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Nutrient foramina in the shafts of lower limb long bones: situation and number

E Sendemir and A Çimen

Uludağ University, Medical Faculty, Anatomy Department, Görükle, 16059 Bursa, Turkey
Anatomy Department of the Uludağ University Medical Faculty

Summary. The location and number of the diaphysial dominant nutrient foramina in 305 specimens of the human lower limb long bones were examined. The diaphysial nutrient foramina on the femur were located at between 26.7-84.4% of the total length; while on the tibia between 11.0-67.2%; and on the fibula between 29.8-67.8% of the total length. The number of the diaphysial nutrient foramina and their distribution on the faces of each bone was also studied.

Les foramen nourriciers des diaphyses des os longs du membre inférieur : nombre et situation

Résumé. La situation et le nombre des principaux trous nourriciers diaphysaires de 305 os longs de membres inférieurs humains ont été examinés. Sur une échelle allant de 0 à 100, partant de l'extrémité craniale de l'os, les trous nourriciers de la diaphyse fémorale sont localisés entre les points 26,7 et 84,4; au niveau du tibia, ces trous sont situés entre 11 et 67,2 et, enfin, au niveau de la fibula entre 29,8 et 67,8. Le nombre de ces trous nourriciers et leur distribution sur les différentes faces des os ont été également étudiés.

Key words : Foramen nutrient — Long bones — Lower extremity

Offprint requests : A Çimen, Uludağ University, Medical Faculty, Anatomy Department, Görükle, 16059 Bursa, Turkey

The success of any transplant lies in the surgeon's ability to preserve its vascular supply [18] and its rapid reconstruction [8], especially in free vascularized bone grafts, which preserve viability of osteocytes, act as a spacefiller and introduce a new vascular bed for the reconstruction of defects following trauma, tumour resection, congenital pseudoarthrosis and cases of difficult non-union of long bones [18].

The nutrient a. is the principal source of blood to a long bone; it is particularly important during its active growth period, and essential during the embryonic stages [2, 17]. A knowledge of the location of the nutrient foramina on the long bones is important and useful in certain surgical procedures to keep the circulation intact [4, 14, 16, 21]. The site of the entrance of the nutrient arteries into the shaft of the bone was first mentioned by Havers in 1691 [12]. The positions of nutrient foramina on the fibula was studied by Bonnel et al [1] on the femur and humerus by Lutken [12], Laing [10, 11] and Carroll [3]; on the radius and ulna by Shulman [19]; on the human long bones by Mysorekar [15] and Forriol et al [4]. Patake and Mysorekar [17] stated that the number of foramina did not seem to have any significant relation to the length of bone and the number of ossification centres. The literature contains only a few investigations regarding the position of the foramina [4, 12, 15]. In this study the location and number of the diaphysial nutrient foramina of the human lower limb long bones were investigated.

Material and method

We measured and analyzed 102 femurs (54 right, 48 left), 134 tibias (72 right, 62 left) and 69 fibulas (33 right, 36 left).

Male skeletons older than 18 years [22] excavated from a burial near Iznik (Nicea) of the Late Byzantine Era (A.D. 10th century) were used in the study. For measurements, diaphysial nutrient foramina which were capable of admitting at least the tip of a 24 gauge needle were taken to be dominant [4, 14]. Anatomic location of every nutrient foramen was noted. The foraminal index was calculated by using the formula [4, 9, 19] : I=(DNF/TL) × 100; where I is the foraminal index; DNF the distance from proximal end of the bone to nutrient foramen and TL the total length of the bone.

Results

The number and location of the nutrient foramina in three long bones of the lower extremity are summarized in the Tables 1-6.

Femur. We tried to determine the exact situation of the foramina, sometimes going against anatomical dogma, because of the great variation of location. Nevertheless, 41.2% of the foramina were on linea aspera; 35.3% were on the medial lip, 10.1% were on the lateral lip and 7.1% were strikingly on the anterior surface of femoral shaft; the rest were scattered. 46% of the femurs had two foramina on their shafts, distributed almost equally on the linea aspera and medial lip. It was interesting to observe two femurs having 8 and 9 nutrient foramen on their shafts which were greater than tip of a 24 gauge needle. There was no femur without a dominant nutrient foramen. The mean length of all the femurs was 44.3 cm. The foramina which were sited on the linea aspera were at the proximal half, while the others were at the distal half. The more the location site varied the more the foramina were located at the distal 2/3 rds of the shaft (Tables 1 and 2).

