Study of Nutrient Foramina in Human Typical Long Bones of Lower Limb

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Background and Aim
Nutrient foramina form important landmarks on human bones as they form portal of entry for nutrient artery. Nutrient artery is an important source of blood supply for a growing bone. Different parameters of nutrient foramina are important in various procedures such as vascularized bone grafting, tumor resections, fracture repair, and other surgical procedures in orthopedics. The objective of the present study was to report the number, position, direction, size, and foraminal index of nutrient foramen in the femur, tibia, and fibula.

Materials and Methods
The present study analyzed the location, direction, size, and the number of nutrient foramina in the diaphysis of 180 long bones of the lower limbs of adults: 60 femurs, 60 tibiae, and 60 fibulae.

Result
The location of the nutrient foramina is predominant on the posterior aspect of the lower limb long bones. Single nutrient foramen found in the tibia (100%), femur (48.3%), and fibula (60%) may represent as a single source of blood supply. The majority of the femur (50%) and few fibulae (5%) had a double nutrient foramen. The mean foraminal index for the lower limb bones was 40.5% for the left and 38.2% for the right side of the femur, 31.69% for the left and 32.3% for the right side of the tibia, and 32.7% for the left and 31.7% for the right side of the fibula.

Conclusion
The present study provides information on the number, size, position, and direction of nutrient foramina of the femur, tibia, and fibula bones.

Introduction
Nutrient foramina form important landmarks on human bones as they form portal of entry for nutrient artery. Nutrient artery is an important source of blood supply for a growing bone. Berard was the first to correlate the direction of the canal with the ossification and growth of the bone. Humphrey while working on the direction and obliquity of nutrient canals postulated the periosteal slipping theory, the canal directed away from the growing end. Harris has stated that the position of nutrient foramina is constant during the growth of long bone. Lutken has stated that the position of nutrient foramina is variable and the typical position of nutrient foramina can be determined after a study on human bones.

Detailed information of nutrient foramen has a great importance in bone transplant and resection techniques and other orthopedic surgical procedures. Therefore, the present study was conducted to find out the exact location, number, size, and direction of nutrient foramina in human typical long bones of the lower limb in Gujarat region.

The objective of the present study was to report the number, position, direction, size, and foraminal index of nutrient foramen in the femur, tibia, and fibula.
Materials and Methods
The present study was done on 180 human long bones (60 femurs, 60 tibiae, and 60 fibulae) of unknown sex obtained from the Department of Anatomy, Smt. N.H.L. Medical College and B. J. Medical College, Ahmedabad, Gujarat.

Inclusion criteria: Bones included were dry, complete, and showed normal anatomical features.

Exclusion criteria: Evidence of previous trauma, skeletal disorders, and osteoarthritic changes.

As complete sets were not available in sufficient number, no attempt has been done to find out symmetry, but as material contained sufficient number of both the sides a comparative study has been tried. The parameters of the right and left sides have been noted separately.

The localization, size, and number of nutrient foramina were analyzed in each bone.

1. The total length of the bone was taken from one end to the other with the help of anthropometric caliper on an osteometric board.
2. Size of nutrient foramina was measured by using 18, 20, and 22 hypodermic needle and divided into three categories, small, medium, and large, respectively (Fig. 1).
3. Position and direction of nutrient foramina on shaft was noted down in relation to the surface of the bone.
4. The nutrient foramen distribution in the shaft of the bone was determined by calculating a foraminal index (F.I.), using the formula:

   \[ F.I. = \frac{DNF}{TL} \times 100 \]

   where DNF is the distance of nutrient from the upper end of the bone, and TL is the total bone length.

   Where more than one nutrient foramina was found, the larger nutrient foramina was considered for foraminal index.

