ORIGINAL ARTICLE

Morphometric Study of Nutrient Foramen in Femur in Marathwada Region

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Abstract:
Background: Long bones receive most of the interosseous blood supply from the nutrient artery (70-80%) and the remaining (20-30%) from periosteal vessels. The importance of the nutrient artery is denoted by its name 'nutrient'. There are only one or two dominant nutrient foramina (DNF) in any long bone. Their location and direction of the nutrient canal is important landmark during fracture reductions, tumors as well as in transplant surgeries. The present study is helpful to orthopedic surgeons as well as microvascular surgeons for the planning of surgery. *Aim:* To study number, location, the direction of nutrient foramina and FI of the femur. *Material and Methods:* This study was conducted on 163 dried human cadaveric femora in the Department of Anatomy, Government Medical Colleges in the Marathwada region. Osteometric board, Vernier calipers, 24 G needles were used to find out various parameters under study. *Results:* We have found that 60.73% of femora had 1 DNF, 34.96% had 2 while 4.29% had 3 DNF. 100% nutrient canals were directed away from the growing end. 80.34% NF was found in the middle segment of the femur on or near linea aspera with mean femoral index (FI) where FI is a ratio of is distance of NF from the proximal end of the femur to L the total length of the bone. It was found to be 44.68. *Conclusion:* The present study provides additional information about the numbers and locations of NF of the femur. Along with that, it adds data about the diameters of the shaft of the bone.

Keywords: femur, nutrient artery, nutrient foramen, femoral index

Introduction:

The bones are specialized connective tissue that form the human body's basic skeletal framework. Extremities are formed by the long bones. Nutrient arteries, Juxta epiphyseal arteries, Epiphyseal arteries and periosteal arteries supply them. Despite the fact that there are four sets, the nutrient artery takes up the majority of nutrition. It develops in the periosteal bud and usually enters the middle of the bone shaft via the nutrient canal. The nutrient foramen is the surface opening of the nutrient canal. It divides within the bone into two branches known as nutritiae, one for each end. Each branch divides into smaller parallel vessels that enter the metaphysis and form hairpin-like loops. These loops connect to the remaining three sets of vessels at the metaphysis. As a result, it is the most vascular region of the long bone. The nutrient artery provides blood to the bone marrow and the inner two-thirds of the diaphysis. The nutrient artery is said to grow away from the growing end because it grows twice as fast as its fellow end [1]. To avoid harm to the nutrient arteries, orthopedic surgeons, microvascular bone transplants, plastic and reconstructive surgeons must be aware of their number, location, direction, and course. Some pathological bone conditions, such as developmental anomalies, fracture healing, or acute hemorrhagic osteomyelitis, are linked to the vascular system of the bones. Doctors must have a thorough understanding of nutrient foramen and their variations in order to predict the prognosis of grafts, tumors, and bone fractures. It is also useful for anthropologists when interpreting height from a bone fragment in medico-legal cases [2]. The femur is the thigh's long bone. It is the bone that is vulnerable to functional and hormonal disruptions, the ageing process, and physical trauma, which account for the majority of fractures and dislocations [3]. One or two nutrient arteries arise from the second perforating artery, which is one of three

perforating branches from the profunda femoris artery, which is a branch of the femoral artery [4, 5].

The profunda femoris artery has been reported to be used in femoral diaphysis transplant surgeries. In such cases, knowledge of the nutrient arteries of the femur is essential. As a result, the current study was undertaken to investigate the number, location, and direction of dominant nutrient foramina in human cadaveric femora.

Aim and Objective:

To study nutrient foramina (NF) of human cadaveric femora under the following heads,

1) Number of NF. 2) Locations i/v/o surface, borders, segments of the bone. 3)The direction of the nutrient canal. 4) Foraminal index (FI). 5) Anteroposterior (AP) and transverse diameters of the bone at the level of nutrient foramen

Material and Methods:

The study included 163 dried human cadaveric femora from the Departments of Anatomy at Government Medical Colleges in Marathwada region. The bones' ages and genders were unknown. There were 83 from the right side and 80 from the left side. The study excluded bones with severe pathological deformities, fractures, or metal rods. The following information was gleaned from the bones.

