

Variations of Nutrient Foramina in Dry Adult Femur Bones: A Cross-sectional Study from Gujarat, Western India

PRIYANKA N SHARMA¹, KINJAL JETHVA², HETAL VAISHNANI³, MANOJ KULKARNI⁴,
PRIYANKA GOHIL⁵, MEGHANA JOSHI⁶



ABSTRACT

Introduction: Nutrient foramina in the femur serve as critical entry points for nutrient arteries supplying the bone marrow and inner two-thirds of the bone, playing a vital role in bone growth and healing. Understanding these variations is essential in orthopaedic surgery to prevent vascular injury and promote fracture healing.

Aim: To determine the prevalence, placement, number, location, size, and direction of nutrient foramina in adult dry femora.

Materials and Methods: A cross-sectional osteological study was conducted in the Department of Anatomy, Government Medical College, Vadodara, Gujarat, India, from August 2013 to January 2014, on 311 dry adult femora. The parameters assessed included total oblique length, zonal distribution (proximal, middle, and distal thirds), surface placement, number, size (categorised by needle gauge), and direction of the nutrient foramina. Data were descriptively analysed using Statistical Package for Social Sciences (SPSS) 23.0 (IBM Corp., Armonk, NY, USA).

Results: The mean oblique length of the femur was 42.65 ± 2.8 cm (range, 34-50 cm). All femora exhibited nutrient foramina, with 510 foramina identified. Most foramina were located in the middle third of the shaft (68.6%), predominantly on the posterior surface (69%). Most femora had one (52%) or two (44.4%) nutrient foramina. Sizes varied, with large foramina (>0.81 mm) being most common (51.8%). The direction was predominantly upward, away from the knee joint, with only one rare downward case observed, and all identified foramina appeared patent on gross examination.

Conclusion: The present study, which was conducted on a large sample size, demonstrated a relatively consistent pattern within the studied sample in the distribution, size, direction, and patency of the femoral nutrient foramina. These findings provide reliable anatomical data to assist orthopaedic surgeons in preserving femoral vascularity and reducing the risk of delayed union or non union of fractures.

Keywords: Anatomical variation, Fracture healing, Long bone vascularisation, Nutrient artery

INTRODUCTION

The femur, the thigh bone, is the longest and most robust bone in the human body, serving as the main load-bearing bone in the thigh. It is prone to fractures and dislocations due to hormonal imbalances, aging, and physical injuries [1-3]. Like all long bones, the femur receives blood from three interconnected vascular systems: the metaphyseal complex, the nutritive system, and the periosteal capillary system. Of these, the nutritive system is the most crucial, providing blood to the bone marrow and the inner two-thirds of the cortical bone [4,5]. Large bones like the femur have their diaphysis supplied by one or more nutrient arteries that traverse the cortex and enter the medullary cavity, where they split into ascending and descending branches. It is widely accepted that these nutrient arteries originate from those involved in the initial invasion of the ossifying cartilage [4,6,7].

The nutrient artery plays a crucial role in the vascularisation of growing bones and enters the shaft obliquely through the nutrient foramina. Nutrient foramina are important anatomical landmarks that serve as portals of entry for the nutrient artery. Each long bone has its own nutrient artery, and some of them even more. They are usually collateral blood vessels of the extremity arteries. One or two major nutrient arteries enter the diaphysis of long bones through one or two Nutritional Foramina (NF), leading into the nutrient canal. In most cases, the nutrient foramen is located away from the growing end of the bone, leading to the well-known axiom that the foramen "seeks the elbow and flees from the knee." The position of the nutrient foramina may be influenced by multiple factors, including growth patterns and biomechanical forces [8-11].

The vascular supply to the femur is complex. The femoral head receives blood from the medial and lateral circumflex femoral arteries,

whereas the trochanteric and subtrochanteric regions are supplied by trochanteric and cruciate arterial anastomoses, respectively. More distally, nutrient foramina directed proximally are typically located along the linea aspera with variability in their number and position. Usually, one foramen is found near the proximal end of the linea aspera and the other near its distal end. The main nutrient artery is commonly derived from the second perforating artery, whereas the presence of two nutrient arteries may indicate derivation from the first and third perforating arteries, reflecting the differential growth rates at the two ends of the limb bone [12,13].

