European Journal of Therapeutics

DOI: 10.5152/EurJTher.2017.147

Original Research / Özgün Araştırma

Morphological and Topographical Anatomy of Nutrient Foramen in The Lower Limb Long Bones

Alt Ekstremite Uzun Kemiklerinde Foramen Nutricium'ların Morfolojik ve Topografik Anatomisi

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ABSTRACT

Objective: The present study aims to determine the number and position of the nutrient foramina (NF) of the human femur, tibia, and fibula and to observe the size, direction, and obliquity of the nutrient foramina.

Methods: We observed 265 adult human, lower limb long bones in the Department of Anatomy of the Gaziantep University. The nutrient foramina were identified with naked eyes, and the obliquity was determined with a hypodermic needle. Gauge 20 and 24 needles were used for size determination. Shape was observed with the naked eye and classified into oval and round types. The nutrient foramina location was determined by dividing total bone length into three segments, and the locations were validated by calculating foraminal index (FI).

Results: Results showed that 79% of the long bones had a single nutrient foramen. More than 96% of the nutrient foramina were directed away from the knees. A total of 87% of the femoral foramina were located in the middle third, 72% of the tibial foramina were located in the proximal third, and 98% of the fibular nutrient foramina were located in the middle third of the specimens. Overall, no foramina were found on the distal third of the studied bones.

Conclusion: Our study findings are in accordance to the findings from several research studies. The assessment of pathological conditions associated with the findings of foramen nutricium in our study may help clinicians and surgeons in planning treatments for applications to be performed in this region. However, it is thought that literature will be a source for basic and clinical sciences by providing reference values.

Keywords: Nutrient foramina, femur, tibia, fibula, foraminal index

ÖZ

Amaç: Bu çalışma femur, tibia ve fibula'da bulunan foramen nutricium (FN) sayısını ve pozisyonunu belirlemek ve FN büyüklüğünü, yönünü ve eğimini saptamak amacıyla yapılmıştır.

Yöntemler: Gaziantep Üniversitesi Anatomi Anabilim Dalı'nda bulunan, erişkin insana ait 265 alt ekstremite uzun kemikleri incelendi. Foramen nutricium çıplak gözle tespit edildi ve hipodermik iğne ile eğimi belirlendi. Büyüklüğünün belirlenmesi için 20 ve 24 gauge iğneler kullanıldı. Şekilleri çıplak gözle gözlemlenerek; oval ve yuvarlak tip olarak ayrıldı. Toplam kemik uzunluğunun üç segmente bölünmesiyle foramen nutricium'un yeri saptandı ve foraminal indeks (FI) hesaplanarak lokasyonlar doğrulandı.

Bulgular: Elde edilen sonuçlara göre, bu kemiklerin %79'unda tek bir FN bulunmaktaydı. Foramen nutricium'ların %96'sından fazlasının yönleri dizin ters yönüne doğru idi. Foramen nutricium, femur'ların %87'sinde orta üçte birlik kısımda, tibia'ların %72'sinde proksimal üçte birlik kısımda, fibua'ların %98'inde orta üçte birlik kısımda bulunmaktaydı. Genel olarak, incelenen kemiklerin distal üçte birlik bölümünde foramen nutricium bulunmadığı tespit edildi.

Sonuç: Çalışmamızın bulguları, literatürdeki birçok çalışmanın bulgularıyla uyumludur. Çalışmamızdaki bulgular foramen nutricium ile ilgili patolojik durumların değerlendirilmesi, bu bölgede yapılacak uygulamalar ile ilgili tedavilerin planlanması ile ilgili klinisyen ve cerrahlara yardımcı olabilecektir. Bununla birlikte literartüre referans değerler sağlayarak temel ve klinik bilimlere kaynak olacağı düşünülmektedir.

