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RESEARCH ARTICLE

THE NUMBER AND LOCATION OF THE DIAPHYSEAL NUTRIENT FORAMEN ON HUMAN DRY LONG BONES OF THE LOWER LIMB IN UTTARAKHAND REGION

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ABSTRACT

Aims and Objectives: The aim of the present study is to observe and analyze the diaphyseal nutrient foramen on the human dry long bones of the lower limb in Uttarakhand region, India, to know the number and location of the diaphyseal nutrient foramen following its general rule which is directed away from the growing end. **Materials and Methods:** The present study consists of 75 human dry long bones of lower limb (25 femur, 25 tibiae, 25 fibulae),taken from the department of Anatomy, Sri Guru Ram Rai Institute of Medical and Health Sciences, Dehradun,Uttarakhand, India. The foraminal indices (by Hughes formula) and mean value were calculated for each bone. Digital calliper was used for the measurements of the nutrient foramen from the higher point of the proximal end of the bone. **Results:** The neurovascular foramen was present in all 75(100%) observed bones. 42 diaphyseal nutrient foramina in Femur, 27 in tibiae and 28 in fibulae were noticed. The maximum nutrient foramina were located along the middle third of the femur with the foramen index ranging between 28.83 and 66.52% of the bone length. In Tibia 23(85.18%) maximum were in the proximal third (Type-1) and 4(14.81%) were in the middle third (Type-2) with the foramen index ranging between 24.45 and 54.38% of the bone length. There was a variation seen in the tibiae at the middle third of the posterior surface, a nutrient foramina was conducted which directed to the upper end of the tibiae **(Photograph-10)** whereas all the other foramina observed directed distally. The maximum nutrient foramina of fibulae were situated in the middle third of the bone with a foramen index ranging between 32.23 and 63.86% of the bone length. There were no foramina in the distal third (Type-3) of any observed bone. There was a variation conducted at the flattened part of the posterior surface showing the double nutrient foramina at the same place near each other at middle 1/3rd of the bone (Photograph-11, Photograph-12) directed distally. **Conclusion:** This study provides the ethnic data on lower limb long bones of Uttarakhand region to compare with bones of various populations. It is helpful for interpretation of radiological images and various surgical procedures also.

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INTRODUCTION

Bone is a living tissue; it requires the nutrition for its growth and development. Its strength provides support and protection to the body. Unlike cartilage, bone adapts to changing mechanical demands, and to regenerate following injury. They adapt to the presence of naturally occurring holes from a foetal age which allow blood vessels to pass through the bone cortex. [1, 2] The Nutrient foramen is the cavity that conducts the nutrient artery and the peripheral nerves. It is directed towards the elbow in upper limb long bones and away from the knee in lower limb long bones.

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The growing end is supposed to grow at least twice as fast as the other end therefore the position, obliquity of the nutrient foramen and the nutrient artery are very variable in their positions. As a characteristic, the diaphyseal nutrient vessels move away from the growth extremity is dominant in the bone. [2, 5] The role of the nutrient foramina in the nutrition and growth of the bones is evident from the term 'Nutrient' itself. It is usually present near the middle of shaft and gives passage to the blood vessels of the medullary cavity of the long bone sand in the cavities of the spongy bone for the entry of nutrient artery. Their positions in mammalian bones are variable and may alter during the growth phase. [2, 3, 4) Long bones consist of three parts: elongated tubular shaft (diaphysis) and two expanded growing ends (the epiphyseal ends).

It contain the medullary cavity filled with bone marrow. They are weight bearing and are found in limbs and act as levers for muscle. A typical long bone develops from a preformed model of hyaline cartilage. The two ends are formed by secondary centres of ossification and the shaft is formed by the primary centre of ossification. There are four parts of young long bone: Epiphyses, epiphyseal plate, metaphysis and diaphysis before the ossification is complete. Metaphysis is the most actively growing area of a long bone. Before the fusion of the epiphysis, the metaphysis is profusely supplied by blood from nutrient, periosteal and juxta-epiphyseal (metaphyseal) arteries. These are end arteries and form hair- pin like bands. Therefore metaphysis is the common site of osteomyelitis in children for bacteria and emboli are easily trapped in hair-pin bends leading to infarction. [3, 5]

