ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Morphometric Study Of Nutrient Foramen In Diaphysis Of Lower Limb Long Bones With Their Clinical Significance.

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ABSTRACT

Knowing the number, location and direction of nutrient foramen which will immensely help orthopedic surgeons, to carry out hassle free surgeries without affecting nutrient artery and help in fast and rapid wound healing. To study the number, location and direction of nutrient foramen in the lower limb long bones. The study was carried on 150 human adult, dry lower limb long bones (50 femur, 50 tibia and 50 fibula) for a period of 6 months in The Oxford Medical College, Hospital and Research Centre, Bangalore. Number of nutrient foramen in each bone are checked, it's location on the surface of shaft of each bone is observed, distance of each foramen from upper end, length of each bone is measured by osteometric board and foraminal index is calculated. Out of 150 lower limb long bones, 81.33% of the long bones had single nutrient foramen. Foramina on these bones were found on the posterior surface of the shaft of bone. Foramina were located either in upper 1/3rd or in the middle 1/3rd of the shaft of each bone and are directed away from growing end, with an exception of fibula where 12% of the foramina were directed upward which is it's growing end. This study provides information regarding normal and variant number, location and direction of nutrient foramen of each lower limb long bones which helps surgeons to plan orthopedic surgeries accordingly.

Keywords: Nutrient foramen, nutrient artery, orthopedic surgeries, location, direction

https://doi.org/10.33887/rjpbcs/2022.13.2.13

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INTRODUCTION

Bones are highly vascularized special connective tissue composed of cells (osteocytes, osteoblasts and osteoclast) intercellular substance impregnated with calcium salts. They function by forming rigid framework of body, protecting of viscera, storing of minerals (calcium and phosphorus) and forming blood cells. To perform all the above functions and for growth and development, bones require nutrition which is supplied by blood. Blood to the bones is supplied by four sets of blood vessels: nutrient artery, periosteal artery, metaphyseal artery and epiphyseal artery. Among these arteries, nutrient artery is the principal source of blood supply to the bones. If nutrient artery is damaged, blood supply to the bones is compensated by other 3 sets of arteries. Nutrient artery enters the bone through the nutrient foramina. Nutrient foramina is an opening in the shaft of long bones which allow the passage of the nutrient arteries and peripheral nerves into medullary cavity through one or more than one nutrient foramen [1,2]. Nutrient foramen may be the area of potential weakness in some individuals [3]. Location of nutrient foramen varies according to the type of bone. Depending on the shape, bones are long, short, flat and irregular bones. It is situated on the compact part of bone. In irregular bones (vertebra) nutrient foramen is situated on their body.

Long bones are the bones which are more in length than breadth. They provide strength, structure and mobility to the body [4]. Long bones of lower limb (femur, tibia, fibula) bear the weight of whole body. Hence, they are more prone for stress. Hence the blood supply of long bones of lower limb is very important.

Nutrient artery originates from the main artery of that particular region [2]. Nutrient artery of femur arise from second perforating artery, branch of profunda femoris artery. In tibia, it arises from posterior/anterior tibial artery. In fibula, it arises from posterior tibial artery [4-6]. Nutrient artery enters the shaft of bone and divides into ascending and descending branches, one for each end. Each branch divide into small, parallel vessels which enter the metaphysis and form hairpin like loop and anastomose with periosteal, juxta-epiphyseal and epiphyseal arteries. Hence, metaphysis is the most vascular part of bone [7]. Nutrient artery supplies bone marrow and inner $^{2}/_{3}{}^{rd}$ of compact part of diaphysis, providing nutrition to osteocytes and osteoblasts. Osteoblasts are responsible for bone formation. Osteocytes maintain the bone mass.

When long bones fracture, there are high chances of nutrient artery to get damaged, depending on the site of fracture. Fracture is also associated with disruption of blood vessels in the adjacent soft tissue resulting in localized bleeding [8]. Because of very rich blood supply to bones than cartilage, bones repair occur more readily than that of cartilage. Nutrient artery blood supply to the long bone is very important as it is principal artery which is required for survival of osteocytes and osteoblasts [9].