Results
Femur
Among the 60 femurs studied, 30 were right and 30 were left sided. Single nutrient foramen was found in 29 bones, double nutrient foramen in 30 bones, and 3 nutrient foramen was found in one bone. Most of the nutrient foramen was found on or near to the linea aspera of the femur. All the nutrient foramen directed upwards, that is, toward hip joint. In majority of the bones (48, 52.2%), the nutrient foramen was related to the medial lip of the linea aspera. Forty percent of the foramina were related to the linea aspera. In four bones, nutrient foramen was related to the lateral lip of the linea aspera.

Tibia
A total of 60 tibiae were studied, of which 30 were left sided and 30 were right sided. All tibiae studied had single nutrient foramen. All the nutrient foramen was found on the posterior surface of the tibia. All the nutrient foramen directed downwards, that is, toward the ankle joint. All bones studied were nutrient foramina present on the posterior surface.

Fibula
Among 60 fibulae studied, 30 were left sided and 30 were right sided. Total number of nutrient foramen was 42, of which single nutrient foramen was found in 36 and double nutrient foramen was found in 3 bones. Twenty-one fibulae had no nutrient foramina. Most of the nutrient foramen identified in the fibula (36, 85.7%) were on the posterior surface. Four fibulae had nutrient foramen on the medial surface. Nutrient foramen was located on the posterior border and medial border in each bone (Table 1).

Discussion
Femur
In the present study mean femur length was 43.1 cm which is higher as compared to other Indian population. The mean length of femur in Maharashtra population was 40.8 cm, in Tamilnadu population was 42.2 cm, in South Indian population was 41.8 cm, in Rajasthan population was 40 cm.\(^1\) The mean length of femur was 43.6 cm in North Indian population.\(^6\) The mean length of femur was 44.3 cm in Turkish population,\(^7\) 40.8 cm in Germans.\(^8\)

In the present study, single nutrient foramen was found in 48% of the femur similar to the study by Ambekar and Sukre.\(^3\) Kalyanasundaram et al\(^4\) and Vinay and Mangala Gowri\(^1\) reported respectively 64 and 67% of the femur had single
nutrient foramina. In the present study, two nutrient foramen were found in 50% of the femur. Mysorekar\(^8\) has also reported a 50% incidence of occurrence of double nutrient foramina in Indian population. The double nutrient foramen of the femur was observed in 30% by Kalyanasundaram et al.\(^4\) 33% by Vinay and Mangala Gowri,\(^1\) and 47.7% by Murlimanju et al.\(^10\) Forriol Campos et al.\(^11\) had reported 60% occurrence of double nutrient foramina in Spanish population. Sendemir and Cimen\(^7\) in Turkish population have recorded 46% occurrence of double nutrient foramina. In the present study, triple nutrient foramina was found in only one femur bone similar to that reported by Poornima and Angadi.\(^12\) Mysorekar\(^8\) has also reported the occurrence of triple nutrient foramina in the femur. Ambekar and Sukre\(^3\) has reported occurrence of five nutrient foramina in 2 femur bones and triple nutrient foramina were observed in 26.9% of the femur bones. Mazengenya and Faremore\(^13\) have reported the occurrence of 6 nutrient foramina on a single femur.

In the present study, all nutrient foramina were observed between the medial and lateral lip of the linea aspera similar to other researchers.\(^3,12\) Vinay and Mangala Gowri\(^1\) have reported that 78.3% of nutrient foramina were present over the posterior surface of the femur.

Mazengenya and Faremore\(^13\) have reported that the majority of the nutrient foramina were on the middle third of the shaft of the femur. Mysorekar,\(^8\) Longia et al.\(^14\) and Kizilkanat et al.\(^15\) have also reported that the nutrient foramina were most commonly located on the middle third of the femur. In the lower limb, the nutrient foramina are directed away from the knees.\(^8\) In the present study, all the nutrient foramina are directed upwards in the femur.

