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Original Research

A Study on Diaphyseal Nutrient Foramen of Humerus

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ABSTRACT

Objective: The aim of this study is to provide detailed data about the nutrient foramen (NF) of the humerus, the entry point of the nutrient artery, used in order to avoid damaging the nutrient artery, which has an important role in the nutrition of the humerus, during surgical approaches to the humeral diaphysis.

Methods: This study was performed on 113 (58 right, 55 left) humeri. The number, direction, location, position, size and foraminal index of the nutrient foramina (NFs) were evaluated. In addition, total length of the humerus and distance between NF and proximal end of the humerus were measured.

Results: One NF was observed on 86 of 113 (76.11%) humeri, two NFs on 17 of 113 (15.05%) humeri, 3 NFs on the one right sided humerus and no NF was observed on 9 of 113 (7.96%) humeri. While 122 (99.19%) of all NFs were directed distally, one (0.81%) NF was directed horizontally. Eighty-six (69.92%) NFs were located on the anteromedial surface, while 18 (14.63%) NFs were found to be located on the medial border, 12 (9.76%) NFs on the posterior surface, 4 (3.25%) NFs on the anterolateral surface and 3 (2.44%) NFs on the lateral border. 20G sized NF was detected on 50 of 123 (40.65%) NFs. 14G and 16G sized NFs were not detected. 5 (4.07%) NFs were located on the proximal 1/3, 113 (91.86%) NFs were located on middle 1/3 and 5 (4.07%) NFs were located on distal 1/3 of the humerus. The mean values of total length of the humerus, distance between NF and proximal end of the humerus and foraminal index were found out to be 301.68±**20.61** mm, 166.70±**32.50** mm and 55.33±**9.48%, respectively.**

Conclusion: It is found out that there is usually one NF on the humerus and that this foramen is directed distally, localized on the anteromedial surface and the middle 1/3 of the humerus and sized at 20G. And also, we observed horizontally directed NF on the humerus. To our knowledge, there is no study which observed horizontally directed NF. There may be differences between populations about the morphology and morphometry of NF. Therefore, being aware for the morphology, morphometry and variations of the NF is important for the orthopaedic surgeons in surgeries such as fracture repairing and vascularized bone graft in order to avoid damaging the nutrient arteries.

Keywords: Humerus, nutrient foramen, morphology, morphometry, anatomy

INTRODUCTION

Arterial supply of the long bones is provided by the nutrient, epiphyseal, metaphyseal and periosteal arteries [1]. Nutrient foramina (NFs) are found on the bones, providing passage for nutrient arteries. These foramina are located on the diaphysis in long bones and elsewhere in irregular bones [2-4] and enable

nutrient arteries to enter the medullary space and supply the bone marrow and inner 2/3 of the cortex [1]. Directions of the nutrient foramina are usually facing away from the dominant growing ends of the long bones [5]. The nutrient artery of the humerus is a branch of the brachial artery. During surgical procedure such as bone repair, bone grafting, vascularized bone microsurgery, detailed information about the nutrition of the bones will be helpful for the orthopaedic surgeons to minimize damage to the nutrient artery of the humerus [6]. The nutrient artery is particularly important during the active growth period of the embryo and foetus and early ossification stage [7]. Fracture of the long bones is a common condition. Delayed union is one of the most common complication of fractures, and poor bone nutrition occurs to be one of the outcomes of such complication. In this respect, the nutrient artery is important for fracture healing [8]. The nutrient foramen (NF) or its nearby regions are also central to the development of longitudinal stress fractures [9].

According to our literature survey, there are few studies about the NF of the humerus within the Turkish population [10, 11]. The aim of this study is to provide detailed data about the NF, the entry point of the nutrient artery, to be used in order to avoid damaging the nutrient artery, which has an important role in nutrition of the humerus, during surgical approaches to the humeral diaphysis.