Anahtar kelimeler: Foramen nutricium, femur, tibia, fibula, foraminal indeks

INTRODUCTION

Bones are building blocks of the human skeleton and form the framework of the human body, its structure, and its mechanisms. Bones are composed of living connective tissues and are calcified in structure (1). The skeletal system comprises ligaments, cartilages, and other connective tissues, which stabilize the human skeleton and interconnect its components. Bones play several functions in the human body, including structural support to the body; protection of the organs; reservoir for storing minerals in the body; and production of different types of blood cells, such as red blood

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Received/Geliş Tarihi: 19.10.2017 • **Accepted/Kabul Tarihi:** 26.10.2017

cells, white blood cells, and platelets (2). Human bones are of two types: compact and spongy. Compact bones are dense bones that form the outer shell of all bones, surround the spongy bones, and contain blood vessels and nutrient foramen (NF). Spongy bones consist of spicules of bones that enclose the marrow and do not contain blood vessels. In addition, bones are classified into different types based on their shape, including long, short, flat, irregular, sesamoid, pneumatized, and sutural or wormian bones. Long bones are tubular bones of the body, for example, humerus and femur and are relatively long and slender (1). They have two metaphyses, two epiphyses, a diaphysis, and a medullary cavity, for example, femur, tibia, fibula, and metatarsals (2, 3).

Bone is an osseous tissue and is highly vascular. The blood supply of a typical long bone is divided into four major sets of blood vessels, which are nutrient vessels, metaphyseal, epiphyseal, and periosteal (2, 4). There is usually one nutrient artery and one vein entering the diaphysis of long bone through NF. The vessel penetrates the shaft to reach the medullary cavity through the nutrient canal. The nutrient artery further divides into the ascending and descending branches approaching the epiphysis (2, 5). The nutrient artery is the main source of blood supply to the long bones and hence, is extremely important in the growth of bones during infancy, childhood, and all phases of ossification. Nutrient arteries are responsible for 70%-80% of the blood supply of the bones, and restriction of this blood supply results in the ischemia of bones (6).

Nutrient foramen is an opening in the shaft of the long bones with a distinct margin. NF provides entry to the nutrient artery and leads it to the nutrient canal. The direction and location of NF are of clinical significance. The location of NF is considered as point of initiation for longitudinal stress fractures, commonly in the tibia and less commonly in the femur, fibula, and patella bones (7). Such fractures usually result in nutrient artery rupture and peripheral vascular disruption. Apart from the importance of nutrient arteries in fracture healing, some other conditions of bones, such as developmental abnormalities and hematogenic osteomyelitis, are also dependent on the vascular system of bones (8). The study of long bone blood supply and the areas of bones supplied by the nutrient artery are important in the development of new techniques in the field of transplantation and resection (9). Given the significance of NF in clinical and morphological fields, it is of paramount importance that the characteristics of NF are studied on an ongoing basis in order to validate the findings from literature and to explore and discover new findings that can play a critical role in the field of medical science.

METHODS

Ethics Committee Approval

As the research study was conducted using the Department of Anatomy owned human bone specimens, ethical committee review was not required. The research was performed according to the World Medical Association Declaration of Helsinki (1964).

Informed Consent

The study was conducted on human lower limb long bone specimens found in the Department of Anatomy, and hence, no consent was required.

Data Collection and Analysis

A total of 265 cleaned and dry adult human bones of the lower limbs were studied. Overall, 107 femur, 91 tibia, and 67 fibula of unknown sex and age were examined in the Department of Anatomy, Faculty of Medicine.

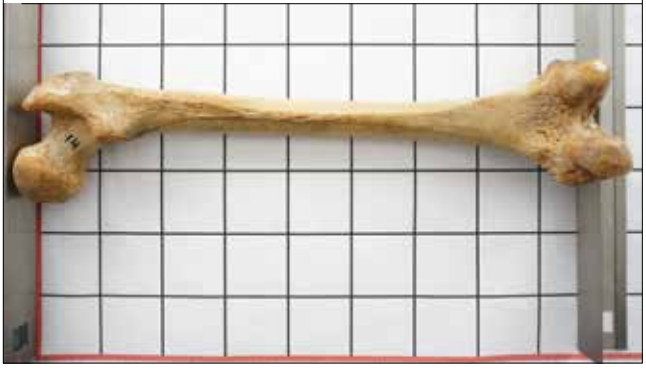
Nutrient foramen was observed in the bones with naked eye and was identified by its elevated margin and by the presence of a distinct groove proximal to NF. Only well-defined foramina on the diaphysis were accepted (Figure 1) and foramina at the bone ends were ignored.

