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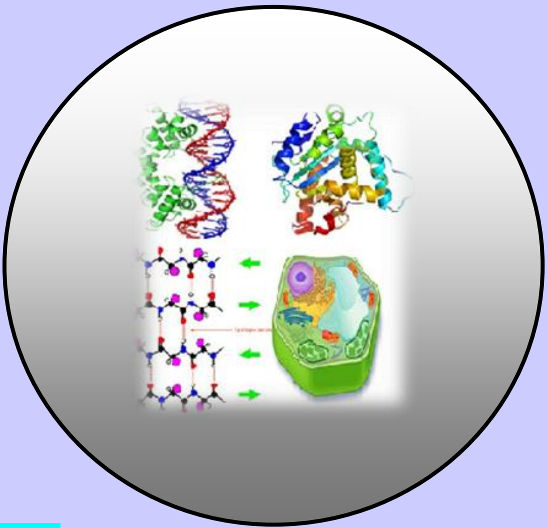

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RESEARCH PAPER

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An Osteological Study of Diaphyseal Nutrient Foramen in Human Tibia

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ABSTRACT

The nutrient foramen (NF) of tibia is located in proximal third of its diaphysis allowing passage of nutrient artery into the medullary cavity. Damage to nutrient artery during fracture may lead to poor repair or bone infarct. We investigated the location, number of diaphyseal foramina, distance and position of foramina in relation to the length of bone and latero-medial, antero-posterior diameter of the bone at nutrient foramen and foraminal index. The study was performed in the Department of Anatomy, King George's Medical University, Lucknow, UP, India. Adult tibia were randomly selected from bone room of the department, the specific age and sex of the bone were unknown. Bones were inspected macroscopically and damaged bones were excluded. The present study was conducted on 100 dried tibia of which 53 belongs to right side and 47 to left side. Length of tibia and various distances of nutrient foramen in relation to the length of the tibia were taken with the help of osteometric board while diameters of nutrient foramen taken by Vernier calliper.

We observed that the mean length of the right tibia was 37.4cm and left tibia 36.5cm. The incidence of nutrient foramen on upper 1/3rd was 55.5% (right tibia 53.4%, left tibia 57.7%), 19.1% NF were on middle 1/3rd (right tibia 24.2%, left tibia 13.5%) and 25.5% NF were at the junction of upper and middle 1/3rd and no foramen was seen on distal third. The direction of 97.2% NF was downwards (right tibia 96.6%, left tibia 98.1%) while only 2.7% NF were directed upwards (right tibia 3.4%, left tibia 1.9%). This osteological study of nutrient foramen can be of help to surgeons to preserve nutrient artery which are crucial in performing successful orthopaedic procedures.
Keywords: Tibia, Diaphysis, Nutrient Foramen and Nutrient artery.

INTRODUCTION

The nutrient foramen of tibia is a cavity in proximal third of flexor aspect of diaphysis allowing passage of nutrient artery into medullary cavity, and conventionally vessel which occupy the nutrient foramen is derived from those that took part in the initial invasion of the ossifying cartilage so that nutrient foramen was the site of original centre of ossification (Payton 1934, Longia et al. 1980). The term 'nutrient' itself indicates the role of nutrient foramen in nutrition and growth of the bone (Kate 1971). Berard (1835) was the first to point out that in human long bones, the nutrient canal were obliquely disposed pointing towards elbow in the upper limb and away from knee in the lower limb, derived an axiom "To the elbow I go and from knee I flee". During childhood, 70% to 80% of interosseous blood supply to long bone is provided by nutrient artery but in its absence periosteal vessel become the sole source of supply (Trueta 1953). Thorough knowledge about blood supply to long bones is one of the important factors for success of new technique in bone transplant and resection in orthopaedics (Guo 1981). It is important to preserve nutrient artery in free vascularized bone graft so that osteocytes can survive in case of tumour resection, trauma and congenital pseudoarthrosis, its preservation also facilitate graft healing in the recipient and promote healing at fracture site (Longia et al. 1980, Sendemir et al. 1991, Gumusburun et al. 1994).

