Study of Morphometric Variations in the Nutrient Foramina of Fibula in Central Rajasthan

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Abstract

The fibula is located lateral to the tibia in the leg. The fibula is the bone of choice for grafting and to reconstruct large defects after tumor resection, because of its length, biomechanical stability, limited donor site morbidity and predictable vascular pedicle. The objectives of the study are: (1) To locate and describe the position, number & direction of nutrient foramina of fibula. (2) To observe any variations in location, position and number of nutrient foramina of fibula in the present study, observations will be made on the 150 adult dry human fibulae. Variations in the number, location and distribution of nutrient foramen will be observed, analysed and compared with earlier studies by various authors. Variation in the number of nutrient foramen will be accounted. Position of Nutrient foramen will be frequently noted.

The present study showed 13.5% variation in number of nutrient foramen. Accurate anatomical knowledge about the location and distribution of nutrient foramen is useful for orthopedic and plastic surgeons in planning the vascularised fibular graft at middle third of the shaft. .

Keywords: Fibula, Foraminal Index, Nutrient foramen, Vascularised fibular graft.

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Introduction

The word foramen is derived from Latin word 'foro' (to pierce) which means an aperture or perforation through a bone or membranous structure. The role of nutrient foramen in nutrition and growth of the bones is evident from term 'Nutrient'itself.[1]

The external opening of the nutrient canal, usually referred to as the nutrient foramen, has a particular position for each bone.[2] The nutrient artery is the principle source of blood to a long bone particularly during its active growth period. The artery to the shaft of the long bone is the largest, called the 'Nutrient Artery'.[3]

The fibula is located on the lateral side of tibia in the leg. Together with tibia, it resembles an ancient brooch or pin. The fibula is much more slender than the tibia and is not directly involved in transmission of weight. It has a proximal head, a narrow neck, a long shaft and a distal lateral malleolus. The shaft has three borders and surfaces, each associated with a particular group of muscles. A little proximal to the midpoint of the posterior surface (14-19 cm from the styloid process), the fibular shaft is pierced by a nutrient foramen, directed distally, which receives a branch of the peroneal artery. The detailed anatomical knowledge of the peroneal artery in relation to the fibula is the key to raising osteofasciocutaneous free flaps incorporating segments of the bone. Free vascularized diaphysis grafts may also be taken on a peroneal arterial pedicle.[3]

The knowledge and position of the nutrient foramina of fibula is important to proceed with the free transplants of the vascularized bone graft. Commonly, the nutrient foramen is located in the middle third of the posterior surface of the fibula. Thus, middle third of fibula must be used for transplant to reconstruct mandible, stabilization of spine and tibia, as well as for dental implants. In harvesting the fibula, this segment is always taken, as the graft is more reliable regarding anastomosis, which includes endosteal and a periosteal blood supply, provided by a constant arteriovenous system with vessels of anastomosable diameter.[4]

The fibular grafts are particularly useful to restore large diaphyseal defects because of their shape and mechanical properties.[5] The study is undertaken, as the knowledge of nutrient foramina of fibula is useful for anthropologists, anatomists, forensic experts, orthopedic and plastic surgeons for fibula graft and micro-vascular bone transfer. The morphometric analysis of the position of the nutrient foramen of the fibula will help in harvesting vascularized graft of the bone, to preserve the circulation within bone, also to reconstruct and close the bone defects.[6]

Material and Method

The present study will be conducted on 150 dry adult human fibulae in the

Departments of Anatomy, in Medical Colleges of Central Rajasthan in Ajmer, Jaipur. Fibulae obtained from undergraduate medical students of our institution and other Medical College and Research Institute, Rajasthan.

The fibulae will be serially numbered from 1 to 150 using blue plastic number plates.

Materials Used

Sliding caliper, Vernier digital caliper, 1-200 blue plastic number plates, Thin stiff wire, Magnifying hand lens, Samsung digital camera, Black marker pen.

Source of data: 150 dry adult human fibulae from the Department of Anatomy, Ajmer, Jaipur and other Institute of Medical Sciences, Rajasthan.

