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Original article

A study of femoral condylar morphometry

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Abstract:

Introduction: Relative incongruent nature of the knee joint surfaces with repetitive high compressive forces augments degenerative bone disease. Joint replacement, the upcoming treatment of choice in degenerative bone diseases, would involve accurate placement of well-fitted distal femur implants and adequate balancing of the surrounding soft tissues. The use of an appropriate femoral component size is essential to maintain the normal functional range of motion of the knee without impingement, hence the study is designed.

Methods: Bicondylar depth, bicondylar width, intercondylar notch depth and intercondylar notch width were measured by a single author using suitable calipers and following standardized methods in all 127 study sample of adult dry femora .

Observations & Results: Mean bicondylar depth 5.270±0.469cm and mean bicondylar width 7.421±0.603cm were obtained in the study of 127 femora. With P 0.348 and 0.751 for both parameters respectively, no significant left-right asymmetry could be demonstrated in the study. Mean intercondylar notch depth 2.731±0.330cm and mean intercondylar notch width 1.882±0.272cm were revealed with all the study samples. Sided dimorphism could not be shown with P 0.565 and 0.380 respectively for intercondylar notch depth and intercondylar notch width. Intercondylar notch width index obtained in the study as 0.254±0.030 with intercondylar notch dept index 0.518±0.043 none having any significant left vs. right variation.

Conclusion: Outcome of the present study viz. bicondylar width, bicondylar depth, intercondylar notch width, intercondylar notch depth along with notch width index and notch depth index will play crucial role in the field of prosthesis designing for Indians.

Key words: Femur, Bicondylar depth, Bicondylar width, Intercondylar notch, Notch Depth Index, Notch Width Index

Introduction:

Man's walk is specifically described as striding, a mode of locomotion during which the energy output of the body is reduced to a physiological minimum by the smooth, undulating flow of the progression. It is a complex activity involving the joints and muscles of the whole body in its performance. Stride is the ability to walk in an upright bipedal progression, successively placing each foot closely under centre of gravity; stabilize the pelvis against rotation by an abductor mechanism, adequate to eliminate large trunk shift; and, utilize the principle of the compound pendulum for the lower extremity so that the advance of each limb is accomplished by gravity and short burst of muscle contraction at accelerations and decelerations. Such energy conservation is an essential feature of man’s locomotor efficiency[1].

The knee joint is a complex synovial joint consisting of the tibiofemoral and patellofemoral articulations. It functions to control centre of body mass and posture in the activities of daily living. This necessitates a large range of movement in three dimensions coupled with the ability to withstand high forces. These conflicting parameters of mobility and stability are only achieved by the interactions between the articular surfaces, the passive stabilizers and the muscles that cross the joint. The relatively incongruent nature of the joint surfaces makes the knee joint inherently unstable. In addition, because it acts as a pivot between the longest bones in the body, and is subjected to considerable loads in locomotion, the joint is also potentially unstable. The long bones may act as levers, increasing the stresses on the stabilizing ligaments. Femur transmits weight from the ileum to the upper end of the tibia through an unstable bony arrangement at the knee joint. The distal extremity of the femur is wider and more substantial, and presents a widely expanded double condyle bearing partly articular surface for transmission of weight to the tibia. Anteriorly the condyles are confluent and continue into the shaft; posteriorly they are separated by a deep intercondylar fossa and project beyond the plane of the popliteal surface. The articular surface is a broad area, like an inverted U, for the patella and the tibia[2]. Human knee differs dramatically from that of other non-human primates, reflecting a highly specialized adaptation to bipedality. Such a change due to a habitual bipedal gait, can account for virtually the entirety of the unique morphology of the human distal femur[3].

In the erect posture, femur distally approaches its fellow, for the purpose of bringing the knee joints near the line of gravity of the body. It is assumed that the plane of the femoral condyles i.e. the bicondylar plane in normal locomotion will be horizontal to the ground[4].

Quantitative anatomy of the distal femur is important for the design of total joint replacement and internal fixation material[5]. Joint replacement involving the distal femur requires the use of highly complex surgical techniques, as this would involve the accurate placement of well-fitted implants and adequate balancing of the surrounding soft tissues. The use of an appropriate femoral component size is essential to maintain the normal functional range of motion of the knee[6, 7]. Hence, study of distal femoral anatomy for Indian population is appropriate with increasing trend of Total Knee Arthroplasty as treatment of choice in degenerative knee diseases. The purpose of the present study was to conduct direct measurements of dried femora in order to record certain morphometric parameters of the femoral condyles pertinent for designing femoral component of the prosthesis for femoral component hemi-arthroplasty or total knee arthroplasty.

