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RESEARCH ARTICLE

A Study of Diaphyseal Nutrient Foramina in Human Femur

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Abstract: ***Introduction***- The diaphyseal nutrient foramina of long bones serve as vital conduits for vascular supply, facilitating bone growth, repair, and remodeling. Their anatomical location, number, direction, and variability hold immense significance in orthopedic surgery, forensic identification, and radiological diagnostics. ***Aim*** - To study the diaphyseal nutrient foramina in human femur ***Material & Method*** - This cross-sectional descriptive study was conducted on 57 (28 right and 29 left) dry, adult human femur of unknown sex. ***Result*** – In the present study, 80% of the femora had a single nutrient foramen. The double foramen was observed in 15% of the cases, and the multiple foramen were found to be present in 5% of the femora. The majority (72%) of nutrient foramina were identified on the posterior surface, closely followed by the medial surface (21%). Only minor percentages were observed on the lateral (5%) and anterior surfaces (2%). In all examined femoral specimens, the nutrient foramina exhibited consistent directional orientation toward the proximal end, reflecting their direction away from the distal growing end. ***Conclusion***- A thorough understanding of the morphological patterns of diaphyseal nutrient foramina enhances anatomical precision in medical, surgical, and academic contexts. In free vascular bone grafting, the nutrient blood supply is extremely important and must be pre served to promote fracture repair, with a good blood supply being necessary for osteoblast and osteocyte cell survival, as well as facilitating graft healing in the recipient (Longia et al., 1980; Gumusburun et al., 1994)

Keywords- Diaphyseal nutrient foramina, femur, nutrient foramen index.

INTRODUCTION

The human skeletal system is a complex framework composed of bones that provide mechanical support, protection to internal organs, and serve as levers for muscle action.[1] Among the different types of bones, long bones such as the femur, tibia, and fibula of the lower limb are of immense functional and structural importance. These bones are primarily involved in weight-bearing, locomotion, and stability, and their physiological integrity is sustained by a rich and regulated blood supply.[2]

For the existence and continued nurturing the bone providing oxygen and nutrient supply; blood vessels play important role. Long bones are vascularized through several channels: the primary nutrient artery that penetrates centrally, the metaphyseal and epiphyseal arteries that access the bone near its extremities, and the periosteal vessels that supply the outer cortical surface.[3]

The nutrient artery supplies the bone marrow, inner two-thirds of the cortex, and contributes significantly to the nourishment and viability of the bone. It plays a pivotal role not only in the growth and development of bones but also in their repair and regeneration following trauma or disease.[4]

The diaphysis or shaft of long bones is where the nutrient foramen is typically located, and it serves as the principal route through which the nutrient artery enters. The position, number, direction, and orientation of the nutrient foramen are relatively consistent but can exhibit significant variation based on factors such as bone type, side of the body, ethnicity, and developmental anomalies.[5]

In clinical settings, especially in orthopaedic and reconstructive surgeries, accurate knowledge of the location and morphology of nutrient foramina is vital. Procedures such as intramedullary nailing, fracture fixation, bone grafting, and tumour resections often involve direct manipulation of the diaphyseal region.[6] Inadvertent injury to the nutrient artery may lead to compromised vascularity, delayed bone healing, or even non-union of fractures. Thus, a detailed anatomical understanding of these structures is essential for minimizing surgical risks and improving patient outcomes.[7]

Despite their functional importance, nutrient foramina are often overlooked in standard anatomical and surgical literature. With growing emphasis on population-specific anatomical databases for improved surgical planning, there is a pressing need to document and analyze these structures comprehensively.[8]

Understanding the spatial anatomy of these foramina is crucial during specific surgical interventions to ensure vascular integrity is maintained. [9-11] Hence, maintaining the integrity of the arterial supply in free vascularized bone grafts is essential to ensure the viability of osteocytes and osteoblasts.[12]

The aim of this study was to examine the spatial distribution and anatomical positioning of nutrient foramina in the adult human femur. The foraminal indices of the femur were calculated as part of the analysis. A study of diaphyseal nutrient foramina in human femur. The location, size, and number of diaphyseal nutrient foramina in human femur vary significantly and have important clinical implications for surgical procedures and fracture healing

MATERIALS AND METHODS

This research was conceptualized as a cross-sectional, descriptive anatomical study, focusing on the morphological and morphometric analysis of diaphyseal nutrient foramina in the human femur.

Inclusion criteria: For the present study 57 dry adult femora were taken from the department of anatomy, Santosh Medical College & Hospital, Ghaziabad.

Exclusion criteria: Femur with any kind of deformities were excluded from the study.

The femur were examined for the number, location, direction, and position of nutrient foramina using standard tools: digital Vernier caliper for bone length, magnifying lens for foramina identification, and flexible metallic probe to confirm canal patency. The bone shaft was divided into proximal, middle, and distal thirds to map foraminal zones. Direction of the foramina was assessed relative to anatomical landmarks, following the axiom "towards the elbow I go, from the knee I flee." The nutrient foramina were recognized by a distinct groove directing toward them and a clearly defined, often subtly elevated margin at the canal's opening. Observations were limited exclusively to diaphyseal nutrient foramina.