Inclusion criteria: 150 dry adult human fibulae irrespective of sex and race.

Exclusion criteria: Deformed fibula, fibula showing gross asymmetry or broken will be rejected as unsuitable for the study.

Number, distribution and direction of nutrient foramen in relation to specific surfaces, border and growing ends of fibulae will be analyzed. Keen observation will be done for direction of nutrient foramen by using magnifying hand lens and then a thin stiff wire will be passed through the foramen to confirm its direction. Then it will be noticed that which part/parts of bone possessed the absence, single or multiple foramen. Nutrient Foramen in each fibula will be encircled using black marker pen.

Statistical Analysis

The collected data will then be entered in the Excel sheet and analyzed by using different formulations. The descriptive statistics, chi-square test, student t-test will be applied for analyzing the data as applicable.

Result

The observations made on the 150 dry adult human fibulae have been listed and the number, location and distribution of the nutrient foramen has been completely tabulated in the master chart, and represented in the tables.

Out of 150 fibulae observed, in 9 (6%) fibulae nutrient foramen was absent, 130 (86.66 %) fibulae showed single NF, 10 (6.50%) fibulae had Double NF and 1 (0.6 %) fibulae had Triple NF.

Table 1: Study of No. of nutrient foramen in 150 fibulae

No. of foramen	No. of fibulae	Percentage
0	9	06.00
1	130	86.50
2	10	06.50
3	1	01.00
Total	150	100

Most common nutrient foramen was Single NF observed in 69 (85.98%) right and 61 (87.09%) left fibula. And less common foramen, Triple NF was seen in one (1.07%) left fibulae.

Table 2: Distribution of nutrient foramina in right (80) and left (70) fibulae

No. of foramen	Right fibulae		Left fibulae	
	No.	%	No.	%
Zero	4	4.67	5	7.52
One	69	85.98	61	87.09
Two	7	8.41	3	4.30
Three	0	0.93	1	1.07

In 150 dry adult human fibulae, 20 (13.50%) fibulae showed variations. Out of these double NF were common with 7 (33.33%) right and 3(14.81%) left fibulae. And absence of NF was on 4 (18.51%) right and 5 (25.92%) left fibulae. Triple NF was noted one in left fibulae (3.07%).

Table 3: Variation in nutrient foramina of 20 fibulae

Side of fibula	Towards growing end	Away from growing end
Right	1	2
Left	2	1

Variations in the Direction of NF

Total number of NF was 153 in 141 fibulae, 131 (85.36%) foramen were directed away from growing end and abnormal direction of NF were seen in 22 (14.63%) foramen, i.e., towards the growing end, violating the law of ossification.

Table 4: Direction of foramen towards and away from the growing end of fibulae in 153 foramen

Fibula	No. of fibulae	Towards growing end		Away from growing end	
		No.	%	No.	%
Right	76	13	8.78	71	45.36
Left	65	9	5.85	60	40
Total	141	22	14.63	131	85.36

In 10 fibulae, double NF was observed in 4 (38.46%) right fibulae with direction one towards the growing end and another away from the growing end was common. Where as in 1 left fibulae, direction of NF towards and away from growing end was equal (15.38%).

Table 5: Direction of double nutrient foramen in 13 fibulae

Side of fibula	Towards growing end	Away from growing end
Right	-	-
Left	2	1

Out of 150 fibulae, one left fibulae had triple nutrient foramen. the direction of one NF was AFGE and the direction of two NF was TGE.

Table 6: Direction of triple nutrient foramen in 1fibula

Side of fibula	No. of fibulae	No. of nutrient foramen	Length wise distribution	Number	%	p-value
Right	76	83	UT	01	0.88	0.7154
			MT	80	96.46	
			LT	02	02.65	
Left	65	70	UT	01	0.88	0.7154
			MT	68	97.82	
			LT	01	0.88	
Total	141	153	UT	02	0.97	
			MT	148	97.07	
			LT	03	1.95	

Variation in Distribution of Nutrient Foramen

In 76 right fibulae, 83 NF were observed, of which one (0.88%) foramen was in upper third, two NF (2.65%) were in lower third and rest of the NF 80 (96.46%) were observed on middle third. In 65 left fibulae, 70 nutrient foramen were observed, of which one each nutrient foramen was in upper (0.88%) and lower third (0.88%) and remaining 68 (97.82%) nutrient foramen was noted in middle third.

