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A Study on the Nutrient Foramina of Long Bones

P Anusha[1], M Prasad Naidu[2*]

1. M.Sc Medical Anatomy, Narayana Medical College and Hospital, Nellore, Andhra Pradesh, India
2. Research Jr Scientist, Advanced research centre, Narayana Medical College and Hospital, Andhra Pradesh, India.

Abstract

The nutrient artery is the principal source of the blood to a long bone, particularly during its growth period in the embryo and fetus as well as during early phases of ossification during childhood. Long bones receive about 80% of the intraosseous blood supply from the nutrient arteries, and in the case of their absence, the vascularization occurs through the periosteal vessels. Since the artery of the shaft of the long bone is the largest, it is called the "nutrient artery". The number and position of the nutrient foramina in the upper and lower limb long bones, the location and direction of nutrient canal and also whether the nutrient foramina obey the general rule that is directed away from the growing end of long bone is determined in this study. The present study confirmed the previous reports suggesting that the nutrient foramen in the tibiae 1 was directed towards the growing end and remaining all were away from the growing end.

Keywords: Long bones, nutrient foramen, foraminal index, nutrient artery

*Corresponding Author: M. Prasad Naidu, Research Junior Scientist, Advanced Research Centre, Narayana Medical College & Hospital, Nellore, Andhra Pradesh, India. Email: www.prasadnaidu.com@gmail.com

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Introduction

The location of nutrient foramen is important in longitudinal stress fractures, as they can either initiate from the nutrient foramina or the supero medial aspect: longitudinal stress fractures are more commonly associated with tibia, but occasionally occur in femur, fibula and patella [1]. Clinical fracture of a long bone is usually accompanied by the rupture of the nutrient artery with variable disruption of the peripheral vessels associated with periosteal detachment. Following fracture the ruptured nutrient artery and the periosteal vessels, together with those in the adjacent soft tissue, start bleeding [2,3]. An understanding of the location and the number of the nutrient foramina in long bones, is therefore important in orthopedic surgical procedures such as joint replacement therapy, fracture repair bone grafts and vascularised bone microsurgery as well as medico legal cases. In free vascular bone grafting, the nutrient blood supply is extremely important and must be preserved to promote fracture repair, a good blood supply being necessary for osteoblast and osteocyte cell survival, as well as facilitating graft healing in the recipient [1, 4].

Detailed data on the blood supply to long bones and the association with the areas of bone supplied has been and continues to be, a major factor in the development of new transplantation and resection techniques in orthopedics. However, there is still a need for a greater understanding of the location and number of nutrient foramina in bones such as Humerus, Radius, Ulna, Femur, Tibia and Fibula [5].

By defining this restricted area of "Nutrient Artery" entering into the nutrient canal, surgeons can avoid that during surgical operations and thereby prevent damage to nutrient artery and minimize or lessen the chances of non–union of fracture of the bone.

The aim of the present study is to determine the number and position of the nutrient foramina in the upper and lower limb long bones. The location and direction of nutrient canal and also to determine whether the nutrient foramina obey the general rule that is directed away from the growing end of long bone.

Materials and Methods

The present study material was of 300 human cleaned and dried bones of the Upper and Lower Limbs. The bones Humerus, Radius, Ulna, Femur, Tibia, Fibula - each 50 bones taken for the study. All the bones that were taken for the study were normal and had no pathological changes were present. The age and the sex of the bone were unknown.

In all these bones after determining the side of bone, the "nutrient foramina" were studied in regards with

1. Number of foramina on the shaft of a bone
2. Surface on which it was located
3. Direction from growing end
4. Location in relation with length of the shaft

Nutrient foramina were distinguished by the presence of a well marked groove leading to the foramen, and by a well marked often slightly raised edge of the foramen at the commencement of the canal. In doubtful cases a dissecting microscope was used to locate the foramen. For direction of canal fine stiff wire was passed through the foramen to confirm its direction.

