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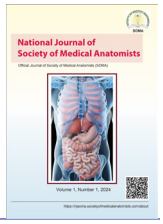

Morphologic and Morphometric Study of Intercondylar Notch of Femur in Relation to Anterior Cruciate Ligament Injuries

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ABSTRACT

Introduction: The distal end of the femur bears two massive condyles which are separated posteriorly by intercondylar notch. The intercondylar notch lodges the anterior cruciate ligament of the knee joint (ACL). The shape of the intercondylar notch has a very crucial role in ACL injuries. Aims and Objectives: The aim of this research was to study morphology and morphometry of the intercondylar notch on dry adult femur and correlate clinically. Materials & Method: 160 dry adult femora (80 right and 80 left) were studied in the Department of Anatomy, Gandhi Medical College, Bhopal. The distal end of the femora was examined for width & and depth of intercondylar notch, bi-epicondylar width (condylar width), and depth of lateral condyle (condylar depth). Results and Conclusion: In the present study, the shape of the intercondylar notch was inverted 'U' shape in 58.75% and inverted 'V' shape in 41.25% femur was found. The mean intercondylar notch width and depth were 22.92±2.72 mm & 28.15±2.5 mm and the mean femoral condylar width and depth were 75.24±5.38 mm and 59.40±4.64 mm respectively. The notch width index and notch depth index were 0.30 and 0.47, respectively. Most of the femurs had inverted 'U' shaped intercondylar notches. A narrow intercondylar notch (ICN) increases the risk of ACL injury and graft failure. Morphometrically, the mean value of all parameters under study on the right and left side femora had no statistically significant difference.

Introduction

The distal end of the femur is widely expanded to provide the bearing surface for the transmission of weight to the tibia. It bears two partly articular massive condyles, which are posteriorly separated by a deep intercondylar notch. The intercondylar notch is limited by the distal border of the patellar surface anteriorly and by an intercondylar line posteriorly, which separates it from the popliteal surface. It is intracapsular but largely extra synovial. Its lateral wall bears a flat postero-superior impression for the proximal attachment of the anterior cruciate ligament, whereas the medial wall bears a similar anteroinferior impression for the proximal attachment of the posterior cruciate ligament.[1] Palmar I (1938), reported that a narrow intercondylar notch of the femur can result in an increased risk of ACL tears.[2] Souryal et al. also observed that the notch width index, was the criterion to estimate the risk of ACL injury.[3] The cruciate ligaments have an intimate embryological and functional relationship to the intercondylar notch. The roof of the intercondylar notch has an inclination of 40 degrees to the longitudinal axis of the femur so that when the knee is in full extension, the roof is near the anterior surface of the ACL.[4] Shepstone L et al. observed that different shapes of intercondylar notches can give variant quantities of space to the ACL. It is concluded that the function of ACL is directly related to the morphology of the intercondylar notch.[5]

The anatomy of the femoral intercondylar notch has a crucial role in the success of ACL grafts. The femoral intercondylar notch houses the ACL and has varying shapes and sizes.[6] Wolters et al. reported intraoperative measurements of patients undergoing ACL reconstruction and suggested that notch dimensions should be used as a guide to determine the technique utilized for ACL reconstruction.[7] It had been suggested that a double-bundle reconstruction should not be performed if an intercondylar notch width is <12 mm.[8] This research aimed to study morphology and morphometry of the intercondylar notch on dry adult femur and correlate this anatomical knowledge clinically. The morphometric measurements vary among different regions and populations due to factors like variations in climate, genetics, nutrition, and factors related to lifestyle. Therefore, there is a constant need to provide region-specific measurements.

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Material and Methods

A total of 160 dry adult human femur bones (right = 80, left = 80) of unknown sex and age were studied in the Department of Anatomy, Gandhi Medical College, Bhopal. The femora were studied and examined after due approval by the institutional ethics committee, and bones with any damage or pathology around the distal end were excluded from the study. The dimensions of the femoral condyles and and intercondylar notch were measured by direct method using a digital Vernier caliper. The parameters of the distal femur studied were height and and depth of intercondylar notch, bi-epicondylar width (condylar width), and depth of lateral condyle (condylar depth). Intercondylar notch shape was observed and classified as inverted U-shaped (Figure 1) or inverted V-shaped (Figure 2). Materials used were a Digital Vernier caliper and a photographic camera. The bi-epicondylar width (Condylar width) was measured as the maximum distance between lateral and medial femoral epicondyles (Figure 3). The lateral condylar depth (condylar depth) was measured as the distance between the most posterior and the most anterior parts of the lateral femoral condyle (Figure 4). The intercondylar notch width was measured as the maximum distance between the medial side of the lateral femoral condyle and the lateral side of the medial femoral condyle (Figure 5). The intercondylar notch depth was measured as the maximum distance between the deepest and the most superficial part of the intercondylar notch (Figure 6).

