



STUDY OF NUTRIENT FORAMINA IN DRY ADULT FEMUR IN CENTRAL INDIA REGION

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ABSTRACT

Introduction:- Femur is the longest weight bearing bone of the body. The accurate knowledge of its blood supply and nutrient foramina is very crucial to prevent intraoperative injuries in orthopaedic, plastic and reconstructive surgeries. **Aims & Objectives:-** To conduct morphological analysis of diaphyseal nutrient foramina of femur with respect to their number, location, direction and size in central India region. **Materials & Method:-** 160 dry adult femora (80 right and 80 left) were studied in the Department of Anatomy, Gandhi Medical College, Bhopal. Femora were examined for length and nutrient foramina for number, size, location, position including foraminal index and direction. **Results & Conclusion:-** Mean femur length was 44.13 cm. (n=160) 41.9% with single nutrient foramina, 50.6% with double foramina, 3.8% with three foramina, 0.6% with four foramina, 0.6% with five foramina and 2.5% femurs with no foramina. The range of size of nutrient foramina was 0.45 mm to 1.27 mm. Most common position was middle one third of the shaft (84.38%) and most common location was linea aspera (63.68%) with all nutrient foramina directed upwards. Knowledge about the exact location and distribution of nutrient foramina in the diaphysis of Femur is essential to avoid damage to the nutrient vessels during surgical procedures. It will help in better fracture healing and microvascular bone grafting.

KEYWORDS : femur, nutrient foramina (NF), blood supply, linea aspera

INTRODUCTION:-

Femur is strongest long bone of the body. It is mainly supplied by four arteries - nutrient artery, epiphyseal arteries, metaphyseal and periosteal arteries. Nutrient artery is the main source of blood supply to femur and is mainly important during active growth period and early stages of ossification. Nutrient arteries are responsible for 70-80% of the blood supply of the long bones and they play a very crucial role in fracture healing and prevention of avascular bone necrosis. [1, 2]

The main nutrient artery of femur is generally derived from the second perforating artery, a branch of profunda femoris artery. If two nutrient arteries are present, they may derive from the first and third perforators. [1] The nutrient artery again divides into ascending and descending branches which anastomose with epiphyseal and metaphyseal arteries. Nutrient foramen continues into a canal, which is directed obliquely. [4] The direction of canal was first described by Berard in French as "Au coudejem' appuis, du genou je m'enfuis" which means "To elbow I go, from the knee I flee" called as Berard's rule of canal direction. [5]

Sufficient knowledge about the location of nutrient foramen (NF) is important for ossification of bone, growth and healing. Surgically aided bone defect repair such as microvascular bone graft relies greatly on the vascularity of the femur for survival of donor and recipient bones. [6]

The long bones are susceptible to longitudinal stress fractures at the location of NF, so understanding of the location and position of NF is critical in making correct clinical diagnosis in such fractures. During surgical procedure particularly in open reduction, surgeons are required to pay careful attention to the site of NF and avoid limited areas of the long bone cortex that contain NF to improve outcome of such procedures. [7] The conditions like fracture healing, developmental abnormalities and hematogenic osteomyelitis greatly depends on the vascular system of bones.[8] The study about blood supply of

long bone and the areas of it supplied by the nutrient artery is important for the development of new techniques in the field of transplantation and resection. [9]

The study of characteristics of NF is of paramount importance on an ongoing basis to validate the findings from literature. The present study was conducted to explore and discover new findings that can play a critical role in the field of medical science in Central India region.

MATERIALS & METHOD:-

A total of 160 dry adult human femur bones (R=80, L=80) of unknown sex and age were studied in the Department of Anatomy, Gandhi Medical College, Bhopal. Bones with visible structural abnormalities were excluded from the study. The number, size, position, location and direction of nutrient foramina were recorded.

The materials used were Osteometric board, hypodermic needles (18, 20, 22, 24gauge), Marker pens, and Photographic camera. Parameters under study were number of NF, Size of NF, position of NF, location of NF, direction of NF, femur length. The size of nutrient foramina was measured with 18, 20, 22 and 24 hypodermic needles. Based on the hypodermic gauge needle number which was admitted by the nutrient foramina, the foramina were categorized into 4 groups. [10]

- Large sized nutrient foramina: The foramina which admitted 18 gauge needles were considered to be between 1.27 mm or more [≥ 1.27 mm].
- Medium sized nutrient foramina: The foramina which admitted 20 gauge needles were considered to be between 0.90 mm and 1.27 mm [≥ 0.90 mm to < 1.27 mm].
- Small sized nutrient foramina: The foramina which admitted 22 gauge needles were considered to be between 0.71 mm and 0.90 mm [≥ 0.71 mm to < 0.90 mm].
- Very small sized nutrient foramina: The nutrient foramina which admitted 24 gauge needles were considered to be between 0.55 mm and 0.71mm [≥ 0.55 mm to < 0.71 mm].

