

Evaluation of Nutrient Foramen in Adult Dry Human Femur

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ABSTRACT

BACKGROUND

Nutrient foramen is a large opening that transfers the arteries that supply the bone to the bone cavity. During surgical procedures, it is very important to have precise and complete information about the location of the foramina to determine whether the fracture line passes close to the nutrient foramina. The purpose of this study was to determine the number and position of the femoral nutrient foramina together with morphometric measurements.

METHODS

A total of 93 dry adult femurs with unknown sexes were examined in this study. The direction, location and the total number of nutrient foramina of the femur were investigated by using an anthropometer (Lafayette instrument, Indiana). Also, foraminal index was calculated.

RESULTS

The analysis revealed that 28 (53.8 %) of the femurs with a single nutrient foramen were on the right side and 22 (53.7 %) were on the left side, respectively. Femurs with double nutrient foramina were 23 (44.2 %) and 18 (43.9 %) on right and left sides, respectively. Femurs with triple nutrient foramina were 1(1.9 %) and 1 (2.4 %) on right and left sides, respectively. The foraminal index of femurs was found as (41, 58 %) and (42, 23 %) on the right and left sides, respectively. The nutrient foramen was mostly 84 (90.3 %) located at the middle third of the femur.

CONCLUSIONS

The findings of this study provide information and details about nutrient foramen which have clinical importance, especially in surgical procedures like bone grafting and microsurgical vascularized bone transplantation.

KEY WORDS

Femur, Foraminal Index, Nutrient Artery, Nutrient Foramina

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BACKGROUND

The femur is the longest and strongest bone of the human body.¹ It consists of a diaphysis and two ends known as epiphyses. Typically, long bones and femur are supplied by four types of arterial systems; namely nutrient, epiphyseal, diaphyseal and periosteal arteries. The periosteal circulation; supplies blood to the structures such as the periosteum, the outer one-third of the underlying cortex and surrounding muscles. Whereas the medullary circulation, which originates from the nutrient artery supplies blood to the bone marrow and inner two-third of the bone cortex.^{2,3,4}

Long bones have a large opening on the shaft named nutrient foramina.¹ Nutrient foramen, which varies in number and location, is located on the surface of the femur called the linea aspera which are directed proximally along the bone; one usually near its proximal end and the second usually near its distal end. After the nutrient artery enters the foramen, it moves through the nutrient canal and opens into the marrow cavity. It forms many small vessels in the bone marrow sinusoids to nourish the cortex and spongy structure of the bone.⁵

Nutritional arteries provide blood supply and vascularization to long bones, which usually meet the need of bones during the growth phase and in the early stages of ossification.^{6,7} During the early phases of ossification, long bones receive about 80 % of their blood flow from the nutritional arteries, and coronary arteries perform this task through the periosteum in case of lack of nutritional arteries.^{8,9} Bone nutrient supply leads to the survival of osteoblast and osteocyte cells in the bone, the role of which is important in bone vascularization and growth of long bones.

Typically in long bones, the vessel feeding the diaphysis moves away from the growing end of the bone.¹⁰ Previous studies have identified several variations regarding the location of the nutrient foramina in the lower extremity bones.¹¹ Therefore, during the application of orthopaedic techniques such as bone resection and transplantation as well as vascularized bone microsurgery, it is an important necessity to understand the position of the foramina of the long bones and the blood supply of the bone with detailed information.^{12,13,14,15}

This study was conducted to provide useful data for orthopaedic surgeons, anatomists and radiologists. For this purpose, morphometric measurements were made in the femoral bone to determine the location, number and foramen index of the femoral nutrient foramina. In addition, as there is genetic, racial, and ethnic diversity among humans, this study also intended to evaluate the nutrient foramina of our population's dry adult human femoral bone.

METHODS

The present study comprised an examination of included 93 dry adult femurs (52 right and 41 left sides). The age and sex of the femur bones used in the study were not known. Femur bones were obtained with the permission of the concerned head and authority of the Anatomy department, Faculty of Medicine, Çukurova University, between December 2020 and February of 2021.

The femurs were cleaned and labelled with site numbers. Only femur bones with good condition were included in the study. Bones that were deformed and damaged, bones with the callous formation and unossified bones were excluded from the study. Length of the bone was measured in cm using Lafayette anthropometer (Lafayette anthropometer is a mechanical sliding caliper which does not require calibration; a range of 0 to 60 cm in 0.1 cm increments which allows for measuring of shoulder width, long bone length and chest depth Model 01290, Lafayette instrument company, Indiana) and parameters estimated were measured using an elastic band and a digital vernier caliper that measured to 0.01 mm (TTI Vernier caliper, 0 - 200 mm). The longitudinal axis of the bone was kept parallel to the longitudinal axis of the anthropometer. The proximal aspect of the caput femoris and the most distal aspect of the medial condyle of the femur were identified and marked to be measured; the grip ends of C-shaped arm branches of the sliding caliper, were rested against the forearms along the longitudinal axis of the bone. Pressure has been applied to the caliper's branches. The arm has been moved ends to the desired landmarks and the scale was read along the base of the caliper to the nearest centimetre.

