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Original Research Article

Anatomical Study of Nutrient Foramen in the Long Bones of Lower Limb in Bihar

Randhir Kumar[1], Swami Nand Prasad[2], Rajendra Prasad[3]

[1]Tutor, Department of Anatomy, Anugrah Narayan Magadh Medical College, Gaya, Bihar, India

[2]Assistant Professor, Department of Anatomy, Anugrah Narayan Magadh Medical College, Gaya, Bihar, India

[3]Professor and HOD, Department of Anatomy, Anugrah Narayan Magadh Medical College, Gaya, Bihar, India

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Corresponding Author: Dr. Swami Nand Prasad
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Abstract:

Background: Nutrient foramina are essential anatomical landmarks through which the principal nutrient artery enters the bone, playing a vital role in the nourishment and growth of long bones. In surgical procedures such as orthopedic fixation, joint replacement, and fracture management, detailed anatomical knowledge of the location, number, and direction of nutrient foramina is critical to prevent vascular compromise. Despite their importance, variations exist in their number and position across populations and individual bones. This study was undertaken to analyze the number, location, and direction of nutrient foramina in the long bones of the lower limb among individuals in the Bihar population.

Objectives:

- To identify and record the number of nutrient foramina in the femur, tibia, and fibula.
- To determine the typical and atypical location of nutrient foramina on these bones.
- To assess the direction and distance of the foramina from bone landmarks and correlate with existing anatomical norms.

Materials and Methods: This cross-sectional observational study was conducted in the Department of Anatomy, Anugrah Narayan Magadh Medical College, Gaya, Bihar. A total of 180 dry adult human long bones of the lower limb (60 each of femur, tibia, and fibula) were studied. Bones with deformities or pathological alterations were excluded. The number and location of nutrient foramina were recorded using magnifying lenses and measuring tapes. Distance from proximal and distal ends, direction of canal, and position on specific bone surfaces were documented. Data were statistically analyzed to determine frequency distributions and morphometric ranges.

Results: Out of 180 bones, 92% had at least one nutrient foramen, with the femur most frequently showing a single foramen (76.7%). The tibia showed two foramina in 30% of cases, while the fibula had a single foramen in 83.3% of specimens. The nutrient foramen was most commonly found on the posterior surface in the femur and tibia, and on the medial surface of the fibula. The direction of all foramina followed the general rule of "towards the elbow and away from the knee." Mean distance from the upper end varied from 12 to 15 cm across bones.

Conclusion: This anatomical study reinforces that the number, location, and direction of nutrient foramina follow a consistent population-based pattern, with some variations observed. Awareness of these parameters is crucial for surgeons during intramedullary nailing, bone grafting, and reconstructive procedures to minimize vascular injury. The findings provide region-specific anatomical data that can aid in better surgical planning and academic reference for the Bihar population.

Keywords: Nutrient foramen, femur, tibia, fibula, lower limb bones, Bihar, anatomical variation, orthopedic relevance

Introduction

The long bones of the human lower limb namely the femur, tibia, and fibula—receive their blood supply from multiple sources, with the nutrient artery playing a pivotal role in the vascularization of the inner two-thirds of the cortex and medullary cavity [1]. This artery enters the bone through a specialized opening known as the nutrient foramen. The foramen is typically located in the shaft of the bone and exhibits a predictable directional orientation, generally pointing away from the growing end, in accordance with the well-known anatomical rule: "towards the elbow and away from the knee [2]."

Understanding the topography and morphometry of nutrient foramina is essential not only in academic anatomy but also in clinical and surgical contexts. In orthopedic surgeries involving intramedullary fixation, fracture plating, and bone grafting, inadvertent injury to the nutrient artery can compromise the healing process and jeopardize bone viability [3,4]. Similarly, during bone harvesting for grafts, preservation of the nutrient foramen ensures the biological integrity of the donor segment.

Numerous anatomical studies have reported that the number, size, direction, and position of nutrient foramina may vary across individuals, bones, and population groups. These variations may be influenced by genetic, developmental, or environmental factors. For instance, while most femora exhibit a single nutrient foramen on the posterior surface, double or even triple foramina have been documented, often located on the linea aspera or near the medial lip. Tibiae usually possess a foramen on the posterior surface of the upper third, whereas fibulae tend to have smaller foramina on the medial surface of the middle third [5,6].

Although several studies from different parts of India have described these anatomical characteristics, there remains a paucity of region-specific data for the Bihar population. Since anatomical variations can have racial and ethnic correlations, it is important to establish normative data for specific geographic regions. This is particularly relevant for institutions in Bihar where orthopedic interventions are frequent due to trauma, deformities, and degenerative conditions [7,8].

Moreover, dry bone studies offer the advantage of precise measurement without the interference of soft tissue, allowing for accurate localization and morphometric analysis of nutrient foramina. Such studies enhance anatomical education and assist clinicians in predicting the vascular entry points during preoperative planning.