Nutrient foramina smaller than the size of 24 hypodermic needle (0.56 mm in diameter) were considered as secondary nutrient foramina whereas those equal or larger than 0.56 mm were accepted as dominant nutrient foramina. [11]

Position of foramina were determined by calculating the Foraminal Index by applying Hughe's formula: $FI = (DNF/FL) \times 100$; FI= Foraminal Index, DNF=distance of the foramen from the proximal end of the bone, FL =total length of Femur. [12]

Based on the Foraminal Index the position of the foramen is of three types:

- type I- FI is <33.33, foramen is present in proximal one third of the shaft
- type II- FI is 33.33 -66.66, foramen is present in middle one third of the shaft
- type III- FI is >66.66, foramen is present in distal one third of the shaft

OBSERVATIONS & RESULTS: -

Table -1: Number of Nutrient Foramina

No. of Nutrient Foramina(NF)	No. of femur bones		Total
	Right	Left	
One	31	36	67(41.9%)
Two	44	37	81(50.6%)
Three	2	4	6(3.8%)
Four	0	1	1(0.6%)
Five	1	0	1(0.6%)
Absent	2	2	4(2.5%)
Total	80	80	160(100%)

Out of 160 femurs, 81 (50.6%) femurs had two NF, 67 (41.9%) femurs had single NF, 6 (3.8%) femurs had three NF, 1 (0.6%) femur had four NF, 1 (0.6%) femur had five NF and 4 (2.5%) femurs had no foramina.

Table -2: Size of Nutrient Foramina

Size of NF	No. of NF		Total
	Right	Left	
≥ 1.27mm	11	12	23(8.98%)
0.90-1.27mm	35	37	72(28.13%)
0.71-0.90mm	31	33	64(25%)
0.55-0.71mm	38	32	70(27.34%)
0.45-0.55mm	15	12	27(10.55%)
Total	130	126	256(100%)

23 (8.98%) nutrient foramina were of large size, 72 (28.13%) nutrient foramina were of medium size, 64 (25%) nutrient foramina were of small size, 97 (37.89%) nutrient foramina were of very small size.

Table -3: Position of Nutrient Foramina

Position of NF	No. of NF		Total
	Right	Left	
Proximal third	19	19	38(14.84%)
Middle third	111	105	216(84.38%)
Distal third	0	2	2(0.78%)
Total	130	126	256(100%)

Out of total 256 nutrient foramina, 38 (14.84%) were present in the proximal third of the shaft and had type I FI. A total of 216 (84.38%) foramina were present in the middle third of the shaft with type II FI and only 2 (0.78%) foramina were present in the distal one third of the shaft (type III). So majority of the nutrient foramina were present on the proximal one third of the shaft.

Table -4: Location of Nutrient Foramina

Location of NF	Side	No. of NF	Total
Linea Aspera	R	32	73(28.52%)
	L	41	

Medial Lip	R	19	37(14.45%)
	L	18	
Lateral Lip	R	5	9(3.52%)
	L	4	
Between two lips of LA	R	25	44(17.19%)
	L	19	
Medial Surface	R	39	76(29.69)
	L	37	
Lateral Surface	R	8	13(5.08%)
	L	5	
Upper Posterior Surface	R	2	4(1.56%)
	L	2	

Out of 256 foramina 73 (28.52%) were located on the linea aspera, 37 (14.45%) were located at the medial lip of linea aspera, 9 (3.52%) were located at the lateral lip of linea aspera, 44 (17.19%) were located between the two lips of linea aspera, 76 (29.69%) were located at the medial surface, 13 (5.08%) were located at the lateral surface and 4 (1.56%) were located at the posterior surface of femurs.

NF in all specimens were directed upward toward proximal end of femur. No NF was directed downward or horizontally. The mean total length of femur was 44.13 ± 2.97 cm (min: 33.60 cm, max: 52 cm)

DISCUSSION: -

Most of the research studies including studies done by Kizilkanat et al, V. Sailkumari et al, Poornima B et al, Zahra et al, Shrestha p. et al, Agrawal et al, Gupta et al found that majority of femur bones had single nutrient foramen but in our study we found that majority of femurs had double nutrient foramina. Our study results were in agreement with studies done by Mysorekar et al, Bridgeman et al, Roopam et al, Kumar et al, Raveena Paul GR, Immanuel Navin Kumar Balla, et al. In our study, 160 femurs were studied and it was observed that majority (50.6%) of femurs had double nutrient foramina, 41.9% femurs had single foramen and 2.5% femurs had no NF. We found upto five foramina in femur. Gumusburun et al. found up to six foramina in femur, whereas Sendemir and Cimen reported as high as nine foramina. (Table-5)