Total Length: Total length of each bone was determined by measuring the distance between the proximal end of the femoral head and the most distal point on the medial condyle. The unit of measurement was centimeter. An osteometric board (Fig. 1) was used to measure the length.

Nutrient foramina: The number of nutrient foramina in bones were counted. All surfaces and borders were thoroughly examined with both naked eyes and a magnifying lens. A dominant foramen was one through which 24G needles could easily pass. They were counted and recorded. The same 24G needle was used to check the nutrient canal's patency and direction. The distance between the proximal end of bone and nutrient foramen was also measured for a subdivision on the basis of segments and to calculate the foraminal index (FI). FI was calculated by using Hughes formula as follows, FI = D/L * 100 where D is the distance of NF from the proximal end of the femur L is the total length of the bone [6].

Figure 1: Osteometric board and other material used for measuring various dimensions of bone & nutrient foramina.

Results:

In the present study, out of 163 total femora, 99 (60.73%) had one dominant NF, 57 (34.96%) had two NF while 7 (4.29%) had three dominant NF and no bone was found with an absent NF. So, taking into consideration of gross number, a total 234 NF were studied individually (Table no. 1). Direction of all 234 foramina (100%) was found to be upwards that is away from the growing end. Location wise 112 NF (47.86%) were found on the intermediate area between two lips of linea aspera, 93 (39.74%) were situated on the medial lip of LA, 21 (8.97%) on the lateral lip of LA, 2 (0.85%) on the lateral surface, 5 (2.13%) on the medial surface and only 1 (0.42%) was found on the anterior surface. After applying appropriate statistical test, it was found significant ($p<0.05$). When sorted from above downwards, 41 NF (17.52%) were found in the upper segment, 188 (80.34%) in the middle segment while 5 (2.13%) were found in the lower segment of the bone as shown in Table no. 2. This observation was confirmed with foraminal index (FI) also, as FI ranges from 26.69 to 74.66, its mean being 44.68. The range of AP diameter at the level of NF was from 1.3cm to 2.8cm, the mean being 2.06cm. The range of transverse

diameter at the level of NF was 1.2cm to 2.5cm, the mean being 2.03cm. After applying appropriate statistical test, it was found significant ($p<0.05$).

Table No. 1: Showing no. of NF

Place ⇩	No. of NF ⇨	01	02	03	Total no. of NF studied
Ambajogai	42	23	19	00	61
Aurangabad	56	31	22	03	84
Nanded	56	39	14	03	76
Latur	09	06	02	01	13
Total	163	99	57 (+57)	07 (+07+07)	234

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1060.667	2	530.333	5.708	.025
Within Groups	836.250	9	92.917	-	-
Total	1896.917	11	-	-	-

Significant at $p<0.05$

Table No. 2: Showing Direction, Locations and segments of NF

	Direction		Location of NF						Segments		
Place	U	D	IA	ML	LL	LS	MS	AS	U	M	L
Ambajogai	61	00	29	19	07	02	04	00	04	56	01
Aurangabad	84	00	19	55	09	00	00	01	12	72	00
Nanded	76	00	55	15	05	00	01	00	20	52	04
Latur	13	00	09	4	00	00	00	00	05	08	00
	234	00	112	93	21	02	05	01	41	188	05
Total	234		234						234		

Where U- upwards, D- downwards, IA- intermediate area between two lips of linea aspera, ML- medial lip of linea aspera, LL- lateral lip of linea aspera, LS- lateral surface of shaft, MS- medial surface of shaft, AS- anterior surface of shaft, U- upper segment, M- middle segment, L- lower segment

ANOVA					
Segment	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4699.500	2	2349.750	8.712	.008
Within Groups	2427.500	9	269.722		
Total	7127.000	11			

Significant at $p<0.05$

In the present study we were not able to apply statistical test on direction and location of NF.