Henderson RG (1978) reported that the position of nutrient foramina in mammalian bones is variable and may change during growth [14]. A thorough understanding of the morphology of nutrient foramina is therefore essential for orthopaedic surgeons, particularly during open reduction and internal fixation of fractures, as inadvertent injury to the nutrient artery may result in delayed union or nonunion. Preservation of the arterial supply is also critical in free vascularised bone grafts, where osteocyte and osteoblast survival depend on adequate perfusion [5,12,15,16].

It has been suggested that the direction of the nutrient foramina may be influenced by muscle traction on the periosteum, accounting for certain anomalous orientations. Knowledge of the growing ends of long bones is particularly important in younger individuals, as injuries or infections at these sites can result in growth retardation or limb deformity. Advances in orthopaedic procedures, including transplantation and resection techniques, necessitate detailed anatomical data regarding the blood supply of long bones and their corresponding vascular territories [12]. Previous studies have described variations in the number and location of nutrient foramina

in the femur; however, most were conducted on limited sample sizes and in different geographic populations. Moreover, rare variations such as multiple nutrient foramina or deviation from the classical direction of the nutrient canal have been sparsely reported. There is a paucity of data from the western Indian population, particularly from the Gujarat region. Hence, the present study was undertaken on a large series of adult dry femora to evaluate the number, size, surface distribution, zonal location, direction, and patency of nutrient foramina. The findings aimed to provide region-specific anatomical data and identify uncommon but clinically significant variations that may influence orthopaedic surgical approaches and fracture management.

MATERIALS AND METHODS

This cross-sectional osteological study was conducted in the Department of Anatomy, Government Medical College, Vadodara, Gujarat, India, from August 2013 to January 2014. Ethical approval for the study was obtained from the Institutional Ethics Committee for Human Research (IECHR Registration No: ECR/85/Inst/GJ/2013).

Inclusion criteria: It comprised of complete, well-preserved adult femora without gross deformity.

Exclusion criteria: It included broken, pathological, malformed, or incompletely ossified femora.

Study Procedure

All available adult dry femora meeting the inclusion criteria in the departmental osteology collection during the study period were included, resulting in a large sample of 311 femora, which represents one of the largest osteological series reported from a single geographic region.

All measurements and observations were performed by a single observer to avoid inter-observer variability. Each femur was examined for the following parameters:

- Total oblique length of the femur was measured using an osteometric board.
- The femoral shaft was divided into three equal zones:
 - Zone I (proximal one-third)
 - Zone II (middle one-third)
 - Zone III (distal one-third)
- Surface placement of nutrient foramina was recorded as anterior, posterior, medial, or lateral.
- The number of nutrient foramina per femur was documented.
- The size of nutrient foramina was assessed using hypodermic needles [7]:
 - Small (0.45-0.70 mm): admitted 26-gauge needle
 - Medium (0.71-0.80 mm): admitted 22-gauge needle
 - Large (>0.81 mm): admitted 21-gauge needle
- The direction of nutrient foramina was determined by inserting a fine probe [7]:
 - Upward direction (towards proximal end)
 - Downward direction (towards the distal end)
- Patency of the nutrient foramina was confirmed by passing a fine wire through the canal.

High-resolution photographs were taken for documentation.

STATISTICAL ANALYSIS

Data collection and analysis were performed using IBM SPSS Statistics, version 23.0 (IBM Corp., Armonk, NY, USA). Statistical analyses were performed using standard statistical software. Continuous variables are expressed as mean±Standard Deviation (SD), and categorical variables are expressed as frequencies and percentages. The distribution patterns of the nutrient foramina with

respect to placement and direction were analysed using frequency analyses.

