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Morphology study with review: Variations of the number, position, size & direction of nutrient foramina of femur (surgical and clinical impacts)

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Abstract: **Background: The Femur bone is a vascular structure with unique features in its blood supply via numerous foramina located over its different segments, being named as nutrient foramina. Among vascular foramina, nutrient foramen is an important one which gives way to the nutrient artery.**

Methods: This study was conducted using descriptive cross sectional based of the study designs & it will include 50 femur bones of different cadaveric specimen's witch will be obtained from the osteology section of our Department of Anatomy. All bones belonged to Sudanese cadavers, the age and gender of which are not determined. All the bones will macroscopically observe for the number, location and direction of the nutrient foramina. A magnifying lens were used to observe the foramina. The nutrient foramina were identified by the well-marked, often slightly raised, edge at the commencement of the canal.

Results: The nutrient foramina of 50 dry adult human Femora, 38 Femora had single nutrient foramen, 9 had two nutrient foramina and 3had absent nutrient foramina. Location of 28 of single nutrient foramina were located at the junction of upper and middle 1/3rd of the femur, 4 of single nutrient foramina were located at the junction of middle and lower 1/3rd of the femur, 6 of single nutrient foramina were located in middle half of the length of the femur, 5 of double nutrient foramina were located in upper and middle position and 4 of double nutrient foramina located at upper and lower position .according to surface relationship ,37 of single nutrient foramen located at posterior surface and 1 at medial surface .7 of double nutrient foramina located at posterior surface and 3at medial surface all nutrient foramina were seen to be directed upwards.

Keywords: **nutrient foramina, vascular foramina, surgical and clinical impacts.**

1. INTRODUCTION

1.1. Background:

Femur is the proximal weight bearing bone of the lower limb. Femur is the most richly vascularized long bone, which derives its nourishment from various arteries of the lower limb. The number and caliber of these arteries determine the quantum of blood supply. The major part of a long bone receives its blood supply from numerous points all along its length through the periosteal and nutrient vessels (1).

Nutrient foramen in nutrition and growth of the bones is evident from term "Nutrient" itself. Knowing of the position of the nutrient foramen can be useful in certain surgical procedures. The nutrient artery is the principal source of blood to a long bone particularly during its active growth period (2). Because the artery to the shaft of the long bone is the largest, it is called the "Nutrient Artery". Nutrient canal (through which nutrient artery enters the shaft) typically become slanted during growth, the direction of slant from surface to marrow cavity points towards the end that has grown least rapidly. This is due to greater longitudinal growth at the faster growing end. The direction of nutrient foramen of all bones is away from growing end (3).

An understanding of the location, number, direction and caliber of diaphysis nutrient foramina in long bones is very important clinically, especially in orthopedic surgical procedures such as joint replacement, fracture repair, bone grafting, vascularized bone microsurgery, peripheral vascular occlusive disease, longitudinal bone growth, non-unions, transplantation and resection techniques, intramedullary reaming and plating, as well as in medico legal cases. An accurate knowledge of the location of the nutrient foramina in long bones help prevent intraoperative injuries in orthopedic, as well as in plastic and reconstructive surgery. Preoperative planning of such procedures is vital for all such surgical interventions, together with an appropriate understanding of the extra osseous vascular supply for a successful outcome. (6)

Knowing of the location, number and direction of the nutrient in the femur is not only important in understanding the physiology of development of bone but also are of significance in healing of fractured bones. Earlier studies have shown that the location and number of NF varies with geographic location. In the present investigation, we wanted to assess whether there is any variation among the Sudanese population with respect to the location, number and direction of the NF in femur (7).

1.2. Justification/rationale:

Bone transplant procedures require a 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 **(4)**.The number and position of the nutrient foramen are also important in success of fracture treatment **(5)**.

1.3. Objectives:

1.3.1. General objective:

Variation in the number, position and direction of nutrient foramina of femur in Sudanese population.

1.3.2. Specific objective:

To:

1) Determine the location of the nutrient foramina.

2) Identify the direction from the growing end.

3) Identify the number of nutrient foramina of the femur bones.

4) Advocate the surgical interventions involving bone.

2. LITERATURE REVIEW

2.1. Anatomy of femur

The femur is the bone of the thigh from its proximal end, the neck originated & proceeds upwards and medially ending in a rounded head; a greater and a lesser trochanters project from the junction of the shaft and the neck, and the shaft ends distally in a pair of large condyles(8) . In the standing position, the shaft passes downwards and medially and this inclination is evident when the femur is held vertically with both its condyles in contact with a horizontal surface. Femoral obliquity is more in females because of the relatively greater pelvic breadth and the shorter femoral length.

The **head** of the femur, capped with hyaline cartilage, is more than half a sphere. Its medial convexity has a pit, the fovea, for the ligament of the head. Anteriorly the articular cartilage extends slightly onto the neck.