The distribution of nutrient foramen was common in middle third 97.07% and less common in upper third 0.97%. P-value was not significant.

Table 7: Distribution of 153 nutrient foramen on the segments of 141 fibulae

Location	NF on 76 Right fibulae		NF on 65 Left fibulae		Total nutrient foramen		p-value
	No.	Percentage	No.	%	No.	%	
MC	43	53.77	35	47.47	78	50.73	0.2155
PS	27	33.01	31	42.42	58	38.04	
IB	7	8.49	01	2.02	08	5.36	
AB	01	0.94	00	1.01	01	0.97	
PB	02	1.88	01	1.01	03	1.46	
MS	00	00	02	4.04	02	1.95	
LS	01	1.88	01	2.02	02	1.95	

Variation in Location of Nutrient Foramen

Nutrient foramina on medial crest were frequent with 43 (53.77%) on right and 35 (47.47%) on left fibulae, least frequent was on anterior border on one each right (0.94%) and left fibula (1.01%). P-Value was not significant.

Table 8: Location of 153 nutrient foramina on Surfaces and borders of fibulae

Number of Nutrient foramen	Right fibulae		Left fibulae	
	No.	%	No.	%
0	04	18.51	05	25.92
2	07	33.33	03	14.81
3	00	3.07	01	03.07

Foraminal Index

The mean and standard deviation of foraminal index of nutrient foramina in upper third was 67.55 + 3.22. The mean and standard deviation of foraminal index of nutrient foramina in middle third was 46.74 + 8.86.

The mean and standard deviation foraminal index of nutrient foramina in lower third was 24.76 + 1.81.The standard deviation was more in the middle third (8.86) compared to upper and lower third of the fibula. The P-value was significant in relation to the number and location of nutrient foramen (P <0.001).

Table 9: Distribution of the nutrient foramen based on the foraminal index of the fibulae

Anatomical site	No. of foramen	Range	Mean + SD	p-value
Anterior border	1	31.31 to 45.83	38.57 + 10.27	0.00000002
Interosseous border	8	53.61 to 68.32	62.95 + 3.97	
Lateral surface	3	46.59 to 53.92	50.43 + 3.52	
Medial crest	77	34.54 to 65.97	44.33 + 7.04	
Medial surface	3	26.04 to 64.36	48.26 + 18.47	
Posterior border	2	42.98 to 64.85	50.31 + 12.64	
Posterior surface	57	23.48 to 71.68	47.99 + 10.05	

The range of foraminal index was 23.48 to 71.68. P < 0.00000002 was significant for location and foraminal index.

Table 10: Number and location of nutrient foramina and their foraminal index of 153 foramens of 141 fibulae

Length of fibula in cm	Right fibula		Left fibula		P-Value
	No.	%	No.	%	
30.1- 34 (Type I)	23	27.43	18	26.08	0.2416
34.1-38 (Type II)	55	66.38	43	60.87	
38.1-41(Type III)	05	6.19	09	13.05	
Total	83	100	70	100	

Correlation of the Length of Fibula with Number of Nutrient Foramen, and the Direction of Nutrient Foramen

Out of 70 left fibulae, nutrient foramen on Type–I was 18 (26.08%), Type-II was 43 (60.08%) and Type-III was 9 (13.04%).

All together, out of 141 fibulae, nutrient foramen was frequently observed in Type-II and association between length of fibula and NF was not established, with P–Value was insignificant.