RESULTS

The study was conducted on 311 fully ossified adult dry femora of unknown age and gender obtained from the Gujarat (Western India) population. The findings, therefore, represent region-specific anatomical characteristics and may vary across different populations due to ethnic and genetic factors. To evaluate the morphology, distribution, number, size, and direction of nutrient foramina. Nutrient foramina were observed in all examined femora.

Total Oblique Length and Zonal Distribution of Nutrient Foramina

The total oblique length of the femur ranged from 34.0 to 50.0 cm, with a mean value of 42.65±2.8 cm. The median oblique length was 42.5 cm, and the interquartile range was 41.0-44.4 cm, indicating moderate variability among the specimens.

A total of 510 nutrient foramina were identified. The majority were located in Zone II, accounting for 350 (68.6%) foramina, followed by Zone I with 148 (29%) foramina. The lowest number was found in Zone III, with 12 (2.4%) foramina [Table/Fig-1].

Placement of nutrient foramina	n (%)
Zone I	148 (29)
Zone II	350 (68.6)
Zone III	12 (2.4)

[Table/Fig-1]: Zonal distribution of nutrient foramina.

Placement of Nutrient Foramina on Femoral Shaft Surface

Out of the total 510 nutrient foramina, 352 (69%) were located on the posterior surface of the femoral shaft. The medial surface accounted for 105 (20.6%) foramina, and 53 (10.4%) were observed on the lateral surface. No nutrient foramen was identified on the anterior surface of the shaft [Table/Fig-2].

Surface of femur	n (%)
Posterior	352 (69)
Medial	105 (20.6)
Lateral	53 (10.4)
Anterior	0

[Table/Fig-2]: Placement of nutrient foramina on surface of femur.

Number of Nutrient Foramina

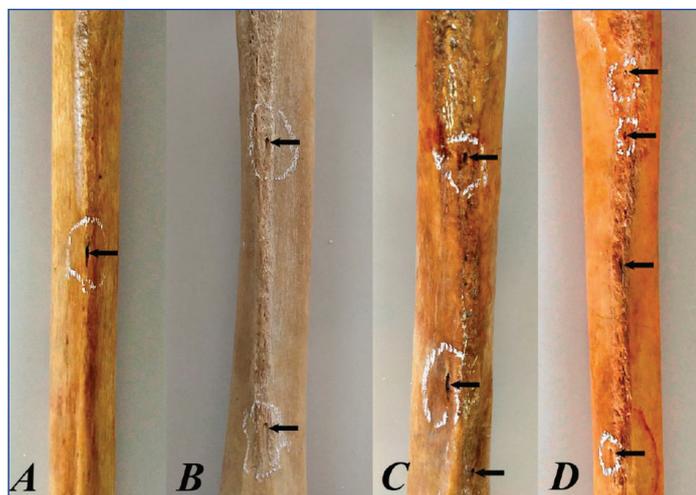
A single nutrient foramen was observed in 162 (52%) femora of the sample. Double nutrient foramina were present in 138 (44.4%) femora, whereas triple nutrient foramina were observed in 10 (3.3%) femora. Four nutrient foramina were observed in 1 femur (0.3%). All nutrient foramina were patent [Table/Fig-3,4].

Size of Nutrient Foramina

A total of 510 nutrient foramina were identified and classified according to size using needle gauge assessment. Of these, 60 (11.7%) were small-sized (0.45-0.70 mm), 186 (36.5%) were medium-sized (0.71-0.80 mm), and 264 (51.8%) were large-sized (>0.81 mm) [Table/Fig-5]. Large-sized foramina constituted the

No. of nutrient foramina	n (%)
Single	162 52
Double	138 44.4
Triple	10 3.3
Quadruple	1 0.3

[Table/Fig-3]: Number of nutrient foramina.



[Table/Fig-4]: Number of nutrient foramina on posterior surface of femora (Black arrows): a) single; b) double; c) triple; and d) quadruple.

Size of nutrient foramina	n (%)
0.45-0.70 mm (small)	60 11.7
0.71-0.80 mm (medium)	186 36.5
>0.81 mm (large)	264 51.8

[Table/Fig-5]: Size of nutrient foramina.

majority, suggesting the presence of a dominant nutrient artery supplying the femoral shaft.