The size of nutrient foramen was determined by using hypodermic needles no. 24 & 26.
Large foramen – accepted the no.24 needle.
Medium foramen – accepted only the no.26 needle.
Small foramen – did not take no.26 needle.
When more than one foramen was present, the larger one was considered dominant (DF), and nutrient foramina smaller than a size of 26 hypodermic needle were considered as being secondary nutrient foramina (SF).

The position of all nutrient foramina was determined by calculating a foraminal index (FI) using the formula:

$$FI= (DNF \backslash TL) \times 100$$

Where
DNF= Distance from the proximal end of the bone to the nutrient Foramina.
TL= Total Length of the Bone.

Determination of total length of the individual bones was taken as follows:
Humerus: The distance between the superior aspect of the head and the most distal aspect of the trochlea.
Radius: The distance between the most proximal aspect of the head of radius and tip of the radial styloid process.
Ulna: The distance between the most proximal aspect of the olecranon and the styloid process.
Femur: The distance between the superior aspect of the head of the femur and the distal aspect of the medial condyle.
Tibia: The distance between the superior margin of the medial condyle and the distal aspect of the medial malleolus.
Fibula: The distance between the apex of the head of the fibula and the distal aspect of the lateral malleolus.
Subdivisions of the position of the Foramina according to foramen index:
The position of the foramina was divided into three types according to the FI as follows:

- ✓ Type 1: FI up to 33.33, the foramen was in the proximal third of the bone.
- ✓ Type 2: FI from 33.33 up to 66.66, the foramen was in the middle third of the bone.
- ✓ Type 3: FI above 66.66 the foramen was in the distal third of the bone.

All measurements were taken to the nearest 0.1mm using a digital vernier calipers.
The results were analyzed and tabulated using the statistical package for the social sciences (SPSS) 8.0 windows. The range, mean and standard deviation of foramina index were determined.

Results

A total of 300 long bones (upper and lower limb long bones) were studied from right and left side and no information was available regarding the age, sex and origin of bones other than that they were from local population.

The parameters that were studied in 300 long bones depending on number of nutrient foramina, direction of foramina and their distribution at different levels on different surfaces are tabulated and analyzed. The observations of the study are presented in tables.

Humerus: Out of 50 bones 26 humeri belong to the right side and 24 humeri to the left side. Total no of nutrient foramina were 60. Single nutrient foramen were found in 36 bones (72%), double nutrient foramina in 12 bones (24%) and no nutrient foramen in 2 bones (4%). The average length of the humeri was 315.1 mm and average distance of nutrient foramina from the upper end was 169.68 mm. Most of the nutrient foramina were found in the middle 1/3 i.e.55 foramina (92%), Rest of the foramina occupies lower1/3 i.e.4 foramina (6%) and only one foramen in upper1/3 (2%). All the nutrient foramina are directed towards the elbow i.e. away from the growing end. Anatomical situation of the nutrient foramina on the shaft at large is on the anteromedial surface; out of 60 foramina 39(67.2%) of foramina were on this surface, 11(19%) of them were on the posterior surface, 7(12%) on medial border and 1.7% foramen on the lateral surface.

Bone	No. of bones	No. of foramina (on each bone)	Percentage (%)
Humerus (n=50)	36 12 02	01 02 00	72% 24% 04%
Radius (n=50)	46 03 01	01 02 00	92% 06% 01%
Ulna (n=50)	50	01	100%

TABLE – 1: Number of nutrient foramina observed in long bones of upper limb.

Radius: Out of 50 bones 25 radii belong to the right side and 25 belong to the left side. Total no. of nutrient foramina was 52. Single nutrient foramen were found in 46 bones (92%), double nutrient foramina in 3 bones (6%) and no nutrient foramen in 1 bone (1%). The average length of the radius was 250.3 mm and average distance of nutrient foramina from the upper end was 85.7 mm. Most of the nutrient foramina were found in the middle1/3 i.e. 32(61.5%) foramina, rest of the foramina occupies uppper1/3 29 (38.5%) foramina. Among 52 foramina only one foramina is directed towards the growing end and remaining are directed towards the elbow i.e. away from the growing end. Anatomical situation of foramen on the shaft of radius at large is on the anterior surface; out of 52 foramen 37(72.2%) were on this surface, 6(11.5%) foramina were on the anterior border, 6(11.5%) foramina were on the interosseous border and only 2(4.8%) foramina were on the posterior border.