Observations were recorded for number of NF. In order to describe the position of NF, all bone specimens were divided into three parts. Total length of femur was measured as the distance between the proximal aspect of the head of the femur and the most distal aspect of the medial condyle (Figure 2) , and tibia full length was determined by using the distance between the proximal margin of the medial condyle and the top of the medial malleolus (Figure 3), whereas total length of fibula was recorded as the distance between the apex of the head of the fibula and the tip of the lateral malleolus (Figure 4). The foraminal index (FI) of a bone is calculated by using the formula: FI=(DiNF/TL)×100; where FI=foraminal index, DiNF=distance from the proximal end of the bone to NF, and TL=total bone length (10). All measurements were recorded using a measuring matrix chart with small squares and two metallic bars, of which one bar was adjustable and other bar was fixed. Each side of a square was equal to 5 cm (Figure 5).

Sizes of NF were measured with 24 and 20 gauge hypodermic needles (Figure 6). NF smaller or equal to the size of 24 hypodermic needles (yellow color, 0.56 mm in outer diameter) was considered as secondary nutrient foramina (SNF), whereas NF larger or equal

Figure 1. Nutrient foramen with distinct groove

Figure 2. Total length of femur



to the size of 20 hypodermic needles (pink color, 0.908 mm in outer diameter) was considered as dominant nutrient foramina.

The results were analyzed using the SPSS (Statistical Package for the Social Sciences) 22.0 packet software (IBM Corp., Armonk, NY, USA). A p value of <0.05 was considered statistically significant. The ranges, means, and averages for various parameters were determined by the left and right side bones and by the femur, tibia, and fibula separately, and were compared using Student's *t*-test.

RESULTS

Figure 3. Total length of tibia

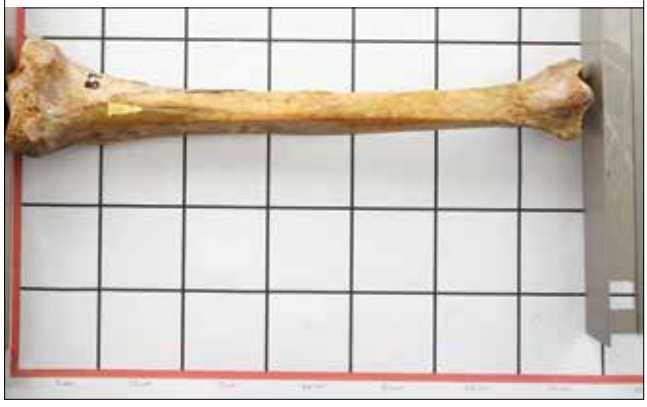


Figure 4. Total length of fibula

Figure 5. Determining location of nutrient foramina by segment

Number of Nutrient Foramina

Overall, 209 (78.8%) bone specimens had a single foramina, 23 (8.7%) had double foramina, 32 (12.1%) had no foramina, and only 1 (0.4%) bone specimen had three NF. Mean number of NF in femur was 1.23±0.7 (min: 0, max: 3), in tibia was 1.03±0.23 (min: 0, max: 2), and in fibula was 0.82±0.46 (min: 0, max: 2).

Out of 23 bones with double foramina, 20 (87%) were femur, 2 (8.65%) were tibia, and only 1 (4.35%) was fibula with a double foramina (Figure 7). The only bone with three foramina was the femur. Out of a total of 32 bones without foramen, 17 (53.13%) were femur, 14 (43.75%) were fibula, and only 1 (3.3%) tibia had no foramen (Table 1).

Direction of Nutrient Foramina

A total of 258 NF were found in 265 bone specimens. Out of all foramina, 112 (43%) were directed upwards, 143 (55%) were directed downwards, and only 3 (1%) were directed horizontally. NF in almost all examined femurs was directed upwards except the three foramina that were directed horizontally (Figure 8). A total of 91 (99%) foramina found on the tibia were directed downwards with only 1 foramen directed upwards and none directed horizontally. A total of 52 (96%) foramina found on the fibula were directed downwards, whereas only 2 (4%) were directed upwards and none was directed horizontally (Table 2, Figure 9).

Total Bone Length

Average total bone length for femur was 43.32±3.71 cm (min: 36 cm, max: 54 cm), for tibia was 35.90±2.79 cm (min: 32 cm, max: 42 cm), and for fibula was 34.65±2.31 cm (min: 30 cm, max: 41 cm) (Figure 2, 3, and 4).

