

.Morphometric Study of Diaphyseal Nutrient Foramen in dried Nigerian femurs: Implications for Microvascular bone graft.

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Abstract.
The femur is supplied principally by the diaphyseal nutrient artery which enters the bone through the diaphyseal nutrient foramen (DNF). This supply is vital for the process of bone ossification, growth and healing. Surgically aided bone defect repair such as microvascular bone graft, relies greatly on the vascularity of the femur for survival of donor and recipient bones.
This study analyzed the number and location of DNF in 95 dried adult Nigerian femurs (43 rights, 52 lefts) of unknown sexes. The direction of the nutrient canal with respect to the growing end and the foramen Index (FI) were also determined.
Majority of the bones (77.89%) had single DNF while only 21.1% had double. The single DNF was located on the Linea aspera (LA) in 48.42%, on the medial lip of LA in 17.89%, on the lateral lip of LA in 12.63%, on the medial surface in 18.95% and on the lateral surface in 2.11%. Double DNF occurred most frequently on the medial surface and Linea aspera. The mean foramen index was 42.46 and all, but one, femurs had their nutrient canal directed away from the growing end.
The occurrence of DNF is frequent in the postero- medial surface, less frequent in the lateral surface and rare in anterior surface of the shaft. Adequate knowledge of the location of DNF is important for improving the outcome of microvascular bone graft and ensuring adequate endo-periosteal blood flow.
Keywords: Diaphyseal nutrient foramen, femur, Microvascular bone graft, Foramen index.

Introduction

Femur growth and surgically aided bone defect repair are related events that are dependent on bone vascularization. The femur is supplied chiefly by diaphyseal artery with little contribution from the metaphaseal and epiphyseal arteries. The diaphyseal nutrient foramen (DNF) is a surface opening leading into the oblique nutrient canal. The diaphyseal nutrient artery usually originates as a branch of second perforating artery, enters the DNF to run through the nutrient canal (Williams *et al*., 2008; Moore *et al.*, 2011). At the medullary end of the nutrient canal, the nutrient artery divides into ascending and descending branches which anastomose with epiphyseal and metaphyseal arteries (Williams *et al*., 2008; Moore *et al*., 2011). The DNF is located away from the growing end of the bone (Mysorekar and Nandedkar, 1979). This is due to differential growth of the two ends of long bones. The DNF is usually located around the center of the linea aspera (Schaeffer, 1953). According to Henderson (1978), the position of nutrient foramen is variable and may alter with growth.
A dual diaphyseal nutrient arteries of femur may be encountered, in which case, the two arteries usually originate from the first and third perforating arteries respectively (Williams *et al*., 2008). These arteries enter the shaft through two foramen located at the proximal and distal ends of linea aspera respectively (Williams *et al*., 2008).
When planning a bone graft for a patient with trauma or tumour resection, the vascularity of the left over bone in the donor site is important as it influences the choice of graft to be used (Menck *et al*., 1997). It is therefore important to conduct a pre-operative angiography in patients to exclude vascular anomalies in both donor and recipient bones (Gumusburun *et al*., 1994). Vascularized bone graft is the preferred method used in bone reconstruction as it ensures the survival of both donor and recipient bones (PhoRWH, 1988).
The morphology of DNF of the femur has not been fully studied in Nigerian population. This study aimed at determining the number and localization of DNF in Nigerian femurs. The foramen index was also calculated.

Materials and Methods.

The study was conducted on 95 dried adult Nigerian femurs of unknown sexes (43 right, 52 left), obtained from the Bone Library of the Department of Anatomy, University of Ibadan. Bones with gross structural abnormalities were excluded from the study.
After side determination, the nutrient foramen was studied with regards to:
1. Number of foramen on bone shaft
2. Location of foramen
3. Direction of foramen from the growing end of the femur

4. Location of foramen in relation to the length of the shaft.

The nutrient foramen was identified as an opening with slightly raised edges leading to a well marked canal. Only diaphyseal nutrient foramen was studied. The patency and direction of the foramen was confirmed by passing a needle through the canal. The femur length (L) was measured as a distance between the proximal end of the head to the distal most part of the medial condyle. The distance (D) between the foramen and proximal end of the head of the femur was also measured. All measurements were done using sliding calipers and scale. The foramen index (FI) was calculated by applying the Hughes (1952) formula as follows:

FI = D/L x 100

For bones with double DNF, the larger of the two foramen was taken into consideration during estimation of FI. Femurs with the foramen were photographed using a Sony digital camera (14.1mega pixels).