Ulna: A total of 50 ulnae studied of which 25 ulnae belong to the right side and 25 ulnae to the left side. Total no. of nutrient foramina were 50 of which single nutrient foramen is observed. Single nutrient foramen is observed in all 50(100%) ulna. The average length of the ulna was 264.7 mm and average distance of nutrient foramen from the upper end was 91.1 mm. Most of the nutrient foramina were found in the upper1/3 i.e. 29(58%), 21 foramina were found in middle1/3 (42%) and no foramen was found in lower1/3. One nutrient foramen was directed towards the growing end and remaining 49 foramina was directed away from the growing end i.e. toward the upper end (elbow joint). Anatomical situation of nutrient foramen on the shaft of ulna mostly is on the anterior surface; out of 50 foramina 35(70%) were on this surface, 10 (20%) foramina were on the anterior border and remaining 5(10%) foramina were on the interosseous border. None of the ulna showed the multiple foramina.

Position	No. of foramina	%	Number of Foramina					
			Single		Two		Three	
			DF	SF	DF	SF	DF	SF
Antero medial surface	39	65 %	29	-	9	1	-	-
Posterior surface	11	18.3%	2	-	3	6	-	-
Lateral surface.	01	1.7 %	-	-	-	1	-	-
Medial border	09	15 %	5	-	-	4	-	-

TABLE – 2: Position and number of dominant foramina (DF) and secondary nutrient foramina (SF) observed in Humerus.

Femur: Out of 50 bones 24 femora belong to the right side and 26 to the left side. Total no. of nutrient foramina were 78 of which single nutrient foramen were found in 23(46%) bones, double nutrient foramina in 26(52%) bones, 3 foramina in 1(2%)bone and no bone with no nutrient foramen. The average length of the femur was 428.8 mm and average distance of nutrient foramen from the upper end was 174.7 mm. Most of the nutrient foramina were found in the middle1/3 i.e. 75(96.2%), 3(3.8%) foramina were found in upper1/3 and no nutrient foramen in lower1/3. 1 nutrient foramen was directed towards the growing end and other foramina were directed away from the growing end. Anatomical situation of nutrient foramen on the shaft of femur greatly is on linea aspera; out of 78 foramina 53(67.9%) were on the surface,21 (26.1%)foramina were on the medial surface, 3(3.8%) foramina were on the lateral surface and only 1(1.2%) foramen on the posterior surface.

Position	Side	Range	Mean ± SD
Anteromedial surface	R L	40.0-67.1 42.4-66.5	56.1±7.1 57.8±6.5
Posterior surface	R L	39.5-46.3 36.7-70.1	42.5±3.4 46.9±10.8
Lateral surface	R L	55.9 -	- -
Medial border	R L	25.9-66.8 56.3-64.8	55.1±14.9 59.8±4.4

Table-3: The Range, mean ± Standard deviation (SD) of foraminal indices of Humerus.

POSITION	SIDE	RANGE	MEAN ± SD
Anterior surface	R L	9.3-44.7 28.8-47.8	33.2±7.2 35.1±5.2
Posterior border	R L	42 -	- -
Interosseous border	R L	36.2-39.3 32.2-43.4	37.8±2.2 37.9±6.0
Posterior surface	R L	36.5-40 -	38.4±2.3 -
Anterior border	R L	42.9 31.1-34.8	- 34.8±4.6

Table – 4: The range, Mean ± Standard deviation (SD) of foraminal indices of Radius.

POSITION	SIDE	RANGE	MEAN ± SD
Anterior surface	R L	29.1-44.8 28.9-46.5	33.2±4.0 35.5±5.9
Anterior border	R L	29.5-39 29.7-37.8	33.6±3.1 32.9±3.6
Interosseous border	R L	31.4-37.4 46	34.0±2.5 -

Table -5: The range, mean ± standard deviation (SD) of foraminal indices of Ulna.