Small foramina were observed in 60 (17.6%) femora, medium-sized foramina in 186 (36.5%) femora, and large foramina in 234 (51.8%) femora. Among the 138 femora with double nutrient foramina, 87 (63%) showed foramina of different sizes, while 51 femora had foramina of the same size, comprising 22 (15.4%) large, 14 (10.6%) medium, and 15 (11%) small-sized foramina [Table/Fig-6].

Size of double nutrient foramina	n (%)
Different size of nutrient foramina	87 (63.0)
Two large sizes of nutrient foramina	22 (15.4)
Two medium size of nutrient foramina	14 (10.6)
Two small size of nutrient foramina	15 (11.0)
Total	138 (100)

[Table/Fig-6]: Double nutrient foramina size.

Of the 10 femora exhibiting triple nutrient foramina, three (30%) showed three different-sized foramina, comprising one small, one medium, and one large foramen. Six femora (60%) showed one small and two medium-sized foramina. One femur (10%) showed one small and two large. In the single femur (10%) with four nutrient foramina, three were small-sized and one was large-sized [Table/Fig-4,7].

Size of triple nutrient foramina	n (%)
One small, one medium and one large size of nutrient foramina	3 (30)
One small and two medium size of nutrient foramina	6 (60)
One small and two large size of nutrient foramina	1 (10)
Total	10 (100)

[Table/Fig-7]: Triple nutrient foramina size.

Direction of Nutrient Foramina

The direction of the nutrient foramina was predominantly upward and away from the knee joint. Only one nutrient foramen exhibited a downward direction, which was a rare finding [Table/Fig-8]. All remaining nutrient foramina were directed in an upward direction.

DISCUSSION

Notably, the present study, conducted on 311 adult dry femora from the Gujarat region, represents one of the largest osteological series



[Table/Fig-8]: Direction of nutrient foramina on femur: upward (red arrow) and downward (black arrow).

documented rare findings such as a total 510 nutrient foramina with the presence of four nutrient foramina. In a femur and an exceptionally uncommon downward-directed nutrient foramen, emphasise the clinical relevance of population-specific anatomical studies. In the present study, the mean total oblique length of the femur was 42.65±2.8 cm. The nutrient foramina were most frequently located in the middle third of the shaft (68.9%), predominantly on the posterior surface (69%), commonly one (52%) or two (44.4%) per femur, and were largely large-sized (>0.81 mm; 45.9%). Almost all foramina were directed proximally away from the knee joint, and all were patent, indicating intact potential vascular channels.

The mean oblique length in the present study (42.65±2.8 cm) closely corresponds with values reported by Krishna MS et al. (43.59±2.8 cm) [3], Rajeev M et al. (42±2.8 cm) [16], Gumusburun E et al., (43.3 cm), and Mohan K et al., (42.55±8.32 cm) [17,18]. Slightly higher values were noted by Dervisevic L et al., (44.34 cm) [4], whereas Akhter Y et al., (38.9±2.51 cm) [10] reported a lower mean. Such differences likely reflect regional, ethnic, genetic, and nutritional influences, underscoring the need for population-specific morphometric data [Table/Fig-9] [3-5,10,16-18].

In the present study, 68.9% of nutrient foramina were located in the middle third (Zone II), followed by 29% in the proximal third (Zone I) and 2.4% in the distal third (Zone III). This predominance of the middle third mirrors reports by Krishna MS et al., (72.4%), Dervisevic L et al., (92.9%), Deswal A et al., (75.6%), Rajeev M et al., (68.5%), and Mohan K et al., (88%) [3,4,8,16,18]. Conversely, Poornima B et al., (56.1%) and Singh AK et al., (55.7%) observed higher proximal-third frequencies, while Ahmed MM et al., (70%) observed a more even distribution across all zones- highlighting population-based anatomical variability [Table/Fig-10] [2-4,6,8,9,16,18].