The **neck** of the femur, as it inclines upwards and medially, makes an angle of about 125° with the shaft in the adult male. This angle of inclination is widest at birth and diminishes until adolescence; it is less in females. The neck is also tilted forwards slightly as it passes proximally to the head. This angle of ante version is about 10–15°. Ridges on the surface of

the neck, particularly on the anterior aspect, indicate the attachment of retinacular fibres of the hip joint capsule which are reflected proximally from the distal attachment of the capsule. Anteriorly the capsule is attached to the **intertrochanteric line**, which extends from the greater to the lesser trochanter where the neck joins the shaft. Posteriorly the capsule is attached halfway along the neck between the articular margins of the head and the prominent **intertrochanteric crest** situated at the junction of the posterior surface of the neck and the shaft. The tendon of obturator externus muscle plays on the relatively smooth bone of the neck distal to the posterior capsular attachment. Many vascular foramina, directed towards the head, perforate the anterior and poster superior surfaces of the neck. In the adult the head receives its blood supply mainly via these foramina from blood vessels mostly from the trochanteric anastomosis and particularly from the medial circumflex artery that run up the neck with the retinacular fibers of the capsule. These vessels and intramedullary vessels running up the neck from the shaft are liable to be ruptured by a trans cervical intracapsular fracture and avascular necrosis of the head is a potential hazard. Blood supply to the head from vessels that accompany the ligament to the head is meagre in the adult.

The **greater trochanter** projects up and back from the convexity of the junction of neck and shaft. Its upper border is projected into an inturned apex. Piriformis muscle is attached here on the medial side. More anteriorly on the medial surface of the trochanter the common tendon of obturator internus and the gemelli is inserted. At the bottom of this surface is the trochanteric fossa for the attachment of the obturator externus tendon. The anterior surface of the greater trochanter shows a J-shaped ridge for the gluteus minimus tendon. The lateral surface shows an oblique strip, sloping downwards and forwards for the tendon of gluteus medius. The apex of the trochanter is level with the centre of the femoral head, and the prominent convexity of the trochanter is at the widest part of the hips. It is covered by the beginning of the iliotibial tract, where gluteus maximus is received. This plays freely over a bursa on the bone. Posteriorly the apex of the trochanter is continued down as the prominent intertrochanteric crest to the lesser trochanter. Nearly halfway down the crest is an oval eminence, the **quadrate tubercle**; quadratus femoris is attached here.

The **lesser trochanter** lies back on the lowest part of the neck. Its rounded surface, facing medially, is smooth for the reception of the psoas major tendon. Iliacus is inserted into the front of the tendon and into the bone below the lesser trochanter.

The **shaft** of the femur has a convex anterior surface and is buttressed by a strong ridge, the **linea aspera**, at the middle third of the concave posterior surface. This narrow ridge has medial and lateral lips. The intertrochanteric line slopes across the front of the neck and shaft at their junction, and continues down below the lesser trochanter as a *spiral line* that runs into the medial lip of the linea aspera. The medial lip continues on as the *medial supracondylar line* to the adductor tubercle on the medial condyle. On the back of the shaft below the greater trochanter is a vertical ridge, the **gluteal tuberosity**, for the deep lower quarter of gluteus maximus. It runs down into the lateral lip of the linea aspera, and this lip is continued on as the *lateral supracondylar line* to the lateral epicondyle.

The intertrochanteric line in its lower half gives origin to vastus medialis, which arises in continuity below this along the spiral line, medial lip of the linea aspera and upper one-third of the medial supracondylar line (the lowest part of this muscle comes from the adductor magnus tendon, not from bone). The medial surface of the femoral shaft is bare bone, over which vastus medialis plays. Vastus lateralis arises from the upper half of the trochanteric line, the lower part of the greater trochanter, the lateral edge of the gluteal tuberosity and the lateral lip of the linea aspera. Vastus intermedius arises from the upper two-thirds of the front and lateral surfaces of the shaft, and articularis genu arises from the front below vastus intermedius.

Pectineus is attached to the upper part of the posterior surface of the femur, behind iliacus. Adductor brevis is attached behind pectineus and down to the proximal part of the linea aspera. Adductor magnus is inserted medial to the gluteal tuberosity, below quadratus femoris, and then along the linea aspera to the medial supracondylar line and down to the adductor tubercle. There is a gap in the supracondylar attachment, a hand's breadth above the knee, through which the femoral vessels pass into the popliteal fossa. Between adductor magnus and vastus lateralis, the short head of biceps femoris arises below the gluteal tuberosity from the whole length of the linea aspera. Between adductor magnus and vastus medialis, adductor longus is inserted into the middle third of the linea aspera.

The popliteal surface of the femur between the supracondylar lines is bare. The anterior surface of the lower shaft is likewise bare below the origin of articularis genu, with the suprapatellar pouch in contact with periosteum deep to quadriceps tendon for a hand's breadth above the knee joint.