Tibia: Out of 50 bones 28 tibiae belong to the right side and 22 to the left side. Total no of nutrient foramina were 50. Single dominant nutrient foramina were found in all 50 tibiae. The average length of the tibia was 359.2 mm and average distance of nutrient foramen from the upper end was 113.34 mm. Most of the nutrient foramina were found in upper1/3 i.e. 44(88%), rest of the foramina occupies middle1/3 i.e. 6(12%). 1 foramen is directed towards the growing end and rest of 49 foramina was directed away from the growing end. Anatomical situation of the nutrient foramen on the shaft of fibula at large is on the posterior surface; out of 50 foramina 47(94%) were on this surface and rest of foramina were on the lateral surface i.e. 3 (6%).

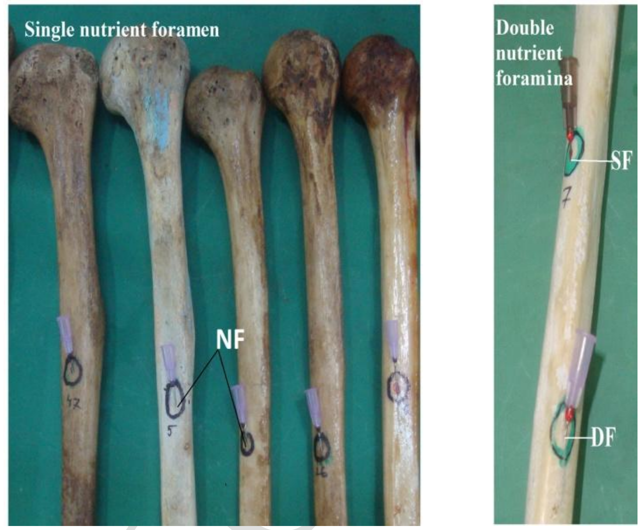

Fig.1: A photograph of the anterior surface of left humeri showing a single nutrient foramen (NF) on the anteromedial surface of the shaft. The foramina are located in the middle third of the bones (Type-2) and are directed downward.

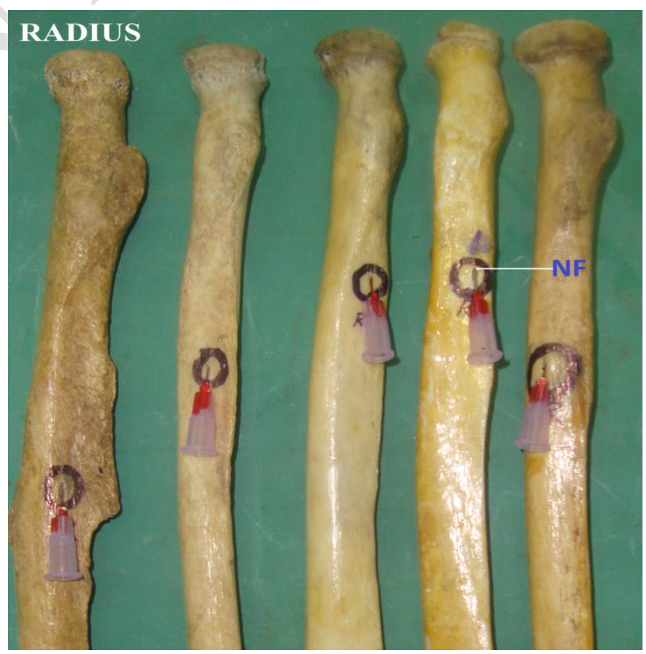

Fig.3: A photograph of the anterior surface of right radii showing a single nutrient foramen (NF) on the anterior surface close to the interosseous border of the shaft.The foramen is located in the middle third of the bone (Typ-2) and is directed upward.