Discussion:

It is generally accepted that the vessels that occupy the nutrient foramen are derived from those that participated in the initial invasion of the ossifying cartilage, resulting in the nutrient foramen being located at the original ossification center [7]. Hughes discovered that femoral variant foramina were common [6]. Variations in the direction of nutrient foramina have been observed in many tetrapods, and the foraminal pattern in mammals and birds is similar [11]. Schwalbe explained that before the appearance of the epiphysis, growth at the two ends of a long bone is equal. Nutrient arteries, which are the primary blood

supply to long bones, are especially important during active growth and the early stages of ossification. As a result, the nutrient arteries should be kept open until the growth process is complete, and even after that. As a result, they are diverted away from the growing end. In the current study, all (100%) nutrient canals were discovered to be directing away from the growing end. Various authors have discovered various numbers of nutrient foramina in the femora. Their comparison with the current study sheds light on the vasculature of the femora in Table No. 3, where the current study's values are calculated in percentage.

Table No.3: Comparison of no. of NF of present study with previous studies

	1	2	3	0
Prashanth[7]	47.7	44.2	3.5	4.6
Nilesh[8]	52.5	22.5	25	0
Rajkumar [10]	32	68	0	0
Nidhi[11]	78	22	0	0
Mysorekar[9]	81	90	3	6
Madhumita[12]	63.66	31.66	1.66	3.33
Sharma[13]	54	42	2	2
Present study	60.73	34.96	4.29	0

Table No. 4: Comparison of location of NF of present study with previous studies

	IA	ML	LL	MS	LS	AS
Prashanth [7]	66	37	05	16	01	01
Mysorekar [9]	48	27	00	14.5	00	00
Rajkumar [10]	27.33	18.66	11.33	24.66	5.33	00
Madhumita [12]	55.7	18.9	21.52	00	3.8	00
Present study	47.86	39.74	8.97	2.13	0.85	0.42

Table No. 5: Location in view of the segments (mention that the numbers are percentages or use a percent symbol after every location identifier)

	US	MS	LS	FI
Nilesh[8]	47.6%	38%	14%	-
Mysorekar[9]	-	90%	-	-
Rajkumar[10]	48%	52%	00	-
Nidhi[11]	21.15%	78.84%	00	46.29
Madhumita[12]	5.06%	94.94%	00	44.27
Sharma[13]	44%	41%	15%	-
Present study	17.52%	80.34%	2.13%	44.68

Where US – upper segment of shaft of the femur, MS – middle segment of shaft of the femur, LS – lower segment of shaft of femur and FI - foraminal index.

Despite the meticulous search, we could not find comparative data on AP and transverse diameters of the shaft of the femora in the literature.

Figure-2a

Figure-2b

Figure-2c

Figure 2: a) femur with three nutrient foramina b) femur with two nutrient foramina c) femur with one nutrient foramina. The position of NF makes an important landmark during orthopedic as well as microvascular bone transfers. Various authors have found various locations of NF which are comparable to the present study as shown in Table no. 4. Where values of the present study are calculated in percentage.

Conclusion:

A lack of blood supply is well known to be one of the causes of delayed or nonunion of fractures. One or two nutrient arteries branching from the Profunda femoris artery supply blood to the femoral diaphysis. As a result, the current study adds to our understanding of the number and location of nutrient foramina in the femora. This study also includes information on the AP and transverse diameters of the femora at the NF level. There are some limitations to this study. These include age and gender differences, which were not taken into account because we were unable to estimate the age and gender of the bones studied. Because the anatomy of foramina differs between males and females, these differences may affect the results.

Conflict of Interest - Nil
Sources of Support - Nil

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