Aims & objectives:

1. To study certain lower femoral anatomy namely bicondylar depth, bicondylar width, intercondylar notch depth and intercondylar notch width from the teaching collection of available dry femora in the Medical Colleges of Kolkata.
2. To generate anthropometric data related to femoral condyles and intercondylar notch, which may be of help in designing femoral component knee prosthesis.

Material & methods:

One hundred and twenty seven isolated femora from a teaching collection of adult human skeletons available in the department of Anatomy of the five Government Medical Colleges of Kolkata were taken for the study. Femori those on naked eye inspections had evidence of fracture, deformity, post-mortem damage or evidence of arthritis were excluded from the study. The bones with complete morphological features were studied.

Various dimensions of the femoral condyles viz. bicondylar width and depth as well as dimensions of intercondylar notch viz. intercondylar notch width and depth measured using suitable standard Calipers. Bicondylar width was measured between both femoral epicondyles[8] (Fig.1). Bicondylar depth was measured at patellar notch midway between the antero-posterior diameters of both the condyles[9] (Fig.2). Intercondylar notch width was taken at the widest part of the notch[9] (Fig.3). Intercondylar notch depth was identified as the maximum height of the intercondylar notch[8] (Fig.4). The same procedures were repeated for all the study samples.

The author performed all measurements singly for consistency. Each measurement was repeated three times and the mean value was recorded. Measurement error was assessed for every anatomical parameter according to the method described by White and Folkens for osteometric studies[10]. All measurements were rounded to two decimal places.

Observation & results:

Out of 127 femur used for the study 62 were of the left side and 65 belonged to the right side. From the frequency distribution table it was observed that bicondylar depth of 49 (78.64%) femora on the left side fell between 4.70 cm and 5.89 cm whereas bicondylar depth of 54 (83.08%) right sided femora measured in the same range (Table 1& 2).

On statistical analysis mean bicondylar depth for left sided femur was 5.235 cm with standard deviation of 0.466. Similarly, mean bicondylar depth for right sided femora was found to be 5.304 cm with standard deviation of 0.475. When total 127 femora considered, mean bicondylar depth of 5.270 ± 0.469 cm was obtained (Table 3). Mean bicondylar depth determined on left side thus slightly lower than that on the right side. Measurements were put to statistical analysis to determine whether these differences were statically significant. Using SPSS software paired t-test applied to the values to obtain t = 0.946 in d f = 61 has a P = 0.348. With P > 0.05, whatever left-right difference is observed in bicondylar width in the present study was not statistically significant.

Out of the 62 left sided femora, bicondylar width of 56 (90.32%) turned out to be in the range of 6.50 cm–8.49 cm. While measuring bicondylar width of 65 right sided femora, 59 (90.76%) were found to be in the same range (Table 4 & 5). When these data analyzed statistically, mean bicondylar width for left sided femur was 7.398 cm with standard deviation of 0.599 and that of right sided femora was 7.443 cm with standard deviation of 0.610. Mean bicondylar width for all the study sample was 7.421 ± 0.603 cm (Table 6). Right sides mean bicondylar width showed little higher value than that on the left side. Statistical analysis with paired t-test applied to the data revealed t = 0.319 in d f = 61 has a P = 0.751. Whatever left-right difference is observed in bicondylar width in the present study, having P > 0.05 was not statistically significant.

Sixty two left sided femora studied to obtain Intercondylar notch depth. Fifty (80.65%) reading among those 62 left sided femur turned out to be in the range of 2.34 cm–3.13 cm. Intercondylar notch depth of 49 (75.39%) out of 65 right sided femora, were found to be in the same range (Table 7 & 8). Mean intercondylar notch depth of the left sided femur was 2.755 ± 0.317 cm and that of the right side was 2.709 ± 0.344. Mean intercondylar notch depth

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for all the study sample was 2.731 cm with standard deviation of 0.330 (Table 9). Statistical analysis with paired t-test showed t = 0.579 in d f = 61 has a P = 0.565. Left-right difference observed in the intercondylar notch depth, having P > 0.05 was not statistically significant.

Intercondylar notch width measured for all the 127 study samples. Fifty three (87.48%) out of 62 left sided reading fell between 1.48 cm and 2.37 cm while measurements of 60 (92.31%) out of 65 right sided femora were found to be in the same range (Table 10 & 11). Mean intercondylar notch widths were 1.865 ± 0.287 cm and 1.912 ± 0.257 cm on the left and the right sides respectively. When total 127 femora considered, mean intercondylar notch width 1.882 cm with standard deviation of 0.272 (Table 12). Paired t-test showed t = 0.884 in d f = 61 having P = 0.380. Thus Left-right difference observed in the intercondylar notch width, having P > 0.05 was statistically insignificant.