Authors and year of study	Ethnicity	Sample size	Mean±SD	Range (cm)
Present study (2026)	Gujarat	311	42.65 ±2.8	34-50
Krishna MS et al., (2016) [3]	Telangana	122	43.59 ±2.8	-
Dervisevic L et al., (2019) [4]	Bosnia and Herzegovina	50	44.34 ±2.6	38-49
Dhankar R et al., (2019) [5]	Rajasthan	100	-	37- 48.3
Rajeev M et al., (2019) [16]	Nepal	80	42 ±2.8	-
Akhter Y et al., (2024) [10]	Kashmir	100	38.9 ±2.51	34-44
Gumusburun E et al., (1994) [17]	Sivas	103	43.3	-
Mohan K et al., (2017) [18]	Tamil Nadu	150	42.55 ±8.32	-

[Table/Fig-9]: Comparison of total oblique length of femur with previous study [3-5,10,16-18].

Authors and year of study	Ethnicity	Sample size	Proximal third	Middle third	Lower third
Present study (2026)	Gujarat	311	148 (29%)	350 (68.9%)	12 (2.4%)
Poornima B et al., (2015) [2]	Karnataka	100	78 (56.1%)	32 (23%)	26 (18.7%)
Krishna MS et al., (2016) [3]	Telangana	122	14 (14.2%)	71 (72.4%)	13 (13.2%)
Dervisevic L et al., (2019) [4]	Bosnia and Herzegovina	50	03 (7.1%)	44 (92.9%)	-
Singh AK et al., (2019) [6]	Bihar	50	39 (55.7%)	13 (18.6%)	16 (22.9%)
Deswal A et al., (2017) [8]	Haryana	112	38 (24.3%)	118 (75.6%)	-
Ahmed MM et al., (2018) [9]	Hyderabad	100	7 (14%)	35 (70%)	8 (16%)
Rajeev M et al., (2019) [16]	Nepal	80	31 (28.7%)	74 (68.5%)	03 (2.8%)
Mohan K et al., (2017) [18]	Tamil Nadu	150	18 (12%)	132 (88%)	-

[Table/Fig-10]: Comparison placement of nutrient foramina with previous study [2-4,6,8,9,16,18].

Regarding surface distribution, 69% of the nutrient foramina in the present study were located on the posterior surface, followed by 20.6% on the medial and 10.4% on the lateral surfaces, with no foramina on the anterior surface. Similar findings were reported by Paul R et al., (46%), Gumusburun E et al., Mohan K et al., (40.8% along linea aspera) [7,17,18], and Krishna MS et al., (30% along media lip and 30% between two lips), supporting the posterior/linea aspera course of the nutrient canal [3]. In contrast, Ahmed MM reported a higher lateral surface frequency (58.8%), and Akhter Y et al., noted medial lip predominance (83.3%), again reflecting ethnic and biomechanical influences [9,10].

The number of nutrient foramina observed in the present study showed considerable variation. Most femora showed one (52%) or two (44.4%) nutrient foramina, with triple (3.3%) and quadruple (0.3%) foramina being rare. Comparable distributions were reported by Dhankar R et al., (68% single, 30% double), Paul R et al., (41% single, 55.5% double), and Rajeev M et al., (66.25% single, 32.5% double) [5,7,16]. Kizilkanat E et al., and Laing PG found only single and double nutrient foramina [19,20]. Notably, no femur without a nutrient foramen was observed in the present study, contrasting with Sharma M et al., (2%) [21], Mysorekar VR (3.3%) [22] and Prashanth

K et al., (4.6%) [11]. The documentation of four nutrient foramina represents a rare and novel observation, strengthened by the large sample size. A detailed comparison of the number of nutrient foramina with that of previous studies is shown in [Table/Fig-11] [2-8,10,11,16-22].

With respect to size, large-sized nutrient foramina (>0.81 mm) were most common (51.8%), followed by medium (36.5%) and small (17.6%) foramina, suggesting the presence of a dominant nutrient artery supplying the femoral shaft. Comparable observations have been reported in previous studies. Large-sized foramina predominated suggesting a dominant nutrient artery, similar to Ahmed MM et al., (64.5%) [9], while Poornima B et al., [2] 64.7% medium, 16.5% small, 7.2% large and Singh AK et al., [6] reported a medium-size predominance 7.1% large, 64.3% medium, 17.1% small, and 11.4% very small nutrient foramina. Krishna MS et al., (2016) observed 32.4% large, 34.2% medium, 21.9% small, and 11.4% very small foramina, showing a more even size distribution [3].

