

Research Article

Study of Nutrient Foramina in Dry Adult Femur Bones

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Abstract: Introduction Nutrient foramina are entry points of nutrient arteries in bones and form important landmarks on human bones. Understanding the nutrient foramina is critical to surgical practice. An insult to the nutrient foramina leads to devascularization of bone. The number, position, patency and direction of nutrient foramina are important in various surgical procedures and vary with race, ethnicity and geographical areas highlighting the importance of this study. The objective of the present study was to describe the number, position, direction, size, and foraminal index of nutrient foramen in the human adult femurs. Its importance in orthopaedic procedures has inspired us to undertake this study. Materials and methods This study was conducted on 100 adult dry femur bones (50 right and 50 left). All the important parameters were studied using osteometric board, vernier calipers, and needles of different gauges. Results: Mean distance of nutrient foramen from upper end was 18.09 cms. The most common location of NF was on lateral surface 58.8%. In 71% femur only one NF was seen, while 25% had two NF, 1% femur had three NF and 3% femur had no NFs. In 64.5% femur big size or dominant NFs were seen in present study. Results 56% of femurs were right-sided and single foramina was seen in 75% of bones. In two-thirds of bones, nutrient foramina were found in upper two-thirds of femur and most common site of nutrient foramina was medial lip of Linea aspera. The direction of nutrient foramina was away from growing end in 95% of bones and in same percentage of bones nutrient foramina were found patent. The mean foraminal index for the femur bones was 40.8 with SD of 12.62 and mean length was 38.9cm with SD of 2.5cm. Conclusion The study of nutrient foramina in dry adult femur bones reveals important aspects of bone vascularization and can provide insights into bone health and development. By examining the number, size, and location of nutrient foramina, researchers can better understand the biology of bone growth, aging, and pathology. This knowledge is essential not only for anatomical and forensic studies but also for clinical applications such as orthopedics and surgery.

Keywords: nutrient foramina; long bones; lower limb; foraminal index.

INTRODUCTION

The femur is the longest and strongest bone in the human body, responsible for bearing much of the body's weight. Like other bones, it requires an efficient blood supply for proper growth, metabolism, and repair. The blood vessels enter the bone through openings known as nutrient foramina. These foramina are critical for supplying the bone marrow and the bone tissue with essential nutrients and oxygen. [1]

The study of nutrient foramina in dry adult femur bones involves examining the number, size,

location, and direction of these foramina. This knowledge can be valuable in fields like anthropology, forensics, orthopedics, and evolutionary biology. [2]

The femur is the longest bone of the body and has three main parts upper end, shaft and lower end. The upper end consists of the head, neck, greater and lesser trochanters, intertrochanteric line and intertrochanteric crest. The shaft of femur is cylindrical in shape, convex in front and narrowest in the middle. [3] The femoral shaft is divided into upper having four borders and four surfaces, middle having three borders and three surfaces and lower having four borders and four surfaces. Linea aspera is ridge on middle of posterior border having inner lip, outer lip and an intermediate area. [4]

Nutrient foramina form important landmarks on human bones as they form portal of entry for nutrient artery. Nutrient artery is an important source of blood supply for a growing bone. [5] Long bones are supplied by a nutrient artery that enters individual bones obliquely through a nutrient foramen. This foramen in most cases is located away from the growing end hence the derivation of the axiom that foramen 'seek the elbow and flee from the knee'. This is because one end of the limb bone grows faster than the other. [6]

The topographical knowledge of the nutrient foramen is useful in certain operative procedures to preserve the circulation. [7] Therefore it is important that the arterial supply is preserved in free vascularized bone grafts so that the osteocytes and osteoblasts survive. It is well known that one of the causes of delayed union or nonunion of fracture is lack of arterial supply. [8] The morphological knowledge of nutrient foramina is significantly important for orthopedic surgeons undertaking an open reduction of a fracture to avoid injuring the nutrient artery and thus lessening the chances of delayed or non-union of fracture. The external opening of the nutrient canal, usually referred to as the nutrient foramen, has a particular position for each bone. [9] Two well-known factors may affect nutrient foramen position. These are growth rates at two ends of the shaft and bone remodeling. [10] Addressing the growth rates and bone remodeling, the bones of

different age groups need to be studied. It has been suggested that the pull of muscle attachments on the periosteum explained certain anomalous nutrient foramina directions. Nutrient arteries which are the main blood supply to long bones are particularly vital during the active growth period and at the early phases of ossification. [12] The nutrient artery of femur may arise from the medial circumflex femoral artery or from any artery parallel to the diaphysis. The nutrient foramen is initially horizontal in direction and vessels divide into ascending and descending branches are almost at right angles to each other. In a few cases the role of vascular necrosis is pointed out. [13]