Number, location and direction (in few) of nutrient foramen varies. Knowledge of location and number of nutrient foramina in long bones are important for orthopedic surgeries such as joint replacement therapy, fracture repair, bone graft and vascularized bone microsurgery [10]. This knowledge is also important during cast application, bone tumor resection, intramedullary reaming, plating as well as medico-legal aspects [11]. Because during any of the above surgical procedures or during any bone interventions, if location and number of nutrient foramen is not known, nutrient artery may be damaged and major blood supply to the bone is compromised which may lead to ischemia and necrosis. Death of osteocytes and osteoblasts may occur, leading to decreased bone mass and demineralization causing osteoporosis which ultimately lead to pathological fractures.

Study of the direction of nutrient foramen is important to know whether all the nutrient foramen are obeying the law of ossification (nutrient foramen is directed away from the growing end).

Knowing the importance of nutrient foramen, we conducted the present study to find out the location, number and direction of nutrient foramen which will prevent the orthopedicians to avoid surgical complications.

MATERIAL AND METHODS

Morphological study was conducted on 150 human adult dry long bones of lower limb. Which includes 50 Femur (25 left and 25 right), 50 Tibia (25 left and 25 right), 50 Fibula (25 left and 25 right).

ISSN: 0975-8585

Age and sex of the bones were unknown. These bones were collected from the Department of Anatomy, The Oxford Medical College Hospital and Research Centre. The study was proceeded after approval from the Institutional Ethical Committee. This study was conducted for the period of 6 months.

Inclusion criteria: This study included completely dry, with normal anatomical features of human lower limb long bones.

Exclusion criteria: Bones with deformities, old fractures, pathological changes are excluded from study.

Materials: Osteometric board, vernier calipers, hypodermic needle, magnifying hand lens and measuring tape.

Parameters: The total length (TL), nutrient foramina (NF), distance of foramen from upper end of the bone (DNF), situation and direction of nutrient foramen.

Methods

Total bone length (cm): Measured with osteometric board.

- Femur: From proximal aspect of head of femur to medial condyle of femur.
- Tibia: From medial condyle to top of medial malleolus.
- Fibula: From head of fibula to the tip of lateral malleolus.

Total number of foramina: Observed by hand lens. The openings with elevated margins are identified as nutrient foramen.

Distance of foramen from upper end of femur (DNF in cm): Measured by vernier caliper. Distance from proximal end of femur to nutrient foramen.

- Foraminal Index (FI): DNF/TL*100.
- Depending on the values of FI, the position of nutrient foramen is classified into 3types:
    - Type-1: From upper end to 33.33%, the foramen in proximal 1/3rd of bone.
    - Type-2: From 33.33% to 66.66%, foramen is in middle 1/3rd.
    - Type 3: Above 66.66%, foramen is in distal 1/3rd.

Situation of Nutrient Foramen:

To identify the area of situation of nutrient foramen, we determine surface and borders of shaft of lower limb bones as per Grey's Anatomy.

Direction of Nutrient foramen: Whether nutrient foramen is directed up/down is noted by inserting hypodermic needle (18-24 gauge) in the foramen.

All the above obtained data were analyzedand graphs were charted using Excel Sheet Mean and Standard Deviation (SD) of Foraminal Index were calculated separately for femur, tibia and fibula.

RESULTS

Majority of lower limb long bone (femur, tibia and fibula) had single nutrient foramen, while few showed double nutrient foramen [Table.1][Fig.1]. Majority of femur showed nutrient foramen on linea aspera while in tibia and fibula, majority of nutrient foramen on posterior surface of shaft rather than medial and lateral surface [Table.2][Fig.2a,2b,2c]. Level of nutrient foramen (upper1/3rd, middle1/3rd and lower1/3rd) was identified by foraminal index. In right femur, nutrient foramen was found on upper 1/3rd of shaft while in left femur, they were found in middle 1/3rd of shaft. In tibia, majority of nutrient foramen were on upper 1/3rd of shaft and in fibula, they were in middle 1/3rd of shaft [Table.3] [fig.3]. Majority of nutrient foramen in femur are directed upward, while in tibia and fibula, they are directed downward [Table.4] [Fig.4].