The **lower end** of the femur carries the two *condyles*, separated behind by an *intercondylar fossa* but joined in front by a trochlear surface for the patella. The lateral condyle projects further forward than the medial, thus helping to stabilize the patella .Both are almost flat inferiorly, but boldly curved on the posterior convexities. In the fossa the cruciate ligaments are attached to smooth areas:the anterior cruciate ligament far back on the lateral condyle alongside the articular margin, the posterior far forward on the medial condyle. The **medial condyle** shows on its convex non-articular medial surface a shallow pit for the tibial collateral ligament; this is the *medial epicondyle*. Above it lies the **adductor tubercle** at the lower end of the medial supracondylar line. The medial head of gastrocnemius arises from the back of the medial condyle and the adjacent popliteal surface of the shaft. The **lateral condyle** shows a vertical arrangement of three smooth-floored pits towards the back of its non-articular lateral surface .The upper pit is for the lateral head of gastrocnemius. Above this, plantaris arises from the lateral supracondylar line. The central pit is at the prominence of the convexity of this surface and is the *lateral epicondyle*, to which the fibular collateral ligament is attached. The lowermost pit receives the popliteus tendon; a groove behind this pit lodges the popliteus tendon when the knee is flexed.

Excepting the clavicle, the femur is the first long bone to ossify. It does so in cartilage.

A centre in the shaft appears at the seventh week of fetal life. A centre for the lower end appears at the end of the ninth fetal month (at birth) and its presence is acceptable medicolegal evidence of maturity. This is the growing end of the bone and the epiphysis, which bisects the adductor tubercle, unites with the shaft after 20 years. A centre appears in the head during the first year after birth, greater trochanter during the fourth year and lesser trochanter at 12–14 years. These upper epiphyses fuse with the shaft at about 18 years of age (8).

2.2 Development of femur:

At the end of the fourth week of development, limb buds become visible as outpocketings from the ventrolateral body wall they consist of a mesenchymal core derived from the somatic layer of lateral plate mesoderm which will form the bones and connective tissues of the limb, covering that a layer of cuboidal ectoderm(9).undifferentiated mesenchymal cells which are rich in blood supply transformed to osteoblast cell the latter secrete bone matrix and change to osteocyte such process is called ossification(13)(14).

2.3 Nutrient artery and foramina of femur:

The medullary or nutrient artery (arteria nutricia), usually accompanied by one or two veins, sends branches upward and downward to the bone marrow, which ramify in the medullary membrane, and give twigs to the adjoining canals. Nutrient arteries are the most apparent blood vessels of the bones.

All bones possess larger or smaller foramina for the entrance of the nourishing blood-vessels; these are known as the nutrient foramina, and are particularly large in the shafts of the larger long bones, where they lead into a nutrient canal, which extends into the medullary cavity (10)(11)

The nutrient artery of the femur mainly arises from the profunda femoris artery although there is variation, the nutrient artery usually enters the bone proximally and posteriorly along the linea aspera usually there is only one nutrient artery (maximum of 2) usually it comes of the 2nd perforating artery after giving off nutrient artery thru its lower 3-4 cm; it then pierces tendons of adductor brevis &magnus. After penetrating posterior cortex, nutrient artery arborizes proximally and distally to provide endosteal circulation to shaft;most of periosteal vessels also enter bone along linea aspera supply the outer 1/4 of cortex, esp. posteriorly at linea aspear; they align themselves perpendicularly to the cortical surface .(12)

2.4. Surgical importance of the nutrient foramen:

Long bones are supplied by a diaphyseal nutrient artery that enters the bone through a foramen called the primary nutrient foramen. The arterial supply to the bone is vital during embryonic stage and early ossification [15]. The vasculature of the bone must be preserved by the surgeon during fracture fixation to enable good healing of fracture site [16]. During bone grafting procedures the recipient bone must have adequate blood supply in order to facilitate the acceptance of the graft [17]. After tumor resection adequate blood supply to the bone is very much essential for bone regeneration [18]. It is therefore essential for surgeons to be familiar with the topography of the nutrient foramina of the bones prior to surgery [19]. This will ensure good success of the surgical procedure and improve the prognosis. The nutrient foramina are always directed away from the growing end of the bones [20]. New surgical procedures on bones are devised on the basis of a

sound knowledge on the location and distribution of nutrient foramina [21]. The femur is involved in several surgical procedures such as external and internal fixation of fractures, knee replacement and bone grafting. I believe that this study will help surgeons operating on the femur by providing valuable information regarding topography of the foramina.

2.5. Number, position and direction of nutrient foramina of femur

Most studies determine the number of nutrient foramina the must be single, double, triple or absent. Nidhi Agrawal state that (78%) femora possessing single dominant nutrient foramen whereas (22%) bones possessing double dominant nutrient foramen.(22).the most common number of nutrient foramina was single. Regarding the position of nutrient foramina of femur in concern of the linea aspera categorized as:

Position A:

1-junction between upper third with middle third

2-at middle third

3-junction between lower with middle third

Position B:

1- Lateral lip of linea aspera

2-medial lip of linea aspera

3-at lina aspera

4-medial surface.

5-lateral surface.