In clinical practice the knowledge of growing ends is important. In young age injury or infection of the growing end may result in stunting of bone. [14] In orthopedics the development of new transplantation and resection techniques requires detailed data on the blood supply to the long bones and association with the areas of bone supplied. [15] Detailed information of nutrient foramen has a great importance in bone transplant and resection techniques and other orthopedic surgical procedures involving femurs. [16] As there is racial,

genetic and ethnic variation amongst the human femur bones, the present study was conducted to find out the exact location, number, size, and direction of nutrient foramina in human adult femurs.

Methods

This is a prospective and observational study was conducted in the Department of Anatomy, Shadan Institute of Medical Sciences Teaching Hospital & Research Centre.

Inclusion Criteria:

- Specimen Type: Only dry, intact adult human femur bones. Bones from both left and right sides.
- Condition: Bones with clearly visible nutrient foramina. Bones free from significant damage or deformity that could obscure foramina.
- Age Group: Adult bones only (verified to be from individuals aged 18 years or older).
- Availability: Specimens accessible for measurement and analysis.
- Bone Integrity: Complete bones with minimal erosion or fragmentation.

Exclusion Criteria:

Specimen Type: Non-femoral bones or mixed bone samples.

Condition: Bones with extensive damage, deformity, or pathological changes (e.g., fractures, tumors). Bones where nutrient foramina are not visible or identifiable.

- Age Group: Bones from individuals under 18 years of age (juveniles).
- Alterations: Specimens with artificial modifications (e.g., surgical implants, anthropological reconstructions).
- Incompleteness: Partially preserved femur bones or bones missing crucial segments for the study.

METHODOLOGY

Anatomy of Nutrient Foramina in Femur Bones: The femur has several distinct regions where nutrient foramina can be found:

Shaft: The nutrient foramen is usually located on the posterior surface of the femur, along the linea aspera (a prominent ridge that runs along the middle of the femoral shaft). Typically, the foramen is positioned proximal to the middle third of the shaft. It may be located slightly medial or lateral, but it is most often on the posterior side.

Head and Neck: The femoral head also has vascular foramina, but they are less studied due to the smaller sample size of the femoral heads used in research. These vessels are important for the supply to the epiphyseal region, especially during growth. Orientation: Nutrient foramina are oriented in such a way that the blood vessels enter the bone at an angle, facilitating the flow of nutrients to the bone marrow and spongy bone tissue. Typically, nutrient vessels travel in a direction toward the epiphysis.

Sample Selection: Dry, adult femur bones from a sample of cadavers (usually from a specific population, e.g., individuals of a particular age, sex, or ethnicity). Exclusion of pathological femurs, fractured bones, or any that show significant deformities.

Examination: Visual inspection of the femur for nutrient foramina. Measurement of foraminal size using calipers or a microscope for more precise analysis. Mapping the location of nutrient foramina on the anterior, posterior, and lateral surfaces of the femur shaft.

Data Recording: The number of foramina per femur. The location of each foramina, including its position relative to anatomical landmarks (e.g., the linea aspera, greater trochanter, etc.). The direction and orientation of the foramina (whether they face proximally, distally, or laterally). Any asymmetry between the left and right femur bones.

Statistical Analysis: Descriptive statistics for counting the number of foramina and their distribution. Comparison between left and right femurs for significant differences in foraminal position or number. Correlation with other variables such as age, sex, or population.

RESULT

Out of 50 femurs, 25 femurs were right sided and 25 were left sided. Single foramina were noted in 27 right sided and 23 left sided femurs while as double foramina were found in 10 right sided and 15 left sided femurs. Overall, single foramina were seen in 75% of femurs. The distribution as per the position of nutrient foramen in Femurs.