Table 11: Association between the length of fibulae and nutrient foramen

Foraminal index	Mean + SD	95% CI	p-Value
Lower 1/3rd	67.55 + 3.22	(62.42 72.67)	0.001
Middle 1/3rd	46.74 + 8.86	(45.50 47.98)	
Upper 1/3rd	24.76 + 1.81	(8.50 41.02)	

Table 12: The length of fibula, location of nutrient foramen with foraminal index

153 NF on	Mean ± SD	Mini	Max
Fibula length	35.4 ± 2.14	30	40
DNF	16.6 ± 3.31	9	27
FI	47 ± 9.46	23.48	71.68

The mean length of fibula in the present study was found to be 35.4 ± 2.14 cm.

The average nutrient foramen was 16.6 ± 3.37. Compared to the average length of fibula, the nutrient foramen was, 354÷166 = 2.13.

The half the length of the fibula is 17.7 cm. The location of nutrient foramen is; 177 – 166 = 1.1 cm. The nutrient foramen is 1.1 cm (Approximately 1 cm), proximal to the midpoint of the fibula.

The foraminal index was between 23.48 and 71.68 with mean FI of 47%.

The P-Value was not significant in association of length of the fibula and the number of nutrient foramen. The single NF and double NF were more frequently observed in the Type II of the fibular length

Table 13: Association between length of fibulae and direction of nutrient foramen

Length of fibula	AFGE	TGE	Total	p-value
30.1- 34	33	08	41	0.4041
34.1-38	85	12	97	
38.1-41	13	2	15	
Total	131	22	153	

Discussion

In the present study, observations were made on the 150 adult dry human fibulae. Variations in the number, location and distribution of nutrient foramen was observed, analysed and compared with earlier studies by various authors. Variation in the number of nutrient foramen was accounting for 13.5%. Position of NF was frequently noted on the middle third of the bone (97.07%), 50.73% of the fibular nutrient foramina was located on the medial crest and 38.04% on the posterior surface. This study varies from other studies in presence of 5.36% of NF on interosseous border, 0.97% each on anterior and posterior border. The direction of 85.36% of NF was distal (away from growing end), while 14.63% had a proximal (towards the growing end) direction. In the fibular length of 34.1-38 cm (Type II), the distribution of single nutrient foramen was 130, double nutrient foramen was 10.

In the present study absence of nutrient foramen was observed in 6% fibulae. This finding is similar to the findings of McKee NH,[7] where absence of NF were observed in 5.6% who conducted study on 322 fibulae and similar to Ongeti,[8] with 5.5% who conducted study on 200 fibulae. This may be due to congenitally absent nutrient vessel or due to nutrient artery of caliber less than 0.5 mm in such cases the bone is likely to be supplied by periosteal arteries.[9]

In the present study 86.5% (130) of the fibulae possessed single nutrient foramen, while 6.5% (10) of the fibulae possessed double nutrient foramina and 1% (1) fibula had triple foramen, which is closer to the study conducted by Gupta R.[10]Gupta R[10] was the only author who observed 4 nutrient foramen in 2 fibulae (1.79%) out of 112 fibulae.

In bones with two nutrient foramina, it suggests that one of them would be the main NF and the other accessory NF; one contained an artery and vein, other only an artery. When three NF were present a solitary artery entered through one foramen, other contained both an artery and vein, and another contained a solitary vein.[11]

In the present study, most of the nutrient foramina of the fibula were situated in the middle third of the bone (97.07%), the rest of the nutrient foramen (1.95%) was located in the distal third of the bone and 0.97% was placed on the upper third. These findings were closer to Gupta R and Anusha P.[12]

The average length of fibula in the present study was 34.5 ± 2.14 cm. The average nutrient foramen was 16.59±3.37. Compared to the average length of fibula, the nutrient foramen was, 345÷166=2.07. The half the length of the fibula is 17.7 cm. The location of nutrient foramen is; 177 – 166=1.1 cm. The nutrient foramen is 1.1 cm (Approximately 1 cm), proximal to the midpoint of the fibula.

