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Research article - Basic and applied anatomy

A morphometric and radiological study of the distal end of femur in West Bengal population

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Abstract

The distal end of the femur has immense importance from the anatomical, functional and clinical point of view. The present study was carried out to assess the individual condylar dimension, maximum bicondylar width, size of intercondylar notch and bicondylar angle on dry femurs and on digital radiographic plates among the population of eastern India. The study was carried out bilaterally on seventy adult dry femurs of unknown sex and also on fifty digital radiographic plates of known age and sex by using Martin's sliding calipers, diaptograph and sigma view software. Among the different parameters, transverse and vertical dimensions of medial condyle and intercondylar width showed significant bilateral asymmetry. From radiologic evaluation, it has been observed that only bicondylar width showed sexual dimorphism on both sides. The present study also reported significant asymmetry in bicondylar width between the two sides in males but not in females, whereas comparison of bicondylar angle between right and left sides revealed significant difference in females in contrast to males. The present study may help in manufacturing a properly sized implant and also help the surgeons during instrumentation of lower end of femur.

Key words

Femoral condyle, intercondylar notch.

Introduction

The femur, by virtue of its position, structure and function is subjected to various traumatic, inflammatory, degenerative and neoplastic processes (Taner et al., 2002; Standring et al., 2008). So, a thorough knowledge of the anatomy regarding surface contours, curvatures, dimensions of the femur is essential for understanding the disease processes and for proper management and reconstruction surgery of joints and fractures (Taner et al., 2002).

The measurements obtained from this study will help to achieve proper alignment of bone fragments and safe instrumentation and fixation of bones. The study will also provide measurements of parameters for designing of implants and artificial joint components that will help in manufacturing prosthesis with ethnic specifications. Proper matching of knee prosthesis with resected surface of knee is one of the key factors for long-term surveillance in total knee arthroplasty (Cheng et al.,1999).

Previous researche revealed that there are differences in anatomical profiles between Asian and Caucasian knee, and suggested smaller size component would be

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more appropriate for Asian populations (Cheng et al.,1999; Cheng et al., 2009; Shah et al., 2014). Various studies have emphasized differences between genders and among ethnic groups. Therefore, quantitative anatomy of the distal femur is essential for the design of total joint replacement and internal fixation materials (Cheng et al., 2009; Dargel et al., 2009; Suryanarayan et al., 2014; Shah et al., 2014).

The femur has been subjected to innumerable measurements from every conceivable aspect. Some of these are of purely academic interest, while others are suitable for forensic and anthropometric application. In the present study we have selected certain parameters of the lower end of the femur which will be of help in the management of fractures and joint injuries in the study population.

Materials and methods

An observational descriptive study with cross-sectional data collection was conducted over one year.

The measurement of different parameters pertaining to the study was carried out on 70 (35 right and 35 left) randomly selected, intact, dry, completely ossified femurs from subjects of unknown age, stature and sex from the Department of Anatomy of

Figure 1 – Measurement of different morphometric parameters of femoral condyles by Martin's sliding caliper.

Figure 2 – Measurement of width and depth of intercondylar notch by Martin's sliding caliper.

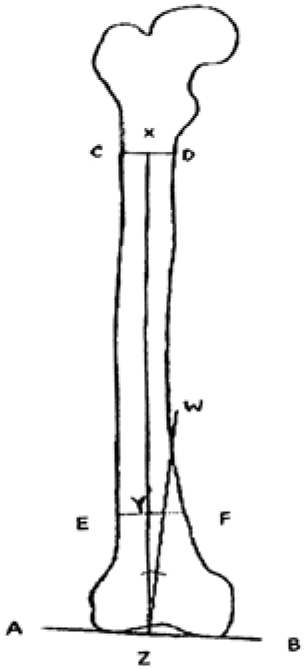

Figure 3 – Measurement of bicondylar angle by Diaptographic image.

the Institute of Post Graduate Medical Education & Research (IPGME&R) and Calcutta National Medical College, Kolkata, and also from the Department of Anthropology, University College of Science, Technology and Agriculture, University of Calcutta. All the studied femurs were devoid of any pathological condition and trauma.

