ORIGINAL ARTICLE

A STUDY OF NUTRIENT FORAMINA IN LONG BONES OF NIGERIANS

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ABSTRACT

Nutrient foramen is a natural opening into the shaft of a bone, allowing for passage of blood vessels into the medullary cavity. This study aims to determine the number, location and direction of nutrient foramina of long bones of the upper limb in the Nigerian population. A total number of 250 long bones (150 humeri, 50 radii and 50 ulnae) were used for the study. In the results, 66% of the humeri had a single foramen, 18% had double foramina and 26% had no foramen. For the radii, 68% had a single nutrient foramen and 32% had no nutrient foramen. 78% of the ulnae had a single nutrient foramen and 22% had no nutrient foramen. All the foramina except one (in the radius) were directed away from the growing end, that is, they were directed towards the elbow. Information and details about these foramina is of clinical importance, especially in surgical procedures like bone grafting and microsurgical vascularized bone transplantation.

Keywords: Nutrient foramen, long bones, foraminal index, Nigerian population

INTRODUCTION

Nutrient foramen is an opening into the bone shaft which gives passage to the blood vessels of the medullary cavity of a bone, for its nourishment and growth [1]. The nutrient artery is the principal source of blood supply to a long bone and is particularly important during its active growth period in the embryo and fetus, as well as during the early phase of ossification [2].

Bones are structures that adapt to their mechanical environment, and from a fetal age adapt to the presence of naturally occurring holes which allow blood vessels to pass through the bone cortex [3]. When compromised especially in childhood, medullary bone ischemia occurs with less vascularization of the metaphysis and growth plate [4].

It has been suggested that the direction of the nutrient foramina is determined by the growing end of the bone, which is supposed to grow at least twice as fast as the non-growing end. As a result, the nutrient vessels move away from the growing end of the bone [1]. As is popularly stated, they 'seek the elbow and flee from the knee' [5], showing their varying directions in both limbs. Variations have been described in the direction of nutrient foramina in the lower limb bones [6]. However, only a few studies have reported variation in direction of the nutrient foramina in the upper limb bones [7].

The study of nutrient foramina is important in both morphological and clinical aspects. Some pathological bone conditions such as fracture healing or acute hematogenic osteomyelitis are closely related to the vascular system of the bone [8]. Detailed data on the blood supply to the long bones is invariably crucial in the development of new transplantation and resection techniques in orthopaedics [2], [9].

Studies on the vascularization of long bones of various populations have been conducted to analyze the nutrient foramina morphometry [2], [10], the nutrient blood supply [11], [12], the vascular anatomy in reconstructive surgeries[13], [14]and the microsurgically vascularized bone transplant [15], [16].

However, there is still a need for a greater understanding of nutrient foramina in bones such as the humerus, radius and ulna. The aim of this study is to record the location, number and direction of nutrient foramina in long bones of the upper limbs of adult Nigerians.

MATERIALS AND METHODS

The study was conducted in the Department of Anatomy, Anambra State University, Uli. The materials for the present study consisted of 250 adult human cleaned and dried bones of the upper limbs. They were divided into three groups: 150 bones of humerus and 50 bones each of ulna and radius. All selected bones were normal with no appearance of pathological changes. The specific age and sex characteristics of the bones studied were unknown.

The nutrient foramina were observed in all bones with the help of a hand lens. They were identified by their elevated margins and by the presence of a distinct groove proximal to them. Only well-defined foramina on the diaphysis were accepted. Foramina at the ends of the bones were ignored.

Direction: A fine stiff broomstick was used to confirm the direction and obliquity of the foramen.

Position: The position of all nutrient foramina was determined by calculating the foraminal index (FI) using the formula:

FI = (DNF/TL) x 100

Where DNF=the distance from the proximal end of the bone to the nutrient foramen; TL=Total bone length [17]

The position of the foramina was divided into three types according to FI as follows:

Type 1: FI below 33.33, the foramen was in the proximal third of the bone.

Type 2: FI from 33.33 up to 66.66, the foramen was in the middle third of the bone.

Type 3: FI above 66.66, the foramen was in the distal third of the bone.

All measurements were taken to the nearest 0.1 mm using an INOX sliding caliper [2]. Photographs were taken by a Casio digital camera (12 mega pixels). Each photograph had a definition of 16x12 cm.

Data Analysis: Data are expressed as means and standard deviations for continuous variables, and percentage for categorical variables.