Fibula: A total of 50 fibulae studied of which 28 fibulae belong to the right side and 22 fibulae to the left side. Total no of nutrient foramina were 54 of which single nutrient foramina were found in 44

(88%) bones, double nutrient foramina were found in 5(10%) bones. None of the fibula showed triple foramen and absence of foramen was found in 1(2%) fibula. The average length of the fibula was 361.2 mm and average distance of nutrient foramen from the upper end was 162.3 mm. Most of the nutrient foramina were found in middle1/3 i.e. 51(94%) bones, 2(4%) bones were found to be having foramina in upper1/3 and only single fibula having foramen in lower1/3 (2%). 46 foramina were directed away from the growing end i.e. away from the knee joint and only 3 foramina were directed towards the growing end. Anatomical situation of nutrient foramen on the shaft of fibula mostly is on posterior surface; out of 54 foramina 41(75.9%) were on this surface and remaining 13(24.1%) foramina were on the medial surface.

Position	Side	Range	Mean ± Sd
Linea aspera	R L	33.6-61.3 32.1-63.6	41.9±7.5 43.7±8.7
Medial surface	R L	35.1-63.2 43.2-64.5	56.9±8.1 57.8±7.1
Posterior surface	R L	27.2 -	- -
Lateral surface	R L	62.1-66.7 47.8	64.4±3.2 -

Table – 6: The range, mean ± standard deviation (SD) of foraminal indices of Femur.

Discussion

In the present study, a single nutrient foramen has a higher percentage (72%) in the humeral bones, compared to those of double (24%) and triple foramina (0%) and no nutrient foramen in 2 bones (4%).

In the present study all the radii examined had (92%) single nutrient foramen, double nutrient foramina in (6%) of bones, and no nutrient foramen in (1%) bone. The same finding was reported by Forriol Campos et al. (1987) and Nagel (1993). In other studies, the majority of radii (more than 90%) were found to possess a single nutrient foramen. In such studies, radii possessing double nutrient foramina were also observed [6].

In the present study (100%) of ulnae examined had a single nutrient foramen. Nagel (1993) who recorded a single nutrient foramen in all specimens examined, other authors reported a single nutrient foramina in more than 91% of ulnae [7, 8]. Furthermore, Longia et al. (1980) observed three nutrient foramina in (1%) of ulnae examined, while Shulman (1959) and Mysorekar (1967) reported the absence of nutrient foramina in (0.6%) and (1.1%) of ulnae, respectively.

In this study, (52%) of the femora examined possessed double nutrient foramina, while (46%)had only one nutrient foramen and (2%) had triple nutrient foramina. In this study, the whole series of tibiae examined had a single nutrient foramen (100%). Previous studies reported the presence of a single nutrient foramen in at least 90% of the tibiae. But, in contradiction with the present results, they also reported the presence of double nutrient foramina in some of the tibiae (Mysorekar, 1967; Longia et al., 1980; Forriol et al., 1987; Sendemir and Cimen, 1991; Nagel, 1993; Gumusburun et al., 1994; Collipal et al., 2007) [11, 12]. It was interesting to notice that, in the present study, both the preaxial bones of the limbs, namely ulna and tibia, possessed only a single nutrient foramen. Further studies will be needed to clarify such observations.

In the fibulae studied, (88%) of the bones presented a single nutrient foramen, while (10%) of the bones possessed double nutrient foramina, and (2%) of the bones had absence of nutrient foramina. Similar data had been reported by Longia et al. (1980), Guo (1981), Mckee et al. (1984), Forriol Campos et al (1987) and Sendemir and Cimen (1991), while Mckee et al. (1984) reported fibulae with three nutrient foramina. On the other hand, Mckee et al. (1984), Gumusburun et al. (1994) and Kizilkanat et al. (2007) reported fibulae with no nutrient foramina [9, 11, 12, 13].

Position of Nutrient Foramina

In this study, 91.6% of the nutrient foramina were located along the whole middle third of the humerus, with the foraminal index ranging between 25.9% and 70.1% of the bone length. In accordance with the present results, previous studies reported the position of the nutrient foramina within the middle third of the bone [9, 10]. In this study, (67.2%) of all humeral nutrient foramina were observed on the anteromedial surface 19% of them were in the posterior surface (1.7%) on the lateral surface and 12.1% on the medial border of the bone. Similar findings had been reported by Longia et al. (1980), Forriol Campos et al. (1987) and Kizilkant et al. (2007) [13, 14]. On the other hand, Mysorekar (1967) reported an equal percentage of foramina on both the anteromedial surface and the medial border.