Digital radiographs of 50 femurs (knee joints of both sides in antero-posterior view) of 25 men and 25 women were taken from the archives stored in the department of Radiology, IPGME&R. No abnormal radiogram was included in the present study. The average age of the study population was 50.54 years with standard deviation 9.68 years.

Direct measurements on dry femurs were carried out using Martin's sliding calipers (Fig. 1). However, for the measurement of the depth of the notch, the lower arm of the Martin's sliding caliper was adjusted in reverse direction (Wilder, 1920) (Fig. 2).

Bicondylar angle was measured indirectly with the help of diaptograph (Wilder, 1920). After getting the picture outline of femur, a tangent line was drawn touching both the condyles. It represented the infracondylar plane (AB). A transverse line was then drawn (CD) just below the lesser trochanter. Subsequently another transverse line was drawn (EF) at a junction of lower ¼ and upper ¾ of the maximum length of the femur. Then the axis of the shaft was obtained by joining the middle points of the above mentioned lines (X and Y respectively). The axis was extended to the infracondylar plane and meeting point of the lines was represented by the point Z. Then a perpendicular line was drawn on AB (infracondylar plane) at

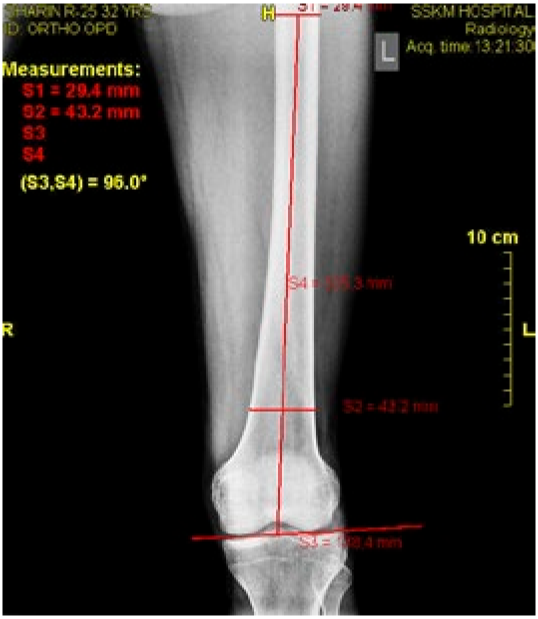

Figure 4 – Measurement of bicondylar angle and width on radiographic plate by using Sigma view.

the point Z. The angle formed between the long axis of the bone and the perpendicular line was measured as bicondylar angle (Fig. 3).

Only the bicondylar angle and width were measured on the radiographic plates by using Sigma view, version 3.6.1.0 of Agfa (Fig. 4). Measurements of condyles and intercondylar notch could not be performed due to overlapping of condylar shadow over one another in lateral view and of patellar shadow over intercondylar area in AP view.

The pilasteric index was computed as percent ratio between antero-posterior diameter of the femoral mid shaft and medio-lateral diameter of the mid shaft.

All the measurements from both radiology and dry skeletons measurements were taken by two workers individually and the average of the values were used to remove observer bias.

Finally, collected data was tabulated in Microsoft excel spread sheet and was analyzed by Statistica version 6 [Tulsa, Oklahoma: Stat Soft Inc., 2001]. In all cases $p<0.05$ was considered as significant.

Results

The details of the data from dry bones are presented in Table 1. Right and left femurs did not show any significant difference between each other in the average value of most parameters, but bilateral asymmetry was observed in the transverse and vertical dimensions of medial condyle and intercondylar notch width ($p<0.05$).

Table 1 – Morphometric parameters on dry femurs according to side (Mean, standard deviation, range and mode). Student's t test for unpaired values, with two tails, was used for statistical analysis (N=35 for the right side and 35 for the left side).