RESULTS

Total 66% of the humeri had a single foramen, 8% had double foramina and 26% had no foramen. For the radii, 68% possessed a single nutrient foramen and 32% had no nutrient foramen. 78% of the ulnae had a single nutrient foramen and 11 (22%) had no nutrient foramen. All the foramina except one (in the radius) were directed away from the growing end.

Table 1: Number of nutrient foramina observed in the long bones of the upper limb

Bone	Number of Foramina	Number of bones (%)
Humerus (n = 150)	0	39 (26)
	1	99 (66)
	2	12 (8)
Radius (n = 50)	0	16 (32)
	1	34 (68)
Ulna (n = 50)	0	11 (22)
	1	39 (78)

Tables 1 to 6 give the details of the results in terms of nutrient foramina number, position and direction, and Figures 1 to 4 give pictorial details of the foramina in the humerus (Fig.1, 2), radius (Fig. 3) and ulna (Fig.4).

Table 2: Foramen index and measurements associated with nutrient foramen in the long bones of the upper limb.

Measurements	Humerus (n=111)	Radius (n=34)	Ulna (n=39)
DNF	18.97±1.85	8.85±1.28	10.33±1.31
TL	33.76±1.75	26.29±1.36	28.28±1.24
FI	56.28±4.90	33.74±4.94	36.70±4.56

Data are means and standard deviation

Abbreviations: DNF = Distance from the proximal end of the bone to the nutrient foramen; TL = Total length of bone; FI = Foramen Index.

Table 3: Position and direction of nutrient foramina observed in the long bones of upper limbs

Bone	Position			Direction
	Type 1	Type 2	Type 3	
Humerus	-	120 (100)	-	Distally
Radius	20 (57.1)	15 (42.9)	-	Proximally (except one which is distal)
Ulna	10 (27.0)	27 (73.0)	-	Proximally

Figure in parenthesise indicate percentage.

Table 4: Position of nutrient foramina observed in the Humerus

Position	Number of Foramina(%)
Anteromedial surface	109 (90.8)
Posterior surface (in the middle of surface)	2 (1.7)
Posterior surface (close to the medial border)	1 (0.8)
Posterior surface (close to the lateral border)	6 (5)
Medial Border	1 (0.8)

Fig 1: A photograph of the anterior surface of a left humerous showing a single nutrient foramen (NF) on the anteromedial surface of the shaft. The foramen is locate in the middle third of the (Type-2) and is directed downward.

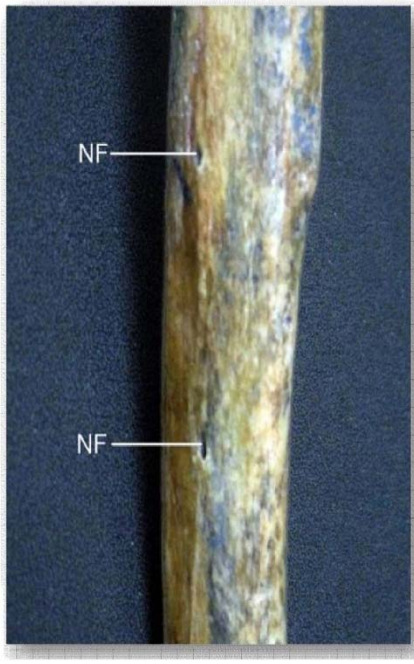

Fig 2: A photograph of a shaft of a humerous showing double nutrient foramina (NF). Both foramina are directed downward.

Fig 3: A photograph of the anterior surface of a right radius showing a single nutrient foramen (NF) on the anterior surface close close to the interosseous border of its shaft. The foramen is located is located in the middle third of the bone (typ-2) and is directed upward.

Table 5: Position of nutrient foramina observed in the Radius

Position	Number of foramina(%)
Anterior surface (Midway between interosseous and anterior border)	16 (45.7)
Anterior surface (close to interosseous border)	5 (14.3)
Anterior surface (close to the anterior border)	11 (31.4)
Posterior surface (close to the interosseous border)	3 (8.6)

Table 6: Position of nutrient foramina observed in the Ulna

Position	Number of foramina (%)
Anterior surface (in the middle of surface)	5 (13.5)
Anterior surface (close to interosseous border)	7 (18.9)
Anterior surface (close to the anterior border)	24 (64.9)

Fig 4: A photograph of the anterior surface of a right ulna showing a single nutrient foramen (NF) on the middle of the anterior surface of the shaft. The foramen is located in the middle third (type-2) and is directed upward.