MATERIAL AND METHODS

The present study analysed 100 dry specimen of tibia of which 53 belongs to right side and 47 belongs to left side, obtained from osteology section of Department of Anatomy King George's Medical University, UP, Lucknow. Damaged incomplete and unossified bones were excluded while bones with normal appearance and no pathological changes were included in the study. The specific age and sex of tibia under study was not known. All bones were observed macroscopically for diaphyseal nutrient foramina which were identified by presence of groove and an elevated edge at the commencement of the canal. Instruments used for study were an osteometric board, Vernier calipers, hypodermic needle to determine the direction of nutrient foramen, hand lens and marking pen. Various parameters were taken using above instruments after numbering tibia serially with marking pen. Following measurements were taken:

1. Length of the tibia by osteometric board (Fig.1).
2. Number of nutrient foramina (NF)
3. Location of nutrient foramen with respect to the soleal line (medial/lateral/on)
4. Location of nutrient foramen with respect to shaft of tibia (upper/middle/lower) by dividing the tibia into three equal parts by placing it on osteometric board.
5. Direction of nutrient foramen by help of hypodermic needle. It was recorded as 'upward' or 'downward' with respect to the proximal end of the long bone being up.
6. Latero-medial diameter of shaft of tibia at nutrient foramen by using Vernier calipers.
7. Antero-posterior diameter of shaft of tibia at nutrient foramen by using Vernier calipers.
8. Distance between the nutrient foramen and the highest point of intercondylar eminence (D).
9. Foraminal index (FI) – By applying Hughes (1952) formula, dividing the distance of the foramen from the intercondylar eminence (D) by the total length of the bone (L) which was multiplied by hundred [FI = (D/L) × 100].

RESULTS

The morphometric study conducted on 100 adult dry human tibia (53 right sided tibia and 47 left sided tibia) revealed the following important observations, which were recorded and the data was compiled.

Out of 53 right sided tibia studied, total 58 nutrient foramen were noticed, which accounts for 48 tibia (90.6%) with single nutrient foramen and 5 tibia (9.4%) with double foramen. Out of 47 left sided tibia studied, total 52 nutrient foramen were noticed, which comprised of 42 left tibia (89.3%) with single nutrient foramen and 5 tibia (10.6%) with double foramen [Fig.2, Table 1]. Out of 58 NF in right tibia, 48 NF (82.8%) were lateral to soleal line, 3 NF (5.2%) were on the soleal line, 1 NF (1.7%) medial to soleal line, 6 NF (10.3%) on lateral border and 0 NF (0%) on medial border. Out of 52 NF in left tibia, 41 NF (78.8%) were lateral to soleal line, 6 NF (11.6%) were on the soleal line, 2 NF (3.8%) were medial to soleal line, 3 NF (5.8%) were on lateral border and 0 NF (0%) on medial border (Fig. 3,4&5,Table 2&3). Out of 58 NF in right tibia, 31 NF (53.4%) were observed in upper 1/3 of shaft, 14 NF (24.2%) in middle 1/3 of shaft and 13 NF (22.4%) at junction of upper and middle. Most of NF in right tibia were directed downwards (96.6%) while only 2 NF were directed upwards (3.4%). Out of 52 NF in left tibia, 30 NF (57.7%) was present in upper 1/3 of shaft, 7 NF (13.5%) in middle 1/3 of shaft and 15 NF (28.8%) at the junction of upper and middle third of shaft. In left tibia also most of the NF (98.1%) was directed downwards while only 1 NF (1.9%) was directed upwards (Fig. 5, Table 4&5). Mean of latero-medial and antero-posterior diameter of the shaft of right tibia at level of NF were 20.6±2.1mm and 28.9±2.6 mm respectively and on shaft of left tibia at level of NF were 18.8±2.2mm and 28.2±3.1mm respectively [Fig.6, Table 6]. Mean Length, mean distance (D) and mean foraminal index of right tibia were37.4±2.7cm,12.3±2.9mm and 32.8±2.9 respectively while that for left tibia were 36.5±2.4cm,11.8±1.4mm and 32.2±3.0 respectively (Table 7).