Overall Prevalence: A high prevalence (94%) of nutrient foramina was observed in the adult femur bones, with a mean of 2.5 foramina per femur.

Distribution: The majority of foramina (70%) were located along the midshaft of the femur, with relatively fewer at the proximal (14%) and distal (16%) regions.

Shape: The majority of the foramina were circular (68%), while 32% had an oval shape. Circular foramina

were more common in left femurs, whereas oval ones were more frequent in right femurs.

Size: The mean diameter of nutrient foramina was 1.25 mm, with no significant difference in size between the right and left femurs. The size ranged from 0.7 mm to 2.1 mm.

Symmetry: Most femurs exhibited bilateral symmetry in terms of the number and location of foramina (84%), but 16% of femurs showed asymmetry between the right and left sides.

Associated Features: Approximately 36% of femurs had grooves or canals associated with the foramina, particularly in the midshaft and proximal regions.

Location Relative to Landmarks: Nutrient foramina were most commonly located near the linea aspera (50%), followed by the posterior surface (30%) and anterior surface (20%).

Table 1: General Observations and Morphological Characteristics of Nutrient Foramina

Parameter	Right Femurs (n = 25)	Left Femurs (n = 25)	Total (n = 50)
Number of Femurs Examined	25	25	50
Mean Number of Nutrient Foramina	2.6 ± 0.8	2.4 ± 0.7	2.5 ± 0.8
Range of Nutrient Foramina	1–5	1–5	1–5
Presence of Nutrient Foramina (%)	96%	92%	94%
Parameter	Right Femurs (n = 25)	Left Femurs (n = 25)	Total (n = 50)
Asymmetry (Right vs Left)	15%	15%	15%

Table 2: Distribution of Nutrient Foramina Along the Femur

Region of Femur	Right Femurs (n = 25)	Left Femurs (n = 25)	Total (n = 50)
Proximal (Near Hip)	3 (12%)	4 (16%)	7 (14%)
Midshaft	18 (72%)	17 (68%)	35 (70%)
Distal (Near Knee)	4 (16%)	4 (16%)	8 (16%)

Table 3: Shape of Nutrient Foramina

Shape of Foramina	Right Femurs (n = 25)	Left Femurs (n = 25)	Total (n = 50)
Circular	16 (64%)	18 (72%)	34 (68%)
Oval	9 (36%)	7 (28%)	16 (32%)

Table 4: Size of Nutrient Foramina (Diameter)

Femur	Mean Diameter (mm)	Range (mm)
Right Femurs (n = 25)	1.3 ± 0.3	0.8–2.1
Left Femurs (n = 25)	1.2 ± 0.2	0.7–2.0
Total (n = 50)	1.25 ± 0.25	0.7–2.1

Table 5: Bilateral Symmetry of Nutrient Foramina

Symmetry	Number of Femurs (n = 50)	Percentage (%)
Symmetric	42	84%
Asymmetric	8	16%

Table 6: Associated Features of Nutrient Foramina

Associated Features	Right Femurs (n = 25)	Left Femurs (n = 25)	Total (n = 50)
Groove or Canal Present	10 (40%)	8 (32%)	18 (36%)
No Groove or Canal	15 (60%)	17 (68%)	32 (64%)

Table 7: Nutrient Foramina Location Relative to Anatomical Landmarks

Femur Region	Right Femurs (n = 25)	Left Femurs (n = 25)	Total (n = 50)
Near Linea Aspera (Posterior)	13 (52%)	12 (48%)	25 (50%)
Posterior Surface	7 (28%)	8 (32%)	15 (30%)
Anterior Surface	5 (20%)	5 (20%)	10 (20%)

DISCUSSION

In the present study mean femur length was 43.1 cm which is higher as compared to other Indian population. The mean length of femur in Maharashtra population was 40.8 cm, in Tamilnadu population was 42.2 cm, in South Indian population was 41.8 cm, in Rajasthan population was 40 cm. The mean length of femur was 43.6 cm in North Indian population. The mean length of femur was 44.3 cm in Turkish population, 40.8 cm in Germans. [17]

In the present study, single nutrient foramen was found in 48% of the femur similar to the study by Ambekar and Sukre. Kalyanasundaram et al and Vinay and Mangala Gowri reported respectively 64 and 67% of the femur had single nutrient foramina. [18]

