Section: Anatomy

Original Research Article

TOPOGRAPHICAL DISTRIBUTION AND MORPHOLOGICAL ANALYSIS OF VASCULAR FORAMINA AT THE DISTAL END OF DRIED ADULT FEMORA

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Received : *12/01/2026*
Received in revised form : *28/02/2026*
Accepted : *15/03/2026*

Keywords:
Femur, Vascular foramina, distal end of the femur, medial condyle.

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DOI: 10.47009/jamp.2026.8.4.80

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2026; 8 (4); 453-457

ABSTRACT

Background: The femur is supplied by multiple nutrient and periosteal arteries that enter the bone through vascular foramina. These foramina serve as entry points for blood vessels, that contribute to the vascularity of the bone and play a crucial role in bone growth, remodeling, fracture healing, and surgical outcomes. The distal end of the femur forms the proximal component of the knee joint and receives its blood supply primarily from the genicular arterial anastomosis. Knowledge of the number, size, and topographical distribution of vascular foramina (VF) in the distal femur is important for orthopedic surgeons during procedures such as total knee arthroplasty, distal femoral osteotomy, fracture fixation, vascularized bone grafting, microsurgical procedures and also in medico-legal cases. The fracture of long bones including the distal femur causes rupture of arteries passing through vascular foramen culminating in local bleeding. Damage to these nutrient vessels may compromise bone vascularity, delay fracture healing, or increase the risk of postoperative complications. Therefore, a detailed anatomical understanding of the vascular foramina of the distal femur is of considerable clinical and surgical importance. **Materials and Methods:** This study is a cross-sectional study done over a period of 2 years from August 2010 to August 2012. 200 Adult Human Femora were studied for the location, number, size and direction of the foramina of the distal end. The foraminal size was assessed by using 26, 22, 21gauge hypodermic needles. **Results:** A total of 11,452 vascular foramina were observed at the distal end of the femur. The medial condyle demonstrated the highest number of vascular foramina (3,359), of all the sizes, with a mean of 16.8 foramina per specimen, 6.63 small sized, 6.43 medium sized and 3.74 large sized vascular foramina. The intercondylar area had the lowest mean number of small (1.88) and medium (3.14) sized foramina, whereas the lateral condyle showed the lowest mean number of large vascular (2.27). Medium-sized foramina were the most frequent overall (4,384) vascular foramina with a mean of 21.92 per specimen. The predominant direction of the vascular foramina was upper oblique (4,238) with a mean of 21.19. **Conclusion:** A detailed understanding of the vascular foramina of the distal femur is valuable during total knee arthroplasty, fracture fixation, bone grafting, and vascularized bone transplantation. Preservation of the vascular supply during these procedures may improve bone viability and reduce postoperative complications such as delayed healing.

INTRODUCTION

Femur is the longest bone of the body, which is one of the weight bearing bones of the body. It is about a quarter of the entire height of the individual.[1] Lower end of the femur is perforated by numerous vascular foramina and this explains the lack of ischemic necrosis after fractures of the lower end of the femur.[2]

A typical long bone is supplied by four groups of arteries, which are a nutrient artery, epiphyseal arteries, juxta epiphyseal or metaphyseal arteries and periosteal arteries.[3] The important blood supply is by the nutrient artery which enters the femur through nutrient foramen. Vascular arteries enter the long bone, via numerous vascular foramina present all over the bone, but more numerously present at the ends of the long bones. These vascular foramina are often at fairly specific sites, some are occupied by the arteries, but most of them contain thin-walled veins[4]. All these foramina are located only on the non-articular surfaces.