DISCUSSION

Tibia is a very vascular bone and its vascularity is chiefly maintained by nutrient artery that enters the shaft of bone obliquely through nutrient foramen which leads into nutrient canal. Site of entry and angulation of nutrient artery are almost constant and characteristically directed away from dominant growing epiphysis, this is because one end of the long bone grows faster than other. Nutrient artery is a branch from posterior tibial artery supplying 2/3rd of cortex and is the principal source of blood supply to shaft of tibia and is important during its active growth period as well as during the early phase of ossification (Lewis 1956, Mysorekar 1967, Patake et al. 1977, Forriol et al. 1987), it is also supplemented by epiphyseal, metaphyseal and periosteal vessels in providing blood supply to the shaft. Morphological knowledge of nutrient foramen is very important for orthopaedic surgeon undertaking an open reduction of the fracture to avoid injury to nutrient artery and thus lessening the chances of delayed or non-union (Joshi et al. 2011).

In the present study, we observed double nutrient foramen in 10 tibia (10%) and the remaining tibia showed single nutrient foramen (90%). The results are very much similar to that of Forriol et al. (1987) who reported 7% double foramen, Gumusburun et al. (1994) observed 84.9% single and 11.3% double foramen, Kirscher et al. (1998) observed 93.5% single and 6.5% double foramen, Udhaya et al. (2013) observed 93% single and 7.14% double foramen.

Patake et al. (1977) opined that the number of foramina does not have any significant relation to the length of the bone. Knowledge of number and location of nutrient foramen in long bones is important in surgical procedure such as in taking short bone grafts and vascularised bone microsurgery (Kizilkanat et al. 2007). In the present study, 8.1% nutrient foramen were on the soleal line (right tibia 5.2%, left tibia 11.6%), 3.3% were medial to soleal line (right tibia 1.7%, left tibia 3.8%) and 81% were lateral to soleal line (right tibia 82.8%, left tibia 78.8%). According to Mysorekar (1967) 4/182 (2.9%) NF were above and rest below soleal line. Observation by Collipal et al. (2007) showed 94.33% bones having NF under soleal line and 3.77% NF over the soleal line. Similarly, Prashanth et al. (2011) reported 95.7% below soleal line and 2.9% above soleal line while Vadhel et al. (2015) observed 95.7% lateral to soleal line and 4.3% over soleal line. So the findings of present study are in concurrence with earlier studies that most of the NF are below soleal line. In our study, 8.1% NF were on lateral border (right tibia 10.3%, left tibia 5.8%) almost similar observation was noted in a study done by Udhaya et al. (2013) where 5% NF were on lateral border. In present study, 55.5% nutrient foramen were on upper $1/3^{rd}$ (right tibia 53.4%, left tibia 57.7%), 19.9% NF were on middle $1/3^{rd}$ (right tibia 24.2%, left tibia 13.5%) and 25.5% NF were at junction of upper and middle $1/3^{rd}$ (right tibia 22.4%, left tibia 28.8%) and no foramen on distal third. In a study by Mysorekar (1967) 78.30% NF were on upper $1/3^{rd}$, 21.60% NF were on middle $1/3^{rd}$ and 0.10% at the junction of upper and middle parts. According to study conducted by Udhaya et al. (2013) 76.42% NF were on upper $1/3^{rd}$, 33% on middle $1/3^{rd}$ and no foramen on distal third. So in most of the population it was present in upper 1/3 except in a study by Kate (1971) where all NF were situated at junction of upper and middle $1/3^{rd}$. Kizilkanat et al. (2007) related the delayed or non-union in the middle and distal third of diaphysis following trauma, to the absence of nutrient arteries entering the bones. In present study, 97.2% NF were directed downwards (right tibia 96.6%, left tibia 98.1%) and 2.8% NF were directed upwards (right tibia 3.4%, left tibia 1.9%) which were in consensus with the findings of Udhaya et al. (2013) in which 95.71% NF were directed downwards on right side and 96.92% NF were directed downwards on left side. Above observations were in accordance with many other researchers (Longia et al. 1980, Forriol et al. 1987, Gumusburun et al. 1994). The direction of nutrient foramen is determined by the growing end of bone. The nutrient artery runs away from growing end and hence the nutrient foramina, to avoid rupture or pull of artery by rapid growth of growing end. The growth rate at two ends of the shaft and bone remodelling are two factors that may affect nutrient foramen position (Henderson 1978).In our study, mean latero-medial diameter of shaft at level of nutrient foramen was 20.6$\pm$2.1mm on right side and 18.8$\pm$2.2mm on left side while mean anterior-posterior diameter of shaft at level of nutrient foramen was 28.9$\pm$2.6mm on right side and 28.2$\pm$3.1mm on left side which almost coincide with study by Collipal et al. (2007) who reported mean latero-medial diameter of the shaft at level of NF on right side 24.1mm and on left side 24mm while mean of antero-posterior diameter of the shaft at the level of NF on right side was 34mm and on left side 33.4mm. In a study conducted by Ankolekar et al. (2013), the mean latero-medial diameter of the shaft at level of NF on right side was 26mm and on left side 28mm while mean antero-posterior diameter of the shaft at the level of NF on right side was 34.5mm and on left side 34mm.