The present study is distinctive in that it evaluated the size of nutrient foramina in relation to their number. In femora with double nutrient foramina, 62.5% exhibited foramina of different sizes, whereas 15.4%, 10.1%, and 11.0% showed two large, two medium, and two small foramina, respectively. In femora with triple nutrient foramina, 60% demonstrated a combination of one small and two medium-sized foramina, 30% exhibited foramina of different sizes, and 10% showed a combination of one small and one large foramen. These findings indicate a hierarchical vascular pattern with a dominant nutrient artery accompanied by accessory vessels.

In the present study, almost all nutrient foramina were directed upward and away from the knee joint, following the classical rule that the nutrient foramen "flees from the knee." Only one nutrient foramen showed a downward direction, making this finding extremely rare in our study population. Thus, more than 99% of the nutrient foramina were directed toward the proximal end. These findings are consistent with those of previous studies. Krishna MS et al., reported that 100% of the nutrient foramina in their study were directed upward [3]. Similarly, Dhankar R et al., observed that all nutrient foramina (100%) were directed proximally [5]. Rajeev M et al., also documented 100% upward direction of nutrient foramina in femora from the Nepalese population [16]. Deswal A et al., reported a consistent upward direction in most cases, with no significant deviation noted [8]. Minor deviations have been reported in some studies. Akhter Y et al., observed that 99% of nutrient foramina were

Authors and year of study	Ethnicity	Sample size	0 Foramen (%)	1 Foramen (%)	2 Foramen (%)	3 Foramen (%)	4 Foramen (%)
Present study	Gujarat	311	-	162 (52%)	138 (44.4%)	10 (3.3%)	1 (0.3%)
Poornima B et al., (2015) [2]	Karnataka	100	-	62 (62%)	37 (37%)	1 (1%)	-
Krishna MS et al., (2016) [3]	Telangana	122	2 (3.57%)	52 (42.09%)	62 (50.62%)	9 (7.49%)	-
Dervisevic L et al., (2018) [4]	Bosnia and Herzegovina	50	-	19 (42.3%)	24 (49.6%)	4 (16%)	-
Dhankar R et al., (2019) [5]	Rajasthan	100	1 (1%)	68 (68%)	30 (30%)	1 (1%)	-
Singh AK et al., (2019) [6]	Bihar	50	-	31 (62%)	18 (36%)	1 (2%)	-
Paul R et al., (2019) [7]	Hyderabad	200	-	82 (41%)	111 (55.5%)	6 (3%)	1 (0.5%)
Deswal A et al., (2017) [8]	Haryana	112	-	73 (48.34%)	34 (22.51%)	5 (3.31%)	-
Akhter Y et al., (2024) [10]	Kashmir	100	-	75 (75%)	25 (25%)	-	-
Prashanth K et al., (2011) [11]	Mangalore	86	4 (4.6%)	41 (47.7%)	38 (44.2%)	3 (3.5%)	-
Rajeev M et al., (2019) [16]	Nepal	80	-	53 (66.25%)	26 (32.5%)	1 (2.5%)	-
Gumusburun E et al., (1994) [17]	Sivas	103	2 (1.9%)	40 (38.8%)	44 (42.7%)	11 (10.7%)	4 (3.8%)
Mohan K et al., (2017) [18]	Tamil Nadu	150	-	96 (64%)	45 (30%)	9 (6%)	-
Kizilkanat E et al., (2007) [19]	Adana	100	-	75 (75%)	25 (25%)	-	-
Laing PG et al., (1953) [20]	Kent	10	-	6 (60%)	4 (40%)	-	-
Sharma M et al., (2015) [21]	Panjab	50	1 (2%)	27 (54%)	21 (42%)	1 (2%)	-
Mysorekar VR et al., (1967) [22]	Puna	180	6 (3.3%)	81 (45%)	40 (50%)	3 (1.6%)	-

[Table/Fig-11]: Comparison of number of nutrient foramina with previous study [2-8,10,11,16-22].

directed away from the growing end, while 1% showed a downward direction, which is comparable to the rare downward-facing foramen noted in the present study [10]. Such exceptions may be attributed to developmental variations, remodelling during growth, or altered muscle pull, which influences the course of the nutrient canal.

