Original Article

DOI: 10.7860/IJARS/2017/27566:2270

Analytical and Morphological Study of Nutrient Foramina of Human Femur

Anatomy Section

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ABSTRACT

Introduction: Nutrient foramina are important as they provide passages to the nutrient arteries into the marrow cavity of long bones, which are the principal source of blood supply and nourishment of long bones. Active bone growth in embryo, fetus and early phase of ossification depend on its blood supply.

Aim: To note the number, position, direction and obliquity of nutrient foramen along with measurement of physiological length, foraminal index and co-relations between foraminal index and distances of nutrient foramina from three important bony landmarks. The present study also included comparison of above data between right and left sided femur.

Materials and Methods: The present study was conducted on 60 adult, dry, cleaned normal human femur (30 right and 30 left), collected from the Department of Anatomy, ESIC & PGIMSR Medical College, Joka, Kolkata for a period of three months from September to November, 2016. The objectives of the study were noted and analysed.

Results: The study revealed predominance of single foramen in 63.66% femur. There was no nutrient foramen in two right sided femor. The nutrient foramina were predominant on middle 1/3rd of femoral diaphysis (94.94%), both on right and left sides mostly on and around linea aspera. All foramina were directed proximally and there was no change in obliquity. The foraminal index ranged between 36.741±2.122 to 58.008±2.218. The study also showed positive co-relations between foraminal index and distance of nutrient foramina from fovea, lesser trochanter, mid intertrochanteric crest separately each being statistically significant.

Conclusion: The present study is useful in calculating the length of a long bone from a given fragment which is important for medicolegal and anthropological work. It is also important for vascular bone grafting.

Keywords: Anthropology, Bone grafting, Foraminal index, Medicolegal

INTRODUCTION

Nutrient foramina are important as they give passages to the nutrient arteries, which are the principal source of blood supply and nourishment of long bones [1]. Study of arterial supply is important as, acute blood vessel occlusion due to thrombosis, lipid emboli, fat cell hypertrophy with compression of intraosseous capillaries, leads to avascular necrosis and bone infarction, whereas osteoporosis results from arteriosclerosis [2]. Four groups of arteries supply a typical long bone - nutrient artery, epiphyseal artery, diaphyseal and periosteal artery [3]. All the nutrient arteries course caudally during embryonic life to force blood from cephalic to caudal side and thus the adult rule 'towards the knee and away from elbow' become logical as one end of long bone growing faster than the other end [4].

Femoral diaphysis is fed by one or two nutrient arteries arising from profunda femoris artery. Profunda femoris artery can be used in femoral diaphysis transplant surgeries [5]. Currently, the detailed study of blood supply to long bones has been found to be a determining factor for the success of new techniques for bone transplant and resection in Orthopedics [6].

Many morphometric and analytical studies have been done to record the number, location, direction of nutrient foramina in femur along with the calculation of foraminal index. However to the best of our knowledge, no study has been found which has made the co-relation between Foraminal Index (FI) and the distance of nutrient foramina from fovea (F1), lesser trochanter (F2), and from mid intertrochanteric line/crest (F3).

Thus, the aim of this study is to observe the detailed features of nutrient foramen in human femur and calculate the indices which would contribute in medico-legal cases and bone

grafting. This would further help in standardising the detailed features of nutrient foramina in human femur for anthropometric purposes.

MATERIALS AND METHODS

The present study was a descriptive study, conducted on 60 (30 left and right sided femur each) adult, dried and cleaned, human femur, obtained from Osteology collections of the Department of Anatomy, ESIC & PGIMSR Medical College, Joka, Kolkata, India, for a period of three months from September to November 2016, after taking ethical approval from the said institution.

The selected bones were anatomically normal with no appearance of pathological changes on observation. The specific race, sex and age characteristics of the bones under study were unknown.

Nutrient foramina present elevated margin and distinct groove proximally and by these two features the nutrient foramina of shaft of femur were identified by means of a hand lens [Table/Fig-1].

[Table/Fig-1]: Nutrient foramina identified by elevated margin and prominant groove proximally.

Inclusion Criteria: (a) Dry, clean, anatomically and pathologically normal human femur were taken.

(b) Only well defined nutrient foramina were observed.

(c) Nutrient foramina only on the shaft of femur were included in the study.

Exclusion Criteria: (a) Specific race, age, sex were not studied as observed bones were taken from osteology collection of dry bones, not from the cadavers.

(b) Any fractured bone or bones with any other pathological changes were excluded from our study.

(c) Nutrient foramina present at the ends of femur were ignored.

(d) Nutrient foramina which were not well defined were excluded.

Following features were studied on the diaphyseal nutrient foramina of each human femur:

1. **Number of nutrient foramina –** Sixty human femurs (30 left and 30 right) were examined for the number of nutrient foramina.

2. **Direction and obliquity of nutrient foramina -** Direction and obliquity of the nutrient foramina were confirmed by introducing a fine stiff wire into the foramina [Table/Fig-2].