The most common position of the nutrient foramina was found to be at the junction between upper third with middle third regarding position A, and at medial lip of lina aspera regardingto position B.

Roopam Kumar(6) statedthatof the The most common location of the NF was on the medial lip of linea aspera (49 %) (6). However Nirmalya Saha(23) reported that the foramina were mostly seen in the upper one third (58.50%).

It has been reported that the nutrient foramina has three direction, upward, downward and inward horizontally .the most common direction is upward (24).

3. MATERIALS AND METHODS

3.1. Study Design:

This study will be conducted using descriptive cross sectional based of the study designs & it will include 50 femur bones of different cadaveric specimen's witch will be obtained from the osteology section of our Department of Anatomy. All bones belonged to Sudanese cadavers, the age and gender of which are not determined. All the bones will macroscopically observe for the number, location and direction of the nutrient foramina. A magnifying lens will be used to observe the foramina. The nutrient foramina will be identified by the well-marked, often slightly raised, edge at the commencement of the canal.

3.2. Study Area and duration:

This study will be conducted in the anatomy departments of the different universities. The period of the study was from August 2016 to January 2017.

3.3. Study Population:

Study population includes cadavers from various anatomy departments

3.4. Sample Size:

Referred to the anatomy departments during the above-mentioned period I will use total coverage of all available cadavers with total size of 50.

3.5. Inclusion Criteria:

All femur bones including cadavers with no pathological deformities in the anatomy departments.

3.6. Exclusion criteria:

Bones, which had gross pathological deformities, is going to be excluded from the study.

3.7. Data Collection:

3.7.1 Data Collection tools:

Data collection sheets were used to include the study of dry femur by direct observation and using macro glass and different cannula size.

3.7.2 Data Analysis:

Data analysis will be both, manually and with SPSS, MS word, Excel computer programs, version 22.

3.7.3. Data Management:

After proper data analysis and interpretation, they were presented and described by using the text, tables, and figures.

3.8. Ethical Considerations:

Consents will be taken from the Anatomy department at the above mentioned medical complexes preceding the data collection, & they will be informed fully about the purpose, methods and intended possible uses of the research, what their participation in the research entails and what risks, if any, are involved.

4. RESULTS

4.1 Number/ density of nutrient foramina

Among 50Feumr studied, 38 Femora had single nutrient foramen, 9 Femora had two nutrient foramina and 3 Femur had absent nutrient foramina.

4.2 Location A of nutrient foramina

28 nutrient foramina of single were located at the junction of upper and middle 1/3rd of the Femur i.e.,

4 nutrient foramina of single were located at the junction of middle and lower 1/3rd of the Femur i.e.

6 nutrient foramina of single were located in middle half of the length of the Femur i.e.

5 of nutrient foramina of double were located at upper third and middle third

4 of nutrient foramina of double were located at upper third and lower third.

4.3 Location B of nutrient foramina

37 of single nutrient are located at posterior surface

1 of single nutrient are located at medial surface

7 of double nutrient foramina located at posterior surface

3 of double nutrient foramina located at medial surface

4.4 direction of nutrient foramina

Among 50 Femora studied, nutrient foramina of all the Femur directed upward.

Table (1): Distribution of nutrient foramina related to number

	Total number of nutrient foramina	Single nutrient Foramina	Double nutrient foramina	Absent of nutrient foramina
	50	38	9	3