Table -5: Comparison of Number of Nutrient Foramina

Researcher	No. of bones	No. of nutrient foramina						
		0	1	2	3	4	5	
V. Sailakumari et al(2019)	114	Nil	95.6	4.38	Nil	Nil	Nil	
Poornima B et al(2015)[10]	100	-	62	37	1	-	-	
Zahra et al(2017)[7]	107	17	69	20	1	Nil	Nil	
Shrestha P et al(2019)	151	-	78.81	31	1	-	-	
Agrawal et al(2016) [15]	100	0	78	22	-	-	-	
Kizilkanat et al(2007) [13]	100	0	75	25	0	-	-	
Gupta et al(2016) [14]	100	3	71	25	1	-	-	
Roopam et al(2016) [17]	312	0	48.46	49.4	6.10	-	-	
Bridgeman et al(1996) [20]	109	2.7	44.03	53.2	0	-	-	
Mysorekar et al(1967) [16]	180	3.3	45	50	1.6	-	-	
Kumar et al(2013) [18]	101	1.9	47.52	50.4	Nil	-	-	
Raveena Paul GR, Immanuel Navin Kumar Balla, et al(2019)	200	-	41	55.5	3	0.5	-	
Present study	160	2.5	41.9	50.6	3.8	0.6	0.6	

Kizilkanat et al, Karmali and Chouhan et al, Agrawal et al, Zahra et al reported that most of NF were located in the middle

third and a small number of NF found on the upper third of the femur. Our study also suggests that 84.38% of NF were located in the middle third and 14.84% on the proximal third with only 0.78% foramina found on the distal third of the femurs.

In our study, Foraminal index ranged from 24.81 to 86.09 which indicates the occurrence of foramina in any region (proximal, middle or distal third of shaft). Among them majority of femur had foraminal index type II, indicating the location of foramina in middle third of the bone. (Table- 6)

Table -6: Comparison of Position of Nutrient Foramina

Researcher	No. of bones	Proximal third	Middle third	Distal third
Karmali and Chouhan et al(2019) [6]	70	20	78.82	1.17
Agrawal et al(2016) [15]	100	21.15	78.84	0
Zahra et al(2017) [7]	107	13	87	0
Present study	160	14.84	84.38	0.78

In our study we found that majority of NF were present either along the linea aspera or its immediate neighbourhood in the middle one third of the femur. In our study out of 256 NF, 63.68% were concentrated along linea aspera. Our results were in concurrence with previous studies done by Agrawal et al, Karmali and Chouhan et al, Zahra et al, V. Sailakumari et al. (Table- 7)

Table -7: Comparison of Location of Nutrient Foramina

Researcher	No. of bones	Linea Aspera	Medial lip	Lateral lip	Between two lips	Medial surface	Lateral surface	Upper posterior surface
Karmali and Chouhan et al(2019)[6]	70	4.7	25.88	9.41	42.35	17.64	0	0
Agrawal et al(2016)[15]	100		32.07	7.5	32.7	16.3	5.6	5.6
Zahra et al(2017) [7]	107	-	34.82	11.61	34.82	16.07	2.68	-
V. Sailakumari et al(2019)	114	93.8	-	-	-	0.87	5.6	-
Present study	160	28.52	14.45	3.52	17.19	29.69	5.08	1.56

Size of Nutrient Foramina

Out of 256 foramina, 8.98% large size foramina, 28.13% medium size foramina, 25% small size foramina, 37.89% foramina were of very small size. 62.11% NF were dominant foramina and 37.89% were secondary foramina.

Direction of Nutrient Foramina

Most of the previous studies found that nutrient NF of femur bone were commonly directed upwards towards proximal end. In our study, almost all foramina were directed upwards and away from the growing end. This finding confirms the "away from the knee and towards the elbow" theory, which claims that all the nutrient foramina in long bones are directed away from the growing ends of the long bones.[7] This also confirms Berard's rule of canal direction.

CONCLUSION:-

The present study conducted on nutrient foramina of 160 dry adult human femora concluded that the double foramina (50.6%) are more common than single (41.9%). Majority of nutrient foramina are concentrated along the linea aspera and in the middle one third of the shaft of femur. Data regarding the blood supply to the long bones is very crucial in the development of new transplantation and resection techniques in orthopaedics. Knowledge about the exact

location and distribution of nutrient foramina in the diaphysis of Femur bone is important to avoid damage to the nutrient vessels during surgical procedures. It will be helpful for better fracture healing and microvascular bone grafting.

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