DIAPHYSEAL NUTRIENT FORAMINA OF THE FIBULA IN EASTERN INDIA

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ABSTRACT

BACKGROUND

Vascular supply of the fibula assumes importance during trauma and surgical procedures in the leg region, as the fibula is a donor for bone grafts, and is also used in vascularized bone microsurgery. We studied the location, direction, and number of diaphyseal nutrient foramina in a random sample of 100 dry fibulas of unknown origin.

METHODS

100 dry adult fibulas, of unknown origin were used. Total length (T) of the fibula, and distance of the nutrient foramen from the upper end were measured, using an osteometric board, and sliding calipers.

RESULTS

The diaphyseal nutrient foramen was single in 85%, double in 11%, absent in 4% of cases, and directed away from the growing end (87%), located in the middle 1/3 of the shaft (FI 34-66), on the posterior surface, or the borders bounding this surface (100%).

CONCLUSIONS

Our study provides detailed information about the location and number of nutrient foramina in the fibula in a random sample of the population of Eastern India.

KEYWORDS

Fibula, Nutrient Foramen, Foraminal Index, Long Bone.

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BACKGROUND

Vascular supply of the fibula assumes importance during trauma and surgical procedures in the leg region, and owing to the use of the fibula as a donor for bone grafts, for reconstruction of long bones, and the mandible.[1,2] Nutrient foramina and canals form during endochondral ossification when the developing bone is vascularized by diaphyseal, epiphyseal, and metaphysical arteries.[3]

METHODS

100 dry adult fibulas (both upper and lower epiphyses were fused with the shaft) of both right & left sides, of unknown origin (i.e. unknown identity, age & sex) were used. Physically damaged & grossly pathological (e.g. fracture, tumour) bones were excluded. An osteometric board, sliding calipers (8" size), a hand lens, 24 gauge hypodermic needles, & self-adhesive labels were used for measurements. The location, number & direction of diaphyseal nutrient foramina were studied. Results were compared with other recent studies. The clinical implications of fibular diaphyseal nutrient foramen and vascular supply were reviewed.

Bones were inspected to exclude any gross pathology or damage, & then labelled with numbers. All three surfaces of the diaphysis of each bone were examined carefully for nutrient foramina with a large magnifying glass. Only well-defined canals or foramina were considered. Once located, foramina were probed with a 24 gauge hypodermic needle to assess patency, direction, angle of obliquity, & calibre (if it allowed the passage of the needle it was considered dominant, and if not, secondary).

Total length (T) of the fibula, from the apex of the head to the most distal point of the lateral malleolus, was measured with an osteometric board, to the nearest millimetre. Location of the nutrient foramina were recorded, specifying the surface of the shaft (medial, lateral, or posterior) on which it is situated (foramina lying within 1 mm of a border were taken to be on that border), & distance of the foramen from the upper end of the fibula (N) (measured from the apex of the styloid process, with callipers, to the nearest millimetre). Direction of the nutrient foramen (upward or downward) was recorded. The foraminal index (I)[4] is expressed as a percentage of the ratio of the distance of the nutrient foramen (N) from the proximal end of the bone to the total length (T) of the bone: $I = (N/T) \times 100$

RESULTS

Of the 100 fibulas examined (50 right, 50 left), the mean length was 356.8 mm, with a range between 316 and 422 mm. The mean length was slightly greater for bones of the

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right side compared with the left (357.0 mm vs 356.7 mm). The location of the main nutrient foramen, as described by the foraminal index (4) had a mean value of 44.5, that is, slightly proximal to the middle of the shaft (Tables 1, 2). The range of values was between 31.6 and 69.6 that is in the middle third of the shaft. Nutrient foramina were absent from the shafts of 4 bones (3R, 2L). Accessory foramina were seen in 11 bones (2R, 9L).