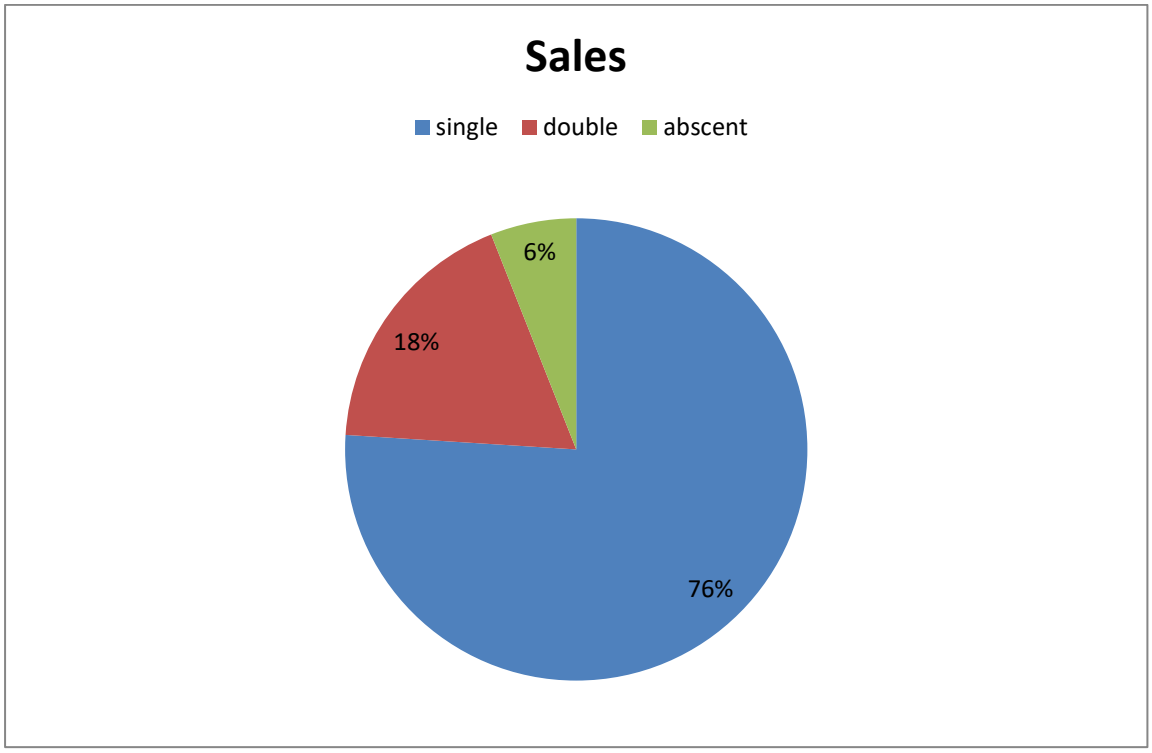

Fig. (1) Distribution of nutrient foramina related to numb

Table: (2): Distribution of the nutrient foramina related to position A

Total number of single foramina	Junction between upper third with lower third	At middle third	Junction between lower third with middle third
38	28	6	4

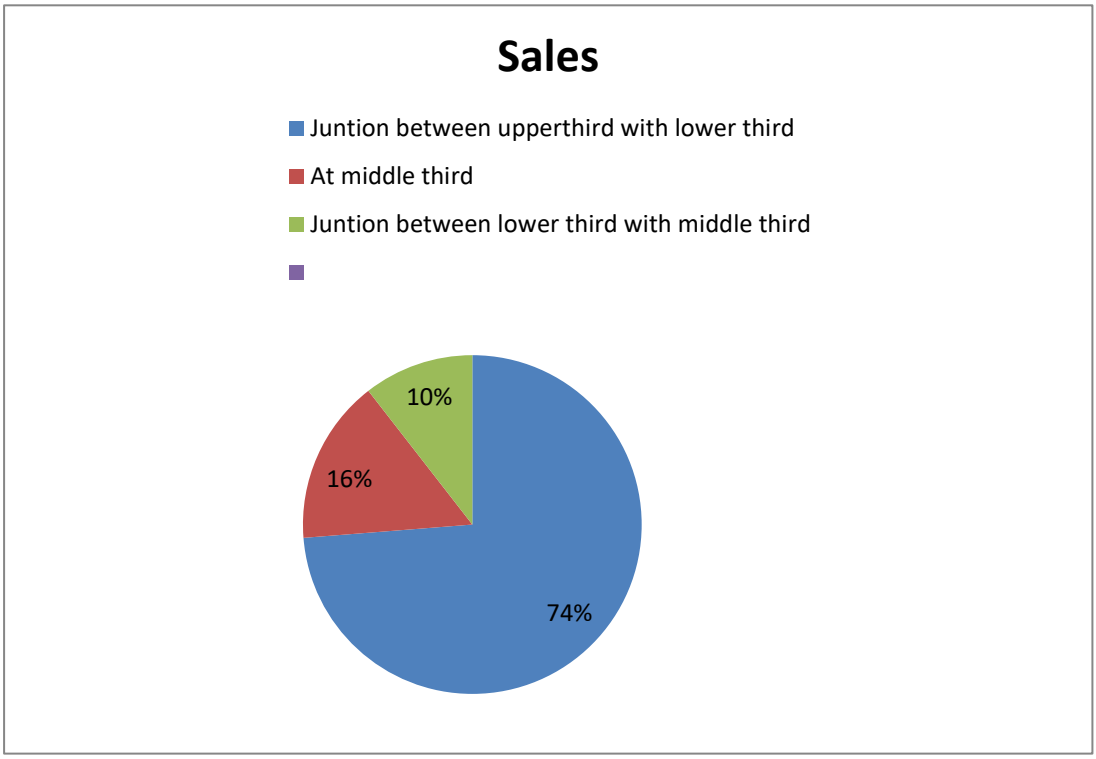

Fig: (2): Distribution of the nutrient foramina related to position A

Table (3): Distribution of single nutrient foramen related to position B:

Total number Single nutrient foramina	Posterior surface related to linea aspera	Medial surface	Lateral surface
38	37	1	0