Parameters	Side	Range	Mean	Standard Deviation (S.D.)	Mode	Test of significance
LCAPD	Right	50-63 mm	56.20 mm	3.36 mm	54 mm	Not significant
	Left	50-65 mm	56.05 mm	4.29 mm	50 mm	
LCTD	Right	22-35 mm	27.80 mm	2.91 mm	28 mm	Not significant
	Left	24-34 mm	28.03 mm	2.56 mm	30 mm	
LCVD	Right	28-36 mm	32.51 mm	2.25 mm	31 mm	Not significant
	Left	27-42 mm	33.05 mm	3.40 mm	30 mm	
MCAPD	Right	47-64 mm	52.97 mm	3.77 mm	52 mm	Not significant
	Left	49-62 mm	54.74 mm	3.85 mm	51 mm	
MCTD	Right	22-28 mm	25.48 mm	2.05 mm	28 mm	$p<0.05$
	Left	24-34 mm	27.28 mm	2.29 mm	25 mm	
MCVD	Right	30-37 mm	34.00 mm	2.27 mm	37 mm	$p<0.05$
	Left	27-39 mm	32.48 mm	3.15 mm	32 mm	
BCW	Right	64-82 mm	71.71 mm	4.50 mm	76 mm	Not significant
	Left	61-79 mm	70.71 mm	5.25 mm	74 mm	
IC_Ht	Right	20-30 mm	23.74 mm	2.30 mm	23 mm	Not significant
	Left	20-28 mm	23.40 mm	2.04 mm	24 mm	
IC_Wd	Right	15-25 mm	20.86 mm	2.52 mm	21 mm	$p<0.05$
	Left	13-25 mm	19.43 mm	2.57 mm	20 mm	
IC_De	Right	18-26 mm	20.86 mm	2.45 mm	21 mm	Not significant
	Left	17-28 mm	21.26 mm	2.31 mm	22 mm	
BCA	Right	6-14 °	9.47 °	1.96 °	10.5 °	Not significant
	Left	6-12.5 °	9.23 °	1.61 °	8.5 °	
	Left	18-29 mm	22.28 mm	2.26 mm	23 mm	
MSTD	Right	22-35 mm	25.97 mm	2.23 mm	26 mm	Not significant
	Left	22-30 mm	26.0 mm	1.97 mm	26 mm	
PI	Right	76.92-104.35	88.25	6.88	85.19	Not significant
	Left	66.67-103.57	85.86	7.59	84.62	

LCAPD: lateral condylar antero-posterior diameter. LCTD: lateral condylar transverse diameter LCVD: lateral condylar vertical diameter. MCAPD: medial condylar antero-posterior diameter. MCTD: medial condylar transverse diameter. MCVD: medial condylar vertical diameter. BCW: bicondylar width. IC_Ht: intercondylar notch height. IC_Wd: intercondylar notch width. IC_De: intercondylar notch depth. BCA: bi-condylar angle. MSAPD: midshaft antero-posterior diameter. MSTD: midshaft transverse diameter. PI: pilasteric index.

Mean bicondylar angle of right and left sides was 9.53° (range: 6°-12.5°) and 10.34° (range: 7°-15°) respectively. Mean bicondylar width (± standard deviation) of right and left side was 79.58 ± 7.81 mm (range: 69-95 mm) and 79.27 ± 7.9 mm (range: 68-95 mm) respectively. Therefore, higher average values of bicondylar angle and width were obtained by radiology than by direct measurement irrespective of the side of femur. The bicondylar angle did not show any significant asymmetry between males and females, but bicondylar width of both sides was significantly higher in males than females ($p<0.05$) (Table 2).

Moreover, the present study (Table 3) also found significant bilateral asymmetry in bicondylar width in males ($p<0.05$) but not in females whereas bicondylar angle was significantly different between right and left sides in females ($p<0.05$) but not in males.