The major blood supply for long bones originates from the nutrient arteries. The nutrient artery is the principal source of blood supply to a long bone and is particularly important during its active growth period in the embryo and foetus, as well as during the early phases of ossification. During childhood, the nutrient arteries provide 70-80% of the interosseous blood supply to long bones. When this supply is compromised, medullary bone ischemia occurs with less vascularization of the metaphysis and growth plate, and in the case of their absence, the vascularization occurs through the periosteal vessels. [2, 5, 6] Nutrient foramina reflect not only bone vascularization but also pathological bone conditions, like fracture healing, developmental abnormalities or acute haematological osteomyelitis. It is emphasized that an understanding of the location, number, direction and calibre of nutrient foramina in long bones is very important clinically, especially in orthopaedic surgical procedures such as bone grafting, vascularized bone microsurgery, peripheral vascular occlusive disease, longitudinal bone growth, non-unions, joint replacement therapy, and resection techniques, intramedullary reaming and plating, as well as in medico legal cases.[4, 6] A considerable interest in studying the number and location of the nutrient foramina is important not only morphologically but also from the clinical aspect. However, there is still a need for a greater understanding of the number, location, size, direction and obliquity of nutrient foramina in bones such as the humerus, radius, ulna, femur, tibia and fibula.

MATERIAL AND METHODS

The present study consists of the 75 adult human cleaned and dried long bones of the lower limb, obtained from the osteology collection in the department of Anatomy of Shri Guru Ram Rai Institute of Medical and Health Sciences Dehradun, Uttarakhand, India. The bones were divided into three groups. Group 1: Consist of 25 femora (14 right sided and 11 left sided). Group 2: Consist of 25 tibiae (13 tibiae right sided and 12 tibiae left sided). Group 3: Consist of 25 fibulae (11 fibulae right sided and 14 fibulae left sided). All selected bones were normal with no appearance of pathological changes. The specific age and sex characteristics of the bones studied are unknown. The bones sides are just observed morphologically by seeing the external features, therefore the unequal count of the bones of the right and left sided were taken for the observation as present in the osteology collection in the department. Determination of the nutrient foramina in all bones was observed with the help of a hand-lens. They were identified by their elevated margins and by the presence of a distinct groove proximal to them. Only well-defined foramina on the diaphysis were accepted. Foramina at the ends of the bone were ignored. The 24 gauge hypodermic needle (0.56 mm in diameter) is used to identify the dominant diaphyseal foramen (Kizilkanat et al; 2007). [9] Osteometric board and scale were used to conduct the total length of the bones. Digital calliper was used to analyse the distance from the proximal end of the bone to the diaphyseal nutrient foramen. (Photograph: 1, 2, 3, 4) The following data was studied on the diaphyseal nutrient foramina for each bone:

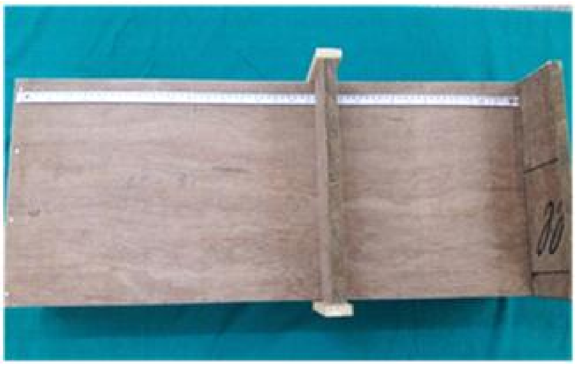
Number: Only well-defined foramina on the diaphysis were accepted.

Position: The position of all nutrient foramina was determined by calculating a foraminal index (FI) by using the formula: FI = (DNF/TL) x 100 (Hughes, 1952; Shulman, 1959). [7, 8]

