An Analysis of the Humeral Nutrient Foramen from a Morphometric Perspective

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ABSTRACT:
Background: The humerus, being the largest bone of the upper limb, relies on a well-established blood supply system for its nourishment and healing processes, particularly in cases of fractures. The presence and characteristics of the nutrient foramen play a crucial role in determining the effectiveness of orthopedic surgical interventions and the healing outcome of fractured bones. Understanding the quantitative and qualitative aspects of the nutrient foramen in the humerus is essential for orthopedic surgeons to minimize the risk of vascular injury during surgical procedures and optimize fracture healing.
Methods: This analytical observational study examined 160 dry humeri (80 right and 80 left) of unknown genders obtained from the anatomy department of a medical college over a three-year period. Bones with previous damage, healed fractures, congenital anomalies, and significant pathological changes were excluded. The nutrient foramina were identified, and their quantity, position, location, and orientation were examined using magnification. The foraminal index (FI) was calculated to determine the location of the nutrient foramen relative to different segments of the humerus. Osteometric measurements were conducted using appropriate tools, and statistical analysis was performed using Microsoft Excel.
Results: The majority (91.25%) of humeri exhibited a solitary nutrient foramen, while a small percentage displayed two (3.75%) or three (1.25%) foramina. Most nutrient foramina were located on the anteromedial surface (89.02%) of the humerus, primarily in the middle one-third segment (86.58%). The mean total length of the humerus was approximately 30.11 cm, with the nutrient foramina situated at an average distance of 16.65 cm from the proximal end. The consistent foraminal index (55.53%) indicated a uniform distribution pattern of nutrient foramina along the length of the humerus.
Conclusion: This study provides valuable insights into the quantity, orientation, and position of the nutrient foramen in the humerus. The findings underscore the importance of understanding the vascular anatomy of the humerus for orthopedic surgical planning and fracture management. Orthopedic surgeons can use this knowledge to minimize the risk of vascular injury during surgical procedures and optimize fracture healing outcomes, ultimately improving patient care and treatment efficacy.

Keywords: diaphysis, foramen index, nutrient artery, nutrient foramina, humerus

INTRODUCTION

Every bone contains nutrient foramina, which are openings for the entry of blood vessels that provide nourishment. These foramina are especially prominent in the shafts of larger long bones. The foramina serve as openings that allow vessels to enter the bone and supply the medullary cavity through nutrient canals. Their points of entry and orientation remain relatively consistent and consistently point away from the dominant growing ends [1]. The nutrient foramen is located in the diaphysis of long bones.

Irregular bones are present in various other locations. Long bones receive blood supply from four distinct arterial systems, namely the nutrient artery, epiphyseal artery, metaphyseal artery, and periosteal artery. The nutrient vessels enter the bone through these foramina and then split into ascending and descending branches within the medullary cavity. These branches provide nourishment to the bone marrow and the inner two-thirds of the compact bone [2]. The femur and humerus bones possess multiple nutrient foramina. Prior to entering the nutrient foramen, the nutrient vessels undergo tortuosity in order to prevent interference with bone movement [3]. Nutrient arteries are crucial for both the active growth period and the consolidation of callus in fractured bones [1].

The incidence of long bone fractures is rising as a result of an increase in road traffic accidents, industrial accidents, sports injuries, and pathological fractures in osteoporotic patients. Nonunion of a fractured long bone may occur as a complication of either a closed or an open reduction [4]. Nonunion of a long bone fracture refers to a condition where the healing process has stopped, as confirmed by clinical and radiological evidence, beyond the expected timeframe. This typically occurs due to various reasons and often necessitates a modification in the treatment approach. A significant factor contributing to nonunion is ischemia, which refers to the inadequate blood supply to the fractured bone. Loss of blood supply to the fracture site can occur due to damage to nutrient vessels, excessive stripping, or injury to the periosteum and muscle [5]. The humerus is the largest and most elongated bone of the upper limb. The nutrient artery that supplies it is a branch of the brachial artery. The nutrient artery penetrates the bone via the nutrient foramen situated on the anteromedial surface slightly below its midpoint, with a downward orientation, and emerges near the medial border [1]. The nutrient artery is the primary provider of blood to the bone, making it crucial for the process of fracture healing. A comprehensive understanding of the blood supply is essential for performing orthopaedic surgical procedures such as vascularized bone microsurgery. The preservation of the blood supply by the nutrient artery is crucial in free vascular bone grafting to facilitate fracture healing [6]. The objective of this study was to ascertain the quantity, orientation, and position of the nutrient foramen in the humerus. The aim of this study is to ascertain the quantity, orientation, and position of the nutrient foramen in the humerus.