The foramen index (FI) was calculated by applying the Hughes [13] formula, dividing the distance of the foramen from the proximal end (D) by the total length of the bone (L) which was multiplied by hundred.

Foraminal Index (FI%): The Foraminal Index (FI%) quantifies the relative position of the nutrient foramen along the bone shaft using the formula:

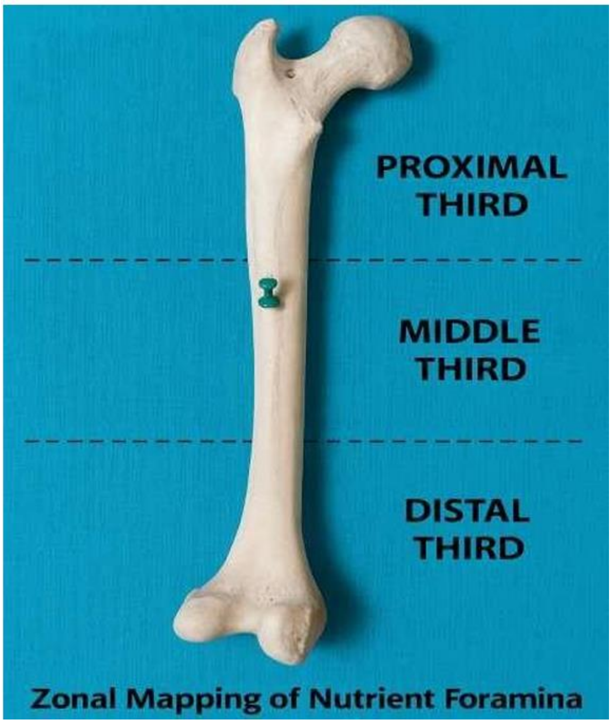
$$\mathrm{FI} = \left(\frac{\text{Distance from proximal end}}{\text{Total bone length}}\right) \times 100$$

It helps categorize the foramen's location into:

- Upper third (FI < 33.3%)
- Middle third (FI = 33.3–66.6%)
- Lower third (FI > 66.6%)

For those bones which had double nutrient foramina, the larger foramen was taken into consideration during the estimation of FI.

Ethical approval was taken from Santosh Medical College and approval number is SU/2025/CRF/210



RESULT

The present investigation systematically explored the diaphyseal nutrient foramina in human femur. A total of 57 dry adult human femora were examined. Each bone was meticulously assessed to identify and characterize nutrient foramina based on their spatial and morphological features.

The analysis revealed that the majority of femora possessed a single, dominant nutrient foramina, located along the linea aspera in the middle third of the shaft. However, occasional variations such as the presence of double or multiple foramina were also observed. (Table no. 1)

Bone	Single foramina (%)	Double foramina (%)	Multiple foramina (%)
N=57	80% (N=45)	15% (N=9)	5% (N= 3)

Table no. 1 No. of Nutrient Foramina

The nutrient foramina were located on the posterior surface, specifically along the linea aspera medial to the medial lip. Approximately 79% of femora displayed foramina on the posterior aspect. On the medial surface about 17% of femur showed presence of foraminas, whereas only in 2% cases foramina was present on the anterior and lateral surfaces. (fig 1)