The intercondylar notch width index and notch depth index (NDI) were calculated with the help of the above parameters. The notch width index (NWI) was calculated as a ratio of the notch width to the condylar width. The notch depth index (NDI) was calculated as a ratio of notch depth to the condylar depth of the femur.9 The present study is a cross–sectional observational study. Descriptive statistics was applied to all variables, and mean, median, mode, range, variance, standard error, and standard deviation were calculated. The student's t–test was applied to see the difference between the measurements of both sides. A level of significance of 5 percent ($P<0.05$) was used for all analyses.

Results

In the present study, inverted 'U' and inverted 'V' shaped intercondylar notches were observed. In most of the femurs, 94 (58.75%) had inverted 'U' shaped intercondylar notches (Figure 1), and 66 (41.25%) femurs had inverted 'V' shaped intercondylar notch (Figure 2). The bi-epicondylar width ranged from 25.18 mm to 86.28 mm. The bi-epicondylar width of most of the femurs, 119 (74.36%) were between the range of 70–74.99 mm with a mean of 75.24 ± 5.38 mm, standard error of mean 0.43, mean ± 2SD 154(96.25%), sample variance 28.96 and confidence level (95.0%) 0.84. The lateral condyle depth ranged from 29.32 mm to 69.63 mm. The lateral condyle depth of most of the femurs, 145 (90.6%) were between the range of 54 – 67.49 mm with a mean 59.40 ± 4.64 mm, standard error of mean 0.37, mean ± 2SD 155 (96.8%), sample variance 21.56 and confidence level (95.0%) 0.72.

The intercondylar notch width ranged from 17.45 mm to 34.17 mm. The intercondylar notch width of most of the femurs, 152 (95%) were between the range of 18.5 – 28.99 mm with a mean of 22.92 ± 2.72 mm, standard error of mean 0.21, mean ± 2SD 155

Figure 1: Inverted 'U' shaped ICN

Figure 2: Inverted 'V' shaped ICN

Figure 3: Measurement of condylar width

Figure 4: Measurement of condylar depth

Figure 5: Measurement of Intercondylar notch width

Figure 6: Measurement of Intercondylar notch depth

(96.8%), sample variance 7.40 and confidence level (95.0) 0.42. The intercondylar notch depth ranges from 21.97 mm to 33.61 mm. The intercondylar notch depth in132 (81.8%) femurs were between the range of 25.6–30.19 mm with mean 28.15 ± 2.5 mm, standard error of mean 0.20, mean ± 2SD 149 (93.1%), sample variance 6.32 and confidence level (95.0) is 0.39. There was no statistically significant difference between the right and left side parameters of the distal end (p value > 0.05). The notch width index was 0.30 and notch depth index was 0.47 in the present study.

Table 1: Shape of Intercondylar Notch

Shape of intercondylar notch	No. of femurs	Percentage
Inverted "V"	66	41.25%
Inverted "U"	94	58.75%
Total	160	100%

Discussion

In the present study, the shape of the intercondylar notch was an inverted 'U' shape in 58.75% and an inverted 'V' shape in 41.25% of specimens were observed. The mean intercondylar notch width and depth were 22.92 ± 2.72 mm & and 28.15 ± 2.5 mm, and the mean femoral condylar width and depth were 75.24 ± 5.38 mm and 59.40 ± 4.64 mm, respectively. The notch width index and notch depth index were 0.30 and 0.47, respectively.

According to Shepstone et al. as the ACL lies inside the femoral intercondylar notch, so it is obvious that the morphology of the intercondylar notch may influence the function of ACL and the risk of its injury. The different shapes of intercondylar notches can give variant quantities of space to the ACL, and it was reported that the function of ACL was directly related to the morphology of the intercondylar notch.[5] Ravichandran et al. concluded that intercondylar notch depth, width, and shape provide an idea about the space available for the ACL. [14] Shelbourne et al. concluded that a notch width index (NWI) of < 0.27 or notch width of <15 mm was a significant risk factor for ACL injury.[15] Wada et al. conducted a study on osteoarthritic (OA) knees and cadaveric knees and concluded that smaller NWI and NDI indicate the presence of dysfunctional ACL in the OA knee, just like smaller NWI predisposes to ACL tear in athletes. They concluded that the intercondylar notch is significantly smaller in knees with severe OA than the normal knees, and this narrowing occurs due to osteophytic growth in the notch. They found a significant correlation between smaller intercondylar notch and ACL tears in the osteoarthritic knees. They said that stenosis of the intercondylar notch can be predicted with the help of the NDI.[9]