**Tibia**

Gupta et al.\(^16\) had reported the mean tibial length 37.75 cm on right side and 37.68 cm on left side bones in South Indian. Ankolekar et al.\(^17\) reported that the mean length of the right tibia was 37.3 cm, of the left tibia was 38.7 cm in coastal region of Karnataka. Ambekar et al.\(^3\) and Kalyanasundaram et al.\(^4\) have reported mean tibial length as 36.19 and 36.58 cm, respectively, similar to the present study that is 36.5 cm. Mazengenya et at\(^13\) have reported the mean tibial length to be 38.44 cm in black South Africans and 37.12 cm in white South Africans. Kizilkanat et al.\(^15\) in Turkish population have reported the length to be 35.8 cm. Udaya Kumar et al.\(^18\) in Telangana region observed the length to be 37.26 on right side and 37.54 cm on left side.

In the present study, all the 60 tibiae have single nutrient foramina similar to that reported by Chatrpati and Misra.\(^19\) Murlimanju et al.\(^10\) Gupta et al.\(^16\) Vadhel et al.\(^20\) and Nidhi et al.\(^21\) Many studies have reported that more than 98% of the tibia had single nutrient foramina.\(^9,13,15,17,22,23\) Udaya Kumar et al.\(^18\) observed double nutrient foramina in 13.51% right sided and 10.39% left sided tibia. Kizilkanat et al.\(^15\) have reported 2% occurrence of double nutrient foramina. Mazengenya and Faremore\(^13\) have reported 1.7% occurrence of double nutrient foramina in white Africans and 0.6% occurrence in black Africans. Murlimanju et al.\(^10\) reported absence of nutrient foramina in 1.4% of the tibia. Occurrence of triple nutrient foramina in the tibia is very rare.

In the present study, all the nutrient foramina observed on the posterior surface of the tibia were similar to other researchers.\(^1,4,17,23\) Mysorekar\(^8\) has reported 74% occurrence of nutrient foramina in the posterior surface. Sendemir and Cimen\(^7\) have reported 90% occurrence of nutrient foramina on the posterior surface. Mazengenya and Faremore\(^13\) have reported the nutrient foramina to be located on the posterior surface in 75.6% of black South Africans and 77.8% in white South Africans. Vadhel et al.\(^20\) have reported that the nutrient foramina were commonly present in the upper third of the tibia. In the present study, all the nutrient foramina are directed downwards in the tibia. Mazengenya and Faremore\(^13\) have reported 0.6% tibial nutrient foramina in black South Africans and 1.7% tibial nutrient foramina in white South Africans to be directed upwards.

**Fibula**

In the present study mean length of fibula was 35.3 cm similar to other studies.\(^3,4\) Vinay et al.\(^1\) has reported mean

<table>
<thead>
<tr>
<th>Table 1 Tabulation of the parameters studied</th>
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</thead>
<tbody>
<tr>
<td><strong>Parameter</strong></td>
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<tr>
<td>----------------</td>
</tr>
<tr>
<td><strong>Total length</strong></td>
</tr>
<tr>
<td><strong>Distance of NF from upper end</strong></td>
</tr>
<tr>
<td><strong>Distance of NF from lower end</strong></td>
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<tr>
<td><strong>Size of NF</strong></td>
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<tr>
<td><strong>Foraminal index</strong></td>
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</tbody>
</table>

All measurement are in centimeters(cms)
Abbreviation: SD-standard deviation, NF- nutrient foramina
femur length was 32.58 cm in South Indian population. Kizilkanat et al have reported the length to be 34.02 cm in Turkish population. Mazengenya et al have reported the length to be 36.76 cm in black South Africans and 36.07 cm in white South Africans.