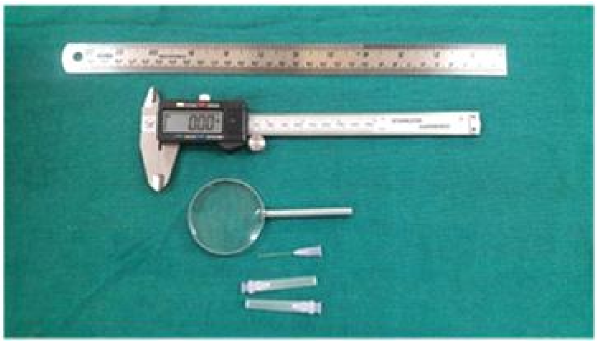
DNF = the distance from the highest point on the proximal end of the bone to the nutrient foramen, was taken to the nearest 0.1 mm using a Digital Calliper for the each bone. TL = total bone length. The distance between the proximal aspect of the head and the most distal aspect of the medial condyle for femur, the distance between the proximal margins of the medial condyle and the tip of the medial malleolus for tibiae and the distance between the apex of the head and the tip of the lateral malleolus for fibulae were observed for the total length measurements with the help of the Ostometric board and scale. The foramen with FI up to 33.33% is considered as type: 1 and is present on the proximal one third of the bone, FI from 33.33% up to 66.66% is considered as type: 2 and is present on the middle third of the bone and FI above 66.66%, were considered as in the distal third of the bone and were type: 3. The results were analysed and tabulated using the Statistical Package of Social Sciences (SPSS) 8.0 windows. The range, mean and standard deviation of FI were determined.

RESULTS

The total of femora observed was 25 out of which 9(36%) had a single foramen, 15(60%) had double foramina and 1(4%) had a triple foramina (Table-1), (Fig.1). The number of the diaphyseal nutrient foramina observed was 42 in the present study. The maximum nutrient foramina were located along the middle third of the femur with the foramen index ranging between 28.83 and 66.52% of the bone length. Of the total 42 foramina, 9(21.42%) were in the proximal third (Type-1) and 33(78.57%) in the middle third (Type-2). There were no foramina in the distal third (Type-3) of the bones. And at surfaces of all 42 femoral foramina, 7(16.66%) were on the medial lip of the linea aspera, 6(14.28%) between the two lips of linea aspera, 2(4.76%) on the gluteal tuberosity, 4(9.52%) at the spiral line, 7(16.66%) on the medial surface (middle 1/3rd), 2(4.76%) medial to spiral line and 14(33.33%) between the spiral line and the gluteal tuberosity (posterior surface at upper 1/3rd of the shaft) (Table-2), (Fig.2). The total tibiae bone examined were 25 in number, out of which 23 tibiae (92%) had a single nutrient foramen while 2(8%) had a



Photograph.1: The Osteometric board



Photograph 2: Scale, Digital calliper, Hand lens, Hypodermic needle (24 gauge)

Photograph.3: Total length of the Tibia in Osteometric board (the distance between the proximal margins of the medial condyle and the tip of the medial malleolus)

Photograph.4: The distance from the apex of the head of the fibula to the nutrient foramen by Digital Caliper

The total of femora observed was 25 out of which 9(36%) had a single foramen, 15(60%) had double foramina and 1(4%) had a triple foramina (Table-1), (Fig.1). The number of the diaphyseal nutrient foramina observed was 42 in the present study. The maximum nutrient foramina were located along the middle third of the femur with the foramen index ranging between 28.83 and 66.52% of the bone length. Of the total 42 foramina, 9(21.42%) were in the proximal third (Type-1) and 33(78.57%) in the middle third (Type-2). There were no foramina in the distal third (Type-3) of the bones. And at surfaces of all 42 femoral foramina, 7(16.66%) were on the medial lip of the linea aspera, 6(14.28%) between the two lips of linea aspera, 2(4.76%) on the gluteal tuberosity, 4(9.52%) at the spiral line, 7(16.66%) on the medial surface (middle 1/3rd), 2(4.76%) medial to spiral line and 14(33.33%) between the spiral line and the gluteal tuberosity (posterior surface at upper 1/3rd of the shaft)(Table-2), (Fig.2). The total tibiae bone examined were 25 in number, out of which 23 tibiae (92%) had a single nutrient foramen while 2(8%) had a double nutrient foramina(Table-1), (Fig.1). The diaphyseal nutrient foramina observed in tibiae was 27. Of the total 27foramina, 23(85.18%) maximum were in the proximal third (Type-1) and 4(14.81%) were in the middle third (Type-2) with the foramen index ranging between 24.45 and 54.38% of the bone length. There was a variation seen in the tibiae at the middle third of the posterior surface, a nutrient foramina was conducted which directed to the upper end of the tibiae (Photograph-10) whereas all the other foramina observed directed distally. There were no foramina in the distal third (Type- 3). All foramina were located on the posterior surface of the tibiae, 1(3.70%) were at soleal line, 10(37.03%) at the lateral part of the posterior surface, 2(7.40%) at the medial part of the posterior surface, 2(7.40%) at the vertical ridge present on the posterior surface, 1(3.70%) at the posterior surface (at middle ^{3rd}), 6(22.22%) were located at the lateral part of the posterior surface near to the vertical ridge, and 5(18.51%) were located at the lateral part of the posterior surface near interosseous border (Table-3), (Fig.3). Out of 25 fibulae examined, 22(88%) showed a single foramen while 2(12%) possessed double foramina (Table-1), (Fig.1). And the total number of the diaphyseal nutrient foramina was 28 in all observed fibulae. The maximum nutrient foramina of fibulae were situated in the middle third of the bone with a foramen index ranging between 32.23 and 63.86% of the bone length. Of the total 28 foramina, 27(96.42%) existed in the middle third(Type-2) and 1(3.57%) were in the proximal third (Type-1). There were no foramina in the distal third (Type-3).There was a variation conducted at the flattened part of the posterior surface showing the double nutrient foramina at the same place near each other at middle 1/3rd of the bone (Photograph-11, Photograph-12) directed distally. And while looking at the location of the diaphyseal nutrient foramina of the examined fibulae of all the 28 fibular foramina, 10(35.71%) were on the medial crest of the posterior surface, 4(14.28%) on the posterior surface between medial crest and interosseous border (concave part/surface), 1(3.57%) on the posterior surface, and 13(46.42%) on the posterior surface between the medial crest and the posterior border (flattened part) (Table- 4), (Fig.4).