[Table/Fig-2]: Direction of nutrient foramina showed by introducing a stiff wire into the foramina.

3. **Determination of physiological length of femur –** Total length of individual human femora was taken as distance between proximal end of head of femur and the most distal aspect of medial epicondyle of femur. Length was measured by osteometric board.

4. **Determination of Foraminal Index (FI) –** FI was calculated by following formula :

FI = (Distance of nutrient foramen from proximal end of femur / Total length) ×100 [7].

All measurements were taken to the nearest of 0.1 mm using a sliding caliper.

5. **Location of nutrient foramina according to FI –** Categorised into three types according to FI as follows :

Type 1: FI upto 33.33 –In proximal 1/3rd of the bone

Type 2: FI 33.33 to 66.66 – In middle 1/3rd of the bone

Type 3: FI above 66.66 – In distal 1/3rd of the bone [8].

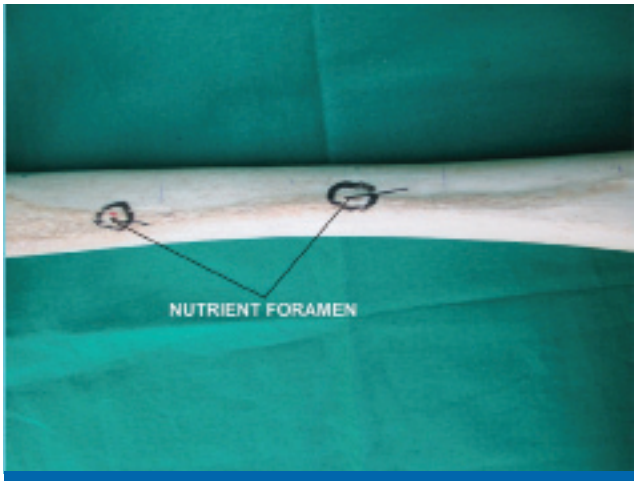
6. **Position of nutrient foramina according to bony regions –** Position of nutrient foramina was observed according to their presence on either Linea aspera, or on its medial or lateral lip, or on the postero-lateral surface of the human femur.

7. **Co-relations of F_1, F_2 and F_3 with FI –** Co-relations of the

distance of nutrient foramina from fovea (F1), lesser trochanter (F2), and from mid intertrochanteric line/crest (F3), with FI were calculated.

RESULTS

1. **Number of nutrient foramina –** Among a total of 60 anatomically normal human femur observed, 38 femur (18 right sided and 20 left sided) showed presence of single nutrient foramen (63.66%) while in 31.66% femur (19 femur- 10 right sided and 9 left sided) double foramina [Table/Fig-3] were observed and in 1.66%, (one left sided femur) triple foramina were found [Table/Fig-4]. Nutrient foramen was absent in two right sided femur, which constituted 3.33% of total bones [Table/Fig-5].



[Table/Fig-3]: Double nutrient foramina.

[Table/Fig-4]: Triple nutrient foramina.

2. **Direction and obliquity of nutrient foramina –** All foramina were directed proximally presenting no change in obliquity.

3. **Determination of physiological length –** Physiological length of each femur was examined which ranged between 41.9 to 46.85 cm with mean±standard deviation was 44.27±1.47 [Table/Fig-6] presenting no statistically significant difference between right and left sides.

(The p-value = 0.499 was considered as non significant).

No of Foramina	No of Bones (%)		Total No of Bones (%) n = 60
	Right (n=30)	Left (n=30)	
Single (1)	18 (60%)	20 (66.66%)	38 (63.66%)
Double (2)	10 (33.33%)	9 (30%)	19 (31.66%)
Triple (3)	0 (0%)	1 (3.33%)	1 (1.66%)
Absent foramina (0)	2 (6.66%)	0 (0%)	2 (3.33%)

[Table/Fig-5]: Number of nutrient foramina in femur under study with percentage.

4. **Determination of Foraminal Index (FI) –** FI ranged between 33.08 and 57.98 with mean ± standard deviation between 36.74±2.12 to 58.01±2.22 [Table/Fig–7].

	Right	Left	Total
Range	42.95–46.85	41.9–46.4	41.9–46.85
Mean±SD	44.49±1.28	43.92±1.83	44.27±1.47

[Table/Fig-6]: Range, mean±standard deviation (SD) of physiological length of human femur (n=60).
p-value – 0.499: Non significant

Location	Range		Mean±SD	
	Right	Left	Right	Left
Linea aspera	34.14–38.84	34.93–54.99	36.74±2.12	39.84±8.52
Lateral lip of linea aspera	40.01–51.16	40.65–48.73	45.58±7.89	45.79±5.72
Medial lip of linea aspera	55.46–59.49	33.08–60.35	58.01±2.22	50.22±12.07
Postero-lateral surface	53. 03–57.98	45.76–46.38	55.51±3.50	46.08±0.44

[Table/Fig-7]: Range, mean±SD of foraminal indices (n=60).

