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Description of The Pattern of Nutrient Foramina of Lower Limb Bones And Its Clinical Relevance

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Abstract: *Nutrient foramina are the largest foramina present in the shaft of a long bone which allows the passage of the blood vessel to enter the bone. Nutrient arteries play an important role not only in the active growth phase of the foetus but also in early stage of ossification. Even though the bone is supplied by many periosteal and diaphyseal arteries the major arterial supply to the long bone is by nutrient arteries. The nutrient artery has a particular position in every long bone and its direction always away from the growing end. The aim of the study was to assess the presence of number and position of nutrient foramina and its clinical relevance. The present study was conducted in 130 dry adult long bones of lower limb (50 femur, 40 tibia, 40fibula) of unknown sex which were collected from Department of Anatomy, Dr S.M.C.S.I Medical College, Karakonam, Kerala. The study was conducted with the help of Digital calipers and magnifying lens. The topographic and morphological features such as number, direction and position of the nutrient foramen was observed and recorded and variations were noticed. Majority of the bones studied showed single nutrient foramen, which was maximally observed in left fibula. Double foramina were maximally recorded in right side femur. The foramen index was Maximum number of nutrient foramen in the middle 1/3rdin femur and fibula and upper 1/3rdin tibia. This data can be used for comparing with other regions and may help in surgical procedures and interpretation of radiological images. Even though many studies have conducted about the position and number of nutrient foramina due to its clinical significance a detailed understanding and analysis of the data is very essential in new transplantation and resection technique in orthopaedics.*

Keywords: *Diaphysis, Foramina index, Long bone, Nutrient artery, Nutrient foramen.*

I. Introduction

Nutrient foramen is an opening in the bone shaft which gives passage to the blood vessels into the medullary cavity of a bone, for its nourishment and growth [1].Bones are structures that adapt to their mechanical environment, and from its fetal age adapt to the presence of naturally occurring holes which allow blood vessels to pass through the bone cortex [2].All long bones are supplied by four sets of arterial system – Nutrient, Epiphyseal, Metaphyseal and Periosteal Arteries. Nutrient Artery is the major source of blood supply to the bone and hence plays an important role in healing of fractures. Nutrient artery do not branch in their canals, but divide into ascending and descending branches in the medullary cavity. 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. As is popularly stated, they "go towards the elbow and flee from the knee" [3], showing their varying directions in both limbs. Nutrient foramen is the largest foramen on the shaft of long bones through which nutrient artery for that bone passes [4].The sites of entry of nutrient foramen and its angulations are almost constant, characteristically away from the growing epiphysis [5], but such a simple mechanism does not account for exceptions to this pattern reported in various species and sites [6]. It has been stated that position of nutrient foramina is variable and typical position of nutrient foramina can be determined after a study on human long bones. Variations have been described in the direction of nutrient foramina in the lower limb bones [7].

The healing of fracture is dependent upon blood supply of the bone. During fracture of shaft usually, nutrient artery is ruptured along with variable disruption of peripheral vessels associated with periosteal detachment [8].Injury to the nutrient artery also occurs during open or closed reduction of the fracture. So it is very important to have a knowledge and understanding of the commonest position of nutrient artery and number of the nutrient foramina of long bones in orthopedic surgical procedures, especially in vascular bone grafting where the blood supply by nutrient artery is very important and must be preserved in order to promote fracture repair [9]. Good blood supply is necessary for osteoblast and osteocyte cell survival as well as facilitating graft healing in the recipient [10].

The number and position of the nutrient foramen are also important in success of fracture treatment. Lots of complications can occur during fibular graft harvesting like neurovascular injuries, compartment syndrome and ankle instability [11]. The bone transplant procedures require a detailed statistical data on position of nutrient foramen specific to that population which can help the surgeons to select the osseous section levels of the receptor in order to preserve the nutrient artery [12]. Thus statistical data regarding the position of nutrient foramen in different populations can improve the results and minimize the complications [13, 14].Nutrient artery is not only important in some pathological bone condition, but also related and responsible for the developmental abnormalities.

