Research Article

An analytical study of number, position, size and direction of nutrient foramina of femur

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Abstract

Background: Bones are structures that adapt to their mechanical environment and from a fetal age also adapt to the presence of naturally occurring holes called as nutrient foramina, which are narrow tunnels that conduct the nutrient arteries and the peripheral nerves.

Objective: To determine the number, position, size, and direction of nutrient foramina of femur and to calculate foraminal index (FI) for each femur.

Materials and Methods: The study was carried out in Department of Anatomy, S.S. Medical College, Rewa, Madhya Pradesh, India. A total of 100 adult human femora (50 right sides and 50 left sides) were collected from Department of Anatomy and Department of Forensic Medicine. We have measured all the four parameters, that is, number, position, size, and direction of nutrient foramina in each bone according to standard method. We have also calculated FI in each femur.

Result: According to FI, most of the nutrient foramina of femur (80%) were located in middle third (Type 2). In respect to number of nutrient foramina, more than 75% femur has single nutrient foramina that represent the only source of blood supply. In our study, the direction of nutrient foramina obeys the "growing end theory."

Conclusion: This study provides additional information about the nutrient foramina of femur especially to orthopedicians, to select the osseous section levels of the receptor in order to place the graft without damaging the nutrient arteries. It also provides valuable guidance for the techniques such as microvascular bone transfer, which are becoming more popular.

KEY WORDS: Femur, nutrient foramina, foraminal index (FI), dominant foramina (DF), secondary foramina (SF)

Introduction

Bone is a living tissue and similar to any other living tissue in the body. It requires nutrition for its growth and development. This is provided by continuous blood supply to the bone.[1] The blood supply to the femoral diaphysis is provided by one or two nutrient arteries arising from the profunda femoris artery branch of femoral artery.[2] It was reported that the profunda femoris artery can be used in femoral diaphysis transplant surgeries. So the number and location of nutrient artery has to be considered in the cases of graft surgeries. Grafts with good vascular supply will certainly have better results.[3] The nutrient artery enters obliquely through a nutrient foramen.[4,5] This foramen, in the majority of cases is directed away from the growing end, hence it is popularly stated that foramina "seek the elbow and flee from the knee."[6, 7] This is because the one end of the limb bone grows faster than the other.[8, 9] Though the foramina are directed away from the growing end, their topography might vary at the non-growing end.[10] So the topographical anatomy of the nutrient foramina may be a worth study. The topographical knowledge of these foramina is useful in certain operative procedures such as in cases of tumour resection, traumas, joint replacement

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therapy, fracture repair, bone grafts, and vascularized bone microsurgery.[11]

Materials and Methods

This study was conducted in the Department of Anatomy, S.S. Medical College, Rewa Madhya Pradesh, India. A total of 100 adult human cleaned and dried femora (50 right sides and 50 left sides) collected from Department of Anatomy and Department of Forensic Medicine. All selected bones are serially numbered and photographed. The specific age and sex characteristics of the bones studied are unknown. The nutrient foramina are observed in all bones with the help of a hand lens. They are identified by their elevated margins and by the presence of a distinct groove proximal to them.[12] Only well-defined foramina on the diaphysis are accepted. Foramina at the ends of the bone are ignored.[13]

The following data are studied on the diaphyseal nutrient foramina of femur:

1. *Number*: Bones were examined for the number of nutrient foramina. With the help of magnifying hand lens, all surfaces and each border were thoroughly examined from proximal to distal end and both dominant and secondary foramina were counted and noted down.
2. *Position*: The positions of all nutrient foramina were determined by calculating a foraminal index (FI) using formula:

   FI = (DNF/TL) × 100 (Hughes & Shulmen 1952)
   DNF = The distance from the proximal end of the bone to the nutrient foramen
   TL = Total bone length.

Subdivisions of foraminal position according to foraminal index (FI) can be grouped into three types as follows[14]:

Type 1: FI from 01 up to 33.33 — The foramen is in the proximal third of the bone.

Type 2: FI from 33.34 up to 66.66 — The foramen is in the middle third of the bone.

Type 3: FI above 66.67 — The foramen is in the distal third of the bone.

3. *Size*: Nutrient foramina smaller than the size of 24 hypodermic needle (0.56 mm in diameter) were considered as secondary nutrient foramina (SF) whereas those equal or larger than 0.56 mm were accepted as dominant nutrient foramina (DF).[15]
4. *Direction and obliquity*: A fine stiff wire was used to confirm the direction and obliquity of the foramen.[16]

All measurements have taken to the nearest 0.02 mm using an Aerospace sliding caliper. Photographs were taken in natural daylight by a Nikon digital Camera of 10 megapixels. Each photograph had a definition of 16 × 12 cm.

Statistical Analysis

The results were analyzed and tabulated. The range, mean, and standard deviation of FI were determined.