The number of foramen nutricium in the femurs was recorded and measurements were taken in relation to the foramen nutricium. Measurements were taken as below.

1. (TLF) Total length of femur= the distance among the proximal aspect of the caput femoris and the most distal aspect of the medial condyle.
2. (DNF) = the distance from the proximal end of the bone to the nutrient foramen.
3. Circumference of the nutrient foramen (foramen nutricium) (body of the femur) = the circumference of the femoral body was measured at the base of the largest foramen nutricium.
4. Transverse diameter of the femur at the location of nutrient foramina.
5. Anteroposterior diameter of the femur at the location of nutrient foramina.
6. Foraminal Index (FI): Hughes formula¹⁶ was used for calculating this index.

$$\text{Foramen Index (FI)} = (\text{DNF} / \text{TLF}) \times 100$$

The position of the foramina was divided into three types according to FI as follows -

- Type 1: $\text{FI} < 33.33$, the foramen was in the proximal third of the bone.
- Type 2: $33.33 < \text{FI} < 66.66$, the foramen was in the middle third of the bone.
- Type 3: $\text{FI} > 66.66$, the foramen was in the distal third of the bone.

Statistical Analysis

Statistical analysis of the data was performed by SPSS 21.0 programme. An independent sample t-test was used for descriptive statistics and bilateral differences, Spearman Pearson correlation test was used for correlation between measurements. Frequency and percentages were calculated.

RESULTS

The following results were obtained. The mean values of 93 femoral (52 right and 41 left sides) bones and bilateral differences are shown in Table 1. The mean total length of the femur on the right side was 42.77 ± 2.99 cm, while it was 43.50 ± 3.25 cm on the left side. No, statistically significant differences between the right and left sides were shown in all measurements, including the total femur length ($P > 0.05$). The correlations between all measurements on the femur are shown in Table 2.

Measurements	Right (N = 52)				Left (N = 41)				P
	Mean	SD	Min	Max	Mean	SD	Min	Max	
TLF (cm)	42,77	2,99	36,60	50,00	43,50	3,25	37,60	54,40	0.265
TDNF (cm)	27,83	2,70	21,10	34,87	27,66	2,67	22,71	33,19	0.757
APDNF (cm)	27,33	2,65	19,97	34,83	26,79	2,87	20,74	32,38	0.348
DNF (cm)	17,73	3,64	12,60	26,20	18,36	4,80	11,53	37,30	0.470
CNF (cm)	8,83	0,70	7,50	10,60	8,76	0,67	7,30	9,90	0.596
FI (%)	41,58	8,91	31,15	63,00	42,23	10,34	28,90	78,53	0.747

Table 1. Descriptive Statistics of Nutrient Foramen of Femur

Measurements (Parameters)		TDNF	APDNF	DNF	CNF	TLF	FI
FI	r	-0.249*	0.245*	0.954**	0.000	-0.121	1
	p	0.016	0.018	0.000	0.996	0.248	
TLF	r	0.524**	0.586**	0.172	0.673**	1	
	p	0.000	0.000	0.100	0.000		
CNF	r	0.767**	0.817**	0.194	1		
	p	0.000	0.000	0.062			
DNF	r	-0.094	0.409**	1			
	p	0.370	0.000				
APDNF	r	0.358**	1				
	p	0.000					
TDNF	r	1					
	p						

Table 2. Correlation between All Measurements on the Femur

** Correlation is significant at the 0.01 level (2 - tailed)

* Correlation is significant at the 0.05 level (2 - tailed)

Nutrient Foramen	Right		Left		Both	
	N	%	N	%	N	%
1	28	53.8	22	53.7	50	53.76
2	23	44.2	18	43.9	41	44.09
3	1	1.9	1	2.4	2	2.15
Total	52	100.0	41	100.0	100	100.0

Table 3. Number and Distribution of Nutrient Foramen

Foraminal Index Type	N	%
1	8	8.6
2	84	90.3
3	1	1.1
Total	93	100

Table 4. Topographical Distribution of the Nutrient Foramina Based on the Foraminal Index of the Femur

A statistically significant negative correlation was found between the transverse diameter of the nutrient foramen and foraminal index ($r = -0.249$, $P < 0.05$). A statistically significant positive correlation was found between the anteroposterior diameter of the nutrient foramen and all other measurements ($r = 0.245 - 0.817$, $P < 0.05$). In addition, the highest statistically significant correlation was found between DNF and foraminal index ($r = 0.954$, $P < 0.001$). The number and distribution of nutrient foramen in the right and left femurs are shown in Table 3.