MATERIALS AND METHODS

Data Collecting

This study was performed on 113 (58 right, 55 left) humeri of adult Turkish population in the Department of Anatomy, Faculty of Medicine, Hacettepe University. The age and sex of the humeri were unknown. The humeri with fracture or deformation were excluded from the study. Ethic approval was taken from the Hacettepe University Non-Invasive Clinical Research Ethics Committee (date: 18/04/2023 number: 2023/07-08).

The following parameters were evaluated;

1. Total length (TL)
2. Number of NF
3. Localization of the NF on the humeral surfaces or borders
4. Size of NF
5. Position of NF on the humerus
6. Direction of NF
7. Distance between NF and proximal end of the humerus (DNF)
8. Foraminal index (FI) = (DNF/TL) x 100

Initially, NFs were defined using a magnifying glass on the surfaces and borders of the humerus, number, and direction (towards the proximally, distally and horizontally) of the NFs were recorded. Size of the NFs were evaluated respectively by 14, 16, 18, 20, 22, and 24 gauge sized hypodermic needles, and which needle fits the foramens's diameter was determined; the needle with the accurate gauge size was noted as size of examined NF. We evaluated diaphyseal NFs on the humerus, epiphyseal NFs were excluded from the study.

The total length of the humerus (TL) was measured using a tape measure from the most proximal end of the head of the humerus to the most distal end of the humerus. The distance between NF and proximal end of the humerus (DNF) was measured between the NF and most proximal end of the head of the humerus (Figure 1.). Foraminal index was calculated using the Hughes formula: FI=(DNF/TL)*100 [12]. The position of the NF was divided into three parts according to FI: proximal 1/3 (FI up to 33.33%), middle 1/3 (FI from 33.33% to 66.66%) and distal 1/3 (FI above 66.66%).

Statistical Analysis

Statistical analysis of the data was evaluated using the SPSS software v23 (Statistical Package for the Social Sciences– SPSS Inc.). The descriptive statistics of the data were given as percentage, mean, standard deviation, minimum and maximum values. The conformity of the data to the normal distribution was examined using histogram graphics and Kolmogorov-Smirnov/Shapiro-Wilk tests. Independent samples t-test was used to compare the differences between sides. A 5% type-1 error level was used to statistical significance.

Main Points;

- Nutrient foramen is found on the diaphysis of the long bones, providing passage for nutrient arteries.
- The nutrient artery is particularly important during the active growth period of the embryo and foetus and early ossification stage.
- During surgical approaches to the humeral diaphysis, protecting the nutrient foramen is important to reduce possible complications.

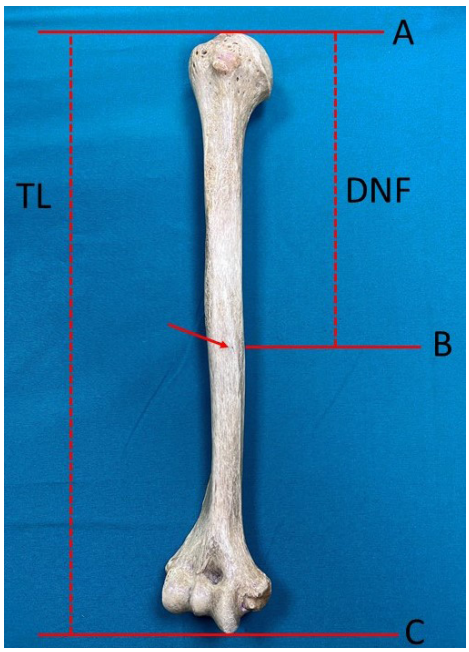

Figure 1. Demonstration of the measurements. A: the most proximal end of the head of the humerus, B: line passing through the nutrient foramen, C: the most distal end of the humerus. TL: total length, DNF: distance between nutrient foramen and proximal end of humerus. Red arrow indicates the nutrient foramen

Figure 2. Demonstration of the two nutrient foramina on humerus, a) anterior view of humerus and anteromedial location of nutrient foramen, b) posterior view of humerus and posterior location of nutrient foramen. Hypodermic needles show the entrance points of nutrient foramina.