Result

In the whole series of 100 femora examined, we have found total number of 159 foramina including both dominant and secondary. There are 78 (78%) femora possessing single dominant nutrient foramina whereas 22 (22%) bones possessing double dominant nutrient foramina [Table 1]. In this study, most of the nutrient foramina (78.84%) were located along the middle third of the femur (Type 2) and the rest (21.15%) were in the proximal third (Type 1), with no foramina detected in the distal third of the femur [Table 1]. The mean FI is 46.29 and range of FI floats between 30.35% and 64.97% of the bone length [Table 3]. The average total length (TL) was 43.67 ± 2.04 cm. Of the 159,122 foramina, (76.72%) were dominant in size whereas 37 foramina (23.27%) were secondary in nature [Table 2]. All nutrient foramina (100%) in the femur were directed proximally (upper end) away from the growing end.

Discussion

Anatomical characteristics of the nutrient foramen, such as its number, position, size, and direction, are important factors considered in orthopedic surgeries including bone grafting and fracture repair. These characteristics also contribute to the prognosis after a fracture because they are essential to blood flow.[17] It has been reported that the ideal bone graft for the free transfer should include endosteal and periosteal blood supply with good anastomosis.[18, 19] Kizilkanat et al. 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 areas of some major attachments such as flexors require more blood supply as compared to extensors because of more activity. Many theories have been put forward to account for the direction of foramina and also the anomalously directed ones. In our study, femur obeys the growing-end theory of Mysorekar that opinioned the direction of nutrient foramina is determined by the growing end of the bone. The growing end is supposed to grow at least twice as fast as the other end. The nutrient artery runs away from the growing end as the growing bone might pull and rupture the artery. So the nutrient foramina are directed away from the growing end.

This study analyzes the following four parameters:

1. *Number of the nutrient foramina*: In this study, 78% femora possessing single dominant nutrient foramina whereas 22% bones had double dominant nutrient foramina [Table 1], which shows the majority of bones have single nutrient foramina that may represent the single source of blood supply. This is in agreement with previous studies reported by Kizilkanat et al. and Pereira et al.
2. *Position of nutrient foramina*: In this study, most of the nutrient foramina (78.84%) were located along the middle third of the femur (Type 2) and the rest were in the proximal third (Type 1) with no foramina detected in the distal third of the femur [Table 1]. Range of FI floats between 30.35% and

Table 1: Number and position of nutrient foramina of Femur

Bone	Number of foramina			Number of bones (%)
Femur (*n* = 81)	0			0 (0%)
	1			78 (78%)
	2			22 (22%)
	2			22 (22%)
	Position of foramina			Direction
	Type 1	Type 2	Type 3	
	21.15 (%)	78.84 (%)	–	All are directed proximally (towards upper end)

Table 2 : Position and number of dominant (DF) and secondary (SF) nutrient foramina observed in the femur

Location	Total no. of foramina	%	No. of foramina				Absent
			Single foramen		Double foramen		
			DF	SF	DF	SF	
Between the two lips of lineaaspera	52	32.7	29	10	10	03	–
Medial lip of lineaaspera	51	32.07	29	04	18	–	–
Lateral lip of lineaaspera	12	7.5	05	02	05	–	–
Posteromedial surface	26	16.3	10	08	08	–	–
Posterolateral surface	09	5.6	01	02	03	03	–
Medial to spiral line	09	5.6	04	03	–	02	–
Total	159	100	78	29	44	08	–

Table 3: The range, mean ± standard deviation (SD) of foramina indices observed in the femur

Location	Side	Range	Mean ± SD
Between the two lips of linea aspera	R	30.35–64.97	41.36 ± 8.73
	L	31.74–62.40	32.05 ± 0.13
Medial lip of linea aspera	R	36.64–60.76	57.96 ± 3.95
	L	31.82–62.62	32.98 ± 1.64
Lateral lip of linea aspera	R	34.79–54.89	43.25 ± 16.48
	L	40.50	40.50
Posteromedial surface	R	48.98–55.59	56.67 ± 1.53
	L	52.06–61.46	58.46 ± 2.34
Posterolateral surface	R	45.84–49.25	47.54 ± 2.41
	L	33.49–51.24	49.07 ± 3.06
Medial to spiral line	R	30.84–33.50	32.31 ± 2.07
	L	32.60	32.60

R, right; L, left.

64.97% of the bone length. These results were in accordance with the studies by Kizilkanat et al., Sammera Yassin Shaheen, and ShamsunderRao and Kothapalli. Also, 68.60% nutrient foramina of the femora was located mainly around the linea aspera and along a narrow strip on either side of it [Table 2].

3. *Size of nutrient foramina*: Our study shows that about 76% nutrient foramina were dominant in nature and 24% were secondary. This result also follows the previous studies.
4. *Direction and obliquity of nutrient foramina*: In this study, all the nutrient foramina in the femur were directed proximally (upper end) away from the growing end (lower end).

Conclusion

The study confirmed previous reports regarding the number, location, size, and direction of the nutrient foramina in the femur. The single foramina were more common as compared to double. All the foramina were located on flexor surface (posterior surface) of femur near the linea aspera especially in middle one-third of bone (Type 2). So it is important to know the exact location and distribution of the nutrient foramina to improve the surgical outcomes. This study provides additional information on the nutrient foramina of femur as techniques such as microvascular bone transfer, which are becoming more popular.

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