Most of the nutrient foramina were presented along with the middle third of the femur and the foraminal index ranging between 28.90 % and 78.53 % of the total bone length. Of the total 93 foramina, 84 (90.3 %) were in the middle third (Type 2), 8 (8.6 %) in the proximal third (Type 1) and 1 (1.1 %) in the distal third (Type 3) (Table 4).

The comparison of the measurements related to the nutrient foramen with the studies conducted on different societies is shown in Table 5.

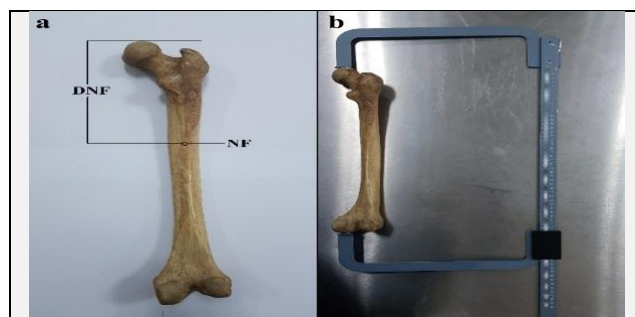


Figure 1. (a) (DNF) = The distance from the Proximal End of the Caput Femoris among the Nutrient Foramen, (b) (TLF) Total Length of the Femur

DISCUSSION

Nutrient foramina provide an opening shaft for the nutritional arteries. In this field previously many authors, have conducted studies on the differences in the location of nutrient foramina of various races. In the present study, the mean total lengths of all 93 femurs were obtained as 43.09 ± 3.1 cm which is almost similar to the results obtained by Hamzhtofigh et al. 42.4 cm, Kirschner et al. 40.8 cm in Germans and Bosnia and Herzegovina 44.34 ± 2.5 cm.^{13,17,18} The current femoral measurements were similar to 44.34 cm in blacks and 44.96 cm in white South Africans¹⁹ and also approximately 10 % longer than 40.1 cm in Americans.²⁰ In a study done by Krishna et al.²¹ it has been reported that the average length of the femur was 43.48 cm on the right side and 43.7 cm on the left side. In addition, the distance of the nutrient foramina to the upper end was 18.75 ± 4.79 cm and 16.98 ± 3.99 cm respectively. Collipal et al.²² observed the average length of the femur as 43.52 cm on the right side and 43.7 cm on the left side and the distance of the nutrient foramina to the upper end as 19.2 ± 4.81 cm, 19.5 ± 4.97 cm respectively. In a study done by Bichitrananda and Meena²³ the mean length of the femur has been reported as 43.6 cm. They also reported that the average distance of the nutrient foramen from the upper end was 15.25 cm. In our study, the average length of femur supports the above previous studies (right side 42.77 ± 2.9 cm and left side 43.50 ± 3.25 cm), and with the average distance of the nutrient foramina from the upper end as $17.73 \text{ cm} \pm 3.64$ on the right side and $18.36 \text{ cm} \pm 4.80$ on the left side (Table 1).

The analysis revealed that 28 (53.8 %) of the femurs with a single nutrient foramen were on the right side and 22 (53.7 %) were on the left side, respectively. In a study done by Mazengenya and Fasemore¹⁹ of adult black and white South Africans, they have been reported that majority of the femora in black South Africans had one nutrient foramen, followed by two on their surfaces. On the contrary, they also stated that situation was different in white South Africans where double nutrient foramina were the commonest followed by a single nutrient foramen. The results in our study were in agreement with reports from other studies, Shrestha et al.²⁴, Longia et al.¹¹ in Indians, Pereira et al.²⁵ and Ranwaera², (58

%) who reported that a single nutrient was the commonest on the shaft of the femur.

When we compare the findings of previous studies, Campos et al.²⁶ (60 %), Prashanth et al.²⁷ (44.2 %), Poornima and Angadi²⁸ (37 %), Bichitrnanda and Meena²³ (59.4 %) reported double nutrient foramina. The observation that about 40.9 % of the bones have two NF is similar to that reported by previous studies. Unlike in our study, they did not separate the bones on the sides of the limbs they belonged to.

In our study, most of the foramen was single nutrient foramen. Dervisevic et al.¹⁸ has reported that the majority of two NF 57.1 % on the right femur and 42.1 % on the left femur. Similarly in our study, bones with two nutrient foramina were observed in 23 (44.2 %), 18 (43.9 %) on the right and left sides, respectively. (Table 3).