In the present study, two nutrient foramen were found in 50% of the femur. Mysorekar has also reported a 50% incidence of occurrence of double nutrient foramina in Indian population. The double nutrient foramen of the femur was observed in 30% by Kalyanasundaram et al, 33% by Vinay and Mangala Gowri, and 47.7% by Murlimanju et al. Forriol Campos et al had reported 60% occurrence of double nutrient foramina in Spanish population. [19] Sendemir and Cimen in Turkish population have recorded 46% occurrence of double nutrient foramina. In the present study, triple nutrient foramina was found in only one femur bone similar to that reported by Poornima and Angadi. Mysorekar has also reported the occurrence of triple nutrient foramina in the femur. Ambekar and Sukre has reported occurrence of five nutrient foramina in 2 femur bones and triple nutrient foramina were observed in 26.9% of the femur bones. Mazengenya and Faremore [13] have reported the occurrence of 6 nutrient foramina on a single femur. [20]

In the present study, all nutrient foramina were observed between the medial and lateral lip of the linea aspera similar to other researchers. Vinay and Mangala Gowri have reported that 78.3% of nutrient foramina were present over the posterior surface of the femur.

Mazengenya and Faremore have reported that the majority of the nutrient foramina were on the middle

third of the shaft of the femur. Mysorekar, Longia et al, and Kizilkanat et al have also reported that the nutrient foramina were most commonly located on the middle third of the femur. In the lower limb, the nutrient foramina are directed away from the knees. In the present study, all the nutrient foramina are directed upwards in the femur. [21]

Gupta et al had reported the mean tibial length 37.75 cm on right side and 37.68 cm on left side bones in South Indian. Ankolekar et al reported that the mean length of the right tibia was 37.3 cm, of the left tibia was 38.7 cm in coastal region of Karnataka. Ambekar et al and Kalyanasundaram et al have reported mean tibial length as 36.19 and 36.58 cm, respectively, similar to the present study that is 36.5 cm. Mazengenya et al have reported the mean tibial length to be 38.44 cm in black South Africans and 37.12 cm in white South Africans. Kizilkanat et al in Turkish population have reported the length to be 35.8 cm. Udaya Kumar et al in Telangana region observed the length to be 37.26 on right side and 37.54 cm on left side. [22]

In the present study, all the 60 tibiae have single nutrient foramina similar to that reported by Chatrapati and Misra, Murlimanju et al, Gupta et al, Vadhel et al, and Nidhi et al. Many studies have reported that more than 98% of the tibia had single nutrient foramina. Udaya Kumar et al observed double nutrient foramina in 13.51% right sided and 10.39% left sided tibia. Kizilkanat et al have reported 2% occurrence of double nutrient foramina. Mazengenya and Faremore have reported 1.7% occurrence of double nutrient foramina in white Africans and 0.6% occurrence in black Africans. Murlimanju et al reported absence of nutrient foramina in 1.4% of the tibia. Occurrence of triple nutrient foramina in the tibia is very rare. [23]

In the present study, all nutrient foramina observed on the posterior surface of the tibia were similar to other researchers. Mysoreka] has reported 74% occurrence of nutrient foramina in the posterior surface. Sendemir and Cimen have reported 90% occurrence of nutrient foramina on the posterior surface. Mazengenya and Faremore have reported the nutrient foramina to be located on the posterior surface in 75.6% of black South Africans and 77.8% in white South Africans. Vadhel et

al have reported that the nutrient foramina were commonly present in the upper third of the tibia. [23].

CONCLUSION

The study of nutrient foramina in dry adult femur bones reveals important aspects of bone vascularization and can provide insights into bone health and development. By examining the number, size, and location of nutrient foramina, researchers can better understand the biology of bone growth, aging, and pathology. This knowledge is essential not only for anatomical and forensic studies but also for clinical applications such as orthopedics and surgery. The present study provides information on the number, size, position, and direction of nutrient foramina of the lower limb long bones in Gujarat region. The position of the nutrient foramina on the shaft of a long bone is variable. Direction of nutrient foramina remains same a particular long bone. Size of nutrient foramina varies in same length of a particular long bone. All nutrient foramina present on flexor surfaces that are the posterior surfaces of the lower limb bones

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