Table 1. Number of nutrient foramina and their distribution over the shaft of femur

Nombre de trous nourriciers et situation le long de la diaphyse du fémur

Number of foramina	Site of location													
	LA		LM		LL		FA		FP		FM		FL	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	12	5	7	4	–	–	–	–	–	–	–	–	–	–
2	18	23	18	20	8	4	1	1	–	1	–	–	–	–
3	7	8	6	7	3	3	–	3	2	–	–	–	–	–
4	7	5	5	7	–	–	2	4	2	–	–	–	–	–
5	1	1	1	2	–	–	1	–	1	2	–	–	1	–
6	6	–	5	–	3	–	1	–	2	–	–	–	1	–
8	–	4	–	–	–	2	–	2	–	–	–	–	–	–
9	–	1	–	2	–	1	–	2	–	1	–	2	–	–

Abb. : LA : linea aspera; LM : medial lip; LL : lateral lip; FA : anterior surface of shaft; FP : popliteal surface; FM : medial surface of shaft; FL : lateral surface; R : right; L : left

Table 2. The number and location of nutrient foramina on femur expressed by means of the foraminal index (FI)

Nombre et localisation des trous nourriciers sur le fémur exprimés selon l'index foraminal moyen (IF)

Anatomic situation	No. of foramina		FI (Mean± St. deviation)	Range
	Right	Left		
Linea aspera	51	47	42.6±10.8	26.7-71.5
Medial lip	42	42	53.5±11.7	29.1-73.5
Lateral lip	14	10	56.9±17.4	33.4-81.0
Anterior surface	5	12	73.3± 9.0	46.8-84.4
Popliteal surface	7	4	76.2± 4.1	70.0-81.9
Medial surface	–	2	77.9± 6.0	73.6-82.1
Lateral surface	2	–	79.1± 0.1	79.1-79.1

Tibia. One nutrient foramen was almost constant in the tibia, only 5.2% had two foramina. But their locations were variable. 90.8% of the foramina were sited on the posterior surface, while in 5.7% they were on the lateral surface. In the rest, foramina were scattered to any point of the shaft, which were mostly the second nutrient foramen. Foramina on the posterior surface were located at an average of 32.3% of the total bone length; and ranged between 24.4-56.3%. Foramina on the lateral surface were located at an average of 38.2% of the total bone length and ranged between 11.0-67.2% (Tables 3 and 4). The range of the foraminal index was 24.4-67.2% for the right tibia and 11.0-53.0% for the left tibia. The mean length of all tibias was 35.9 cm.

Fibula. There was no dominant nutrient foramina on 18.9% of the fibulae; and 7.2% had two foramina while the rest had one. 88.5% of the nutrient foramina were located on the medial surface, 9.8% on the posterior and 1.6% on the lateral surfaces.

Most of the foramina were near the midpoint of the shaft even though it was not statistically significant. The range of location was

Table 3. Number of nutrient foramina and their distribution over the shaft of tibia

Nombre et distribution des trous nourriciers du tibia

Number of foramina	Cases		Total (%)	Site of location					
	Right	Left		FP	FL	MI	MA	MM	FM
1	69	58	94.8	120	6	1	–	–	–
2	3	4	5.2	8	2	1	1	1	1

Abb. : FP : posterior surface; FL : lateral surface; MI : interosseous margin; MA : anterior margin; MM : medial margin; FM : medial surface

Table 4. The number and location of nutrient foramina on tibia expressed by means of the foraminal index (FI)

Nombre et localisation des trous nourriciers du tibia exprimés selon l'index foraminal moyen (IF)

Anatomic situation	No. of foramina		FI (Mean± St. deviation)	Range
	Right	Left		
Posterior surface	67	61	32.3± 3.5	24.4-56.3
Lateral surface	6	2	38.2±19.1	11.0-67.2
Interosseous margin	1	1	28.8±64.1	28.8-64.1
Anterior margin	–	1	49.1	49.1
Medial margin	–	1	36.2	36.2
Medial surface	1	–	57.1	57.1

Table 5. Number of nutrient foramina and their distribution over the shaft of the fibula

Nombre et distribution des trous nourriciers de la fibula

Number of foramina	Cases		Total (%)	Site of location		
	Right	Left		FM	FP	FL
0	4	9	18.9	–	–	–
1	26	25	73.9	47	3	1
2	3	2	7.2	7	3	–

Abb. : FM : medial surface; FP : posterior surface; FL : lateral surface

Table 6. The number and location of nutrient foramina on fibula by means of the foraminal index (FI)