Table 1 : Number & percentage of nutrient foramen				
Number of foramen	1 foramen	%	2 foramen	%
Femur(50)	36	72	14	28
Tibia(50)	42	84	8	16
Fibula(50)	44	88	6	12
Total(150)	122	81.33	28	18.6

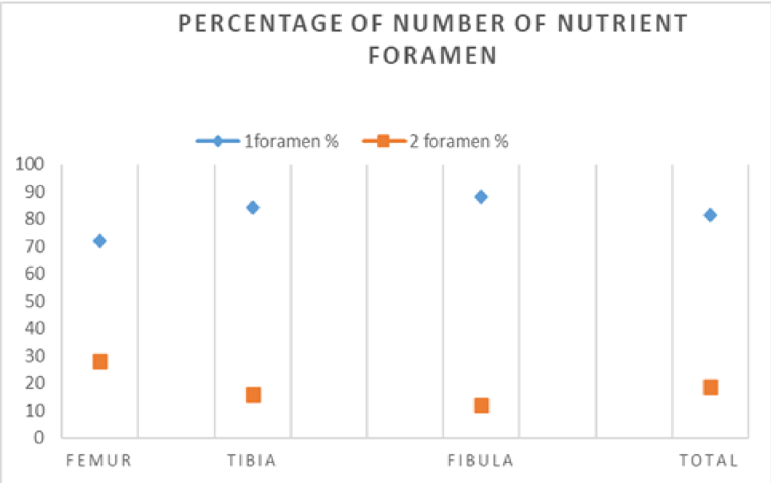


Table.2: Location (surface of the bone) of nutrient foramen			
Bones	Location	Number of bones	%
Femur	Linea Aspera	44	88
	Medial surface	4	8
	Lateral surface	2	4
Bones	Location	Number of bones	%
Tibia	Posterior Surface	46	92
	Medial Surface	4	8
Bones	Location	Number of bones	%
Fibula	Posterior surface	44	88
	Medial Surface	3	6
	Lateral Surface	3	6

Fig.2a: Location of foramen in Femur

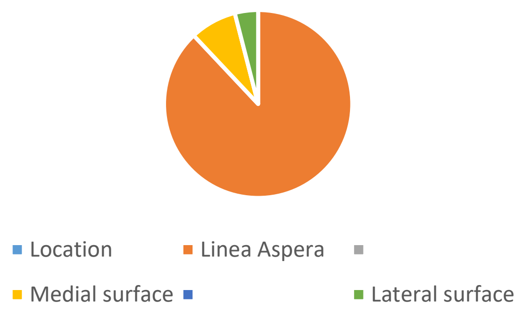


Fig.2b:Location of foramen in Tibia

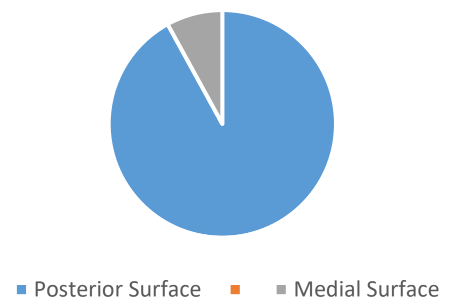


Fig.2c: Loaction of foramen in Fibula

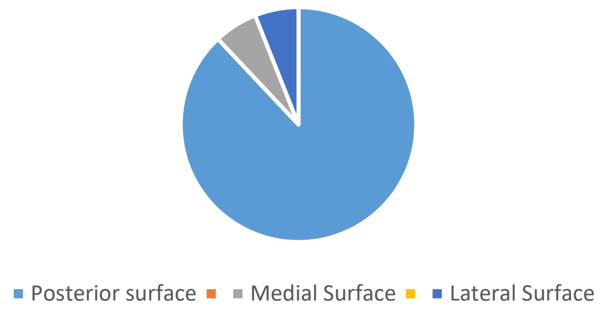


Table.3 Foraminal Indices

	Right	Left
Femur	24.5	40.5
Tibia	18.31	16.62
Fibula	44.78	31.82

Fig. 3 Foraminal indices (level ofnutrient foramen on the shaft)