The distal end of Femur is more massive, being a double knuckle.[5] It consists of Medial and Lateral Condyles, Epicondyles, Intercondylar fossa or notch and Articular surface.[6] Medial Condyle is narrower and more curved. It is farther from the shaft than the lateral condyle. An adductor tubercle at the lower end of the medial supracondylar ridge lies above the medial condyle. Medial Epicondyle is the prominence, situated immediately behind and above the medial condyle. Lateral Condyle is broader and more massive than the medial condyle because it bears the larger share of weight transmission. It is laterally flat and less prominent than medial condyle.[1] It is in line with the femoral shaft.[5] A pit for popliteus muscle lies below its epicondyle. Lateral Epicondyle is the eminence, situated on the posterior part of the lateral surface of the lateral condyle. Intercondylar Fossa or Intercondylar Notch is bounded by the opposed surfaces of the condyles and separates them behind and below[1]. It consists of medial and lateral surfaces and a floor[6]. Its floor slopes upwards and backwards to a horizontal ridge, called the intercondylar line[1]. A more depressed subsidiary notch affects the lateral part of intercondylar fossa.[5] The perforated area in the distal end is known as Area cribrosa vasorum femoris. The area is subdivided into 5 regions depending upon the location. Area cribrosa vasorum supracondyloidae femoris anterior is the anterior supracondylar area. Area cribrosa vasorum supracondyloidae femoris posterior is the posterior supracondylar area. Area cribrosa vasorum condyloidae femoris medialis is the medial condylar area. Area cribrosa vasorum condyloidae femoris lateralis is the lateral condylar area. The intercondylar incisura, between the two upper attachments of the cruciate ligaments, is the intercondylar perforated area is Area cribrosa vasorum intercondyloidae femoris is the intercondylar perforated area[2].

Lower end of the femur is supplied by the osteal branches of the genicular arteries. The arteries are descending genicular artery of femoral artery, superior medial and lateral genicular arteries, inferior medial and lateral genicular arteries, and the middle genicular artery which are the branches of popliteal artery.[6] The descending genicular artery and superior medial genicular arteries anastomose and supply the medial condyle; lateral condyle is supplied mainly by the lateral superior genicular artery. Anterior supracondylar area is supplied by the above-mentioned arteries. Posterior supracondylar area is supplied by all the genicular arteries, and the intercondylar area is supplied by the middle genicular artery.[2] All these arteries ramify beneath the periosteum and enter the Volkmann's canals to supply the Haversian system in the outer 1/3rd of the bone.[3]

In the lower limb, the lower end of the femur and the upper end of the tibia are the growing ends. The nutrient arteries along with veins pass through vascular foramen. One of the factors responsible for delayed union or non-union of fracture is the lack of arterial supply. It is a known fact that the process of repair of a traumatic or surgically induced fracture takes place very slowly. Therefore, the morphological knowledge of vascular foramen is very essential for orthopedic surgeons carrying out an open reduction of a fracture to avoid injuring the nutrient artery and thus decreasing incidences of delayed/non-union of the fracture.[7]

There is no satisfactory description of the detailed vascular channels of the distal end of the femur. Exact information is essential for an understanding of the vascular supply of the bone.

MATERIALS AND METHODS

This study is a cross-sectional study done on 200 Adult Human Femurs of unknown sex over a period of 2 years from August 2010 to August 2012. The study was done at Gandhi Medical College, Secunderabad, Osmania Medical College, Hyderabad, Deccan Medical College, Hyderabad & SVS Medical College, Mahabubnagar, in Telangana. The location, number, size and direction of the vascular foramina in each part of the distal end of the dried human adult femurs were noted.

The upper end was studied under the following areas of distribution.

1. Anterior Supracondylar Area
2. Posterior Supracondylar Area
3. Medial Condyle
4. Lateral Condyle
5. Intercondylar Area

The size of the vascular foramina was observed by using 21, 22 and 26 size gauge needles and categorized into 3 groups.

1. Small 0.45 to 0.70mm which admitted 26-gauge needle
2. Medium 0.71 to 0.80 mm which admitted 22-gauge needle
3. Large > 0.81mm which admitted 21-gauge needle.

Statistical analysis was done.