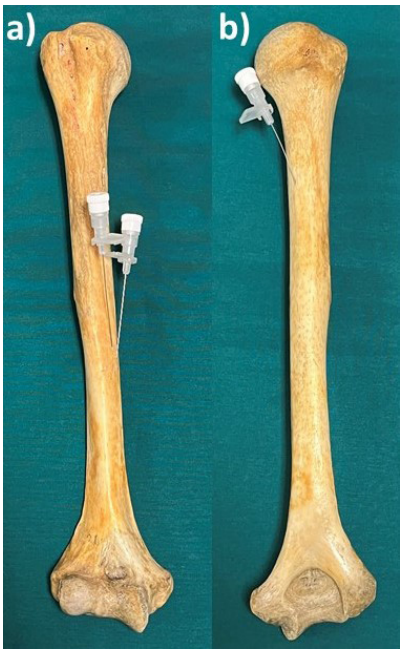

Figure 3. Demonstration of the three nutrient foramina on humerus, a) anterior view of humerus and anteromedial locations of two nutrient foramina, b) posterior view of humerus and posterior location of nutrient foramen. Hypodermic needles show the entrance points of nutrient foramina.

RESULTS

Number of NF: In total, 123 NFs were observed on 113 humeri. Only one NF was observed on 41 of 58 (70.69%) right humeri and 45 of 55 (81.82%) left humeri. Overall, 86 of 113 (76.11%) humeri were found to have one NF each. Besides these, humeri that had 2 NFs were observed on 10 of 58 (17.24%) right humeri, and 7 of 55 (12.73%) left humeri. Overall, 17 of 113 (15.05%) humeri had 2 NFs (Figure 2.). On one of the right sided humerus, 3 NFs were observed (Figure 3.). There was no NF on 6 of 58 (10.35%) right humeri, 3 of 55 (5.45%) left humeri for a total of 9 of 113 (7.96%) humeri.

Direction of NF: While 122 (99.19%) of all NFs were directed distally, one (0.81%) NF was directed horizontally. All of the NFs on the right side, were directed distally, while 58 of 59 (98.3%) of the NFs on the left side were directed distally, and only one of these 59 (1.7%) NFs was directed horizontally.

Localization of the NF on the humeral surfaces or borders: Eighty-six (69.92%) NFs were located on the anteromedial surface, while 18 (14.63%) NFs were found to be located on the medial border, 12 (9.76%) NFs on the posterior surface,

4 (3.25%) NFs on the anterolateral surface and 3 (2.44%) NFs on the lateral border. On the right side, 43 of 64 (67.19%) NFs were located on the anteromedial surface, while 10 of 64 (15.63%) NFs were found to be located on the posterior surface, 9 of 64 (14.06%) NFs on the medial border, 1 of 64 (1.56%) NF on the anterolateral surface and 1 of 64 (1.56%) NF on the lateral border. On the left side, 43 of 59 (72.88%) NFs were located on the anteromedial surface, while 9 of 59 (15.25%) NFs were found to be located on medial border**,** 3 of 59 (5.09%) NFs on anterolateral surface, 2 of 59 (3.39%) NFs on posterior surface and 2 of 59 (3.39%) NFs on lateral border (Figure 4.). No NF was observed on the anterior border of the humerus.