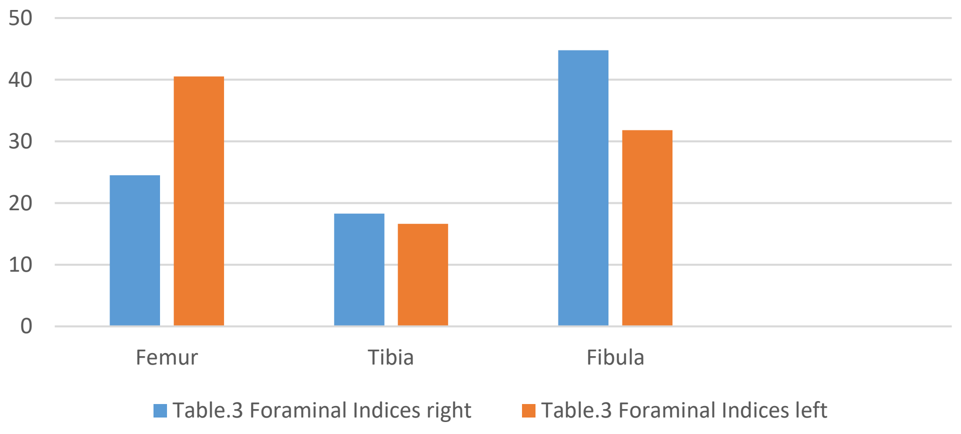
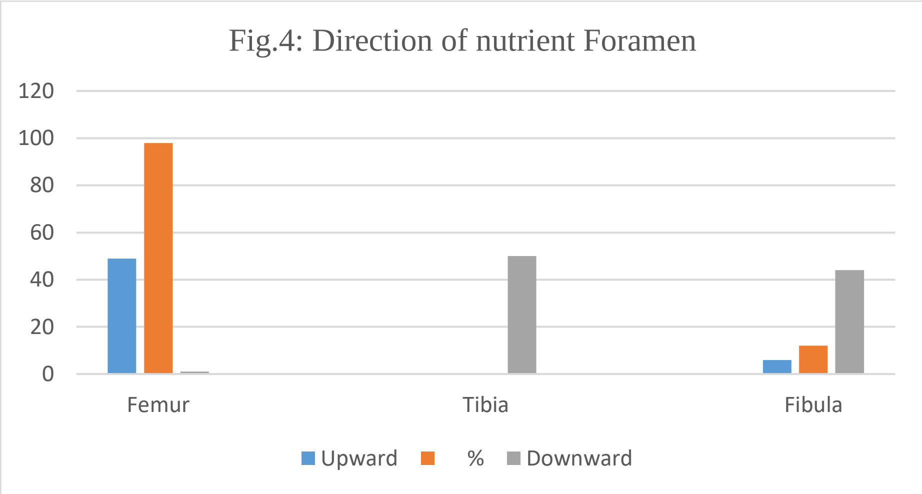


Table.4: Direction of nutrient foramen				
	Upward	%	Downward	%
Femur	49	98	1	2
Tibia	0	0	50	100
Fibula	6	12	44	88



DISCUSSION

Healing of any bone wound either after surgery or fracture depends on its vascularity [12]. Nutrient foramen is the common area of fracture when bones become weak as in osteoporosis [13]. During orthopedic surgeries like level of cast application, graft transplant, tumor removal etc., knowledge of number, location and direction of nutrient foramen is very important inorder to prevent injury to the nutrient artery [14]. If bone has good blood supply healing will be better and early as good vascularity is required for the survival and proliferation of osteoblasts and osteocytes [15]. If the nutrient artery is injured, blood supply is decreased which lead to necrosis of the bone [13]. Hence for the better and early orthopedic postoperative recovery, this study was done to know whether there is variation in the number, location and direction of nutrient foramen of lower limb bones which will help the orthopedicians, vascular surgeons and radiologists immensely.