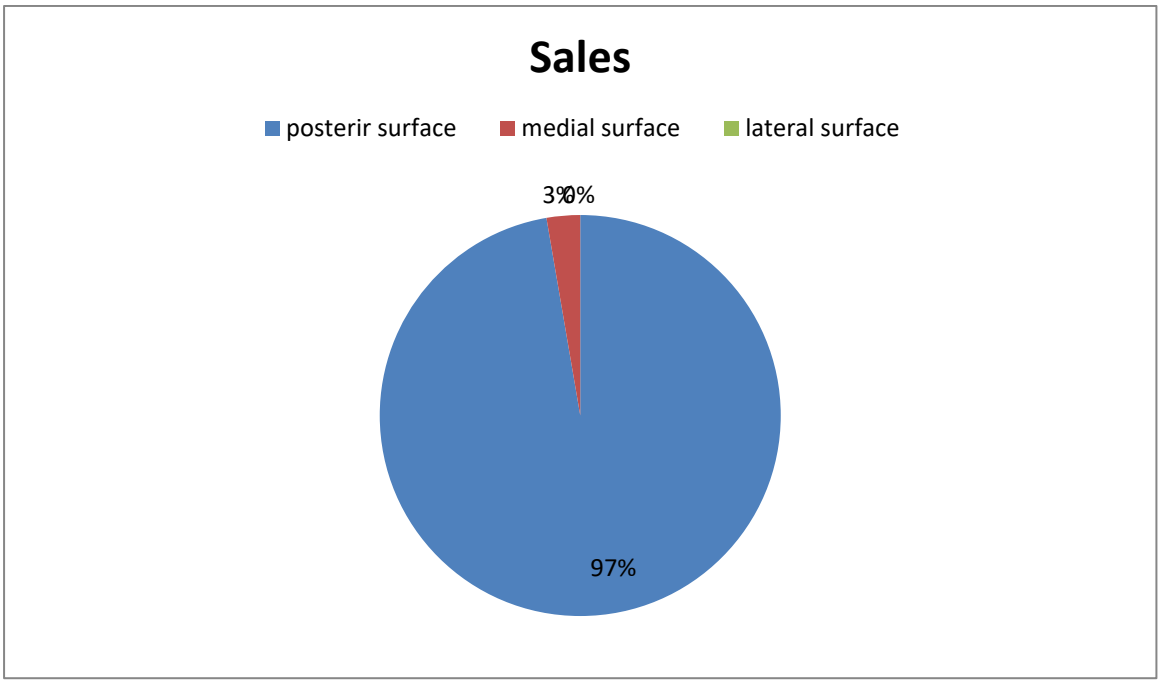

Fig. (3) Distribution of single nutrient foramen related to position B:

Table (4): Distribution of double nutrient foramina related to position A:

Total number of double nutrient foramina	Upper Middle	Upper lower
9	5	4

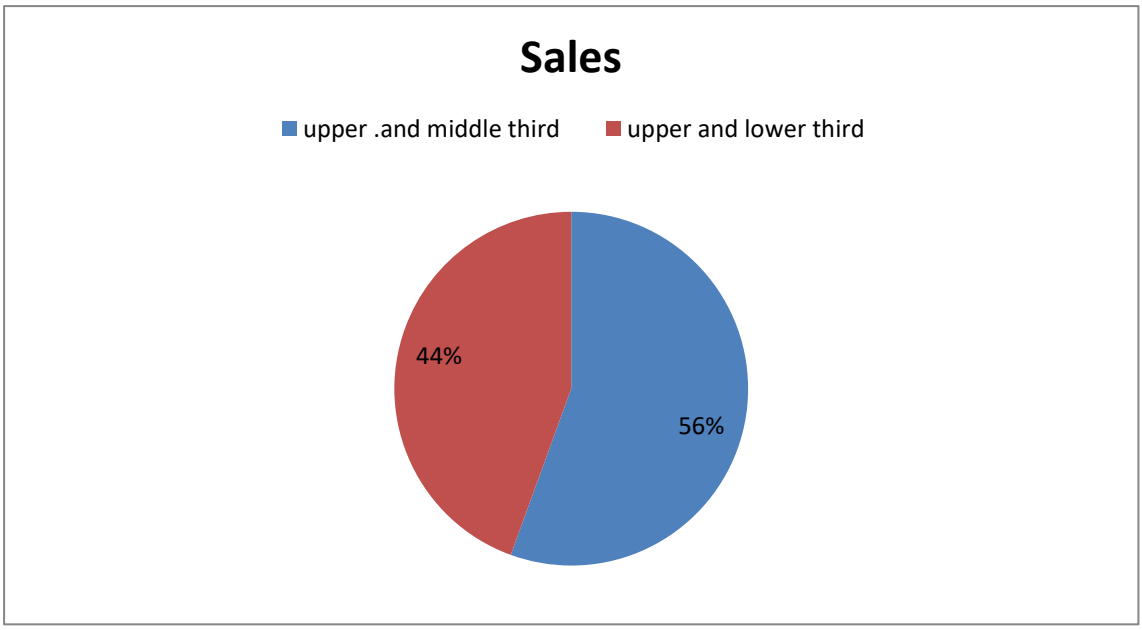

Fig. (4): Distribution of double nutrient foramina related to position A:

Table (5): Distribution of double nutrient foramina related to position B

Total number of double nutrient	Posterior surface related to linea aspera	Medial surface	Lateral surface
9	7	3	0