DISCUSSION

In the observation of 25 femora in the present study, 9 (36%) bone had only one nutrient foramen, 15 (60%) possessed double nutrient foramina, while 1(4%) posses the triple nutrient foramina. In the previous literatures, a discrepancy was noticed regarding the number of nutrient foramina in the femora. Many authors stated that the majority of femora studied had double nutrient foramina [10, 11, 12] while others reported the presence of a single foramen in most specimens. [9, 13, 14, 15]

Table 1. The number of the nutrient foramina observed in the long bones of the lower limb.

S.No.	Bone	Total No. of Bone	Number of bone	Number of foramina	%
1	Femur	n = 25	9	1	36
			15	2	60
			1	3	4
2	Tibia	n = 25	23	1	92
			2	2	8
3	Fibula	n = 25	22	1	88
			3	2	12

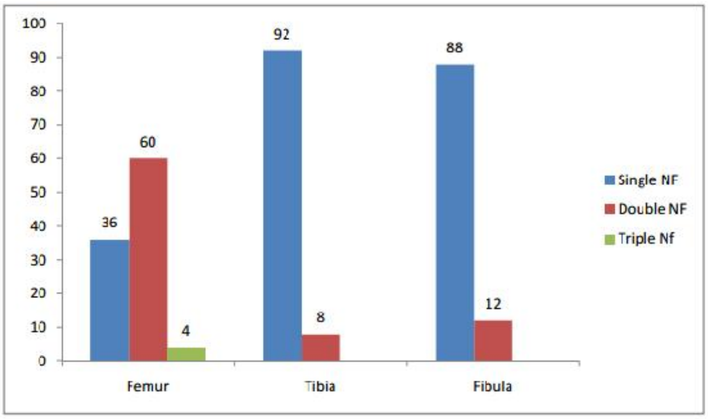


Figure 1. Showing the % of NF in the lower limb long bones

Table 2. The Location of the nutrient foramina observed in the Femora

S.No.	Location	Total number foramina	Number of NF	%
1	Between lineaaspara	42	6	14.28
2	Posterior surface (upper 1/3rd)		14	33.33
3	At medial lip of lineaaspara		7	42
4	Medial surface (upper 1/3rd) medialto spiral line		2	4.76
5	Medial surface (middle 3rd)		7	16.66
6	At spiral line		4	9.52
7	At gluteal tuberosity		2	4.76