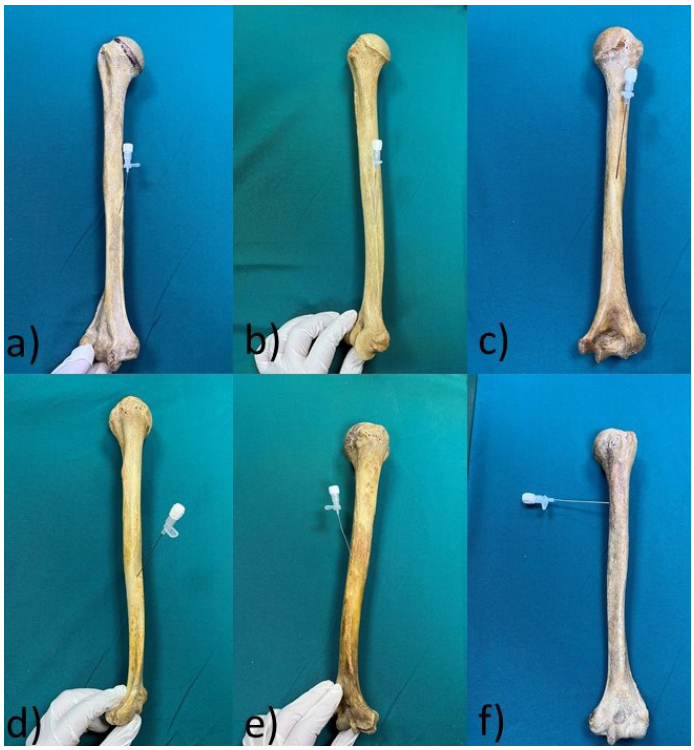

Figure 4. Views of the localizations of the nutrient foramen on humerus. a) on the anteromedial surface, b) on the medial border, c) on the posterior surface, d) anterolateral surface, e) lateral border, f) horizontally directed nutrient foramen

Size of NF: The most common sized NFs were detected as 20G sized, comprising of 28 of 64 (43.75%) NFs on the right side, 22 of 59 (37.29%) NFs on the left side and 50 of 123 (40.65%) NFs in total. 14G and 16G sized NFs were not detected.

Position of NF on the humerus: 5 (4.07%) NFs were located on the proximal 1/3, 113 (91.86%) NFs were located on middle 1/3 and 5 (4.07%) NFs were located on distal 1/3 of the humerus. On the right side, 3 of 64 (4.68%) NFs were located on the proximal 1/3, 58 of 64 (90.64%) NFs on middle 1/3 and 3 of 64 (4.68%) NFs on distal 1/3. On the left side 2 of 59 (3.39%) NFs were located on the proximal 1/3, 55 of 59 (93.22%) NFs on middle 1/3 and 2 of 59 (3.39%) NFs on the distal 1/3.

Total length of humerus: The mean value of the total length of humerus was measured 301.68**±20.61** mm in all humeri, while observed to be 302.69±21.83 mm on the right side, and 300.67**±19.48** mm on the left side.

Distance between NF and proximal end of the humerus: The mean value of distance between the NF and the proximal end of the humerus was measured 166.70**±32.50** mm in all humeri, and 165.86**±36.43 mm** on the right side, and 167.61**±27.91 mm** on the left side.

Foraminal index: The mean value of foraminal index was calculated to be 55.33**±9.48% in all humeri, and** 54.95**±10.63% on the right side and** 55.73**±8.13% on the left side.**

Morphological and morphometric properties of NFs were summarized under Table 1. and Table 2. There were no significant differences between the right and left side regarding the total length of the humerus (p=0.620), distance between NF and proximal end of the humerus (p=0.767) and foraminal index (p=0.649) measurements.

Table 1. Morphometric properties of the nutrient foramen

Parameter	Side	Mean±SD	P value
TL (mm)	Right	302.69±21.83	0.620
	Left	300.67±**19.48**	
	Total	301.68±**20.61**	
DNF (mm)	Right	165.86±**36.43**	0.767
	Left	167.61±**27.91**	
	Total	166.70±**32.50**	
FI (%)	Right	54.95±**10.63**	0.649
	Left	55.73±**8.13**	
	Total	55.33±**9.48**	

TL: total length of humerus, DNF: distance between nutrient foramen and proximal end of the humerus, FI: foraminal index

