gold standard for treatment of osteoarthritis and other degenerative disorders of knee.^[10] The current challenges in knee prosthetic design are centered on attempting to produce normal kinematics, reducing wear and tear and hence achieving greater longevity, so one requires information on the anthropometry of the proximal articular surface of the tibia. Our study will provide key information in designing appropriate size-matched unicompartmental and total knee prosthesis in Indian scenario, taking the 'sex factor' into consideration. The purpose of this study is to analyse the dimensions of upper end of tibia for planning of UKA and to compare the morphometric data with other studies in different populations. Proper designing of the prosthesis is essential for correction of varus and valgus deformities of the knee during knee arthroplasty.^[11]

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