Distance of NF from Upper End of Long Bone

Mean distance of NF from upper end of the femur was recorded at 19.47±5.06 cm (min: 11 cm, max: 31 cm). Mean distance of NF from upper end of the tibia was recorded at 11.66±1.75 cm (min: 9 cm, max: 23 cm) and from upper end of the fibula at 16.32±3.20 cm (min: 11 cm, max: 24 cm).

Distance of NF from Lower End of Long Bone

Mean distance of NF from lower end of the femur was 23.84±5.08 cm (min: 13 cm, max: 37 cm). Mean distance of NF from lower end of the tibia was 24.23±2.28 cm (min: 18 cm, max: 30 cm) and from upper end of the fibula was 18.32±2.69 cm (min: 11 cm, max: 24

Figure 6. Determining size of nutrient foramina with hypodermic needles

Figure 7. Double nutrient foramen on linea aspera of femur

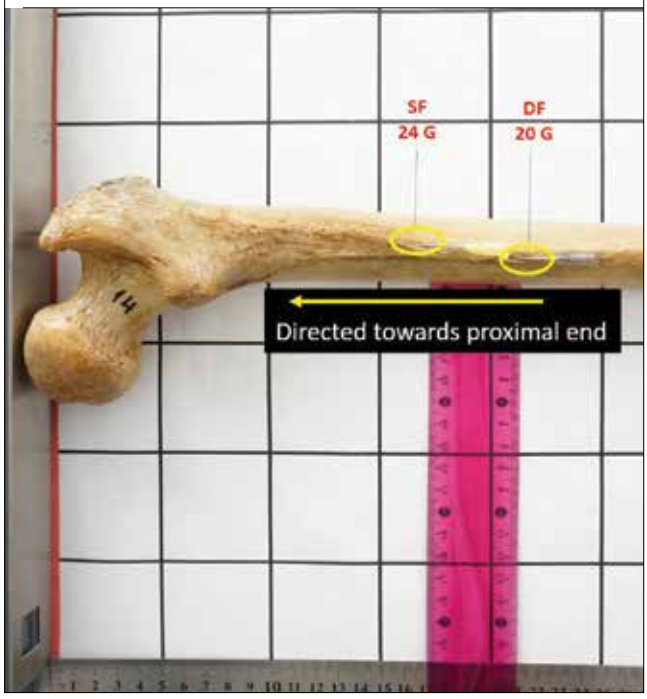
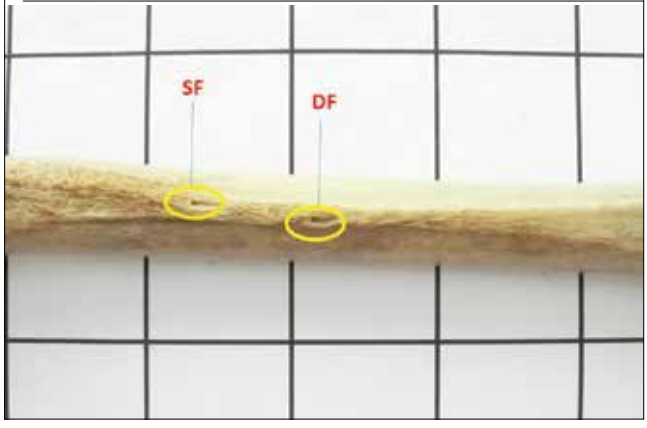


Figure 8. Nutrient foramina of femur directed upwards

Figure 9. Nutrient foramina directed towards the growing ends



Tablo 1. Number of nutrient foramina observed

Long bones		No. of bones	No. of nutrient foramina 0	1	2	3
Femur	Left	54	9	32	13	0
	Right	53	8	37	7	1
	Total	107	17	69	20	1
Tibia	Left	51	1	49	1	0
	Right	40	0	39	1	0
	Total	91	1	88	2	0
Fibula	Left	23	8	15	0	0
	Right		6	37	1	0
	Total	67	14	52	1	0
Grand total (all bones)		265	32	209	23	1

Tablo 2. Direction of foramina (numbers and percentage)

Long bones	No. of foramina	Direction of nutrient foramina (no) Upwards	Downwards	Horizontal
Femur	112	109 (97%)	0 (0%)	3 (3%)
Tibia	92	1 (1%)	91 (99%)	0 (0%)
Fibula	54	2 (4%)	52 (96%)	0 (0%)
Total	258	112 (43%)	143 (55%)	3 (1%)

cm).