Choi in 2001 has described position of nutrient foramen among Koreans, 3 cm proximal to the mid length of the fibula. The Kenyan fibula is 15-20 cm longer than the Mongolians. This position of NF showed always is noted to avoid injury to the nutrient foramen, which carries nutrient artery.[13]

Adequate dissection around the position and the location of the nutrient foramen will minimize the length of the incision in harvesting the fibular vascularised graft. This will minimize the complication of compartment syndrome.[14]

In this present study, 50.73% of the fibular foramina were located on the medial crest and 38.04% on the posterior surface. Similarly, Mysorekar6 reported that 56% of NF were located on the medial crest while 33% over posterior surface of fibula. However, some authors observed more nutrient foramina on the posterior surface compared to those on the medial crest and medial surface. The present study varies from other studies in presence of 5.36% of NF on interosseous border, 0.97% each on anterior and posterior border.

In the present study, the direction of 85.36% of NF was distal, while 14.63% had a proximal direction, in accordance with the Sanjeev,[15] Gupta R,[15] Anusha P.[16] Mysorekar[16] quoted that variation, in the direction of nutrient foramina were found only in the fibula and NF were situated much below the middle third of the bone. If the nutrient artery in these fibulae arose from lower part of peroneal artery, the anomalous direction could be explained on this assumption. This could be due to peculiar ossification of bone. It is possible that in fibula one end may act as growing end for a certain period and then subsequently the other.[17]

Conclusion

The fibula is located on the lateral side of tibia. Together with tibia, it resembles an ancient brooch or pin.. The word foramen is derived from Latin word 'foro' (to pierce) which means an aperture or perforation through a bone or membranous structure. The location of nutrient foramen has importance in relation to plan for the fibular graft, as the middle third of shaft is taken for implant.

The objective of the present study was to locate and describe the position, number and direction of nutrient foramina of fibula, and to observe for any variations in the same.

The present study was conducted on 150 dry adult human fibulae in the Department of Anatomy, J.L.N. Medical College, Ajmer. Measurements were taken using Vernier and digital calipers. The parameters were noted meticulously and the statistical analysis for nutrient foramen and foraminal index was made by using student's t-test and was considered significant whenever $p \leq 0.05$, to determine the relationship between the studied parameters.

Most common nutrient foramen was single nutrient foramen 86.50% fibulae, with distribution of 50.73% foramen on medial crest, 38.04% foramen on posterior surface in accordance with classical description of

location of nutrient foramen from iterature. And least frequent location of foramen was on anterior border in 0.97% fibulae, which has not been observed in any of the previous studies. The absence of foramen was in 6% fibulae, double nutrient foramen in 6.5%, triple nutrient foramen in 1%fibulae. The distribution of 97.07% foramen was on the middle third of the fibula.

The average length of fibula in the present study was 34.5 ± 2.14 cm. The average nutrient foramen was 16.59±3.37. Compared to the average length of fibula,the nutrient foramen was, 345÷166 = 2. 07. The half the length of the fibula is17.7 cm. The location of nutrient foramen is; 177 – 166 = 1.1 cm. The nutrient foramen is 1.1 cm (Approximately 1 cm), proximal to the midpoint of the fibula

The direction of nutrient foramen, away from growing end was in 85.36% nutrient foramen and towards the growing end was in 14.63% nutrient foramen. The location of single and double nutrient foramen was frequently observed in the fibular length of 34.1 – 38 cm (Type II). The mean and standard deviation of foraminal index was 46.74 ± 8.86 for the nutrient foramen on middle third of the shaft. This observation correlates positively with the findings in similar studies conducted by various authors

Association between length of the fibula with total number of nutrient foramen, location of nutrient foramen and direction of nutrient foramen was not sufficiently justified.

The morphometric study of nutrient foramen with regard to the number, location and position is assumed to be of great importance for clinicians, radiologists, orthopaedicians and vascular surgeons. The knowledge and position of the nutrient foramina of fibula is important to proceed with the free transplants of the vascularized bone graft. Commonly, the nutrient foramen is located in the middle third of the posterior surface of the fibula. Thus, middle third of fibula must be used for transplant to reconstruct mandible, stabilization of spine and tibia, as well as for dental implants. In harvesting the fibula, this segment is always taken, as the graft is more reliable regarding anastomosis, which includes endosteal and a periosteal blood supply, provided by a constant arteriovenous system with vessels of anastomosable diameter.

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