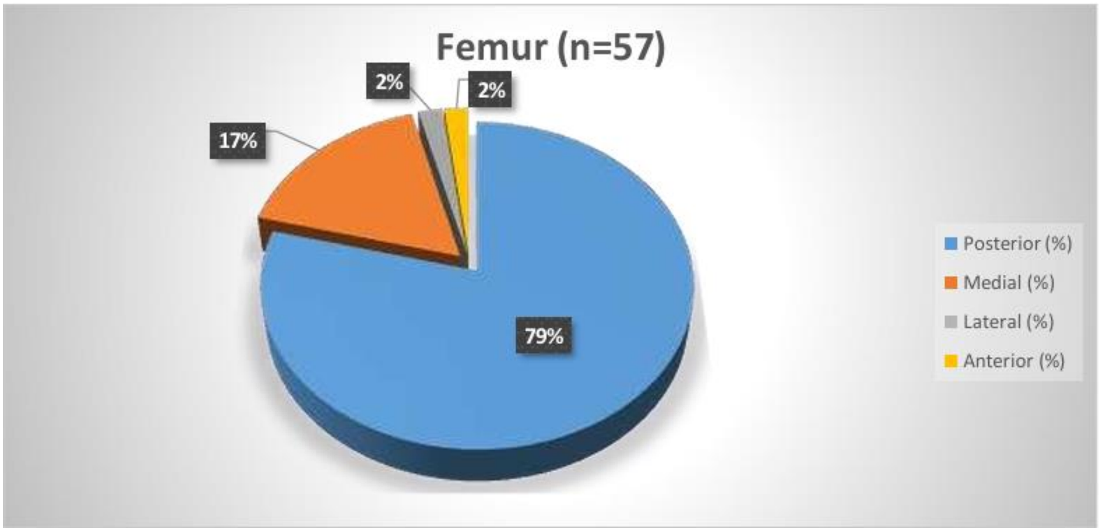


fig. 1 showing surface distribution of nutrient foramina

The femoral nutrient foramina exhibited significant positional consistency, with the majority located within the middle third of the shaft, predominantly along the posterior surface, specifically near or within the linea aspera region. This anatomical location was consistently noted in approximately 88% of the femora studied. The positional regularity of femoral foramina enhances the reliability of this region as a critical landmark during surgical and diagnostic procedures. (table no. 2)

Bone	Predominant position	Percentage %
Femur	Posterior surface, Middle third	88% (N= 50)

Table no. 2 Position of the nutrient foramina

The femoral index of right and left femur is shown in table no. 3

Femur- No. of nutrient foramina						Foramina index	
Side	N	Absent	Single	Double	Triple	Range	Mean
Right	28	1	24	2	1	32-48	40.5
Left	29	0	25	3	1	34-50	41.5

Table no. 3 Showing left and right foramina index of femur

DISCUSSION

Blood vessels supplying the bone are essential for bone survival as they help in distributing oxygen, nutrients, immune cells and removing metabolic waste material. They help in regeneration of bone and hematopoiesis. (14)

In present study, a single nutrient foramen was predominant, observed in 49 specimens (86%). Double foramina were noted in 7 specimens (12%), representing a significant yet minor anatomical variation. The absence of a nutrient foramen was rare, observed in only 1 specimen (2%) our findings are similar to other studies which shows that the frequency of occurrence of single nutrient foramen is more than double nutrient foramen as in the findings of Jyothi Lakshmi G L and Asharani SK e they observed single nutrient foramen in 56 bones, double nutrient foramen in 44 bones. [16]

In present study, we noted that nutrient foramens were located in the middle third of the shaft in 88% of the bones, along the posterior surface near or within the linea aspera region similar to study done by Akhter et al. [17] where 85% of the foramina were on Linear aspera. In a study done by Gumusburun E et al [18] out of 188 foramina 65% were present on the Linea aspera and its Lips. Jyothi Lakshmi G L and Asharani SK e [16] investigated that nutrient foramens were located in the middle third part of the bone in 72% of the cases and in upper third of the bone in 28% of the cases. In study of Pasli B et al [15] they noted that all the nutrient foramina were present on the posterior surface adjacent to linea aspera. 16 nutrient foramina were located (12.90%) in upper 1/3rd, 104 (83.87%) in middle 1/3rd and 4 (3.23%) in lower 1/3rd. Our investigations are similar to the other studies which show that nutrient foramen are present in the middle one third of the femur in the most of the cases.

The mean foramen index of the femur bones was observed as 48.2 by Gumusburun et al. [18], 38.9 by

Prashanth et al. [19], 56.72% in the population of Rohilkhand region of India by Raj Kumar et al. [20]. In the present study the mean foramen index of left is 41.2 and of right it is 40.5 which is similar to Oladayo Sunday Oyedun [21] who observed that the mean Foramen Index of left femurs was (44.40 ±9.34) significantly higher than that on the right femurs (40.11±8.50).

Morphometric analysis revealed that single nutrient foramina were most common, although occasional dual foramina were observed. The foraminal index (FI) demonstrated a positive correlation with total bone length, suggesting that longer femora tend to have more distally placed foramina. Side-wise comparisons showed minor asymmetries, but these were not statistically significant, indicating a relatively stable anatomical pattern across specimens.

Accurate localization of femoral nutrient foramina is critically important in orthopedic surgery. Procedures such as intramedullary nailing, fracture stabilization, and bone graft extraction risk damaging the nutrient artery, which can impair blood flow within the bone and result in delayed healing or non-union. To mitigate such complications, the study underscores the importance of detailed preoperative imaging and a thorough understanding of femoral anatomy. In complex trauma cases, especially those involving comminuted fractures, awareness of foraminal positioning can inform surgical strategy and implant placement, helping preserve vascular integrity and optimize outcomes.

From a forensic and radiological standpoint, the nutrient foramen serves as a reliable landmark for bone identification and orientation. Its consistent location and directionality aid in reconstructive modeling and skeletal profiling, especially in fragmented remains. Moreover, the foraminal index can assist in estimating bone length and stature, contributing to anthropometric assessments.

CONCLUSION

The nutrient artery enters the bone through the nutrient foramen usually present on the diaphysis is an important source of blood supply. Most of the nutrient foramina are typically located in the middle third of femur just adjacent to the linea aspera on the posterior surface of femur. The knowledge of variations in nutrient foramina is of great importance in treating the patients with trauma having long bone injuries, cases of congenital pseudoarthrosis and other surgical procedures where nutrient artery has to be preserved.

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