Location of NF Bby Segment of Long Bones

Out of all 258 foramina observed, 82 (32%) were present on the upper third of the long bones and had FI≤33.33. A total of 176 (68%) foramina were present on the middle third of the long bones with FI score of 33.33-66.66. No foramina were found on the lower third of the long bones. Of all foramina found on the femur, majority (87%) were on the middle segment, and of those found on the tibia, majority (72%) were on the upper segment of the long bones. Fibula showed a reverse pattern as compared with tibia as 98% of the foramina found on the fibula were located in the middle third (Table 3).

Location of NF by Surface of Long Bones

All 112 (100%) foramina found on the femur were found on the posterior surface of femur specimens with slight variation in location with relation to the lateral and medial lips of the linea aspera. A total of 3 out of 112 (2.68%) femoral foramina were found lateral to the lateral lip and 18 out of 112 (16.07%) foramina were found medial to the medial lip, whereas 39 out of 112 (34.82%) were found between the lateral and medial lips of the linea aspera. A total of 13 out of 112 (11.61%) femoral foramina were found on the lateral lip, whereas 39 out of 112 (34.82%) were found on the medial lip of the linea aspera.

Overall, 100% of the foramina present on the tibia were found on the posterior surface. A total of 19 out of 54 (35%) foramina found

on the fibula were located on the medial crest, whereas the remaining 35 (65%) were located on the posterior surface.

Size of Nutrient Foramina

A total of 172 out of 258 (67%) foramina found on the specimens were SNF. In femur specimens, approximately 63% of NF was SNF. In tibia, majority (71%) of the foramina were dominant, whereas in the case of the fibula, 100% of the foramina were SNF.

Comparison of NF Characteristics in Relation to the Left and Right Sides

Out of a total of 265 bone specimens, 128 (48%) were of the left side, whereas 137 (52%) were of the right side. A total of 54 (50.5%) femur specimens were of the left side, whereas 53 (49.5%) were of the right side. Of the 112 NF found on femur specimens, 58 (51.8%) were found on the left femur, whereas 54 (48.2%) were on the right femur. Mean number of NF for the left femur was 1.25±0.68, whereas mean number of NF for the right femur was 1.29±0.72. No significant difference was found in numbers of NF between the left and right femurs (p=0.627). Of the 109 upward facing foramina found on the femur, 57 (52.3%) were found on the left femur, whereas 52 (47.7%) were found on the right femur. Out of the total foramina found on the femur, 70 (63%) were SNF of which 37 (52.85%) were found on the left femur and 33 (47.15%) were found on the right femur. Mean FI of the left femur was 45.29±11.46, and mean FI of the right femur was 44.57±10.25.

A total of 51 out of 91 (56%) tibia were of the left side, whereas 40 (44%) were of the right limb. Of 92 NF found on the tibia, 51 (55.4%) were on the left tibia, whereas 41 (44.6%) were on the right. Mean number of NF for the left tibia was 1.01±0.24, whereas mean number of NF for the right tibia was 1.04±0.21. No significant difference was found in number of NF on the left and right tibias (p=0.543). Out of the total foramina found on the tibia, 65 (71%) were SNF of which 34 (52.3%) were found on the left tibia, and 31 (47.7%) were found on the right tibia. Average FI for foramina found on the left tibia was 32.05±4.6, whereas FI for NF found on the right tibia was 32.39±2.21.

A total of 23 out of 67 (34.3%) fibula specimens were of the left limb whereas 44 (65.7%) were of the right limb. Of 54 NF found on fibula specimens, 27.7% were found on the left fibula, whereas 72.3% of NF were found on the right fibula. Mean number of NF on the left fibula was 0.65±0.48, whereas mean number of NF on right fibula was 0.91±0.41.

Our study findings suggest that there was no significant difference between the left and right side femurs, tibias, and fibulas in terms of total size of bones and NF, distance of NF from upper and lower ends, and location of NF by FI (Table 4, 5, and 6). The present study found that there is a significant difference between number of NF found on the left and right fibulas (p=0.025).