The site of entrance of the main artery into the humerus makes it vulnerable to be damaged in cases of exposure and plating of the medial column in supracondylar fractures of the humerus. So it had been advocated to plating these fractures both medially and laterally with fixation extending up to the diaphysis [13].

In the present study, 61.5% of the total nutrient foramina were distributed most often in the middle third of the radius and 38.5% were in the proximal third, with the foramen index ranging between 9.3% and 47.8% of the bone length. The ratios of the present study were close to those reported by Mysorekar (1967) who found 62% of foramina located in the middle third of the bone and 36% in the proximal end. On the other hand, some reports such as those of Shulman (1959), Forriol Campos et al. (1987), Nagel (1993) and Kizilkanat et al. (2007) [15, 16, 17] stated that the majority of nutrient foramina were located in the proximal third of the bone. In the present study, 72.2% of all radial foramina were on the anterior surface, of the bone. Such results were in accordance with the previous studies [15] who stated that the majority of nutrient foramina were located on the anterior surface of the bone.

Regarding the ulna, the nutrient foramina (42%) were in the middle third while majority 58% were in the proximal third of the bone, with the foramen index ranging between 22.4% and 55.7% of the bone length. No nutrient foramina were detected in the distal third of the ulnae. Reviewing the literatures, some authors reported that the majority of nutrient foramina were located in the middle third [ ] while others stated that most of foramina were in the proximal third []. However, all authors agreed that there were no nutrient foramina in the distal third of the ulna.

In the present study, 70% of the nutrient foramina were located on the anterior surface of the ulnae. In all previous studies, and in accordance with the present results, the nutrient foramina were mostly observed on the anterior surface of the ulna [].

The blood supply to the sites of muscle attachment to the proximal half of the radius and ulna is directly reinforced by the nutrient arteries. There are, however, no significant muscle attachments to the distal half of the radius and ulna, corresponding to a general lack of nutrient foramina. Delayed or nonunion in the middle or lower diaphysis following trauma may be directly related to the absence of the nutrient arteries entering the bones in these areas (Kizilkanat et al., 2007). The posterior surface of both radius and ulna often lack nutrient foramina especially in the middle and dorsal diaphysis. That is why the dorsal localization for the plate is preferred during operative procedure (Giebel et al., 1997).

In the present study, most of the nutrient foramina (96.2%) were located along the middle third of the femur; the rest (3.8%) were in the proximal third, with the foramen index ranging between 27.2% and 66.7% of the bone length. With no foramina detected in the distal third of the femur. These results were in accordance with those of Forriol Campos et al. (1987), Sendemir and Cimen (1991), Gumusburun et al. (1994) and Kizilkanat et al. (2007) [13, 14, 15]. However, these findings did not coincide with those of Ferriol Campos et al. (1987) who stated that the nutrient foramina were closer to the hip joint. In this study, 58.33% of the nutrient foramina of the femora were located mainly at the absence of vessels entering this part of bone. In this study, 67.9% of the nutrient foramina of the femora were located mainly around the linea aspera and along a narrow strip on either side of it. These results were similar to those of Longia et al. (1980), Sendemir and Cimen (1991) and Gumusburun et al. (1994) [12, 13, 15] who stated that most of nutrient foramina were concentrated along the linea aspera.

In the present study, most of the nutrient foramina in the tibiae were in the proximal third 88%, with the foraminal index ranging between 32.4 and 68.1% of the bone length. Nutrient foramina were located in the middle third in the rest of the tibiae examined (12%). There were no foramina in the distal third. Similarly, many authors reported the presence of the majority of nutrient foramina in the proximal third of the tibia [16]. On the other hand, Kizilkanat et al. (2007) stated that most of nutrient foramina were located in the middle third with the foramen index ranging between 27 and 63% of the bone length. In the present series, all nutrient foramina studied were located on the posterior surface of the tibiae. Similar results were reported by Mysorekar (1967), Longia et al. (1980), Forriol et al. (1987), Sendemir and Cimen (1991), Nagel (1993), Gumusburun et al. (1994), Kizilkanat et al. (2007) and Collipal et al. (2007) [13, 14 15, 16].