Nombre et localisation des trous nourriciers de la fibula exprimés selon l'index foraminal moyen (IF)

Anatomic situation	No. of foramina		FI (Mean± St. deviation)	Range
	Right	Left		
Medial surface	29	25	46.5±8.7	29.8-67.8
Posterior surface	3	3	43.3±6.1	33.8-57.3
Lateral surface	–	1	52.3	52.3

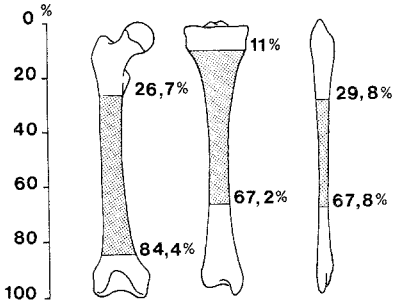

Fig. 1
Ranges of positions of the foraminal index in the three long bones of the lower limb

29.8 to 67.8% of the total bone length (Tables 5 and 6), where the mean length for all the fibulae was 35.3 cm.

Discussion

Femur. Out of 102 femurs examined, we observed 6 nutrient foramina on three; 8 foramina on two femurs and 9 foramina on one femur; femurs with more than three foramina are not mentioned in the literature.

Beyond these having many nutrient foramina, we observed that 26.5% of the femurs had one, 46% had two, 12.7% had three and 7.8% had four foramina.

Out of 180 femurs he had analyzed, Mysorekar [15] reported 3.3% having none, 45% with one, 50% with two and 1.6% with three foramina. Lutken [12] observed one on 53.4%, two on 44.4% and three foramina on 2.2% of his 410 femurs. And Forriol et al [4] reported that 30% of his 31 femurs had one, 60% had two, and 10% had three foramina.

When we consider their location, our results are similar to those of Mysorekar [4, 15] having about 41.2% of the foramina on the linea aspera, while Lutken [12] reported 71.1% in his study.

The foramina are gathered in the 3/6th or 4/6th of the shaft in our study, and in Lutken [12] and Mysorekar [15]. But Forriol et al [4] reported that his index was 38.4% for his femurs. Gray [5] states that the nutrient foramina are near to the proximal end of linea aspera, if more than one they are near to the distal end.

Tibia. The number of foramina we observed are very much like Mysorekar [15], Trueta [21], and Forriol et al [4] having one foramen in more than 90% of the tibias, and rarely a second foramen. Also their locations are concentrated on the posterior surface. Mysorekar [15] reports many foramina scattered on various parts of the shaft, like our findings. The mean foraminal index is 32.3% for 90.8% of the foramina, while it is 80% of Mysorekar's [15] and 35.6% for all of Forriol et al's [4] study. Macnab and De Haas [13] states that the nutrient a. enters the tibia at the junction of the upper third and middle third.

Fibula. In our study 74% of fibulas had a single nutrient foramen, 7% had two and 19% had none. McKee [14] reported that out of his 323 fibulas, 5.5% had none, 86.4% had one, 7.7% had two and only one had three foramina. Forriol et al [4] observed one foramen in all of his fibulas. Mysorekar [15] found one foramen on 92.8%, two on 3.3% and none on 3.9%. Guo [6] found 10 fibulae having two and 5 having none out of his 295 fibulae.

The location of the nutrient foramen in the 3/6th of the shaft is in agreement with Mysorekar [15], Taylor [20] and Bonnel et al [1]; and at variance with the results of Forriol et al [4], Guo [6, 7] and McKee [14] who reported location in the upper third.

We observed 88.5% of the foramina on the medial surface, 9.8% on the posterior surface and 1.6% on the lateral surface. Also Mysorekar [15] observed 56% of the foramina on the medial surface and 26% on the posterior surface; and Forriol et al [4] reported an equal distribution on both faces. But there is a striking difference with McKee's [14] findings who observed 67.5% of the foramina on the posterior surface, 13% on the medial surface and 18% on the medial crest; almost a mirror image.

Our variable findings suggested to us the possibility of a difference in ancient bones, because of the hard living conditions as warriors. Unfortunately, we could not find any data regarding the same topic on ancient bones, so that we could compare our results.

There are also important variations between other investigators, because there is no definite method of dividing the shaft by standard measures, which makes it difficult to compare data. The use of the foraminal index formula would be the best.

In order to make living tissue transfer simple and safe with predictable and consistent results, preoperative arteriograms of the donor and recipient limbs is still important in outlining possible vascular anomalies, in both the recipient and donor limbs.

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