Tablo 3. Location of nutrient foramina by segment of long bone

		Location by segment (numbers and percentage)		
Long bones	**No. of foramina**	**Upper third**	**Middle third**	**Lower third**
Femur	112	15 (13%)	97 (87%)	0 (0%)
Tibia	92	66 (72%)	26 (28%)	0 (0%)
Fibula	54	1 (2%)	53 (98%)	0 (0%)
Total	258	82 (32%)	176 (68%)	0 (0%)

DISCUSSION

Number of Nutrient Foramina

Many research studies have reported the presence of a single foramen in most of the studied long bones (11–16). Our study findings reveal that single NF was more likely (78.8%) to be observed as compared with double and triple NF in all long bones of the lower limbs. Some studies have reported double foramina in a majority of observed femurs (9, 17–20), whereas some of

Tablo 4. Group statistics for femur

	Group statistics for femur				
	Side	**N[1]**	**Mean**	**Standard deviation[2]**	**p[3]**
Distance from upper ends	L[4]	58	19.60	5.15	0.802
	R[5]	54	19.36	5.01	
Distance from lower ends	L	58	23.72	5.40	0.783
	R	54	23.98	4.75	
Position by foraminal index	L	58	45.29	11.46	0.729
	R	54	44.58	10.25	
Total bone length	L	58	43.32	3.63	0.994
	R	54	43.32	3.84	

[1] Sample size/number of bones
[2] Standard deviation is the dispersion or variation in a distribution of data from the mean in both directions
[3] The p–value, or calculated probability, is the probability of finding the observed results when the null hypothesis of a study question is true (www.stats–direct.com/help/basics/p_values.htm)
[4] Left side
[5] Right side

the research studies suggest that a very small number of femur bones have been observed for the presence of three NF (7, 11, 18, 19). In our study, 107 femurs were studied for number of foramina, and it was observed that majority (64.5%) of femurs had only one foramen each, whereas 20 (18.7%) femurs had double foramina and only one femur bone had three foramina; a total of 17 femurs (16%) had no NF. Gumusburun et al. (18) found up to six foramina in femur, whereas Sendemir et al. (21) reported as high as nine foramina. However, the finding of a large number of foramina was confined to only a small fraction of the study sample Gumusburun et al. (18) found <1% of sample having six foramina and <6% of sample having four or more foramina). We were not been able to record more than three foramina on any of the studied specimen which could be the result of our definition of nutrient foramina in the present study. As described earlier, we identified NF by its elevated margin and by the presence of a distinct groove proximal to NF, and only well-defined foramina on the diaphysis were accepted. We also excluded foramina at the ends of the bones as NF is commonly located on the shaft.

Reportedly, almost 90% of the tibia had a single foramen, and double nutrient was observed in a smaller fraction of tibia (9, 17–19, 21). Majority of tibia observed in our study had only single foramina (96.7%); however, a small fraction (2.2%) had double foramina and one tibia had no foramina.

Of the 67 fibulas studied, 77.6% of bones presented a single NF, whereas 20.9% of fibula had no NF and only a small fraction (1.5%)

Tablo 5. Group statistics for tibia

	Group statistics for tibia				
	Side	**N[6]**	**Mean**	**Standard deviation[7]**	**p[13]**
Distance from upper ends	L[9]	51	11.77	2.13	0.478
	R[10]	41	11.51	1.10	
Distance from lower ends	L	51	24.39	2.52	0.460
	R	41	24.03	1.93	
Position by foraminal index	L	51	32.50	4.60	0.884
	R	41	32.39	2.21	
Total bone length	L	51	36.17	2.96	0.285
	R	41	35.54	2.53	

[6] Sample size/number of bones

[7] Standard deviation is the dispersion or variation in a distribution of data from the mean in both directions

[8] The p–value, or calculated probability, is the probability of finding the observed results when the null hypothesis of a study question is true (www.statsdirect.com/help/basics/p_values.htm)

[9] Left side

[10] Right side

Tablo 6. Group statistics for fibula

	Group statistics for fibula				
	Side	**N[11]**	**Mean**	**Standard deviation[12]**	**p[13]**
Distance from upper ends	L[14]	15	16.97	3.43	0.365
	R[15]	39	16.07	3.11	
Distance from lower ends	L	15	17.20	2.85	0.056
	R	39	18.75	2.53	
Position by foraminal index	L	15	49.51	8.36	0.142
	R	39	46.02	7.46	
Total bone length	L	15	34.16	2.31	0.347
	R	39	34.83	2.31	

[11] Sample size/number of bones

[12] Standard deviation is the dispersion or variation in a distribution of data from the mean in both directions

[13] The p–value, or calculated probability, is the probability of finding the observed results when the null hypothesis of a study question is true (www.statsdirect.com/help/basics/p_values.htm)

[14] Left side

[15] Right side

had double foramina. Similar findings have been observed by studies reporting majority of fibula with a single foramen (11, 17, 19, 21, 22). Some studies also reported fibula with no NF, hence confirming the findings of our study (15, 17, 18, 21, 23). McKee reported three NF on the fibula (22).