5. **Location of nutrient foramina according to FI –** 94.94% nutrient foramina were located on middle third of femur while in 5.06% cases, nutrient foramina were located on the proximal third. However, no nutrient foramen was located on the distal third of femur [Table/Fig–8].

*79 nutrient foramina (n=79) were found in 60 femur under study.

6. **Position of nutrient foramina according to bony regions –** In a total of 79 nutrient foramina observed, 76 were found to be located on and around the linea aspera on both right and left sides while three nutrient foramina (one right sided and two left sided) were located on the postero - lateral surface of shaft of femur [Table/Fig–9].

Segments of Femur	No of Nutrient Foramina (%)		Total No of Nutrient Foramina (%) (n=79)*
	Right	Left	
Proximal 1/3rd	0 (0%)	4 (9.76%)	4 (5.06%)
Middle 1/3rd	38 (100%)	37 (90.24%)	75 (94.94%)
Distal 1/3rd	0 (0%)	0 (0%)	0 (0%)

[Table/Fig-8]: Position of nutrient foramina according to segments of femur.
*79 nutrient foramina (n=79) were found in 60 femur under study.

Location	No. of NF (%)		Total No. of NF (%) (n=79)*
	Right (n=38)	Left (n=41)	
Linea aspera	24 (63.16%)	20 (48.78%)	44 (55.7%)
Lateral lip of linea aspera	7 (18.42%)	10 (24.39%)	17 (21.52%)
Medial lip of linea aspera	6 (15.79%)	9 (21.95%)	15 (18.99%)
Postero-lateral surface	1 (0.02%)	2 (0.04%)	3 (3.80%)

[Table/Fig-9]: Position of nutrient foramina according to bony regions.
*79 nutrient foramina (n=79) were found in 60 femur under study.

7. **Correlations of F1, F2, F3 with FI –** Strong positive correlations (r value) between Foraminal Index (FI) and F1, F2 and F3 respectively. All were found to be statistically significant [Table/Fig-10].

Variables	r value	p-value	Comments
FI and F1	0.988	< 0.00001	Significant
FI and F2	0.992	< 0.00001	Significant
FI and F3	0.988	< 0.0001	Significant

[Table/Fig-10]: Correlations and significance among different variables.

DISCUSSION

In the present study, 63.33% of total human femur had only one nutrient foramen, which is nearly similar to the study findings of Poornima B et al., (62 %) in 2015 [9], while studies by Gumusburun E et al., [10] and Kizilkanat E et al., [7] reported the same in approximately 30% of dry femur specimens. Observation of 31.33% (19 among 60 femur) of femur having two nutrient foramina, is nearly similar to those reported by Sendemir & Cimen [11] and Gumusburun E et al., [10]. However it differs from the values reported by Kizilkanat E et al., (60%) [7]. Three nutrient foramina were found in 1.66% of bones examined which is similar to study done by Pereira GA M et al., [12] and Poornima B et al., [9]. According to Gumusburun E et al., 1.9% showed absence of nutrient foramina, on the contrary our study revealed 3.33% of observed bones having no nutrient foramina [10] which is nearly similar to the study done by Murlimanju BV et al., (4.6%) [13].

In the present study, most of the nutrient foramina (75 among 79 foramina i.e., 94.94% of total foramina) were located along the middle third of the femur, rest 4 (5.06% among total foramina) were located on the proximal third with no foramina detected in the distal third of femur. These findings were in accordance with those of Sendemir & Cimen [11], Gumusburun E et al., [10] and Kizilkanat E et al., [7]. In the present study, 55.7% of nutrient foramina were found on linea aspera, 21.52% and 18.99% were on lateral and medial lip of linea aspera respectively, while only 3% were on postero-lateral surface of shaft of femur. Similar, findings were revealed in the studies by Sendemir & Cimen [11], and Gumusburun et al., [10] and Seema et al., [14]. 100% nutrient foramina (NF) were directed proximally in this study, but according to Kumar R et al., [15] two nutrient foramina among 101 were directed distally. According to the present study, positive correlations were found between FI and F1, F2, F3 which were not reported before to the best of our knowledge. So, foraminal index can also be calculated from F1, F2, and F3 following regression equation.

CONCLUSION

The present study provided anthropological and morphometric data about nutrient foramina of human femur. New information about the foraminal index was obtained which would be helpful for orthopedic surgical procedures like bone grafting. Further, it would also be useful for radiological and medico legal purposes. This study is planned to continue further on other long bones collected from population of West Bengal, which would be of immense value for anthropometric purpose.

ACKNOWLEDGEMENTS

Authors are sincerely thankful to all the faculty members of the Department of Anatomy, ESIC & PGIMSR Medical College, Joka, Kolkata, India.

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FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Publishing: **Apr 01, 2017**