The majority (87%) of main foramina were directed downwards, away from the growing end. However, 9% were directed upwards (anomalous) (Table 2). In the case of the accessory foramina, all were located more distally than the main foramen, except in 3 cases. Of the 11 bones with 2 foramina, 7 accessory foramina were directed downwards, and 4 were directed upwards (i.e. anomalous). In 6 bones both main and accessory foramina were directed downwards, and in 4 bones the main foramen was directed downwards, and the accessory foramen directed upwards (Figure 1). In 2 of the 3 bones where the more proximal foramen was smaller in calibre (accessory) than the distal (main) foramen, the proximal foramen was directed downwards, and the distal one was directed upwards. In the remaining bone the directions were the opposite of this - the proximal foramen was upwards, and the distal one downwards. In all the 11 bones which double foramina, reciprocity was seen - that is, one foramen (the more proximal one in 9 cases) was large and the other was smaller in size.

The majority (83.3%) of the main foramina were located on the posterior surface of the shaft, anterior to the medial crest. In 6 bones (6.3%) the foramen was on the medial crest, and in 5 (5.2%) cases was posterior to the medial crest. In one bone each it was located on the medial surface and posterior border, and in 3 bones (2R, 1L) on the medial border (Table 3)**.** In the case of the 11 accessory foramina, there were 7 in front, and one each on, and behind the medial crest, respectively. One was on the lateral surface, and one on the medial (anterior) surface (Table 3, Figure 1).

Sample	Total Length (TL)	Distance of Foramen from Proximal End (DNF)	Foraminal Index (FI)
Right (n = 50)	357.0 (±26.8), 321 - 422	162.5 (±30.8), 120 - 238	45.6 (±8.6), 33.0 - 69.6
Left (n = 50)	356.7 (±25.3), 316 - 412	154.5 (±30.2), 110 - 226	43.5 (±8.2), 31.6 - 64.3
Total (n = 100)	356.8 (±25.9), 316 - 422	158.4 (±30.6), 110 - 238	44.5 (±8.4), 31.6 - 69.6

Table 1. Dimensions & Index (Mean, Standard Deviation, Range)

	0	1	2*	Main Down	Main Up	Accessory Down	Accessory Up
Right (n = 50)	3 (6%)	45 (90%)	2 (4%)	41 (82%)	6 (12%)	2	-
Left (n = 50)	1 (2%)	40 (80%)	9 (18%)	46 (92%)	3 (6%)	5	4
Total (n = 100)	4 (4%)	85 (85%)	11 (11%)	87 (87%)	9 (9%)	7	4

*In all bones with double foramina, reciprocity was seen.

Table 2. Number and Direction of Nutrient Foramina

	AMC	MC	PMC	MS	LS	PB	MB
Right (n = 47)	41 (87.2%)	2 (4.3%)	2 (4.3%)	-	-	-	2 (4.3%)
Left (n = 49)	39 (79.6%)	4 (8.2%)	3 (6.1%)	1 (2%)	-	1 (2%)	1 (2%)
Total (n = 96)	80 (83.3%)	6 (6.3%)	5 (5.2%)	1 (1%)	-	1 (1%)	3 (3.1%)

AMC, posterior surface anterior to medial crest; **MC**, posterior surface on medial crest; **PMC**, posterior surface posterior to medial crest; **MS**, medial surface; **LS**, lateral surface; **PB**, posterior border; **MB**, medial border; **AB**, anterior border.

Table 3. Location of Main Nutrient Foramen

Study	N (R+L)	Number of Foramina 0	1	2	Direction of Canal Down	Up	Surface of Shaft P	M	L	Other	Total Length mm (SD)	DNF mm (SD)	Foraminal Index (FI)
Present study, (2018)	100 (50+50)	4 (4%)	85 (85%)	11 (11%)	87 (87%)	9 (9%)	91%	-	-	3% on MB, 1% on PB	356.8 (±25.9)	158.4 (±30.6)	44.5 (±8.4)
S, Bilodi, & Siva Reddy, (2014)[6]	189 (83+106)	2%	85%	13%		9 (5%)	56 (29.6%)	40 (21.2%)	42 (22.2%)	7.9% MB, 2.1% PB, 0.5% AB	314-326		48.14 (0.46)
Seema, Verma, Mahajan, & Gandhi, (2015)[7]	60 (30+30)	-	50 (83%)	10 (17%)	-	-	-	-	-	-	347 (23.6), 343.6 (27.2)	169.3 (33), 170.1 (31.2)	-
Agrawal, Tiwari, & Shrivastava, (2015)[8]	160	-	171 (100%)	-	152 (88.9%)	19 (11.1%)	165 (96.5%)	-	6 (3.5%)	-	-	-	39.6±5.29
Jayaprakash, (2016)[5]	50 (30+20)	4 (8%)	45 (90%)	1 (2%)	45 (95.7%)	2 (4.3%)	47 (94%)	-	-	-	405 (4.69)	177 (4.27)	43.73 (9.69)
Sinha, Mishra, Kumar, Gaharwar, & Sushobhana, (2016)[9]	100 (50+50)	-	78%	22%	100%	-	97.5%	-	-	2.4% medial crest	-	-	36.3-58.2