Number of nutrient foramens

The point where nutrient artery enters the shaft of long bones determines the number of nutrient foramen [15]. Majority of the bone have single nutrient artery which arise from the main artery of the respective particular region [2]. In our present study, we observed majority of lower limb bones, 81.3% have single nutrient foramen and 18.6% have double nutrient foramen. 36(78%) of femur, 42(84%) of tibia and 44(88%) of fibula have single nutrient foramen. 14(28%) of the femur, 8(16%) of tibia and 6(12%) of fibula a have double nutrient foramen. These findings are similar to the study of other authors [1,3,7,10,13]. [Table.1] [Fig.1]. This knowledge of number of nutrient foramen will help orthopedic surgeon to decide whether the nutrient artery arise from the main region artery or from the branch of that artery [4-6].

Location of nutrient foramen (Level on the shaft and surface of the shaft)

Location of nutrient foramen is one of the important factor in fracture of bones. Long bone fracture is followed by rupture of nutrient artery depending on the site of fracture. Injury to the nutrient artery is associated with disturbance in the peripheral vascularity along with decreased bone vascularity [15]. Normally, nutrient foramen is located either in upper 1/3rd or middle 1/3rd of the shaft of lower limb long bones. Nutrient foramen is rarely found in the distal 1/3rd or lower part of the shaft of lower limb long bones. Hence distal 1/3rd of lower limb long bones have poor blood supply which is the cause of delayed healing in this region [12].

Depending on the classification of foraminal positions on the basis of values of foraminal index,[16] in our present study we found, nutrient foramen of right femurs were on upper 1/3rd while of left femurs were on middle 1/3rd of the shaft. The nutrient foramen of right and left tibia was on middle 1/3rd of the shaft. The nutrient foramen of right fibula was on upper1/3rd and of left fibula were on middle 1/3rd of the shaft [Table3] [Fig.3]. This shows nutrient foramina are absent in lower 1/3rd of the shaft of all lower limb long bones which is similar to the findings of other authors. [12,16,17].

Along with knowledge of level of nutrient foramen on the shaft, the surface on which it is present is equally important. Location of nutrient foramen is frequently associated with continuous vascularity to the particular surface of respective bone like surface having more muscle attachment will have more blood supply. In lower limb, posterior compartment / flexor compartment has large mass of muscle attachment compared to the extensor compartment, therefore posterior compartment / posterior surface has more blood supply. Hence nutrient foramen in lower limb bones arepredominantly found on their posterior surface [18]. In our present study, 44(88%) of nutrient foramen were found on linea aspera of femur which is on the posterior surface. 46(92%) of nutrient foramen were on posterior surface of tibia. 44(88%) of nutrient foramen were on posterior surface of fibula [Table.2] [Fig.2a,2b,2c]. These finding were similar to the findings of other authors [12,16-18].

Direction of nutrient foramen:

It depends on the growing end of the bone. The growing end is the end of the bone which grows faster than the other end [19]. Normally direction of nutrient foramen follows the law of ossification. Nutrient foramen is directed away from the growing end) except fibula where direction may vary [20]. Obliquity of nutrient canal is determined by the change in direction of nutrient artery at its origin [15]. Nutrient foramen is oblique because as the bone growth stops at one end, vessels change direction by the pressure of bone growth at the opposite end [7].

In our present study, femur showed 49(98%) of nutrient foramen were directed upward, in tibia 50(100%) of nutrient foramen were directed downward.In fibula 44(88%) of nutrient foramen were directed downward, while 6(12%) of them in fibula were directed upward which is similar to the findings of author. Findings of femur and tibia are similar to the findings of other authors [4,15,19,20].

CONCLUSION

In this study we found that there can be variation in the number, location and direction of nutrient foramen of lower limb long bones. Majority of the bones had single nutrient foramen which are located on posterior surface with their direction away from the growing end. Nutrient foramens are situated in upper 1/3rd or middle 1/3rd of the shaft and no foramens were found in lower 1/3rd of the shaft. Compared to the direction of nutrient foramen of femur and tibia, few nutrient foramina of fibula are directed toward the growing end, thus violating the law of ossification. This knowledge will surely help the orthopaedic surgeons to carry out surgeries without affecting the vascularity of the bone and thus help in fast surgical wound healing and prevent the bone ischemia.

AKNOWLEDGEMENT

We all authors would like to thank our institution for providing all the necessary commodities to carry out the research work. We would like to thank attenders of our department of Anatomy who helped in collecting bones and instruments.

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