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.

In the present series, most of the nutrient foramina of the fibula were situated in the middle third of the bone (94.4%), with a foramen index ranging between 28.9% and 46.5% of the bone length. The single fibula nutrient foramina (1.9%) were located in the distal third of the bone, while 3.7% had nutrient foramen in the upper third. These results were in agreement with most of the previous studies (Mckee et al., 1984; Forriol Campos et al., 1987; Sendemir and Cimen, 1991; Gumusburun et al., 1994; Collipal et al., 2007) [11, 12,13, 15]. On other hand, Guo (1981) reported that the majority of foramina were located in the proximal third of the fibula.

In this study, 75.9% of the fibular foramina were located on the posterior surface of which 66.66% of foramina were on the medial crest and 75.9% on the posterior surface and remaining 24.1% on the medial surface. Similarly, Mysorekar reported that 56% of nutrient foramina were located on the medial crest while 33% lied on the posterior surface of fibula. However, some authors observed more nutrient foramina on the posterior surface compared to those on the medial crest [18] reported that the majority of foramina were on the medial surface of the fibula. Knowing the variations in the distribution of the nutrient foramina is important preoperatively, especially regarding the fibula used in bone grafting. In the majority of the specimens, the nutrient foramina were located in the middle third of the fibula which is the segment that must be used for the transplant, if one desires that the implant include endosteal vascularization and peripheral vascularization [16, 18]. It is very important that the nutrient blood supply is preserved in free vascularized bone grafts so that the osteocytes and osteoblasts in the graft survive, and the healing of the graft to the recipient bone is facilitated with the usual replacement of the graft by creeping substitution [19].

The present study proved that most of the nutrient foramina were observed to lie on the flexor surface of the bones. Thus, on the humerus, radius and ulna they were mostly on the anterior surface while on the femur, tibia and fibula, they were located on the posterior surface. Kizilkanat et al. (2007) stated that the position of the nutrient foramina was directly related to the requirements of a continuous blood supply to specific aspects of each bone, for example where there were major muscle attachments. It might be that, being more bulky, stronger and more active, flexors need more blood supply compared to extensors of limbs.

Direction of Nutrient Foramina

In this study, all the nutrient foramina in humerus were directed distally (away from the growing ends). Similar observations were reported by Lutken who stated that all canals which were found in humerus were directed distally.

In the radii examined, one foramen was directed towards the growing end and all others were away from the growing end. Similar observations were reported by Shulman and Mysorekar who stated that all nutrient foramina on the diaphysis of radius entered obliquely and were directed towards the elbow.

The nutrient foramina of all ulnae examined one had a proximal direction and remaining all was away from the growing end. Similar observations were reported by Shulman and Longia et al. who stated that all nutrient foramina on the shaft of the ulna entered obliquely and all were directed towards the elbow. In the current work, all nutrient foramina in the femur was directed towards the growing end and one nutrient foramina was directed away the growing ends. Lutken (1950) and Longia et al (1980) reported foramina having a distal direction in 1% and 0.5% of femora, respectively.

The present study confirmed the previous reports suggesting that the nutrient foramen in the tibiae 1 was directed towards the growing end and remaining all were away from the growing end. On the other hand, Longia et al. (1980) observed nutrient foramina directed towards the knee in 3.5% of tibiae examined.

Regarding the fibula, the direction of 3 nutrient foramina was directed towards the growing end, while 46 foramina were directed away from the growing end. In accordance with the present results, Longia et al. (1980) reported nutrient foramina having a proximal direction in 9.5% of fibula examined.

Conclusion

With the exception of femur, majority of nutrient foramina of all bones were single in number and were primary in size. Most of the nutrient foramina were concentrated in the middle third of the bone with exception of tibia and ulna in which the nutrient foramina were predominantly observed in the proximal third. Nutrient foramina were mostly located on the anterior surface of the shaft of bones of the upper limb and posterior surface of the shaft of bones of lower limb.