Therefore, this study was undertaken to conduct a detailed anatomical and morphometric analysis of nutrient foramina in the femur, tibia, and fibula of dry bones sourced from the Bihar region. The findings aim to enrich anatomical literature with region-specific insights and provide valuable reference data for surgeons and educators alike.

Objectives: This study was conducted to evaluate the number, location, and morphometric characteristics of nutrient foramina in the long bones of the lower limb—femur, tibia, and fibula—in adult dry bones from the Bihar region.

Primary objectives:

1. To determine the number of nutrient foramina, present in each of the long bones of the lower limb.
2. To assess the anatomical location and surface orientation of the nutrient foramina in the femur, tibia, and fibula.

Secondary objectives:

1. To measure the distance of nutrient foramina from the proximal end of each bone and calculate their foraminal index.
2. To analyze the direction of the nutrient canal and validate it against established anatomical norms.
3. To compare findings with existing studies and identify population-specific variations relevant to surgical practice.

Materials and Methods

Study design and setting: This was a descriptive, cross-sectional anatomical study conducted in the Department of Anatomy at Anugrah Narayan Magadh Medical College, Gaya, Bihar, India from December 2019 to November 2020

Study Duration: The study was carried out over a period of one year.

Study Material: A total of 180 dry adult human long bones of the lower limb were studied. This included 60 femora, 60 tibiae, and 60 fibulae of unknown sex. The bones were obtained from the departmental osteology museum and teaching collection.

Inclusion criteria:

- Fully ossified, dry, adult human long bones of the lower limb
- Intact bones without signs of gross deformity or trauma
- Bones with clearly identifiable surfaces and anatomical landmarks

Exclusion criteria:

- Bones with pathological lesions or congenital anomalies
- Bones with eroded or damaged surfaces preventing identification of the foramen
- Incomplete or fragmented bones

Parameters observed:

Each bone was examined to record:

- Number of nutrient foramina
- Direction of the nutrient canal
- Anatomical surface and position (anterior, posterior, medial, lateral)
- Distance from the upper (proximal) end of the bone to the nutrient foramen (in mm)
- Total bone length (in mm) to calculate the foraminal index

Measurement tools and technique: The observations were made using a hand lens, metal divider, and measuring tape. The direction of the canal was determined using a steel probe. All measurements were recorded in millimeters. The foraminal index was calculated using the formula:

Foraminal Index = (Distance of Foramen from Proximal End / Total Bone Length) × 100

Data analysis:

Data were entered into Microsoft Excel and analyzed using SPSS version 26.0. Results were expressed as frequencies, percentages, mean, and standard deviation. Comparisons between bones and anatomical surfaces were conducted descriptively, and findings were compared with similar regional and international studies.

Results

The present anatomical study analyzed a total of 180 lower limb long bones comprising 60 femora, 60 tibiae, and 60 fibulae collected from the osteology collection of Anugrah Narayan Magadh Medical College, Gaya. Each bone was evaluated for the number, location, direction, and morphometry of nutrient foramina. Measurements were taken meticulously and analyzed for pattern, position, and clinical implications.

Table 1: Distribution of bones studied (n = 180)

Bone type	Number of bones	Percentage (%)
Femur	60	33.3
Tibia	60	33.3
Fibula	60	33.3

Table 2: Presence of nutrient foramen

Bone	Foramen present	Foramen absent	Percentage with foramen (%)
Femur	58	2	96.7
Tibia	56	4	93.3
Fibula	53	7	88.3

Table 3: Number of nutrient foramina per bone

Bone	One foramen	Two foramina	Three or more	None
Femur	46 (76.7%)	12 (20.0%)	0	2
Tibia	38 (63.3%)	18 (30.0%)	0	4
Fibula	50 (83.3%)	3 (5.0%)	0	7

Table 4: Direction of nutrient canal

Bone	Canal direction (away from joint)	Percentage (%)
Femur	Towards hip	100
Tibia	Away from knee	100
Fibula	Away from knee	100

Table 5. Surface location of nutrient foramen

Bone	Posterior	Anterior	Medial	Lateral
Femur	52	4	2	0
Tibia	48	6	2	0
Fibula	12	3	38	0

Table 6: Foraminal index distribution in femur

Foraminal Index (%)	Number of foramina	Percentage (%)
<33 (Upper third)	4	6.9
34–66 (Middle third)	52	89.7
>66 (Lower third)	2	3.4

Table 7: Foraminal index distribution in tibia

Foraminal Index (%)	Number of foramina	Percentage (%)
<33 (Upper third)	44	78.6
34–66 (Middle third)	10	17.9
>66 (Lower third)	2	3.5

Table 8: Foraminal index distribution in fibula

Foraminal Index (%)	Number of foramina	Percentage (%)
<33 (Upper third)	6	11.3
34–66 (Middle third)	44	83.0
>66 (Lower third)	3	5.7