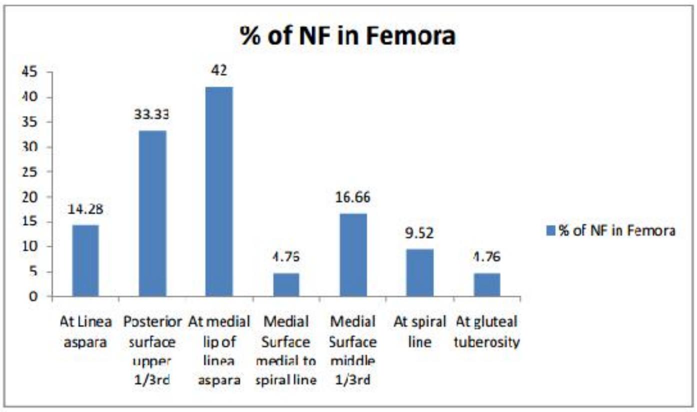


Figure 2. Showing the % of NF in different surfaces of Femora

SN	Location	Total number of foramina	Number of NF	%
1	At soleal line		1	3.703
2	At lateral part of the posterior		10	37.037
	surface (upper 1/3rd)			
3	At medial part of the posterior		2	7.407
	surface (upper 1/3rd)			
4	At the vertical ridge	27	2	7.407
5	At posterior surface (middle 1/3rd)		1	3.703
6	At lateral part of the posterior		6	22.22
	surface near vertical ridge			
	(upper 1/3rd)			
7	At lateral part of the posterior		5	18.518
	surface near lateral (interosseous)			
	border			
	(upper 1/3rd)			

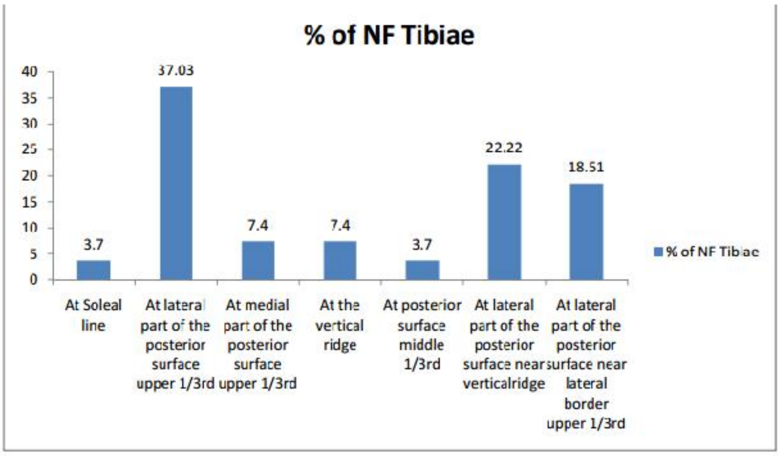


Figure-3:Showing the % of NF indifferent surfaces of Tibiae.

Table 4. The Location of the nutrient foramina observed in the Fibulae.

S.No.	Location	Total number of foramina	Number of NF	%
1	At the medial crest present at the posterior surface (upper $1/3^{rd}$)	28	10	35.71
2	At the posterior surface		1	3.57
3	At flattened part of the posterior surface (upper $1/3^{rd}$)		13	46.42
4	At concave part of the posterior surface (upper$1/3^{rd}$)		4	14.28

Table – 5: The range and mean ± standard deviation (SD) of the foraminal indices of the bones of the lower limb

S.No.	Bone	Total number of Bone	Side	%	Range	Mean±SD
1	Femur	n = 25	R=11	44	28.83-66.52	43.52± 12.27
			L=14	56	29.85-65.98	44.92± 11.82
2	Tibia	n = 25	R=13	52	24.45-54.38	31.14± 7.35
			L=12	48	26.5-35.17	31.13± 2.42
3	Fibula	n = 25	R=11	44	37.3-62.15	-43.53± 7.21
			L=14	56	32.23-63.86	45.02± 9.29

Photograph.5: Femur- showing the double nutrient foramina, one (at the end of the spiral line), second (at medial surface near medial lip of linea aspara.

Photograph.6: Femur- showing the single nutrient foramen at posterior surface (upper $1/3^{rd}$) between the gluteal tuberosity and the spiral line

Photograph.7: Tibiae- showing the single nutrient foramen at the posterior surface (middle $1/3^{rd}$) with the direction upwards

(Photograph.8: Fibulae- showing the double nutrient foramen at the flattened part of the posterior surface.