Discussion

In the present study, different morphometric parameters were recorded from dried bones as well as from digitalized radiographic plates. Most of the previous anatomical

Table 2 – Bicondylar angle and width as measured on skiagrams (mean, standard deviation, range and mode). Student's t test for unpaired values, with two tails, was used for statistical analysis. N = 25 for males and N = 25 for females

	RBCA (degree)		LBCA (degree)		RBCW (mm)		LBCW (mm)	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Range	6-12.5	6-12.4	7-15	7-15	70-95	69-79	68-95	69.5-80
Mean	9.78	9.29	10.44	10.34	84.46	74.71	83.47	75.08
Standard Deviation	1.64	2.03	1.93	1.94	8.14	2.99	7.42	3.35
Mode	9	8	12	9	80	76	88	80
Test of significance	Not significant		Not significant		p<0.05		p<0.05	

RBCA: bicondylar angle of right femur. LBCA: bicondylar angle of left femur. RBCW: bicondylar width of right femur. LBCW: bicondylar width of left femur.

Table 3 – Bicondylar angle and width depending on sex and side. Paired t test.

	Male				Female			
	LBCA (degree) (n=25)	**RBCA (degree) (n=25)**	**LBCW (mm) (n=25)**	**RBCW (mm) (n=25)**	**LBCA (degree) (n=25)**	**RBCA (degree) (n=25)**	**LBCW (mm) (n=25)**	**RBCW (mm) (n=25)**
Arithmetic mean	10.4400	9.7840	83.4680	84.4600	10.3440	9.2920	75.0800	74.7120
Standard deviation	1.9328	1.6433	7.4160	8.1380	1.9438	2.0283	3.3562	2.9903
Two-tailed probability	not significant		p<0.05		p<0.05		not significant	

RBCA: bicondylar angle of right femur, LBCA: bicondylar angle of left femur, RBCW: bicondylar width of right femur, LBCW: bicondylar width of left femur.

Table 4 – Comparison of measurement of intercondylar width from different studies.

Author	Method	Year	Width (mean±SD) (mm)	Remarks
Shelbourne et al. (1998)	Radiographic study	1998	80.15±4.5 (Female) 92.7±5.1 (Male)	Value is significantly higher in males than females
Wada et al. (1999)	Direct measurement on cadaver and patient with severe osteoarthritis at the time of TKA	1999	78.0 – 80.0 (Range)	Result is similar to present study
Taner et al. (2002)	Osteometric study of Anatolian femur	2002	77.3±5.2 (Left) 76.8±5.9 (Right)	The values appeared insignificantly larger on the left side
Angelo et al. (2004)	Radiographic study in Brazilians	2004	82.17±4.92 (Right) 82.13±5.42 (Left)	Values lower than those of the present study
Angelo (2007)	Radiographic study in Brazilians	2007	82.15±5.12 (Male) 70.05±6.05 (Female)	Significant sexual dimorphism
Terzidis et al. (2012)	Osteometric study in Caucasian dried femur	2012	83.9±0.63 (Average value)	No significant asymmetry between sides
Yang et al. (2014)	CT scan study in Chinese	2014	79±5.0 (Male) 71.2±4.3 (Female)	Significant sexual dimorphism
Suryanarayan et al. (2014)	CT scan study in Asians	2014	70.46±5.8 (Average)	
Shah et al. (2014)	CT scan study n Indians	2014	68.3±3.9	

and morphometric studies were conducted with indirect methods including radiography, computerized tomography, magnetic resonance imaging, and 3D modeling (Wada et al., 1999; Angelo et al., 2007; Cheng et al., 2009; Chaichankul et al., 2010; Shah et al., 2014; Suryanarayan et al.,2014; Yang et al., 2014). Given the fact that cadaveric material is scarce, these methods offer the advantage of describing anatomy in large samples since they can be performed in living subjects. However, the indirect methods have been found to be inaccurate even after correction for magnification, technique, and projection (Wada et al., 1999). In the present study, parameters recorded from radiographic plates showed higher values than those from direct measurements.