All nutrient foramina in the present study were patent (100%), indicating intact and potential vascular channels. This finding is comparable with reports by Krishna MS et al., Dhankar R et al., and Rajeev M et al., [3,5,16]. In contrast, Akhter Y et al., reported approximately 95% patency, whereas Prashanth K et al., and Gumusburun E et al., observed occasional non patent foramina [10,11,17]. The preservation of patent nutrient arteries is crucial during orthopaedic procedures to prevent compromised vascularity, delayed union, or non union.

The concentration of nutrient foramina in the middle third and posterior surface implies that posterior approaches, intramedullary nailing, and diaphyseal plating pose a higher risk to the nutrient artery. Surgeons should therefore minimise posterior cortical drilling and periosteal stripping, particularly in the mid-diaphyseal region, and remain vigilant for multiple or unusually directed foramina. Preservation of large, patent nutrient arteries is crucial to maintain femoral vascularity and reduce the risk of delayed union or non union.

Limitation(s)

The study was conducted on femora from a single geographic population, which may limit the generalisability of the findings to other ethnic or regional groups.

CONCLUSION(S)

In one of the largest osteological series of femora studied, the mean oblique length was 42.65±2.8 cm. A total of 510 nutrient foramina were identified, most commonly located in the middle third of the shaft (68.9%) and predominantly on the posterior surface of the diaphysis (69%). The majority of femora exhibited one (52%) or two (44.4%) nutrient foramina, with large-sized foramina (>0.81 mm) being the most frequent (45.9%). Almost all nutrient foramina were directed proximally away from the knee joint, and all were patent. Owing to the large sample size, the present study provides robust and reliable anatomical data that may assist orthopaedic surgeons in preserving femoral vascularity and reducing the risk of delayed union or non union of fractures.

Acknowledgement

The authors express profound gratitude to the altruistic individuals who donated their bodies for educational and research purposes.