Sinha et al have reported that out of 100 fibulae, 78% showed single foramen and 22% double foramen. Vinay and Mangala Gowri have reported that the total number of nutrient foramina was 83 in 80 fibulae and only 3 had two nutrient foramen. Ambekar and Sukre have reported the presence of one nutrient foramen in 63.5% of fibulae, two nutrient foramina in 7.7% of fibulae, and three nutrient foramina in 1.9% of fibulae. Many studies have reported only single nutrient foramen present in the fibula. Ambekar and Sukre have reported that the foramen was present in 98.3% on the right side and 96.7% on the left side on the posterior surface of the fibula. Mysorekar and Kalyanasundaram et al observed that the most common location of the nutrient foramina was on the medial crest on the posterior surface of the fibula. Vinay and Mangala Gowri have reported that 87.8% nutrient foramen was found on the posterior surface. Mazengenya and Faremore have reported that 89.15% nutrient foramen was on the posterior surface of the lower limb long bones in Gujarat region. The position of the nutrient foramina on the shaft of a long bone is variable. Direction of nutrient foramina remains same in both directions of the nutrient foramina was on the posterior surface of the fibula. The present study provides information on the number, size, position, and direction of nutrient foramina of the lower limb long bones in Gujarat region. The position of the nutrient foramina on the shaft of a long bone is variable. Direction of nutrient foramina remains same in both directions of a particular long bone. Size of nutrient foramina varies in same length of a particular long bone. All nutrient foramina present on flexor surfaces that are the posterior surfaces of the lower limb bones.

Conclusion

The present study provides information on the number, size, position, and direction of nutrient foramina of the lower limb long bones in Gujarat region. The position of the nutrient foramina on the shaft of a long bone is variable. Direction of nutrient foramina remains same in both directions of a particular long bone. Size of nutrient foramina varies in same length of a particular long bone. All nutrient foramina present on flexor surfaces that are the posterior surfaces of the lower limb bones.

Conflict of Interest

None declared.

Table 2 Foraminal index (mean values) (comparison with other studies)

<table>
<thead>
<tr>
<th>Author</th>
<th>Femur Right</th>
<th>Femur Left</th>
<th>Tibia Right</th>
<th>Tibia Left</th>
<th>Fibula Right</th>
<th>Fibula Left</th>
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</thead>
<tbody>
<tr>
<td>Kalyanasundaram et al (Tamil Nadu)</td>
<td>40.55</td>
<td>34.74</td>
<td>39.93</td>
<td></td>
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<tr>
<td>Vinay and Mangala Gowri (South India)</td>
<td>46.49</td>
<td>48.58</td>
<td>31.85</td>
<td>45.94</td>
<td>45.03</td>
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<tr>
<td>Joshi and Mathur (Rajasthan)</td>
<td>41.54</td>
<td>49.96</td>
<td>31.67</td>
<td>45.94</td>
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<td>45.03</td>
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<tr>
<td>Jha and Chauhan (North India)</td>
<td>44.25</td>
<td>45.70</td>
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<tr>
<td>Mysorekar (Poona, Maharashtra)</td>
<td>47.4</td>
<td>31.6</td>
<td>31.9</td>
<td>52.2</td>
<td>52.2</td>
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<tr>
<td>Murlimanju et al (Mangalore)</td>
<td>38.9</td>
<td>32.5</td>
<td>49.2</td>
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<tr>
<td>Mazengenya and Faremore (black Africa)</td>
<td>41.87</td>
<td>31.6</td>
<td>43.33</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Mazengenya and Faremore (white Africa)</td>
<td>44.58</td>
<td>33.15</td>
<td>46.86</td>
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<td></td>
</tr>
<tr>
<td>Ankolekar et al (Karnataka)</td>
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<td>35.92</td>
<td>34</td>
<td>-</td>
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<td></td>
</tr>
<tr>
<td>Pereira et al (South Brazil)</td>
<td>43.7</td>
<td>32.7</td>
<td>46.1</td>
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<tr>
<td>Sinha et al (Kanpur, Uttar Pradesh)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>45.86</td>
<td>46.82</td>
<td></td>
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<tr>
<td>Gupta et al (South India)</td>
<td>-</td>
<td>34.66</td>
<td>34.83</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present study (Gujarat)</td>
<td>38.23</td>
<td>40.45</td>
<td>32.29</td>
<td>31.68</td>
<td>50.06</td>
<td>49.02</td>
</tr>
</tbody>
</table>

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