DISCUSSION

Number of Nutrient Foramina: In the present study, a single nutrient foramen had a higher percentage (66%) in the humeral bones, compared to that of double (8%). Many studies reported a percentage approximately similar to that of the present result [4], [18]. The range of occurrence of double foramina varied from 13% [6] to 26% [7] and 42% [18]. Also, some reported the absence of nutrient foramina in some humeri [1], [2]; they stated that in such cases, the periosteal vessels were entirely responsible for the blood supply of the bone. This is in accordance to the report of this present study as 26% of humeri observed were without nutrient foramen (Table 1).

Total 68% of the radii examined in the present study had a single nutrient foramen (Table 1). In other studies, the majority of radii (more than 90%) were found to possess a single nutrient foramen [2], [19].

Other authors reported a single nutrient foramen in more than 88% of ulnae [2], [7]. This corresponds with the observations in the ulnae in the present study (Table 1).

Position of Nutrient Foramina: In this study, 100% of the nutrient foramina were located along the middle third of the humerus (Table 3). In accordance with the present results, other studies reported the position of the nutrient foramina within the middle third of the bone [2], [20]. Also, 90.8% of all humeral nutrient foramina were observed on the anteromedial surface of the bone (Table 4). Similar findings had been reported by Kizilkanat et al. [2] and Kumar et al [7].

In the present study, 42.9% of the total nutrient foramina were distributed most often in the middle third of the radius and 57.1% were in the proximal third (Table 3). The ratios of the present study were close to those reported by Kizilkanat et al. [2] and Kumar et al. [7]. Also, 45.7% of all radial foramina were on the anterior surface of the bone (Table 5). Such results were in accordance with the previous studies [7], [19] who stated that the majority of nutrient foramina were located on the anterior surface of the bone.

Regarding the ulna, the majority of nutrient foramina (73%) were in the middle third while 27% were in the proximal third of the bone (Table 3). No nutrient foramina were detected in the distal third of the ulnae. Some authors reported that the majority of nutrient foramina were located in the middle third [18] while others stated that most of foramina were in the proximal third [6], [7]. However, all agreed that there were no nutrient foramina in the distal third of the ulna. Also, 64.9% of the nutrient foramina were located on the anterior surface of the ulnae (Table 6). In all previous studies, the nutrient foramina were mostly observed on the anterior surface of the ulna [2], [19].

Direction of Nutrient Foramina: In this study, all the nutrient foramina in humerus were directed distally (away from the growing ends). In the radii examined, the direction of the nutrient foramina was proximal (except for one) (Table 3). The nutrient foramina of all ulnae examined had a proximal direction. This is similar to the study by Kumar et al [7], only that the variation was seen in the humerus.

Clinical Relevance: An understanding of the position and number of the nutrient foramina in long bones is important in orthopaedic surgical procedures such as joint replacement therapy, fracture repair, bone grafts and vascularized bone microsurgery [2]. The foramen may be a potential area of weakness in some patients and, when under stress because of increased physical activity or decreased quality of the bone, the foramen may allow development of a fracture. Position of the fracture relative to the nutrient foramen of the long bone and the patterns of edema are the secondary signs in the key of the diagnosis of this type of fracture [21].

The healing of fractures, as of all wounds, is dependent upon blood supply, Injury to the nutrient artery at the time of fracture, or at subsequent manipulation, may be a significant factor predisposing to faulty union. If surgeons could avoid a limited area of the cortex of the long bone containing the nutrient foramen, particularly during an open reduction, an improvement in the management of this problem might be attained [22].

Recent results confirmed the hypothesis that vascularized bone and joint allograft survival depends strongly on the blood supply and control of rejection [23]. Anatomical factors were suspected to be responsible for this phenomenon. These anatomical facts are necessary for the success of free vascularized elbow allografts. In order to really undertake vascularized elbow joint allograft, the exact topography of nutrient foramina of the humerus, radius, and ulna must be specified to preserve diaphyseal vascularization of the recipient. The levels of osseous section are selected according to the localization of the diaphyseal nutrient foramina of the three bones in order to preserve diaphyseal vascularization of the recipient to support the consolidation with the osseous graft 23.

CONCLUSION

The study confirmed previous reports regarding the number and position of the nutrient foramina in the long bones of the limbs. It also provided important information to the clinical significance of the nutrient foramina.

Accordingly, a well understanding of the characteristic morphological features of the nutrient foramina by orthopaedic surgeons is recommended. Exact position and distribution of the nutrient foramina in bone diaphysis is important to avoid damage to the nutrient vessels during surgical procedures.

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