Table 1: Frequency distribution of bicondylar depth in left sided femora. n = 62

Bicondylar depth (cm)	**Frequency in numbers**	**Percentage of total**
3.90 - 4.29	1	1.61%
4.30 - 4.69	6	9.68%
4.70 - 5.09	20	32.26%
5.10 - 5.49	14	22.58%
5.50 - 5.89	15	24.19%
5.90 - 6.29	6	9.68%
TOTAL	**62**	**100.00%**

Table 2: Frequency distribution of bicondylar depth in right sided femora. n = 65

Bicondylar depth (cm)	**Frequency in numbers**	**Percentage of total**
3.90 - 4.29	1	1.54%
4.30 - 4.69	3	4.61%
4.70 - 5.09	18	27.69%
5.10 - 5.49	19	29.23%
5.50 - 5.89	17	26.16%
5.90 - 6.29	7	10.77%
TOTAL	**65**	**100.00%**

Table 3: Comparison between Bicondylar depth of left and right side. n = 127

Sidedness	**Number of femora studied**	**Mean Bicondylar depth**	**Standard Deviation**
Left	62	5.235	0.466
Right	65	5.304	0.475
TOTAL	**127**	**5.270**	**0.469**

t = 0.946 **d f = 61** **P = 0.348**

Table 4: Frequency distribution of bicondylar width in left sided femora. n = 62

Bicondylar width (cm)	Frequency in numbers	Percentage of total
6.00 - 6.49	4	6.45%
6.50 - 6.99	15	24.19%
7.00 - 7.49	12	19.35%
7.50 - 7.99	19	30.65%
8.00 - 8.49	10	16.13%
≥ 8.50	2	3.23%
TOTAL	**62**	**100.00%**

Table 5: Frequency distribution of bicondylar width in right sided femora. n = 65

Bicondylar width (cm)	Frequency in numbers	Percentage of total
6.00 - 6.49	3	4.62%
6.50 - 6.99	17	26.15%
7.00 - 7.49	14	21.54%
7.50 - 7.99	16	24.62%
8.00 - 8.49	12	18.46%
≥ 8.50	3	4.62%
TOTAL	**65**	**100.00%**

Table 6: Comparison between bicondylar widths of left and right side. n = 127

Sidedness	Number of femora studied	Mean bicondylar width	Standard Deviation
Left	62	7.398	0.599
Right	65	7.443	0.610
TOTAL	**127**	**7.421**	**0.603**

t = 0.319 **d f = 61** **P = 0.75**

Table 7: Frequency distribution of Intercondylar notch depth in left sided femora. n = 62

Intercondylar notch depth (cm)	Frequency in numbers	Percentage of total
2.14 - 2.33	3	4.84%
2.34 - 2.53	15	24.20%
2.54 - 2.73	14	22.58%
2.74 - 2.93	10	16.13%
2.94 - 3.13	11	17.74%
3.14 - 3.33	8	12.90%
≥ 3.34	1	1.61%
TOTAL	**62**	**100.00%**

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Table 8: Frequency distribution of Intercondylar notch depth in right sided femora. n = 65

Intercondylar notch depth (cm)	Frequency in numbers	Percentage of total
2.14 - 2.33	8	12.30%
2.34 - 2.53	20	30.77%
2.54 - 2.73	9	13.85%
2.74 - 2.93	11	16.92%
2.94 - 3.13	9	13.85%
3.14 - 3.33	7	10.77%
≥ 3.34	1	1.54%
TOTAL	**65**	**100.00%**

Table 9: Comparison between Intercondylar notch depth of left and right side. n = 127

Sidedness	Number of femora studied	Mean Intercondylar notch depth	Standard Deviation
Left	62	2.755	0.317
Right	65	2.709	0.344
TOTAL	**127**	**2.731**	**0.330**

t = 0.579 **d f = 61** **P = 0.565**

Table 10: Frequency distribution of Intercondylar notch width in left sided femora. n = 62

Intercondylar notch width (cm)	Frequency in numbers	Percentage of total
1.18 - 1.47	6	9.67%
1.48 - 1.77	17	27.42%
1.78 - 2.07	23	37.10%
2.08 - 2.37	13	20.97%
≥ 2.38	3	4.84%
TOTAL	**62**	**100.00%**

Table 11: Frequency distribution of Intercondylar notch width in right sided femora. n = 65

Intercondylar notch width (cm)	Frequency in numbers	Percentage of total
1.18 - 1.47	3	4.61%
1.48 - 1.77	21	32.31%
1.78 - 2.07	23	35.39%
2.08 - 2.37	16	24.62%
≥ 2.38	2	3.07%
TOTAL	**65**	**100.00%**

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Table 12: Comparison between Intercondylar notch width of left and right side. n = 127