Table 4. Comparison with Recent Studies

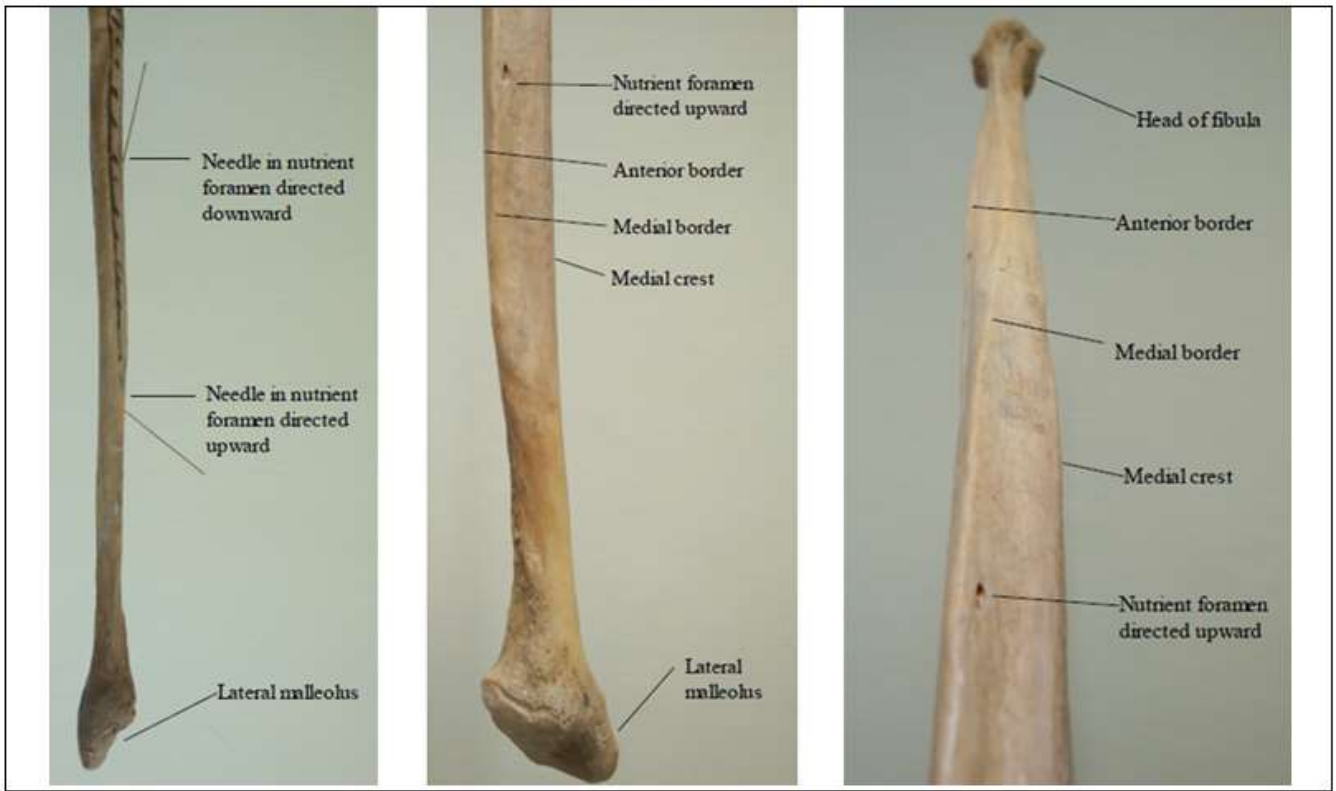

Figure 1

DISCUSSION

Our study found the average length of the fibula to be 356.8 mm, a value similar to other studies. However, Jayaprakash[5] observed a significantly longer average length of 405 mm.