RESULTS

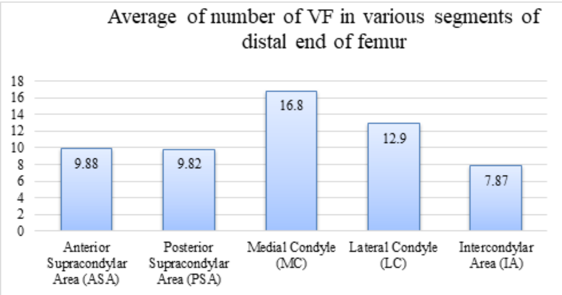
The present study was conducted to know the quantitative analysis of the topography and morphology of vascular foramina of distal end of femur.

I. Location & Number of Vascular Foramina

The average number of vascular foramina at the distal end was noticed, and the maximum number of vascular foramina were on the medial condyle of the femur and the minimum number were on the intercondylar area.

Table 1: Showing the location and number mean, min-max & Standard deviation of vascular foramina in various segments of Femur (distal end)

Segment of the distal end	Average	Min-Max	SD	Total No. of VF
Anterior Supracondylar Area (ASA)	9.88	22-Apr	3.04	1975
Posterior Supracondylar Area (PSA)	9.82	25-Apr	2.83	1963
Medial Condyle (MC)	16.8	30-Sep	3.98	3359
Lateral Condyle (LC)	12.9	23-Jun	3.07	2582
Intercondylar Area (IA)	7.87	14-Mar	7.87	1573
Total No. of Vascular Foramina in the Distal End of 200 Femurs = 11452				



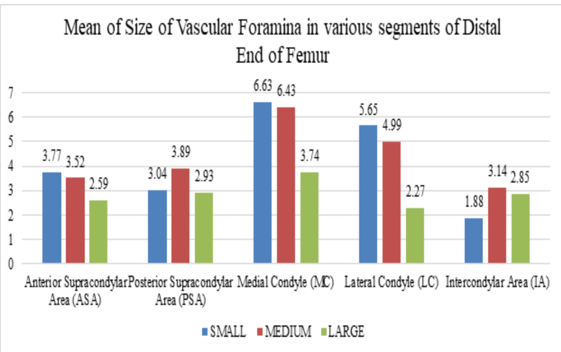
Graph 1: Showing the average of number of vascular foramina in various segments of Femur (distal end)

II. **Size of the Vascular Foramina**

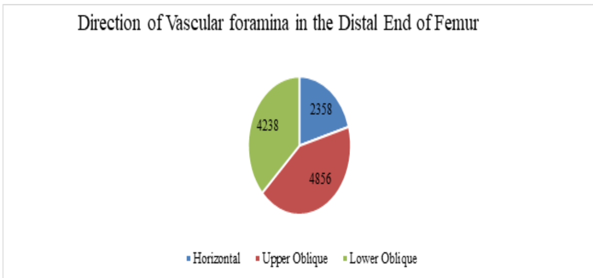
The average number of vascular foramina of different sizes, at the distal end was noticed, and the maximum number of large, medium and small sized foramina were on the medial condyle of the femur. The minimum number of small and medium sized were on the intercondylar area and large were on lateral condyle.

Table 2: Showing the correlation between size and number of vascular foramina of Femur (distal end)

Segment of the distal end	SMALL			MEDIUM			LARGE		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
Anterior Supracondylar Area (ASA)	754	3.77	2.12	703	3.52	1.64	518	2.59	2.11
Posterior Supracondylar Area (PSA)	608	3.04	2.42	769	3.89	1.76	586	2.93	1.83
Medial Condyle (MC)	1325	6.63	3.08	1286	6.43	2.66	748	3.74	3.24
Lateral Condyle (LC)	1130	5.65	2.59	998	4.99	2.5	454	2.27	2.56
Intercondylar Area (IA)	376	1.88	1.75	628	3.14	1.72	569	2.85	1.59



Graph 2: Showing the correlation between size and mean of vascular foramina of Femur (distal end)



Graph 3: Showing the direction of vascular foramina of Femur (distal end)

III: Direction of Vascular Foramina

Out of 11,452 foramina in the distal end, 2358 no. of vascular foramina were directed horizontally, 4856 no. of vascular foramina were in upper oblique direction and 4238 no. of vascular foramina were in lower oblique direction.