The direction of nutrient foramina followed the growing end theory, with variations in the direction observed in some tibia and fibulae.

The results of the present study confirmed previous findings regarding the number and position of nutrient foramina of long bones of the limbs and provided clinical information concerning the nutrient foramina which could be useful as reference for surgical procedures.

References

1. Al-Motabagoni. The arterial architecture of the human femoral Diaphysis. J. Anat. Soc. India 2002;51(1): 27 - 31.
2. Bridgeman, G., Brookes, M. Blood supply to the human femoral diaphysis in youth and senescence. J. Anat. 1996;188:611 - 621.
3. Collipal, E., Vargas, R., Parra, X., Silva, H., Sol, M. Diaphyseal nutrient foramina in the femur, tibia and fibula bones. Int. J. Morphol. 2007;25 (2): 305 - 308.
4. Craig, J.G., Widman, D., van Holsbeeck, M. Longitudinal stress fracture: patterns of edema and the importance of the nutrient foramen. Skeletal Radiol. 2003;32: 22 - 27.
5. Emine Kizilkanata, Neslihan Boyana, Esin T. Ozsahina, Roger Soamesb, Ozkan Oguza. Location, number and clinical significance of nutrient foramina in human long bones. Ann. Anat. 2007;189: 87 - 95.
6. Giebel, G., D., Meyer, CH., Koebke, J., Giebel, G. Arterial supply of forearm bones and its importance for the operative treatment of fractures. Surg. Radiol. Anat.1997;19:149 - 153.
7. Gotzen, N., Cross, A., Ifju, P., Rapoff, A. Understanding stress concentration about a nutrient foramen. J. Biomech. 2003;36: 1511 - 1521.
8. Gumusburun, E., Adiguzel, E., Erdil, H., Ozkan, Y., Gulec, E. A study of the nutrient foramina in the shaft of the fibula. Okajimas Folia Anat. Jpn.1996;73(2-3): 125 - 128.
9. Gumusburun, E., Yucel, F., Ozkan, Y., Akgun, Z. A study of the nutrient foramina of lower limb long bones. Surg. Radiol. Anat. 1994;16: 409 - 412.
10. Guo, F. Fibular blood supply. Chin. Med. J. 1981;94: 396 - 400.
11. Guo, F. Observation of the blood supply to the fibula. Arch. Orthop. Traumat. Surg. 1981;98: 147 - 151.
12. Kirschner, M. H., Menck, J., Hennerbichler, A., Gaber, O., Hofmann, G.O. Importance of arterial blood supply to the femur and tibia for transplantation of vascularized femoral diaphyses and knee joints.World J. Surg. 1998;2: 845 - 852.
13. Longia, G.S., Ajmani, M.L., Saxena, S.K., Thomas, R.J. Study of diaphyseal nutrient foramina in human long bones. Acta Anat. (Basel) 1980;107: 399 - 406.
14. McKee, N. H., Haw, P., Vettese, T. Anatomic study of the nutrient foramen in the shaft of the fibula. Clin. Orthop. Rel. Res.194;184:141 - 144.
15. Nagel, A. The clinical significance of the nutrient artery. Orthop. Rev.1993;22: 557 - 561.
16. Sendemir, E., Cimen, A. Nutrient foramina in the shafts of lower limb long bones: situation and number. Surg. Radiol. Anat. 1991;13: 105 - 108.
17. Skawina, A., Litwin, J.A, Gorzyca, J., and Miodonski, A.J. The vascular system of human fetal long bones: A scanning electron microscope study of corrosion casts. J. Anat.1994;;185: 369 - 376.
18. Skawina, A., Wyczolkowski, M. Nutrient foramina of humerus, radius and ulna in Human Fetuses. Folia Morphol. 1987;46: 17 - 24.
19. Wavreille, G., Remedios, Dos, C., Chantelot, C. Anatomic bases of vascularized elbow joint harvesting to achieve vascularized allograft. Surg. Radiol. Anat. 2006;28 : 498-510.