In regard to the number of diaphyseal nutrient foramina, of the 100 fibulae examined in our study, a single foramen was found in 85% (85) bones, compared to 85%, 83%, 100%, 90%, & 78% in other studies.[6,7,8,5,9] Two foramina were found in 11%[11] of bones examined in this study, compared to 13%, 17%, 0%, 2% & 22% respectively in the above cited studies.[5,6,7,8,9] Foramina were absent in 4% (4 out of 100) of fibulae examined in this study, compared to 2%, 0%, 0%, 8%, 11.5% respectively in the above cited studies.[5,6,7,8,9] No correlation was found (coefficient 0.02) between the total length of the bone and the number of nutrient foramina.

With respect to location, our study found the main nutrient foramen to be located on the posterior surface (94%), or on the borders bounding this surface, 3% on the medial border and 1% on the lateral border. Of the foramina located on the posterior surface 83% were anterior to the medial crest, 6% on the crest, and 5% posterior to the crest. Agarwal et al[8] & Jayaprakash[5] had similar observations of 96.5% & 94% respectively. Bilodi[6] observed only 39.6% foramina on the posterior surface, with 21.2% on the medial surface & 22.2% on the lateral surface.

The majority (87%) of main foramina were directed downwards, away from the growing end. However, 9% (6R, 3L) were directed upwards (anomalous), similar to observations of Bilodi et al,[6] Agarwal et al[8] & Jayaprakash[5] with 5%, 11.1% & 4.3% respectively. Sinha et al[9] did not observe any anomalously directed foramina.

Bones are structurally constructed to reduce stress concentration around the weakness created in cortical bone by the nutrient foramen.[10] The compact bone in the vicinity of the foramen is more compliant, & is reinforced by a ring of increased stiffness some distance away from the foramen, and also by a collar of lamellar bone along the inside edge of the foramen. Despite this, bone in the region of the nutrient foramen is still subject to longitudinal stress fractures, identifiable in axial MRI scans, with both bone and surrounding soft tissue changes.[11]

Fibular bone grafts are used as a source of cortical bone for structural support of defects, such as fresh malunited & ununited fractures, osteotomies, and for arthrodesis.[1] The fibula is also used as whole bone transplant to bridge defects in the shafts of upper limb bones, & to replace the distal end of the radius, or the distal end of the fibula. During harvesting of the fibula for grafting, the nutrient artery to the fibula may have to be ligated.[1] The fibula is the commonest bone used for free vascularized bone grafting. A segment of the bone, along with its blood supply, including a pedicle from the peroneal artery with its venae comitantes, as well as the flexor halluces longus, in which the peroneal vessels are contained, may be harvested from the donor site.[1]

Since 1989, the fibula has been used in maxillofacial surgery as a donor bone for reconstruction of mandibular defects.[2,12]

CONCLUSIONS

Diaphyseal foramina were single in 85 of the 100 bones examined, absent in 4, and double in 11 bones. All the main nutrient foramina were located on the posterior surface of

the shaft, or the medial and posterior borders bounding this surface, with one exception. 85.4% foramina were located anterior to the medial crest, 6% were on the medial crest, and 5% were posterior to the medial crest. 1% each were on the posterior border, medial border, and medial surface respectively. Most of the foramina were located in the middle third of the shaft, with a mean foraminal index of 44.5 and a range of 31.6-69.6. 87% of main foramina were directed downwards, and 9% were directed upwards (anomalous). Obliquity of the nutrient canals was much less than in the tibia. No correlation was found between the length of the fibula and the position of the nutrient foramen, or between total length and number of nutrient foramina. All accessory foramina were located more distally than the main foramen, except in one case. There was no relationship between the direction of the main and accessory foramina. All the accessory foramina were located on the posterior surface of the shaft, or the medial and posterior borders bounding this surface, with one exception, where it was on the lateral surface. In bones with single foramina, all the foramina were dominant. Bones with two foramina showed reciprocity, i.e. one foramen was dominant and the other was accessory.

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