Table 2. Morphologic properties of the nutrient foramen

Parameter		Side		
		R n(%)	L n(%)	T n(%)
Direction	Proximally n (%)	0	0	0
	Distally n (%)	64 (100)	58 (98.3)	122 (99.19)
	Horizontally n (%)	0	1 (1.7)	1 (0.81)
Localization	Anteromedial surface n (%)	43 (67.19)	43 (72.88)	86 (69.92)
	Anterolateral surface n (%)	1 (1.56)	3 (5.09)	4 (3.25)
	Posterior surface n (%)	10 (15.63)	2 (3.39)	12 (9.76)
	Medial border n (%)	9 (14.06)	9 (15.25)	18 (14.63)
	Lateral border n (%)	1 (1.56)	2 (3.39)	3 (2.44)
	Anterior border n (%)	0 (0)	0 (0)	0 (0)
Size	14G n (%)	0 (0)	0 (0)	0 (0)
	16G n (%)	0 (0)	0 (0)	0 (0)
	18G n (%)	4 (6.25)	7 (11.87)	11 (8.94)
	20G n (%)	28 (43.75)	22 (37.29)	50 (40.65)
	22G n (%)	18 (28.13)	21 (35.59)	39 (31.71)
	24G n (%)	14 (21.87)	9 (15.25)	23 (18.70)
Number of NF	0 n (%)	6 (10.35)	3 (5.45)	9 (7.96)
	1 n (%)	41 (70.69)	45 (81.82)	86 (76.11)
	2 n (%)	10 (17.24)	7 (12.73)	17 (15.05)
	3 n (%)	1 (1.72)	0 (0)	1 (0.88)
Position	Proximal 1/3 n (%)	3 (4.68)	2 (3.39)	5 (4.07)
	Middle 1/3 n (%)	58 (90.64)	55 (93.22)	113 (91.86)
	Distal 1/3 n (%)	3 (4.68)	2 (3.39)	5 (4.07)

R: right, L: left, T: total, n: number, G: gauge, NF: nutrient foramen

DISCUSSION

In the previous studies about the morphology and morphometry of the NFs of the humerus and in our study show that there is usually one NF on the humerus, directed distally, localized on the anteromedial surface and the middle 1/3 of the humerus [1, 10, 11, 13-18]. The knowledge of the morphologic variations and morphometric properties of the NF is important for the orthopaedic surgeons for the purpose of avoiding damage to the nutrient artery while performing open reduction and internal fixation of the fracture [19]. Existence of intact arterial supply is significant in healing of fractured bones [16]. In some fractures, despite appropriate treatment, bone healing is observed to be either slow or not at all [6]. The lack of adequate arterial supply is known as one of the most important reasons for such condition [1].

When we examine the number of the NFs as per previous studies, 1 NF was generally observed in each humerus. This study reported one NF on 86 (76.11%) of the humeri, similar to the findings of Desai and Damor [14] in India 69 (74.11%), Poudel and Satyal [18] in Nepal 40 (80%), Pereira et al. [17] in Brasil 154 (88,5%), and Ehab Kamal Ali [15] in Egypt 210 (84%). The incidence of 1 NF on the humerus was found to be lower in the studies performed by Öztürk et al. [11] in Türkiye 39 (66.1%), Singh et al. [1] in India 38 (61.29%), Mansur et al. [16] in India 154 (60.87%), Arfan et al. [13] in India 52 (60.40%), Cihan and Toma [10] in Türkiye 59 (57.28%) and higher in the study by Kumar et al. [20] in India 73 (91.25%) compared to our study. The present study showed that no NF was detected on 9 (7.96%) of the humeri, which was similar to the findings of Desai and Damor [14] 10 (10.8%), Ehab Kamal Ali [15] 5 (2%), Mansur et al. [16] 5 (1.98%), Cihan and Toma [10] 7 (6.80%) and Kumar et al. [20] 3 (3.75%). Unlike these studies, Singh et al. [1] and Pereira et al. [17] did not detect a humerus devoid of NF. Only a few studies observed triple NFs in the humerus. We found one humerus with triple NFs in compared to the findings of Arfan et al. [13] 5 (5.81%), Mansur et al. [16] 16 (6.32%), Singh et al. [1] 5 (8.06%), Cihan and Toma [10] 8 (7.77%) and Öztürk et al. [11] 1 (1.7%). There are very rare studies that found out more than 3 NFs. Öztürk et al. [11] found 4 foramina on 1 humerus