In present study, mean length was 37.4±2.7cm on right side and 36.5±2.4cm on left side. The results are in accordance with that of Collipol et al. (2007) who observed mean length of tibia 35.5cm on right side and 35.4cm on left side. Udhaya et al. (2013) reported mean length of tibia 35.2±2.4cm on right side and 35.9±2.1cm on left side while Ankolekar et al. (2013) reported mean length of tibia 37.3cm on right side and 38.7cm on left side. The mean distance (D) of right tibia between the NF and the highest point of intercondylar eminence was 12.3±2.9cm and of left tibia was 11.8±1.4cm in present study. The findings of our investigation were similar to the reports of Udhaya et al. (2013) and Ankolekar et al. (2013).

Table 1. Showing percentage of single and double nutrient foramen in tibia.

Side	Total No. of bones	Bones having single foramen		Bones having double foramina		Total no. of nutrient foramen
		No.	%	No.	%	
Right	53	48	90.6	5	9.4	48+(5x2) = 58
Left	47	42	89.3	5	10.6	42+(5x2) = 52
						Total = 110

Table 2. Showing position of nutrient foramen (NF) in relation to soleal line.

Side	Total no. of NF	NF on Soleal line		NF medial to Soleal line		NF lateral to Soleal line	
		No.	%	No.	%	No.	%
Right	58	3	5.2	1	1.7	48	82.8
Left	52	6	11.6	2	3.8	41	78.8
Total	110	9	8.1	3	2.7	89	81

Table 3. Showing position of nutrient foramen (NF) in relation to border of tibi

Side	Total no. of NF	NF at lateral border		NF at medial border	
		No.	%	No.	%
Right	58	6	10.3	0	0
Left	52	3	5.8	0	0
Total	110	9	8.1	0	0

Table 4. Showing position of nutrient foramen (NF) in relation to shaft of tibia.

Side	Total no. of NF	Location of NF on Shaft					
		Upper 1/3		Middle 1/3		Junction of upper and middle parts	
		No.	%	No.	%	No.	%
Right	58	31	53.4	14	24.2	13	22.4
Left	52	30	57.7	7	13.5	15	28.8
Total	110	61	55.5	21	19.1	28	25.4

In our present study, the mean foramen index (FI) of right side was 32.8±2.9 and of left side was 32.2±3.0. Almost similar observations were reported by Gumusburun et al. (1994), Collipol et al. (2007) and Udhaya et al. (2013). Study of relative relationship between the length of bone and distance of nutrient foramen from either end is useful in calculating the length of a long bone from given fragment, which is important in medicolegal and anthropological work (Longia et al.1980).

Figure 1. Measuring length of tibia by osteometric board.

Table 5. Showing Direction of Nutrient foramen (NF).