II. Aims & Objectives Of The Study

1. To study the number and position of nutrient foramina in lower limb bones and their clinical significance.
2. To calculate the Foramina Index of long bones of lower limb

III. Methodology

For the present study 130 dry adult long bones of lower limb (50 femur, 40tibia, 40fibula) of unknown sex were collected from Department of Anatomy, Dr S.M.C.S.I Medical College, Karakonam, Kerala, India. All selected bones were normal with no appearance of pathological changes. The specific age and sex characteristics of the bones were unknown. Each bone was studied for the presence of (a) number and (b) position of nutrient foramen. The prominent foramen was identified by the presence of a well-marked probe and considered as the nutrient foramen, others were ignored. Location of the nutrient foramen was determined by calculating the Foramina Index (FI) according to Hughes [6] using the formula **FI=DNF/TLX100**where DNF=Distance from the proximal end of the bone to the nutrient foramen and TL=Total bone length. Total length of the bone was measured as the following:

In femur: distance from the proximal aspect of head to the distal aspect of medial condyle.
In Tibia: Distance from the proximal part of intercondylar area to the distal part of medial epicondyle.
In fibula: Proximal part of styloid process to the lower end of lateral malleolus.

All measurements were taken with magnifying lens, and digital calipers. Data obtained were analyzed with the help of SPSS (Software Package for Statistical Analysis) software and the range and mean was calculated.

For assessing the position of foramen **FI** was divided into three types as follows:
Type1: FI below 33.33, the foramen was in the proximal third of the bone.
Type II: FI from 33.33 up to 66.66, the foramen was in the middle third of the bone.
Type III: FI above 66.66, the foramen was in the distal third of the bone

IV. Results

Different parameters that help in determining the number and location of nutrient foramina

Table:1 Number of nutrient Foramina in Lower limb bones

Lower limb bones	Position	Bones showing single foramina		Bones showing double foramina	
		Number	Percentage	Number	Percentage
Femur	Right	21	72.4	8	27.5
	Left	16	76.2	5	23.8
Tibia	Right	18	81.8	4	18.2
	Left	15	83.3	3	16.7
Fibula	Right	18	90	2	10
	Left	20	100	-	-

Table: 2 Parameters for calculating the Foramen Index of Lower limb bones

Mean Measurement (m.m)	Femur		Tibia		Fibula	
Side of the bone	Right	Left	Right	Left	Right	Left
DNF	206.89	223.10	144.56	135.76	161.50	145.66
TF	422.69	423.12	369.23	364.33	354.36	353.04
FI	48.94	50.08	39.13	37.26	45.81	41.24

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

Table : 3 Assessment of Position of Nutrient Foramen according to FI

Bone with Position		Upper 1/3rd	Middle 1/3rd	Lower 1/3rd
Femur	Right	4	22	3
	Left	1	18	2
Tibia	Right	17	1	4
	Left	15	1	2
Fibula	Right	2	16	2
	Left	2	18	0

In right side femur out of 29 bone studied, 21 (72.4%) bones showed single nutrient foramen and 8 (27.5%) showed double foramina in the diaphysis. In left side 21, 16 (76.2%) showed single foramen and 5 (23.8%) were having double foramina. Direction of the foramina was toward the upper end of femur (Table:-1). The present study noticed that 80% of the nutrient foramina were located close to the middle part of linea aspera (which is the sharp posterior border of femur), in 10% the foramen was located proximal end of linea aspera and in the remaining 10% it was seen near the distal end of the linea close to the popliteal surface of femur (Table:-3).

In tibia, on right side, out of 22 bones, 18 (81.8%) and on the left side out of 18, 15 (83.3%) were single foraminate and the remaining were double foraminate. In 80% of bones studied the foramen was located close to the lower border of soleal line (which is an oblique line in the posterior surface close to the upper end). In 5% it was close to the vertical line on the posterior surface near its middle part and 15% it was near the lower end of the vertical line.

In fibula, the 18 (90%) out of 20 showed single nutrient foramen and 2 (10%) showed double foramina. On the left side all bones studied were single foraminate. In 85%) the foramina were seen near the middle of the median crest, in 10% it was near the upper end of the crest and in the remaining it was near the lower end of fibula. The present study also noticed the direction of nutrient foramina in tibia and fibula and was found towards the ankle.