In our study, triple nutrient foramina were found 1(1.9 %) on right and 1(2.4 %) on the left side of the femur in disagreement with Ferriol Campos et al.²⁶ who reported approximately 10 % of the femur and Ranaweera et al.² who reported 6 %. Prashanth et al.²⁷ and who reported 3.5 %. In accordance with our study, Pereira et al.²⁵ reported 1.28 % of the femur with triple nutrient foramina. Although Sharma²⁹ identified 2 % and Prashanth et al. 4.6 % femur with absent nutrient foramina in their study.^{22,23} In our findings we did not observe any femur with absent nutrient foramen. This finding is in accordance with Shrestha et al.²⁴ and Pereira et al.²⁵ who did not report any absent nutrient foramina in their study.

Position of Nutrient Foramina: In the present study, most of the nutrient foramina 84 (90.3 %) were found to be located along the middle third of the femur and the rest were in the proximal third, and in the distal third of the femur (Table 3). These results were in accordance with those of Dervisevic et al.¹⁸ (96.4 %), Ranaweera et al.² (85.19 %), Murali Krishna et al.²¹ (73.11 %), Gupta and Ambekar et al.³⁰ (78.22 %). However, these findings did not coincide with those of Hamzehtofigh et al.¹⁸ (72.15 %) and Rashid et al.³¹ (61.18 %), Ferriol Campos et al. who has reported that the nutrient foramina were presented in the upper third of the femur.

Our study has shown that the foraminal index varies between 28.90 % and 78.53 %. This shows that foramina formation can occur in any part of the bone, such as the proximal, middle or distal third of the bone. In addition, the results of this study are consistent with the previous studies by Vinay et al.³² Krishna et al.²¹ and Dervisevic et al.¹⁹ Gupta and Ambekar,²⁷ the majority of foramina are located in the middle third of the femoral bone and have shown that it is a type II of a foraminal index.

Hamzehtofigh et al.¹⁷ examined the localization and number of nutrient foramina in 65 dry femoral bones of unknown age and gender belonging to the Iran population. They reported the anteroposterior diameter of the location of the nutrient foramen of femur as 41.8 ± 32.2 mm and the transverse diameter of the location of the nutrient foramen of femur as 51.2 ± 44.9 mm. Whereas in our study the anteroposterior diameter of the nutrient foramen of the femur was 27.33 ± 2.65 mm on right and 27.66 ± 2.87 mm on the left side. In our study, the transverse diameter of NF of the femur was 17.73 ± 3.64 mm on right and 18.36 ± 4.80 mm on left sides. In a study done by Collipal et al.²² the anteroposterior diameter was 27.7 ± 3.6 mm on right and

28.1 ± 2.1 mm on the left side. They reported a transverse diameter of 27.4 ± 2.3 mm on right and 27.1 ± 4.8 mm on the left side. In our study, the transverse diameter of the nutrient foramen of the femur was in accordance with Collipal et al.²²

The nutrient foramen underlines the significance of perforating arteries to provide the blood supply to the medullary wall and bone marrow. During surgical interventions, the nutrient artery area of the femur has to be handled with caution for subtrochanteric fractures to prevent haemorrhage. The nutrient artery may be involved in traumatic injuries, which make the location of nutrient foramen very important. The present study conducted on nutrient foramina of 93 femurs (52 right and 41 left sides) of dry adult human femora and has shown that most of the nutrient foramina are located in the middle third of the femur. In addition, double nutrient foramina were observed as a common finding in our study.

CONCLUSIONS

The findings of our study are consistent with the findings of previous studies on the number and location of the nutrient foramina in the femur. This study also provided important information on the clinical significance of nutrient foramina. During surgical procedures, it is very important to know the exact location and distribution of the nutrient foramina in the bone diaphysis and to avoid damaging the nutrient vessels. There is a need for larger-scale future research supported by larger sample sizes and radiographic studies.

Researcher (Year)	Population	N	Type 1	Type 2	Type 3
Rashid et al. (2019)	India	85	52 (61.18 %)	31 (36.47 %)	2 (2.35 %)
Gupta & Ambekar (2016)	Nepal	124	26 (20.97 %)	97 (78.22 %)	1 (0.81 %)
Dervisevic et al. (2019)	Bosnia & Herzegovina	47	3 (6.38 %)	44 (93.62 %)	0 (0 %)
Ranaweera et al. (2020)	Sri Lanka	81	12 (14.81 %)	69 (85.19 %)	0 (0 %)
Hamzehtofigh et al. (2018)	Iran	172	8 (4.65 %)	80 (46.51 %)	84 (48.84 %)
This study (2020)	Turkey	93	8 (8.6 %)	84 (90.3 %)	1 (1.1 %)

Table 5. Comparison of Measurements Related to Nutrient Foramina in the Femur with Different Populations

Data sharing statement provided by the authors is available with the full text of this article at jemds.com.

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