Side	Total no. of NF	NF directed downwards		NF directed upwards	
		No.	%	No.	%
Right	58	56	96.6	2	3.4
Left	52	51	98.1	1	1.9
Total	110	107	97.2	3	2.7

Table 6. Showing Lateromedial and Anteroposterior diameter at Nutrient Foramen.

Side	Lateromedial Diameter	Anteroposterior Diameter
	Mean±SD	Mean±SD
Right	20.6±2.1mm	28.9±2.6mm
Left	18.8±2.2mm	28.2±3.1mm

Table 7. Showing Length of tibia, distance of Nutrient foramen (NF) from highest point of intercondylar eminence and foraminal index of tibia.

Side	Length of tibia (L)	Distance of NF from intercondylar eminence of tibia (D)	Foraminal Index (FI)
	Mean±SD	Mean±SD	Mean±SD
Right	37.4±2.7 cm	12.3±2.9 cm	32.8±2.9
Left	36.5±2.4 cm	11.8±1.4 cm	32.2±3.0

(a) (b)

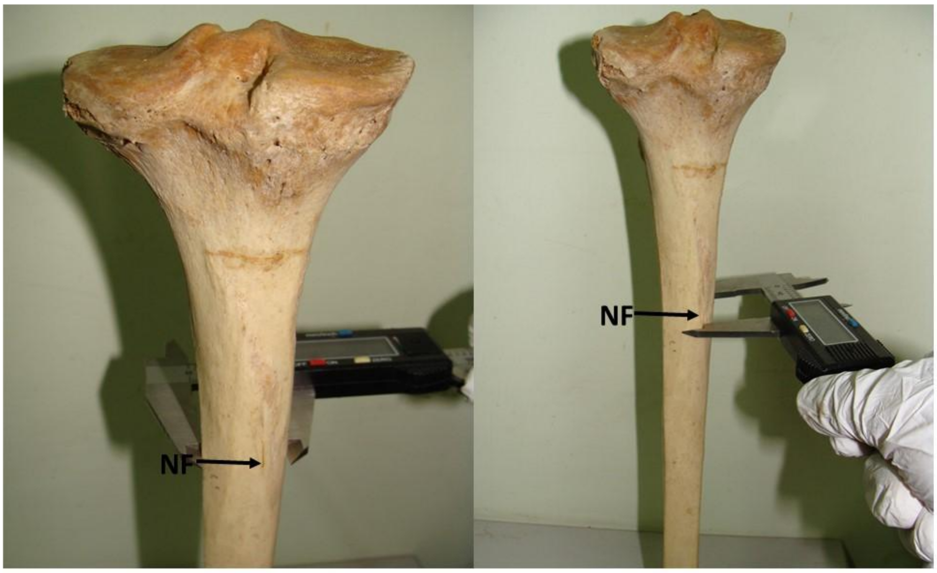
Figure 2

Figure 2 (a). Tibia showing single nutrient foramen (arrow).
Figure 2 (b). Tibia showing double nutrient foramen (arrows).

Figure 3. Right tibia showing double nutrient foramen (arrow) one on soleal line (SL) and other lateral to soleal line(SL) both directing downward.

Figure 4. Left tibia showing double nutrient foramen (arrow) one medial to soleal line (SL) and directing upward while other is lateral to soleal line (SL) and directing downward.

Figure 5. Right tibia showing double nutrient foramen (arrow) one lateral to soleal line (SL) and is in upper 1/3 of shaft directing downward while other is on lateral border of tibia and it is in middle 1/3 of shaft of tibia directing upward.



(a) (b)

Figure 6

Fig. 6 (a): Showing Lateromedial diameter at nutrient foramen (NF).
Fig. 6 (b): Showing Anterioposterior diameter at nutrient foramen (NF).

CONCLUSION

The detail study of nutrient foramen will help surgeons to perform successful microvascular bone transfer without damaging nutrient artery. Knowledge of position of nutrient foramen in relation to shaft of tibia can be related to non-union following trauma in middle and lower parts of shaft of tibia.

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