and 5 foramina on 1 humerus. In the study of Mansur et al. [16], 5 humeri had 4 NFs. Cihan and Toma [10] detected 4 NFs on 3 humeri (2.91%) and 5 NFs on 2 humeri (1.94%). In our study, no humerus with more than 3 foramina was observed (Table 3.).

The NF was generally directed distally in all humeri, similar to in previously conducted studies [1, 10, 13, 14, 16, 18]. Unlike these studies, 2 (2.4%) of the NFs were directed proximally in the study of Öztürk et al. [11], while in our study, 1 (0.81%) of the NFs were found out to be directed horizontally (Table 3.). To our knowledge, there is no study which observed horizontally directed NF.

While the NF is usually located on the anteromedial surface of the humerus in the studies, it can also be observed on other borders and surfaces of the humerus [1, 10, 11, 13, 15, 16, 18]. In the studies conducted by Ehab Kamal Ali [15], Mansur et al. [16], Singh et al. [1], Cihan and Toma [10] and Kumar et al. [20] no NF was detected on the anterior border, as is the case in our study. No NF was observed to be located on the anterolateral surface and lateral border by Öztürk et al. [11], and Ehab Kamal Ali [15] and Mansur et al. [16] have not observed any NF on the medial and lateral border, and no NF was observed on the lateral border according to the study by Arfan et al. [13] (Table 3.).

NFs are usually localized in the middle 1/3 of the humerus, there may also be NFs localized on the proximal 1/3 and distal 1/3 [1, 10, 11, 13, 14, 16]. Unlike other studies, no NF was detected on the proximal 1/3 of the humerus in the studies performed by Poudel and Satyal [18], Kumar et al. [20] and Cihan and Toma [10] (Table 3).

Table 3. Comparison of the morphologic properties of nutrient foramen

Studies	Population	Sample size	Number of NF n(%)	Direction of NF n(%)	Localization of NF n(%)	Position of NF n(%)	Size of NF n(%)
Cihan and Toma (2023) [10]	Türkiye	103 (52 R, 51 L)	0: 7 (6.80) 1: 59 (57.28) 2: 24 (23.30) 3: 8 (7.77) 4: 3 (2.91) 5: 2 (1.94)	PD: - DD: 153 (100) HD: -	AM: 96 (62.7) AL: 9 (5.8) AS: 3 (1.9) PLS: 26 (16.9) PS: 18 (11.7)	P: - M: 42 (89.3) D: 5 (10.6)	
Kumar et al. (2022) [20]	India	80 (40 R, 40 L)	0: 3 (3.75) 1: 73 (91.25) 2: 3 (3.75) 3: 1 (1.25) 4: - 5: -	PD: - DD: 82 (100) HD: -	AM: 73 (89.02) AL: 8 (9.76) PS: 1 (1.22) MB: - LB: - AB: -	P: - M: 71 (86.58) D: 11 (13.42)	
Öztürk et al. (2022) [11]	Türkiye	59 (24 R, 35 L)	0: 1 (1.7) 1: 39 (66.1) 2: 16 (27.1) 3: 1 (1.7) 4: 1 (1.7) 5: 1 (1.7)	PD: 2 (2.4) DD: 81 (97.6) HD: -	AM: 38 (45.79) AL: - PS: 21 (25.30) MB: 16 (19.28) LB: - AB: 1 (1.20) ITS: 7 (8.43)	P: 9 (10.8) M: 64 (77.1) D: 10 (12.1)	
Singh et al. (2018) [1]	India	62 (32 R, 30 L)	0: - 1: 38 (61.29) 2: 19 (30.65) 3: 5 (8.06)	PD: - DD: 91 (100) HD: -	AM: 50 (54.95) AL: 11 (12.08) PS: 11 (12.08) MB: 18 (19.78) LB: 1 (1.09) AB: -	P: 2 (2.19) M: 86 (94.5) D: 3 (3.3)	
Mansur et al. (2016) [16]	Nepal	253 (108 R, 143 L)	0: 5 (1.98) 1: 154 (60.87) 2: 73 (28.85) 3: 16 (6.32) 4: 5 (1.98)	PD: - DD: 368 (100) HD: -	AM: 327 (88.86) AL: 17 (4.62) PS: 24 (6.52) MB: - LB: - AB: -	P: 2 (0.54) M: 349 (94.84) D: 17 (4.62)	