Direction of Nutrient Foramina

It is evident from previous studies that nutrient foramina found on the femur bone are commonly directed upwards (10, 17); however, a small fraction (<1%) of the foramina on the femora are directed towards the knee (11, 12). In our study, 97% of NF found on the femora was 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. This is very clearly explained by Hughes (10) suggesting that the nutrient artery enters the shaft of the long bone at an angle of 90°. As the shaft grows in length away from the growing end, the nutrient canal or artery is carried with its growth. This suggests that the course nutrient artery or canal in the long bones is directed away from the growing end. We also found 3% horizontally directed NF on femur specimens, and no foramina in femur were found to be directed towards the knee.

Collipal et al. (9) and Agarwal et al. (16) reported that most of NF found on the tibia is directed away from the knee, whereas Longia et al. (11) reported a small fraction of NF is directed towards the knee. Our study also found that 99% of NF present on the tibia was directed away from the knee, whereas only 1% of NF was directed towards the knee.

In the case of fibula, findings similar to tibia were observed, where 96% of the 54 observed NF were directed away from the knee, whereas only 4% were directed towards the knee. Literature confirms the finding of our study and reported similar variation in the direction of NF found on fibula (7, 11).

Location of Nutrient Foramina

Kizilkanat et al. (15) and Gumusburun et al. (18) reported that most of NF found on the femur is located in the middle third and a small number of NF found on the upper third of the studied femur bones. Our study also suggests that 87% of NF found on the femora was located in the middle third of the bone, and the rest was on the upper/proximal third with no foramina found on the distal third of the femora observed. Our study also suggests that 69% of NF in femur specimens was found either on or lateral to the medial lip of the linea aspera, whereas the remaining was concentrated along the linea aspera. The present study results are in accordance with previous studies suggesting that NF is concentrated along the linea aspera (11, 13, 18, 21, 24, 25).

Literature suggests that several studies have found most of NF on the proximal third and posterior surface of the tibia (9, 11, 16–18). In our study, 72% of NF found on the tibia was in the proximal third of the bone, whereas the remaining was found in the middle third and no NF was observed on the lower third. It may be for this reason that the fractures of the distal third of the tibia usually show a delayed union owing to the absence of NF and poor blood supply (26). Overall, 100% of the foramina found on the tibia were on the posterior surface. Contrary to our findings, Kizilkanat et al. (15) found most of NF in the middle third of the tibia.

Findings from our study suggest that 98% of NF found on the fibula was situated in the middle third of the bone, whereas only 2% of NF was found on the upper third. This is in accordance with the findings from previous studies suggesting high vasculature in the middle third of the fibula (9, 17–19, 21, 22, 27). Our study found that majority (65%) of NF was on the posterior surface, whereas a sizeable number (35%) was found on the medial crest. In literature, variations were observed in relation to the presence of NF on the surface of the fibula. For instance, Sendemir et al. (21) confer the presence of majority of NF on the medial surface of the fibula, whereas Mysorekar (17) suggests that majority of NF is found on the medial crest. Our literature review suggests that majority of NF is found on the posterior surface of the fibula (9, 15, 19, 22).

Understanding the NF location is important for surgeons especially in instances of bone grafting where the fibula is used. As our study and literature confirm that majority of studied bones suggest that the middle third of fibula is highly vascularized, this section will be ideal for use in bone grafting operations where implants with endosteal and peripheral vascularization are required (22).

Size of Nutrient Foramina

Literature suggests that two-thirds of NF found on the lower limb long bones are secondary foramina (11, 28). Our study found that almost two-thirds of the total NF of the long bones were SNF. Two-thirds (63%) of the femoral NF was secondary, whereas more than half of the foramina on the tibia were SNF, and 100% of the foramina found on the fibula were secondary. Other studies have reported that majority of the foramina observed are dominant (15), whereas Sendimir et al. (21) found that all femoral foramina are dominant.