In femur the maximum length (Table:- 2) was, observed in right side as 445m.m and the minimum was noticed in left side as 387.5m.m. Majority of the femur studied showed Foramen Index (FI) between 33.3 - 66.6 i.e., the position of nutrient foramen in the middle 1/3rdof shaft. In tibia the maximum length was observed in right side as 383.4m.m and the minimum was recorded as 381m.m in both sides and the FI marked mostly in the upper 1/3rd (less than 33.3) in both sides. In case of total length of fibula, the maximum was observed in right side as 376.5m.m and minimum was recorded as 325m.m in left fibula. FI showed maximum in middle1/3rd.

V. Discussion

Number and Percentage of incidence of nutrient Foramina

Nutrient arteries are the major source of blood supply to the long bones and its entry to the bone is at right angles. The direction of nutrient foramen is away from the growing end of the bone which is based on the "growing end hypothesis". The position, number and arrangement of nutrient foramen in each and every long bone follow a definite pattern. In the present study, majority of the long bone showed single diaphyseal nutrient foramen. The percentage occurrence of it in femur right side was 72.4 and left side 76.2 and in tibia it was 81.8 on right side and 83.3 on the left side. In right fibula the percentage was 90 and in left side all are single foraminate. This result is agreeing with the previous findings of Longia *et.,al* [9]. Kizilkanat [15] in his studies also reported that femur had either single or double nutrient foramen in diaphysis. Study conducted by Forriol *et.,al* [16] reported 100% of single foramen in fibula. The percentage of occurrence of double foramina in the present study ranged from 23.8- 27.5 in femur, 16.7- 18.2 in tibia and 0-10 in fibula. This finding is agreeing with previous results of Sharma *et.,al* [17]. Mazengenya *et.,al* [18] in his studies recorded the incidence of six foramina on a single bone, but in our study we noticed the presence of either single or double nutrient foramina in these bones. Some other studies reported that if nutrient foramen is absent, the diaphysis is supplied by periosteal arteries, but in the present study all bones showed nutrient foramina, but the absence of the same was reported in femur [19].

Position of nutrient Foramina

In the present study the mean length of femur was observed as 422.69 mm and the maximum and minimum length in right side ranged between 445 mm and that of left was 442.3- 387.5 mm with a mean of 423.12 mm. This finding is agreeing with similar observations of Kizilkanat [15].The position of nutrient foramen in femur was maximally on the middle 1/3rd of the shaft and were mainly located around the linea aspera in both sides shares the similar results with other research studies[15,17,20,21]. In tibia the present study

observed the mean length as 369.23 mm in right side and the maximum and minimum length ranged between 383.4 and 348 mm and in the left it was between 381 –348 mm and a mean of 364 mm and observed maximum number of nutrient foramina in the upper1/3rd (77% in of right side and 83% of left side). Earlier research studies [9, 15] reported the same, but Kizilkanat [15] observed maximum in the middle 1/3rd. In fibula nutrient foramina was maximally present on the middle 1/3rdof shaft and is close to the median crest in both sides (80% on right 90% in left). This finding shares similarity of the observations of Sharma *et.,al* [17] and Mazengenya *et.,al* [18].Study of the nutrient foramen regarding its position and number will decrease confusion in accidental ligation of nutrient artery which leads to decrease in the blood flow resulting in mal-union or non-union. The information pertaining to distance of nutrient foramen from the ends is very useful in determining the total length which has importance in medico-legal aspects i.e., from the length of bone height of the individual can be reconstructed [15].

VI. Conclusion

Majority of the bones studied showed single nutrient foramen, which is maximally observed in left fibula and minimally in right femur. As the position of nutrient foramen is concerned in femur and fibula majority of the bones showed the foramen on the middle 1/3rd and in tibia upper 1/3rd. The position and number of nutrient foramen which contains the nutrient artery is clinically very significant in fracture repair and bone grafting. It is very essential to have a thorough knowledge and understanding of these facts for the success of surgeries and healing process thereafter.

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