Sidedness	Number of femora studied	Mean Intercondylar notch width	Standard Deviation
Left	62	1.865	0.287
Right	65	1.912	0.257
TOTAL	**127**	**1.882**	**0.272**

t = 0.884 **d f = 61** **P = 0.380**

Table 13: Comparison between notch width index of femur on left and right side. n=127

Sidedness	Number of femora studied	Mean notch width index	Standard Deviation
Left	62	0.252	0.032
Right	65	0.256	0.029
Total	**127**	**0.254**	**0.030**

t = 0.929 **d f = 61** **P = 0.356**

index of femur on left and right side. n=127

Sidedness	Number of femora studied	Mean notch depth index	Standard Deviation
Left	62	0.527	0.044
Right	65	0.511	0.042
Total	**127**	**0.518**	**0.043**

t = 1.837 **d f = 61** **P = 0.071**

Fig 1: Measuring bicondylar depth

Fig 2: Measuring bicondylar width

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Fig 3: Measuring intercondylar notch depth

Fig 4: Measuring intercondylar notch width

Discussion:

There is general agreement that knee joint experiences overt stress and strain due to its role in weight bearing and locomotive functions. Two longest bones of human body forming knee joint, thus transmitting body weight while allowing mobility, but at the cost of mechanical instability. Such mechanical instability is the most common cause of osteophyte formation, as demonstrated clinically[8, 11, 12] as well as experimentally[13, 14, 15]. Replacement arthroplasty has become popular mode of management permanent degenerative bone diseases involving knee[6, 16]. However, to achieve long-term success in total knee arthroplasty, the use of geometrical matched prosthesis, which simulates the natural conditions of knee joints, is a prerequisit[6, 7, 16].

Morphology of the femoral condyles along with intercondylar notch play crucial role in the stability of the knee joint, hence are the areas of interest for many researchers. In the present study, bicondylar depth came fairly constant. On statistical analysis of the obtained data, some insignificant left-right asymmetry observed (Table 3). Bicondylar depth was found 5.6±0.8cm by Wada et al.[8] in Japanese population which was found 5.270±0.469cm in the present study. Bicondylar width measured in the current study for both sided femora and left vs. right variation whatever obtained found to be statistically insignificant (Table 6). In one study Terzidis et al.[5] found mean bicondylar width as 8.39 cm±0.63cm in Caucasian (Greek) population. Whereas, 7.421±0.603cm obtained in the present study samples of short statured Indian population, supposed to be due to proportionate lesser value of all dimensions from their Caucasian counterpart.

Intercondylar notch morphology was studied by many workers[17, 18, 19, 20, 21, 22, 23, 24]. Intercondylar notch depth measured for 62 left and 65 right sided femora, show no sided dimorphism (Table 9). In a significant study Wada et al.[8] demonstrated intercondylar notch depth 2.95±0.45cm in Japanese population. Mean intercondylar notch depth obtained in the present study is 2.731±0.330cm. Wada et al.[8] also demonstrated intercondylar notch width, which came 1.70±0.50cm. In the current study 1.882±0.272cm intercondylar notch width was obtained in Indian population. No significant left-right asymmetry was observed in this study (Table 12).The notch width index represented the ratio of mean intercondylar notch width to mean bicondylar width. Wada et al.[8] reported intercondylar notch width index in the range of 0.22±0.04, which the

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present study showed 0.254±0.030. On paired t-test of the data in 61 degree of freedom t=0.929 has come with a P=0.356, hence insignificant (Table 13). The notch depth index was calculated as a ratio of mean intercondylar notch depth to mean bicondylar depth[8]. In their study Wada et al.[8] demonstrated intercondylar notch dept index as 0.51±0.11 in Japanese population, whereas 0.518±0.043 was obtained in the current study for its Indian counterpart. Statistical analysis using paired t-test reveal a t=1.837 in degree of freedom 61, that returned a P=0.071, hence left-right indices asymmetry obtained are insignificant (Table 14). Comparable similes have been observed in the indices computed in the present study with Indian population with that of the Japanese study group of Wada et al.

Conclusion:

A mismatch between the prosthesis size and bone may result in a number of severe complications. It has been demonstrated that using an undersized component will result in implant loosening, whilst an oversize component may cause impingement of the surrounding soft tissues. The use of appropriate component size is therefore crucial to produce long-term success and patient compliance following knee arthroplasty. To meet the rapidly growing need of appropriate prosthetic component for different ethnic groups biomedical engineers are in search for Indian data base for designing prosthesis for Indian recipients. Outcome of the present study viz. bicondylar width, bicondylar depth, intercondylar notch width, intercondylar notch depth along with notch width index and notch depth index will play crucial role in the field of prosthesis designing of short statured Indians.

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