Comparison of NF Characteristics in Relation to the Left and Right Sides

In our study, characteristics of NF found on the right and left femurs were observed to have minimal variation. Our study suggests that finding NF on the right fibula was 44% more likely as compared with that on the left fibula.

Understanding of the location and number of NF and nutrient arteries in the long bones is of utmost importance in the field of orthopedic surgery and orthopedic procedures, including femoral diaphysis transplants, fibular grafting, fracture repair, joint replacement therapy, and microsurgical procedures involving vascularized bones (15). The femoral diaphysis is provided by the nutrient arteries arising from the profunda femoris artery that can be used in the transplant surgery of femoral diaphysis. The healing of fractures, as of all wounds, is dependent upon blood supply, and hence, highly vascularized bone graft will be critical in the outcomes of such transplant surgeries. To attain better outcomes, the position and number of NF need to be determined by surgeons (29).

Literature suggests that the tibia is highly susceptible to longitudinal stress fractures; however, such fractures also occur in the femora but less commonly in fibula. The reason is that the long bones are generally weak and susceptible to fracture at the location of NF. As a result, such longitudinal stress fractures generally initiate from the position of NF on these long bones, thus understanding of the location and position of NF is critical in making correct clinical diagnosis in such fractures. Moreover, manipulating fractures of the long bones, particularly in open reduction, requires surgeons to pay careful attention to the site of NF and avoid limited areas of the long bone cortex that contain NF resulting in an improved outcome of such procedures (7).

The fibula is commonly used for grafting. The periosteum and the nutrient artery are normally transferred with a piece of fibula bone that is to be grafted so that it can remain viable and grow well at the site where it is transplanted. In this way, it can help restore the blood supply of the bone to which it is attached. To ensure viable fibular graft, it is again important to understand the location of NF and to secure the best fibular graft (30).

CONCLUSION

Our study has attempted to compile the findings from different research studies and has used these findings to validate the outcomes of the present research. To the best of our knowledge, our study not only presents observations that are consistent with literature but also identifies the deviations found in the literature and their importance in the field of medical science. Our research will be useful not only for practicing clinicians but also for upcoming medical professionals and new graduates to understand the importance of NF in long bones.

Ethics Committee Approval: Authors declared that the research was conducted according to the principles of the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects"(amended in October 2013).

Informed Consent: Informed consent was not received because data analysis for the study was made retrospectively.

Peer-review: Externally peer-reviewed.

Author contributions: Concept – S.U.Z., P.K., İ.B.; Design - S.U.Z., P.K., İ.B.; Supervision - P.K.; Resource - S.U.Z.; Materials - S.U.Z., İ.B.; Data Collection and/or Processing - S.U.Z., İ.B.; Analysis and/or Interpretation - S.U.Z., P.K., İ.B.; Literature Search - S.U.Z.; Writing - S.U.Z., P.K.; Critical Reviews - P.K., İ.B.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

Etik Komite Onayı: Yazarlar çalışmanın World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects", (amended in October 2013) prensiplerine uygun olarak yapıldığını beyan etmişlerdir

Hasta Onamı: Çalışmamızda retrospektif olarak veri analizi yapıldığından hasta onamı alınmamıştır.

Hakem Değerlendirmesi: Dış Bağımsız.

Yazar Katkıları: Fikir - S.U.Z., P.K., İ.B.; Tasarım - S.U.Z., P.K., İ.B.; Denetleme - P.K.; Kaynaklar - S.U.Z.; Malzemeler - S.U.Z., İ.B.; Veri Toplanması ve/veya İşlemesi - S.U.Z., İ.B.; Analiz ve/veya Yorum - S.U.Z., P.K., İ.B.; Literatür Taraması - S.U.Z.; Yazıyı Yazan - S.U.Z., P.K.; Eleştirel İnceleme - P.K., İ.B.

Çıkar Çatışması: Yazarlar çıkar çatışması bildirmemişlerdir.

Finansal Destek: Yazarlar bu çalışma için finansal destek almadıklarını beyan etmişlerdir.

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How to cite:

Zahra SU, Kervancioğlu P, Bahşi İ. Morphological and topographical anatomy of nutrient foramen in the lower limb long bones. Eur J Ther 2018; 24: 36–43.