Table 2: Descriptive statistics of the femoral intercondylar notch and femoral condyle

Values	Intercondylar notch width	Condylar width	Intercondylar notch depth	Condylar depth
Mean	22.92	75.24	28.15	59.40
Standard Error	0.21	0.43	0.20	0.37
Median	22.56	75.87	28.07	59.51
Mode	22.12	73.45	28.26	60.17
Standard Deviation	2.72	5.38	2.50	4.64
Mean ± 2SD	155 (96.8%)	154 (96.25%)	149 (93.1%)	155 (96.8%)
Sample Variance	7.40	28.96	6.23	21.56
Kurtosis	1.14	7.23	-0.30	10.38
Skewness	0.68	-1.53	-0.02	-1.95
Range	(17.45–34.17) 16.72	(43.27–86.28) 43.01	(21.97–33.61) 11.64	(29.32–69.63) 40.31
Minimum	17.45	43.27	21.97	29.32
Maximum	34.17	86.28	33.61	69.63
Confidence Level (95.0%)	0.42	0.84	0.39	0.72

Table 3: Comparison of the morphometric data of the distal end of right and left side femurs

Values in mm ± SD	Right side (n=80)	Left side (n=80)	Statistical significance
Intercondylar notch width	23.11 ± 2.85	22.73 ± 2.59	0.38
Condylar width	75.71 ± 5.56	75.39 ±3.96	0.67
Intercondylar notch depth	28.05 ± 2.59	28.25 ± 2.41	0.60
Condylar depth	59.39 ± 4.44	59.56 ± 3.97	0.98

Table 4: Comparison of the present study with the morphometric data of various studies

Values in mm (Mean ± SD)	Ameet K.J. et al (2014) [10]	Fatih Yazar et al (2011) [11]	AK Prasanna Veera (2018)[12]	Ananya Biswas et al (2017) [13]	Present study
Intercondylar notch width	17.9±2.7 mm	20.85±2.76 mm	18.49± 11.8 mm	20.14±2.54 mm	22.92± 2.72mm
Condylar width	72.9±5.3 mm	78.43±5.76 mm	73.79± 14.5 mm	71.21±4.8 mm	75.24± 5.38mm
Intercondylar notch depth	26.3±2.4 mm	26±2.34 mm	26.95± 12.7 mm	23.57±2.17 mm	28.15± 2.50mm
Condylar depth	57.3 ± 4.3 mm	60.94±4.5 mm	56.18± 13.7 mm	56.12±3.8 mm	59.40± 4.64mm
NWI	0.24	0.26	0.25	0.28	0.30
NDI	0.45	0.43	0.48	0.42	0.47

Ameet K J et al. found inverted 'U' and inverted 'V' shaped notches in 73.2 % and 26.8% of specimens.10 Ravichandran and Melanie (2010) observed inverted 'U' and inverted 'V' shaped notches in 67% and 33% of specimens.[14] In the present study, similar findings about the shape of the intercondylar notch were found. Wolf MR et al found that smaller intercondylar notch dimensions didn't appear to be a risk factor for graft impingement and subsequent graft failure. Therefore, there would be no need for an additional notchplasty procedure to widen the intercondylar notch. Surgeons may be able to further individualize surgery in terms of graft size and single- or double-bundle ACL reconstruction techniques during the procedure through the use of intraoperative notch measurements.[6] Lund-Hanssen et al. conducted a retrospective study on imaging of female handball players with previous ACL rupture and normal knees. They concluded that female handball players with a notch width of 17 mm or less were six times more prone to ACL tear.[16] Souryal et al. also found in a prospective case series that patients with bilateral ACL tears had significantly smaller notch widths than normal knees without ACL injury.[3]

Conclusion

It is observed that femurs had mainly two types of intercondylar notches, inverted 'U' shaped and inverted 'V' shaped. Most of the femurs had inverted 'U' shaped intercondylar notchs. Many studies suggested that the shape of the intercondylar notch has a very crucial role in ACL injuries. Narrow ICN increases the risk of ACL injury and graft failure. Morphometrically, the mean value of all parameters under study on the right and left side femora had no significant statistical difference, but individually it is important to consider for better reconstructive surgeries. The present study provides morphologic and morphometric data for the distal end of the femur by direct method of measurement. The anthropometric measurements may vary among different regions and populations due to factors like variations in climate, genetics, nutrition, and factors related to lifestyle. Hence, these measurements should be constantly updated. This study provides morphometric data of femoral condyles and intercondylar notch for designing more suitable femoral implants for various orthopedic reconstructive surgeries related to the knee joint, especially for the Madhya Pradesh region population that will improve the outcome of such surgeries, decrease the risk of complications and allow early rehabilitation.

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