MATERIALS AND METHODS

The current study, which falls under the category of analytical observational research, examined 160 dry humeri (80 right and 80 left) of unknown genders. These specimens were obtained from the anatomy department of the Medical College of central India over a period of three years. This study excluded bones that exhibited previous damage and healed fractures, congenital anomalies, and significant pathological changes. 16 bones were eliminated based on the aforementioned criteria. Side determination was performed on all humeri. The nutrient foramina were identified based on the presence of a clearly defined groove that leads to the foramen. The nutrient foramen of all humeri was examined to determine the quantity, position, location, and orientation. The nutrient foramen was observed using a magnifying glass. If the humerus possesses more than two nutrient foramina, the foramen that exhibits greater dimensions is referred to as the dominant foramen, while the remaining one is denoted as the secondary foramen.

The nutrient foramen's location was determined using the foraminal index (FI), which is calculated using the formula: FI = DNF/TL x 100. DNF represents the distance between the nutrient foramen and the closest part of the humerus, while TL refers to the overall length of the humerus.

The location of the nutrient foramen was categorised into three types based on FI: type 1 = FI < 33.33, where the foramen is situated in the upper third of the humerus; type 2 = FI between 33.33 and 66.66, where the foramen is situated in the middle third of the humerus; type 3 = FI > 66.66, where the foramen is situated in the lower third of the humerus.

The osteometric board was used to measure the total length of humeri in centimetres. The distance between the nutrient foramen and the closest point on the humerus was measured using a digital vernier calliper, with the measurements recorded in centimetres. The data collected was recorded and subjected to statistical analysis using a Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, WA).

Results

Table 1 presents the incidence of nutrient foramina in the humerus, based on the examination of 160 humerus bones (80 right, 80 left). The majority of specimens (91.25%) exhibit one nutrient foramen, with slightly more prevalence on the right side (46.25%) compared to the left (45%). A small proportion of bones lack any nutrient foramen (3.75%), while a similar percentage display two (3.75%) or three (1.25%) nutrient foramina. These findings underscore the common occurrence of a single nutrient foramen in the humerus, with minor variations observed in a subset of specimens.

TABLE 1: Incidence of the number of the nutrient foramen of the humerus

	Right		Left		Total	
No. of nutrient foramen	**No. of humerus (n = 80)**	**Percentage (%)**	**No. of humerus (n = 80)**	**Percentage (%)**	**No. of humerus (n = 160)**	**Percentage (%)**
-	2	1.25%	4	2.50%	6	3.75%
1	74	46.25%	72	45%	146	91.25%
2	4	2.50%	2	1.25%	6	3.75%
3	-	-	2	1.25%	2	1.25%
	80		80		160	

Table 2 presents the distribution of nutrient foramina locations relative to different surfaces of the humerus, based on the examination of 164 humerus bones (82 right, 82 left). The majority of nutrient foramina are located on the anteromedial surface, accounting for 89.02% of the total, with similar frequencies observed on both the right (87.80%) and left (90.24%) sides. A small percentage of foramina are found on the posterior surface (1.22%), predominantly on the right side (2.44%). Additionally, nutrient foramina are present on the anterolateral surface, representing 9.76% of the total, with equal distribution between the right and left sides. These findings highlight the predominance of nutrient foramina on the anteromedial surface of the humerus, with minor occurrences on the posterior and anterolateral surfaces.

TABLE 2: Location of the nutrient foramen in relation to different surfaces of the humerus

Surface	Right		Left		Total	
	Number (n = 82)	Percentage (%)	Number (n = 82)	Percentage (%)	Number (n = 164)	Percentage (%)
Anteromedial	72	87.80	74	90.24	146	89.02
Posterior	2	2.44	-	-	2	1.22
Anterolateral	8	9.76	8	9.76	16	9.76
Total	82	100	82	100	164	100

Table 3 outlines the site of the nutrient foramen in relation to different segments of the humerus, based on the examination of 164 humerus bones (82 right, 82 left). In the middle third segment, the majority of nutrient foramina are observed, accounting for 86.58% of the total, with slightly more prevalence on the left side (87.80%) compared to the right (85.36%). In the distal third segment, a smaller proportion of foramina are found, constituting 13.42% of the total, with a slightly higher incidence on the right side (14.63%) compared to the left (12.19%). No nutrient foramina are reported in the proximal third segment. These findings indicate a concentration of nutrient foramina in the middle third segment of the humerus, with lesser occurrences in the distal third and none in the proximal third.

TABLE 3: Site of the nutrient foramen in relation to different segments of the humerus

Situation	Right		Left		Total	
	Number (n = 82)	Percentage (%)	Number (n = 82)	Percentage (%)	Number (n = 164)	Percentage (%)
Proximal 1/3	-	-	-	-	-	-
Middle 1/3	70	85.36%	72	87.80%	142	86.58%
Distal 1/3	12	14.63%	10	12.19%	22	13.42%
Total	82	100%	82	100%	164	100%

Table 4 presents data on the length of the humerus and the distance of the nutrient foramina from the proximal end, along with the foraminal index, based on the examination of 160 humerus bones (80 right, 80 left). The mean total length of the humerus is approximately 30.11 cm, with slight variations between the right (30.07 cm) and left (30.15 cm) sides. The distance of the nutrient foramina from the proximal end averages around 16.65 cm, with minimal differences between the right (16.63 cm) and left (16.66 cm) sides. The foraminal index, representing the percentage of the distance of the nutrient foramina from the proximal end relative to the total length of the humerus, is consistent at approximately 55.53% for both sides. These findings indicate a similar distribution pattern of nutrient foramina along the length of the humerus on both sides, as reflected by the consistent foraminal index.