Ehab Kamal Ali (2021) [15]	Egypt	250 (125 R, 125 L)	0: 5 (2) 1: 210 (84) 2: 35 (14)		AM: 171 (61) AL: 28 (10) PS: 81 (29) MB: - LB: - AB: -		
Pereira et al. (2011) [17]	Brasil	174	0: - 1: 154 (88.5) 2: 20 (11.5)				
Arfan et al. (2022) [13]	India	86 (40 R, 46 L)	0: 4 (4.65) 1: 52 (60.40) 2: 25 (29.06) 3: 5 (5.81)	PD: - DD: 117 (100) HD: -	AM: 64 (55.17) AL: 3 (2.58) PS: 20 (17.24) MB: 27 (23.27) LB: - AB: 2 (1.72)	P: 8 (6.89) M: 103 (88.79) D: 5 (4.31)	0.814+-0.213 mm
Poudel and Satyal (2019) [18]	Nepal	50 (29 R, 21 L)	0: 2 (4) 1: 40 (80) 2: 8 (16)	PD: - DD: 56 (100) HD: -	AM: 44 (88) AL: 1 (2) PS: 2 (4) MB: LB: AB:	P: - M: 41 (82) D: 5 (10)	
Desai and Damor (2022) [14]	India	93 (44 R, 49 L)	0: 10 (10.8) 1: 69 (74.1) 2: 14 (15.1)	PD: - DD: 97 (100) HD: -		P: 1 (1.03) M: 92 (94.85) D: 4 (4.12)	
This study	Türkiye	113 (58 R, 55 L)	0: 9 (7.96) 1: 86 (76.11) 2: 17 (15.05) 3: 1 (0.88)	PD: - DD: 122 (99.19) HD: 1 (0.81)	AM: 86 (69.92) AL: 4 (3.25) PS: 12 (9.76) MB: 18 (14.63) LB: 3 (2.44) AB: -	P: 5 (4.07) M: 113 (91.86) D: 5 (4.07)	14G: - 16G: - 18G: 8.94 20G: 40.65 22G: 31.71 24G: 18.70

R: right, L: left, NF: nutrient foramen, n: number, PD: proximally directed, DD: distally directed, HD: horizontally directed, AM: anteromedial, AL: anterolateral, PS: posterior surface, AS: anterior surface, PLS: posterolateral surface, MB: medial border, LB: lateral border, AB: anterior border, ITS: intertubercular sulcus, P: proximal, M: middle, D: distal, G: gauge