Different morphometric parameters of the lower end of femur were measured in the present study. Most of them showed no significant differences between sides as reported by Dragel et al. (2009) in their study. Terzidis et al. (2012) performed a study on 360 dried femurs and reported that the mean (± standard deviation) medial and lateral condylar antero-posterior distances (depth) were 5.87 ± 0.41cm (range: 5.12–6.60cm) and 5.85 ± 0.40 cm (range: 5.11-6.60cm) respectively. The values were slightly higher than those of the present study.

Table 5 – Comparison of bicondylar angle from different studies:

Authors	Year	Region	Right (mean±SD) (Degree)		Left (mean±SD) (Degree)	
			Male	Female	Male	Female
Pearson et al. (1919)	1919	English	8.69 ± 0.09	9.39±0.11	11.59±0.08	11.77±0.10
Singh et al. (1974)	1974	North India	8.16±2.21	8.82±2.17	7.79±2.20	8.67±2.21
Pandya et al. (2008)	2008	India , Gujrat	8.88±2.05	10.50±2.42	8.76±2.24	10.83±1.94
Mahajan et al. (2011)	2011	India, Punjub	8.17	8.82	7.89	8.57
Ukhoha et al. (2011)	2011	Nigeria	8.35±0.24	8.16±0.82	8.66±0.23	8.91±0.18
Sharma et al. (2014)	2014	India, Madhypradesh	6.37±1.82	8.21±2.12	7.35±2.37	8.73±2..30
Present study (2016)	2016	India, Radiology	9.78±1.64	9.29±2.03	10.44±1.93	10.34±1.94
Present study (2016)	2016	Dry bone	9.77 ± 1.96		9.23 ± 1.61	

Bicondylar width was significantly greater in men than in women.

The intercondylar notch is one of the most interesting areas for measurement by different methods like radiograph, computerized tomography, magnetic resonance imaging and thus can help to assess knee pathology mostly associated with cruciate ligament injury. Angelo et al. (2007) reported in their radioghraphic studies that the average intercondylar notch width (± standard deviation) in case of Brazilian males and females was 22.67 ± 4.45 mm and 21.56 ± 3.21 mm respectively, with significant difference between them. Both these values are higher than those of our study. The average value of intercondylar notch depth in the present study is less than that (29.50 ± 4.5 mm) obtained by Wadha et al. (1999) by direct measurement of embalmed cadaveric knees.

Measurement of intercondylar width of different studies is depicted in Table 4. According to Wada et al. (1999) the normal bicondylar width was 78.0-80.0 mm which is similar to the present study. Studies conducted by Taner et al. (2002) and Terzidis et al. (2012) reported a higher average value than the present study. The recorded measurements according to the study of Angelo et al. (2004, 2007) were less than those of the present study.

In the present radiological study, bicondylar angle did not show any significant sexual dimorphism on either side, which is similar to the result reported by Tardieu et al. (1997). But the results differ from those obtained by Igbigbi and Sharrif (2005) and Pandya et al. (2008) who found significant sexual dimorphism bilaterally, whereas, Singh et al. (1974) observed significant difference between males and females only on the left side. Direct measurement of bicondylar angle was documented in different populations by different workers.

Conclusion

It seems obvious that anthropometric measurements show differences between various populations even in the same population in different age groups and sex, and the measurements deserve to be constantly updated. The fixation of fractured fragments requires an appropriate knowledge of the dimensions of the femur. The insertion of intramedullary nails, plates, screws and pins are to be done with caution to avoid injury to ligaments, blood vessels, nerves and joints. The measurements and indices obtained from this study will allow safe instrumentation and fixation. In addition, the distances and curvatures determined by this study will help in the proper alignment of bone fragments.

The study will also help in formulating parameters for manufacturing implants using data derived from a population of West Bengal according to gender and side. Moreover, the measurements of different landmarks will assist in constructing different prosthesis for immobilization of the femur, hip and knee. Such readymade casts and casings will make the work of the orthopedic surgeons easier and prevent injuries over bony prominences.

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