TABLE 4: Length of the humerus, the distance of nutrient foramina from the proxi

Parameter	Right (n = 80)	Left (n = 80)	Total (n = 160)
Mean total length (cm)	30.07 ± 1.89	30.15 ± 2.02	30.11 ± 1.94
Distance of nutrient foramina from the proximal end (cm)	16.63 ± 1.23	16.66 ± 1.22	16.65 ± 1.22
Foraminal index	55.53%	55.54%	55.53%

Discussion

The current study, which falls under the category of analytical observational research, examined 160 dry humeri (80 right and 80 left) of unknown genders.The current study demonstrated that a solitary nutrient foramen was observed in 91.25% of humeri. Laing (93%) [7] and Bhatnagar et al. (90%) [8] also observed a comparable result in their studies. Several studies have documented a reduced occurrence of a single nutrient foramen [9,10]. Joshi et al. [10] and Arfan et al. [9] found that only 63% and 60.40% of humerus bones, respectively, had a single nutrient foramen. The current study revealed that the occurrence of double nutrient foramen was observed in 3.75% of humeri, a rate that closely aligns with the findings of Laing (7%) [7] and Bhatnagar et al. (7.14%) [11]. Joshi et al. [10] discovered that 33% of humeri exhibited a higher occurrence of a double nutrient foramen. The majority of authors noted the existence of triple nutrient foramina in humeri [12-14]. The current investigation noted that a triple nutrient foramen was present in 1.25% of humeri, a percentage that closely aligns with the findings of previous studies conducted by Halagatti and Rangasubhe (2%) [13] and Bhatnagar et al. (1.43%) [11]. This study found that 3.75% of humeri lacked a nutrient foramen, which is consistent with the findings of a previous study by Ramya Sree et al. [14], who reported a similar occurrence of 3.67%. In these cases, the humeri were instead supplied by periosteal arteries [15].

The nutrient foramen is located on the front and inner side of the humeral shaft, close to the medial border. However, its exact position may vary. The study found that 89.02% of the foramina were situated on the anteromedial surface, which is consistent with the findings of Chandrasekaran et al. (89.92%) [16] and Mansur et al. (88.86%) [17]. In contrast, a study conducted in Pakistan by Khan et al. [18] found that nutrient foramina were more commonly located on the anteromedial surface, with a prevalence of 96%.

According to the present investigation, the study revealed that 86.58% of nutrient foramina were positioned in the middle one-third of humeri, whereas 13.42% were situated in the distal one-third. No nutrient foramina were observed in the proximal one-third of the humerus. This discovery is consistent with the results reported by Chandrasekaran et al. [16] and Yaseen et al. [19] while less than Arfan et al. [4], Mansur et al. [17] and Pankaj et al. [19] they observed more than 91% of foramen were observed in the middle one-third of the humerus.

The nutrient artery serves as the primary blood supply during the period of active growth in long bones. Berard (1835) was the first to describe the correlation between the direction of the nutrient canal and the process of ossification and growth of bone. [20]The humerus is also supplied with blood by metaphyseal and periosteal arteries, which originate from the axillary and brachial arteries. Orthopaedic surgeons performing open reduction of fractures must possess a comprehensive understanding of the different variations of the nutrient foramen. This knowledge is crucial in order to prevent injury to the nutrient artery, thereby reducing the risk of delayed union or nonunion of the fracture [10]. The preservation of an undamaged blood supply is crucial for the successful healing of a fractured bone [21]. The occurrence of delayed union or nonunion of a bone fracture is widely recognised to be caused by insufficient arterial supply [22].

Conclusions

This study determines that the nutrient foramen of the humerus is not solely limited to the anteromedial surface, but it can also be present on the anterolateral and posterior surfaces. Furthermore, a nutrient foramen was observed on the middle and distal thirds of the humerus shaft. The majority of the humerus had a solitary nutrient foramen, although two or three nutrient foramina were also observed in the humerus. Orthopaedic surgeons can benefit from understanding the precise details of the number, location, site, and direction of nutrient foramen. This knowledge allows them to effectively avoid this area during procedures such as internal fixation, fracture repair, bone grafting, joint replacement therapy, and vascularized bone microsurgery. By doing so, the risk of damaging the nutrient artery can be minimised. The nutrient artery's impairment can result in the failure of bone to heal properly or the delay in its healing after a fracture occurs in the humerus shaft.

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