Table 4. Comparison of the morphometric properties of nutrient foramen

Studies	Population	Sample size	TL (mm)	DNF (mm)	FI (%)
Cihan and Toma (2023) [10]	Türkiye	103 (52 R, 51 L)	R: 304.39±20.04 L: 303.54±20.22	R: 172.49±23.17 L: 166.68±25.26	55.77
Kumar et al. (2022) [20]	India	80 (40 R, 40 L)	301.1±19.4	166.5±12.2	55.53
Öztürk et al. (2022) [11]	Türkiye	59 (24 R, 35 L)	311.33±30.9	160.92±45.67	52.39±14.84
Mansur et al. (2016) [16]	Nepal	253 (108 R, 143 L)	270.22	149.71	55.20
Arfan et al. (2022) [13]	India	86 (40 R, 46 L)	304.22±21.98		56.83±7.80
Poudel and Satyal (2019) [18]	Nepal	50 (29 R, 21 L)	297.09	142.95	48.12
Desai and Damor (2022) [14]	India	93 (44 R, 49 L)	R: 300.8±17.8 L: 302.3±20.8	R: 185.8±40.5 L: 187.8±48.3	R: 53.27 L: 49.96
This study	Türkiye	113 (58 R, 55 L)	301.68±**20.61**	166.70±**32.50**	55.33±**9.48**

R: right, L: left, TL: total length of humerus, DNF: distance between nutrient foramen and proximal end of the humerus, FI: foraminal index

There are only a few studies which measured the diameter of the NF. Arfan et al. [13] measured the mean diameter of the foramen as 0.814+-0.213 mm. In our study, majority of NFs were sized at 20G (1.1 mm) (Table 3.). The diameter of the NF may provide us necessary information about the diameter of the nutrient artery.

The mean TL was measured as 301.68**±20.61 mm in our study which is similar to the studies of** Cihan and Toma [10] in Türkiye (right: 304.39±20.04 mm, left: 303.54±20.22 mm), Kumar et al. [20] in India (301.1±19.4 mm), Öztürk et al. [11] in Türkiye (311.33±30.9 mm), Arfan et al. [13] in India (304.22±21.98 mm), Desai and Damor [14] in India (right: 300.8±17.8 mm, left: 302.3±20.8 mm) and higher than the studies of Mansur et al. [16] in Nepal (270.22 mm) and Poudel and Satyal [18] in Nepal (297.09 mm). The mean DNF was measured 166.70**±32.50 mm in our study which is in accordance to the studies of Kumar et al.** [20] (166.5±12.2 mm), Öztürk et al. [11] (160.92±45.67 mm), Cihan and Toma [10] (right: 172.49±23.17 mm, left: 166.68±25.26 mm), lower than that of Desai and Damor [14] (right: 185.8±40.5 mm, left: 187.8±48.3 mm) and higher than that of Mansur et al. [16] (149.71 mm) and Poudel and Satyal [18] (142.95 mm). The mean FI was calculated in our study as 55.33**±9.48%, which is in accordance to the studies of** Cihan and Toma [10] (55.77%), Kumar et al. [20] (55.53%), Mansur et al. [16] (55.20%), Arfan et al. [13] (56.83±7.80%) and higher than that of Öztürk et al. [11] (52.39±14.84%), Poudel and Satyal [18] (48.12%), and Desai and Damor [14] (right: 53.27%, left: 49.96%). The foraminal index indicates where the NF is located from the proximal to the distal parts of the humerus. Foraminal index values found in studies show us that the NF is generally localized on the middle 1/3 of the humerus. Comparison of the morphologic and morphometric properties of NFs were summarized in Table 3. and Table 4.

Limitations

This study has certain limitations. The age and sex of the bones were unknown. Due to such absence of information, the age and sex differences for NF could not be evaluated. In addition, the sample size was limited to 113 bones. Further studies may be performed with larger sample size and known age and sex of the bones.

CONCLUSION

In conclusion of our study, it is found out that there is usually one NF on the humerus and that this foramen is directed distally, localized on the anteromedial surface and the middle 1/3 of the humerus and sized at 20G. And also, we observed horizontally directed NF on the humerus. To our knowledge, there is no study which observed horizontally directed NF. There may be differences between populations about the morphology and morphometry of NF. Therefore, being aware for the morphology, morphometry and variations of the NF is important for the orthopaedic surgeons in surgeries such as fracture repairing and vascularized bone graft in order to avoid damaging the nutrient arteries.

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