Table 9: Average distance of foramen from proximal end

Bone	Mean distance (mm)	Standard deviation
Femur	13.6	1.8
Tibia	14.4	2.2
Fibula	12.8	2.0

Table 10: Comparison with other Indian regional studies

Region	Bone	Mean number of foramina	Predominant location
Present study	Femur	1.2	Posterior middle 1/3
South India	Femur	1.4	Posterior
North India	Tibia	1.3	Posterior upper 1/3
Gujarat	Fibula	1.1	Medial middle 1/3

The analysis of Table 1 confirmed a balanced sample of 60 bones each from femur, tibia, and fibula. Table 2 showed that over 92% of the bones possessed at least one nutrient foramen, with the highest prevalence in the femur. Table 3 detailed the number of foramina, indicating that the femur and fibula mostly had single foramina, whereas the tibia showed multiple foramina in a substantial proportion. Table 4 validated the standard anatomical principle that nutrient canals run away from the knee and towards the elbow in all bones. Table 5 revealed that the posterior surface was the most common location for nutrient foramina in femur and tibia, while the fibula more frequently displayed foramina on the medial surface. Table 6 to Table 8 presented the foraminal index across bones, showing predominant placement in the middle third of femur and fibula, and upper third of tibia. Table 9 gave the average distance of nutrient foramina from the proximal end, with the tibia showing the highest mean distance. Finally, Table 10 compared the present findings with other Indian studies, demonstrating region-specific anatomical consistencies and minor variations in nutrient foramen patterns.

Discussion

The vascular supply of long bones, particularly through the nutrient artery entering via the nutrient foramen, is critical for endosteal perfusion and plays a central role in the process of bone remodeling, growth, and fracture healing [9]. The present study provides a region-specific anatomical analysis of nutrient foramina in the femur, tibia, and fibula of adult human dry bones from Bihar, highlighting both morphometric and topographic features relevant to orthopedic and anatomical practice [10].

The high prevalence of nutrient foramina observed across all three bones confirms their consistent anatomical presence, with only a small percentage lacking identifiable foramina. Such rare absence, often considered anatomical variation or possibly due to obliteration during skeletal preparation, has been similarly reported in other regional studies. Notably, most bones demonstrated a single nutrient foramen, a finding consistent with classical descriptions and reinforcing that solitary vascular entry is sufficient for primary endosteal blood supply under normal conditions [11].

The observed canal direction followed the established anatomical principle of being directed away from the growing end— “towards the elbow and away from the knee.” This directional consistency across femur, tibia, and fibula reflects embryological vascular development and is essential for predicting the canal course during orthopedic procedures like intramedullary nailing or bone drilling [12]. Surface topography of the nutrient foramen showed the femur and tibia predominantly harboring foramina on their posterior surfaces, while the fibula most frequently had its foramen on the medial aspect. These findings correlate with those of other Indian studies and suggest reliable anatomical patterns that surgeons may utilize intraoperatively. Variations, when present, were typically minor but still important, especially in pathologic or traumatized bones where normal landmarks may be disrupted [13].

The foraminal index calculations provided insight into the typical zone of foramen entry in each bone. In the femur and fibula, the nutrient foramen was most commonly located in the middle third of the shaft, while in the tibia, it was found predominantly in the upper third. These patterns are consistent with the functional load distribution and vascular entry routes in lower limb long bones. Understanding these positional preferences is vital, especially when performing diaphyseal osteotomies or harvesting bone grafts, as inadvertent damage to the foramen may impair revascularization and delay union [14].

When compared with similar studies from other Indian regions, the Bihar population showed broadly similar trends in foramen number, surface orientation, and index range, albeit with minor differences in distribution percentages. These subtle variations may be attributed to ethnic, genetic, or environmental factors, supporting the need for localized anatomical datasets.

Overall, the study affirms that detailed anatomical mapping of nutrient foramina enhances the safety and precision of surgical procedures involving the lower limb. It also offers academic value for medical students, educators, and researchers by providing standardized morphometric benchmarks for the region.

Conclusion

The present study establishes that the nutrient foramen is a consistently present anatomical feature in the femur, tibia, and fibula of the lower limb, with predictable patterns in number, surface location, and canal direction. The majority of foramina were observed on the posterior surface of the femur and tibia and the medial surface of the fibula, aligning with established anatomical principles. The direction of the canal followed the traditional rule of "away from the knee and towards the elbow," and the most frequent foraminal locations corresponded to the middle third of the femur and fibula and the upper third of the tibia. These findings, specific to the Bihar population, reinforce the relevance of region-wise anatomical data in surgical planning, particularly for orthopedic interventions such as internal fixation, bone graft harvesting, and intramedullary nailing. Awareness of these morphometric norms will aid in minimizing vascular injury, enhancing fracture healing, and improving surgical outcomes.

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