Photograph 9. Fibulae- showing the double nutrient foramina at the same surface (flattened part of the posterior surface) and present near each other

Three nutrient foramina were observed in a small number of femora (2.19% - 10.7%). [11, 12, 13, 14] Number of the nutrient foramina seen as high as six [12] and up to nine [16] while others confirmed the absence of nutrient foramina in some femora. [10, 12, 15] In the present study, most of the nutrient foramina (83.33%) were located along the middle third of the femur; the rest were in the proximal third, with no foramina detected in the distal third of the femur. These results were in accordance with the previous studies. [9, 10, 11, 12, 16] However, these findings did not coincide with others who stated that the nutrient foramina were closer to the hip joint. [11, 13] Similar to the present study Laing (1953) attributed the lack of the nutrient foramina in the lower third of the femur to the absence of vessels entering this part of bone. Femoral diaphyseal foramina were located at linea aspera, gluteal tuberosity, spiral line, between the spiral line and the gluteal tuberosity in the resent study (Table-2), (Fig.2). Others stated that more than 58.33% of nutrient foramina where concentrated along the linea aspera. [12, 13, 14, 16.] Among of all 25tibiae examined maximum 23(92%) had a single nutrient foramen while 2(8%) had a double nutrient foramina similarly to some of the previous studies. They also reported the presence of double nutrient foramina in some of the tibiae. [10, 11, 12, 14, 16] Maximum foramina were found in the proximal third (Type-1). Similarly, many authors reported the presence of the majority of nutrient foramina in the proximal third of the tibia. [10, 12, 14] On the other hand some stated the presence of the maximum nutrient foramina in the middle third of the bone. [9] A nutrient foramina was conducted at the middle third of the posterior surface of the tibia, which directed to the upper end of the tibia as a variation (Photograph.7) where as all the other foramina observed, directed distally. Similar to what other had stated all foramina were located at soleal line, at the vertical ridge, near interosseous border present on the posterior surface (Table-3), (Fig.3) on tibiae in the present study. [9, 10, 11, 12, 14, and 16].

Similar to the other reports, in the total observed fibulae maximum bones presented a single nutrient foramen and few bones possessed double nutrient foramina. [10, 11, 14, 16] While Mckee et al. (1984) reported fibulae with three nutrient foramina. [17] On the other hand some reported fibula with no nutrient foramina. [9, 10, 12, 17] . The maximum nutrient foramina of fibulae were situated in the middle third of the bone and few were in the proximal third. These results were in agreement with most of the previous studies. [10, 11, 12, 16, 17 and 18] Nutrient foramina were located on the medial crest and on the posterior surface of fibula (Table- 4), (Fig.4) in the present study similarly to some of the previous studies. [10] However, some authors observed more nutrient foramina on the posterior surface compared to those on the medial crest. [9, 11, 12, 17, 19] Others reported that the majority of foramina were on the medial surface of the fibula. [16] There was a variation conducted at the flattened part of the posterior surface showing the double nutrient foramina at the same place near each other at middle 1/3rd of the bone (Photograph.8, Photograph.9) directed distally in the present study. There were no foramina in the distal third (Type-3) of the femur, tibiae and fibulae.

CONCLUSION

The present study provides the information of number and location of the diaphyseal nutrient foramina on the long bones of the lower limb in Uttarakhand region, India, and results are consistent with the previous studies. Most of the nutrient foramina were observed on the flexor surface of the bones and predominantly single. It might be that, being more bulky, stronger and more active, flexors need more blood supply compared to extensors of limbs. The foramen may be a potential area of weakness in some patients and, when under stress because of increased physical activity or decreased quality of the bone, the foramen may allow development of a fracture. The areas of nutrient foramen distribution must be avoided during surgery as in most of the cases it can be a single source of blood supply. The healing of fractures, as of all wounds, is dependent upon blood supply. The rate of healing of a fracture is related to the vascular supply of the bone. The areas or regions with a good blood supply are more rapidly healed than those with a poor blood supply. The tibia is a good example of such process. Because of the absence of nutrient foramina in the distal third of the tibia, fractures in that region tend to show delayed union or malunion. Knowing the variations in the distribution of the nutrient foramina is important preoperatively, specially regarding the fibula used in bone grafting. This study will provide the ethnic data for comparison as well as in various surgical procedures and in interpretation of radiological images.

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