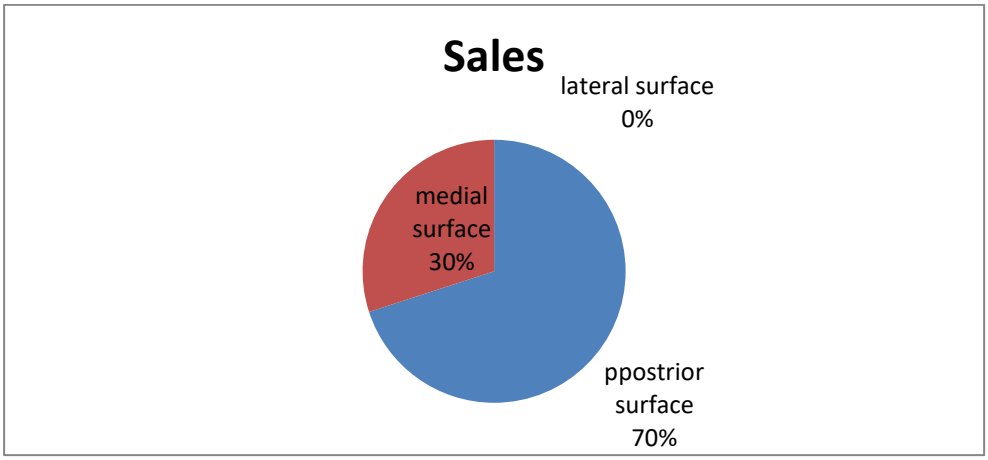

Fig. (5): Distribution of double nutrient foramina related to position

Table (6): Distribution of single nutrient foramina related to direction

Total number of single foramina	upward	inward	downward
37	37	0	0

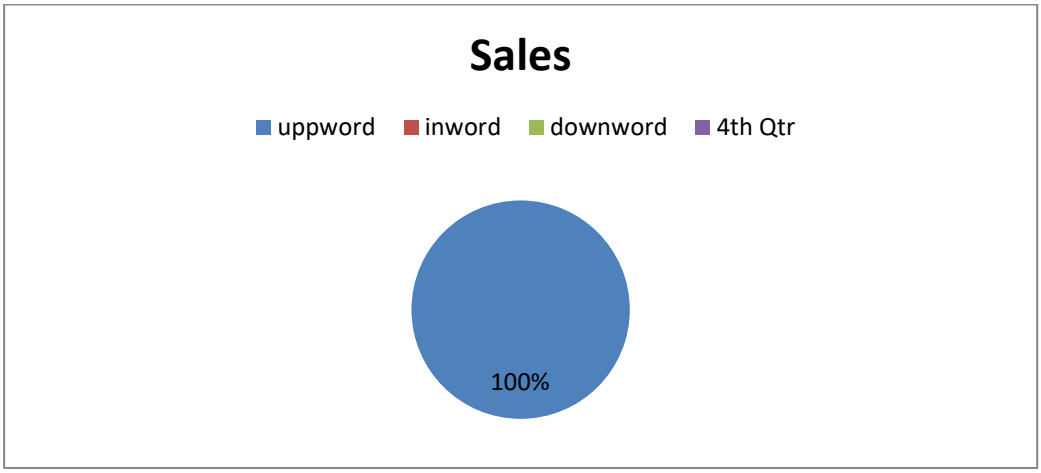

Fig. (6): Distribution of single nutrient foramina related to directi

Table (7): Distribution of double nutrient foramina related to direction:

Total number of double nutrient foramina	upward	inward	downward
9	9	0	0

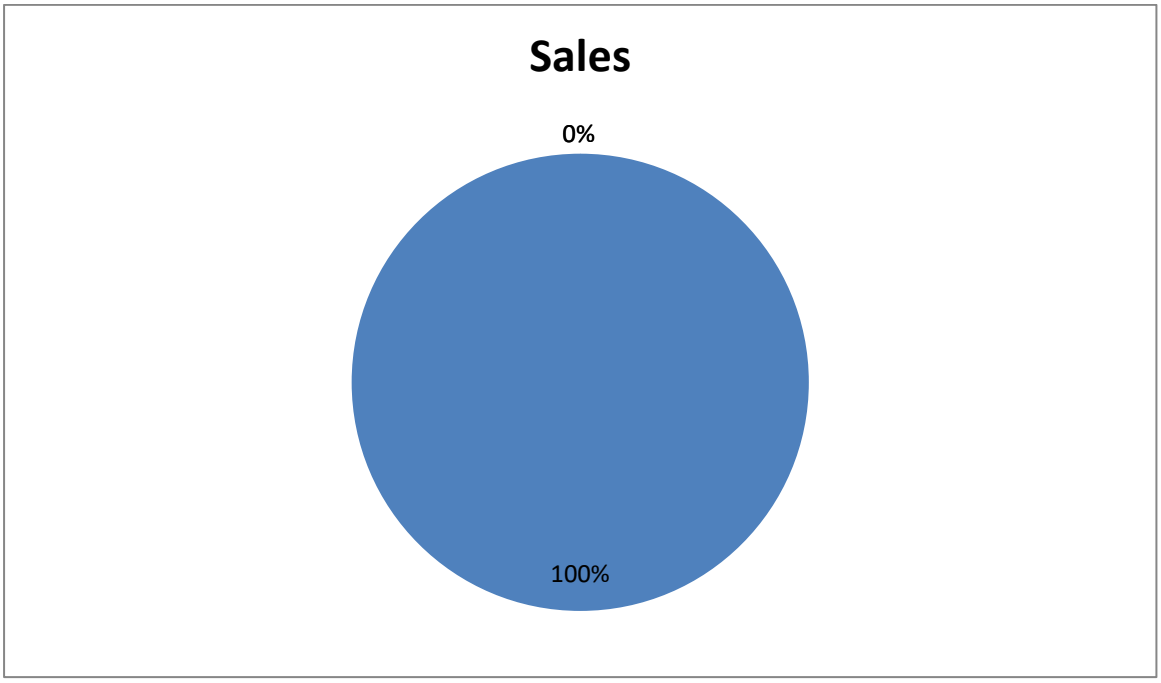

Fig. (7): Distribution of double nutrient foramina related to direction:

5. DISCUSSION

Nutrient foramen in nutrition and growth of the bones is evident from term "Nutrient" itself. Knowledge of position of nutrient foramen can be useful in certain surgical procedures. The nutrient artery is the principal source of blood to a long bone particularly during its active growth period (2).

A typical long bone is fed by four groups of arterial systems, which are - a nutrient artery, epiphyseal, diaphyseal and periosteal arteries [24]. The Femur bone is a highly vascular structure with unique features in its blood supply. The nutrient arteries of the Femur usually arose from the perforating branches of the profunda femoris artery, less commonly direct from the profunda femori and rarely from the lower segment of the femoral artery. The course of the nutrient arteries will be constant, the arteries run under the adductor magnus muscle, and through the nutrient foramina which lay on or near the linea aspera of the Femur. The nutrient foramina of the Femur are usually situated on the posterior surface, near the linea aspera of the Femur (24).

Mysorekar VR studied for the number, position, and symmetry of the diaphyseal nutrient foramina. His study showed that the arrangement of the diaphyseal nutrient foramina in the long bones of the limbs usually follows a definite pattern. There are often two nutrient foramina in the Femur. In the Femur, the nutrient foramina are restricted to the linea aspera or its immediate neighborhood in the middle third of the bone [**4]**.

Poornima B and Angadi A V study the nutrient foramina of 100 dry adult human Femora, 62 Femora had single nutrient foramen, 37 had two nutrient foramina and 1 had three nutrient foramina. Location of 78 nutrient foramina were located at the junction of upper and middle 1/3rd of the femur, 26 nutrient foramina were located at the junction of middle and lower 1/3rd of the femur, 32 nutrient foramina were located in middle half of the length of the femur, 3 nutrient foramina were located in other locations of the femur bones. Direction of nutrient foramina of all the Femora were directed upwards and density of nutrient foramina was found more close to medial lip of linea aspera and at the junction of upper and middle 1/3rd of the shaft of Femur. (24)

Henderson RG determined the positions of the Femoral and Tibial nutrient foramina by direct measurement in rats of 40, 49 and 59 days of age using a travelling microscope. The Femoral nutrient foramina remained constant in position with increasing age. In case of the Femur, this can be accounted for entirely by differences in growth rates at the epiphyseal plates of the femur compensating for the disproportion in the distances of the foramen from the two plates[**3]**.

In the present study, the nutrient foramina of 50 dry adult human Femora, 38 Femora had single nutrient foramen, 9 had two nutrient foramina and 3had absent nutrient foramina. Location of 28 of single nutrient foramina were located at the junction of upper and middle 1/3rd of the femur, 4 of single nutrient foramina were located at the junction of middle and

lower 1/3rd of the femur, 6 of single nutrient foramina were located in middle half of the length of the femur, 5 of double nutrient foramina were located in upper and middle position and 4 of double nutrient foramina located at upper and lower position .according to surface relationship ,37 of single nutrient foramina located at posterior surface and 1 at medial surface .7 of double nutrient foramina located at posterior surface and 3at medial surface Direction of nutrient foramina of all the Femora were directed upwards.

Blood supply to Femur bone is essential during the growing period, during the early phases of ossification, and in surgical procedures such as bone grafts, tumour resections, traumas, congenital pseudoarthrosis, and in transplant techniques.

6. CONCLUSION & RECOMMENDATIONS

- Single nutrient foramina is the most common presentation.
- Single nutrient foramina are most commonly located in the upper third of the femur, they are mostly positioned in relation to the posterior surface of the linea aspera.
- Double nutrient foramina are most commonly located in the upper & middle part of the femur, they are mostly related the posterior surface of the linea aspera.
- Posterior surface related to linea aspera is most common location of double nutrient foramina
- Upward direction is most common direction of nutrient foramina.

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