REFERENCES

- [1] Lewis OJ. Blood supply to developing long bones with special reference to the metaphyses. *J Bone Joint Surg Br.* 1956;38(4):928–33.
- [2] Poornima B, Angadi AV. A study of nutrient foramina of dry adult human femur bones. *International Journal of Biomedical Research.* 2015;6(6):370–3.
- [3] Krishna MS, Udaya Kumar P, Sirisha V, Rajesh V. Morphological and morphometric study of the nutrient foramina in dry human femur bones of Telangana region. *International Journal of Anatomy and Research.* 2016;4(2):2464–8. doi:10.16965/ijar.2016.239.
- [4] Dervisevic L, Dervisevic A, Ajanovic Z, Hasanbegovic I. Analytical and morphometric study of nutrient foramina of femur and its clinical implications. *International Journal of Research in Medical Sciences.* 2019;7(4):1324–9.
- [5] Dhankar R, Kataria S, Bharat, Raichandani L. Morphometric study of nutrient foramina in adult human femur in Western Rajasthan. *International Journal of Applied Research.* 2019;5(5):116–8.
- [6] Singh AK, Kumari R. Evaluation of nutrient foramina of the dry adult human femur bone of North Indian population. *Academia Anatomica International.* 2019;5(2):18–21.
- [7] Paul R, Balla IN, Sreelatha S, Rajasree TK, Sailaja KT. Variations of the nutrient foramina in dried human femur. *International Journal of Anatomy and Research.* 2019;7(3.1):6780–5.
- [8] Deswal A, Srivastava SK, Saxena A, Bala A. Morphometric study of nutrient foramina in human femur bone. *Global Journal for Research Analysis.* 2017;6(8):4-6.
- [9] Ahmed MM. Study of nutrient foramina in dry adult femur bones. *Journal of Contemporary Clinical Practice.* 2018;4(2):84–9. doi:10.18683/jccp.2018.1091.
- [10] Akhter Y, Fatima K, Bhat GM, Shah BA, Irshad M, Ali Z. Study of nutrient foramina in dry adult femur bones in a medical college from North India. *Indian Journal of Clinical Anatomy and Physiology.* 2024;11(3):151–5.
- [11] Prashanth K, Murimanju B, Prabhu LV, Chettiar GK, Pai MM, Dhananjaya K. Morphological and topographical anatomy of nutrient foramina in the lower limb long bones and its clinical importance. *Australas Med J.* 2011;4(10):530–7. doi: 10.4066/AMJ.2011.725. Epub 2011 Oct 31. PMID: 23386863; PMCID: PMC3562873.
- [12] Datta AK. *Principles of General Anatomy.* 6th ed. Kolkata: Current Books International; 2010. p.75–7.
- [13] Standing S, editor. *Gray's Anatomy: The Anatomical Basis of Clinical Practice.* 40th ed. New York: Churchill Livingstone; 2008. p.3441–6.
- [14] Henderson RG. The position of the nutrient foramen in the growing tibia and femur of the rat. *J Anat.* 1978;125(3):593–9.
- [15] Craig JG, Widman D, Van Holsbeeck M. Longitudinal stress fracture: Patterns of edema and the importance of the nutrient foramen. *Skeletal Radiol.* 2003;32(1):22–7.
- [16] Rajeev M, Shrestha R, Pradhan A. Morphometric study of nutrient foramen of femur in Nepalese population. *Journal of Human Anatomy.* 2019;3(1):000139.
- [17] Gumusburun E, Yuçel F, Ozkan Y, Akgun Z. A study of the nutrient foramina of lower limb long bones. *Surg Radiol Anat.* 1994;16(4):409–12.
- [18] Mohan K, Devaraj B, Ramanathan S, Rethinasamy S. Morphometric study of nutrient foramen in the long bones of lower limb. *Int J Anat Res.* 2017;5(2.3):3943–8. doi:10.16965/ijar.2017.225.
- [19] Kizilkanat E, Boyan N, Ozsahin ET, Soames R, Oguz O. Location, number and clinical significance of nutrient foramina in human long bones. *Ann Anat.* 2007;189(1):87–95. doi:10.1016/j.aanat.2006.07.004.
- [20] Laing PG. The blood supply of the femoral shaft: An anatomical study. *J Bone Joint Surg Br.* 1953;35-B(3):462–6.
- [21] Sharma M, Prashar R, Sharma T, Wadhwa A, Kaur J. Morphological variations of nutrient foramina in lower limb long bones. *Int J Med Dent Sci.* 2015;4(2):802–8.
- [22] Mysorekar VR. Diaphyseal nutrient foramina in human long bones. *J Anat.* 1967;101(Pt 4):813–22.

PARTICULARS OF CONTRIBUTORS:

1. Associate Professor, Department of Anatomy, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India.
2. Professor, Department of Anatomy, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India.
3. Professor and Head, Department of Anatomy, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India.
4. Professor, Department of Anatomy, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India.
5. Tutor, Department of Anatomy, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India.
6. Associate Professor, Department of Anatomy, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Priyanka N Sharma,
Associate Professor, Department of Anatomy, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth, At and PO. Piparia, Ta. Waghodia, Dhiraj Hospital, Vadodara-391760, Gujarat, India.
E-Mail: priyanka.sweet28@gmail.com

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. NA

PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Jan 25, 2026
- Manual Googling: Feb 17, 2026
- iThenticate Software: Feb 19, 2026 (15%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

Date of Submission: **Jan 16, 2026**
Date of Peer Review: **Feb 01, 2026**
Date of Acceptance: **Feb 21, 2026**
Date of Publishing: **Apr 01, 2026**