Photograph 1: Vascular foramina on the medial condyle and its epicondyle

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Photograph 2: Vascular foramina on the lateral condyle and its epicondyle

Photograph 3: Vascular foramina on the posterior supracondylar surface

Photograph 4: Vascular foramina on the anterior supracondylar surface

Photograph 5: Vascular foramina on the intercondylar area

DISCUSSION

In the present study maximum no. of vascular foramina in the distal end of the Femur, studied in 200 femora were 11,452. Maximum no. of vascular foramina were observed in the Medial condyle (n=3359), and minimum were on Intercondylar area (n=1573), Maximum average number of vascular foramina was observed in the medial condyle (16.8) and minimum average number of vascular foramina was observed in the Intercondylar area (7.87). The maximum no. of small sized foramina 1325 were located on the Medial Condyle and minimum 376 on the Intercondylar area. The maximum no. of medium sized vascular foramina 1286 were on the located on the Medial condyle and least 628 on the Intercondylar area. The maximum no. of Large sized vascular foramina 748 were located on the Medial condyle and least 454 on the Lateral condyle. Most of the foramina were in upper oblique 4856 followed by lower oblique direction 4238.

H. Yahamoto etal in 2010 studied the arterial supply of the distal medial femoral condyle and its implications in harvesting vascularized bone grafts. The location, branching pattern, internal diameter, and distribution of perforators of the descending genicular artery and superior medial genicular artery in 19 fresh cadaveric lower limbs were recorded. The average number of perforating vessels was greatest in the posterior distal quadrant of the condyle. The blood supply of the medial femoral condyle is plentiful and consistent making it a useful source for free vascularized bone grafts.[8] This study is similar to our study which confirms Medial condyle has the richest blood supply.

Deepa Bhatt et al in 2021 studied 300 dried femur and stated that maximum no. of VF were on the Medial condyle and minimum in the Central part of Intercondylar area. Large sized VF were on the Left Supra Condylar Posterior area and Medial Condyle. Medial Condyle has presented highest no. of VF of all sizes, which similar to the present study. Direction of VF The direction of VF in the lower end documented was horizontal 37.89%; upper oblique 35.77%; and lower oblique 26.34%,[9] which is contrary from the present study.

ISSN (O): 2687-5365; ISSN (P): 2753-6556

John Tran et al in 2025 studied 19 dried femurs and stated that location of epiphyseal nutrient foramina was variable on distal femur. Laterally, distribution of nutrient foramina showed percentages of 11.5 %, 44.7 %, 36.5 %, and 7.3 % in the first, second, third, and fourth quadrants, respectively. Distribution on the medial distal femur showed percentages of 12.4 %, 40.4 %, 35.5 %, and 11.5 % in the first, second, third, and fourth quadrants, respectively[10] which is similar to present study.

The density of VF through which the vessels traverse at lower end were not only numerous but also constant and uniformly scattered.[11]

While harvesting the condyles for grafting, vascularity has to be taken into consideration to avoid the donor site complications. The topographic knowledge of larger VF of lower end which admits bigger vessel entry, would help the surgeon to be vigilant during graft preparation, instrumentation, and its fixation.[2] Consistent scattering of VF and their larger size provide plentiful periosteal blood supply to Medial Condyle allowing adequate corticocancellous bone flap harvest without jeopardizing the nutrition.[12]

CONCLUSION

This study deals with the quantitative analysis of vascular foramina of distal end of femora and provides the information about the areas of maximum and minimum blood supply of distal end of femora to the surgeons. This knowledge helps to direct the orthopaedic surgeons in preservation of blood supply of medial and lateral condyles, during surgical procedures such as bone grafting, and microsurgical vascularized bone transplantation, to preserve the circulation intact in open- and closed-wedge distal femoral osteotomies. Medial condyle having the highest blood supply is also used for the vascularized bone grafts.

Acknowledgment: I would like to thank my mentor and thesis guide Dr. S. Sreelatha, for guiding me throughout.

Conflicts of Interest: There are no conflicts of interest.

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