Results

Of the 95 femurs studied, Single DNF was observed in 74 (77.89%) while double DNF was present in 21(22.10%). (Table 1). The DNF was directed up towards the proximal end in 94 femurs (98.95%) and forward anteriorly in 1 femur (1.05%). The DNF was observed in the following vertical zones of posterior femur::-on the Linea aspera (LA), Medial Lip of Linea aspera (ML), Lateral Lip of Linea aspera (LL) , Medial surface (MS) and Lateral Surface (LS). (Figs 1& 2). Single DNF was located on the LA in 46 (48.42%), on the ML in 17(17.89%), on the LL in 12(12.63%), on the MS in 18(18.95%) and on the LS in 2 femurs (2.11%).(Table 2). The most common site of DNF was LA while the least common was LS. (Table 2). In bones with double DNFs, the most common sites of the dual DNF were MS and LA, occurring in 33.33% of femurs with double DNF (Table 3). The most proximal of the two DNFs had predilection for MS while the distal occurred on the LA.
The mean Foramen Index (FI) of all the studied DNFs was 42.46 ± 9.18. The mean FI of DNF on the left femurs (44.40 ±9.34) was significantly higher than that on the right femurs (40.11±8.50) (p= 0.02).

Discussion.

In the present study, single DNF was found in 77.9% of the studied femurs. This is higher than 40-54% reported by some investigators (Forrio *et al*.,1987; Mysoreka *et al.*,1967; Sendermir and Cimen,1991) (Table 4).Double DNF was found in 44.2% by Prashart *et al*.,(2011); 4.6% by Sendermir and Cimen,(1991); 51% by Mysorek (1967); 52% by Anusha *et al*., (2013) and 60% by Forriol *et al* (1987), in comparison to 22.1% found in the present study. The difference in the occurrence of DNF in the different populations may be related to variation in genetic constitution and food habit. These factors have been shown to determine the number and site of DNF. (Srivastava *et al*.,2012).
Although no bone showed absence of DFN in this study, previous studies have reported absent DNF in 1.9% and 4.6% by Gumusburun *et al*.,1994 and Prashant *et al*., (2011) respectively. In the absence of DNF, the shaft of the femur receives irrigation from the periosteal vessels. (Trueta, 1953).
The deviation from the normal upward slanting direction of the nutrient canal in one femur may be due to equal growth rate of both proximal and distal ends of the femur. According to Schwalbe (1876) and Prashant *et al*.,(2011), the nutrient canal was initially horizontal (straight anteriorly) before the appearance of the epiphysis due to equal growth rate at both ends. As the epiphysis appears, the lower end grows faster than the upper, resulting in the upward slanting of DNF. In accordance with the present result, previous studies reported the occurrence of DNF in vertical zones on or beside the linear aspera. (Sendermir and Cimen, 1991, Prashant *et al.*, 2011, Lutken 1950, and Mysorekar, 1967). In line with the predictions of Williams and Warwick,(1995), dual DNFs was most frequently observed in the combined MS and LA sites.
The least occurrence of the DNF on the lateral surface of the femur in the present study and the absence in anterior surface make these two sites the safest for orthopedic manipulations. At these sites, injury to the DNF is unlikely. The value of FI (42.46) in my study is close to that reported by Pereira *et al*., 2011(43.7), Forrio Compos *et al*., 1987(38.42) and Gumuburun *et al.*, 1994(44.82).
Based on the size of the defect to be covered, a long or short vascularized bone graft may be indicated. As the nutritive areas of the arteries supplying the femur differ, the choice of artery employed in vascular pedicle depends on the length of femur to be resected, For transplantation of the femoral diaphyses, the deep femoral artery is recommended while femoral artery is used for longer grafts. (Kirschner *et al.*,1998). For shorter grafts, one must consider the number and location of the nutrient foramen. (Kirschner *et al*.,1998). In transplant techniques, the osseous level of the recipient bone should be selected such that the graft can be placed without damaging the DNF thus preserving the diaphyseal vascularity.(Wavreille *et al.*, 2006).Also, the segment of the donor bone to be grafted must contain DNF if endosteal vascularization is to be included.
As the study was conducted on femurs of unknown sexes, the gender difference in FI could not be determined. Also the exact artery giving off the DNF could not be ascertained. A further cadaver- based study is therefore

advocated in which the origin of the DNF and the sex of the femurs can be determined. Such study will enable us investigate the effect of gender on bone growth and the pattern of anastomosis between diaphyseal and epiphyseal vessels.

Conclusion

The occurrence of DNF is frequent in the postero- medial surface, less frequent in the lateral surface and rare in anterior surface of the shaft. The occurrence of double DNF is lower than those reported in other populations. Adequate knowledge of the location of DNF is important for improving the outcome of microvascular bone graft and ensuring adequate endo-periosteal blood flow.

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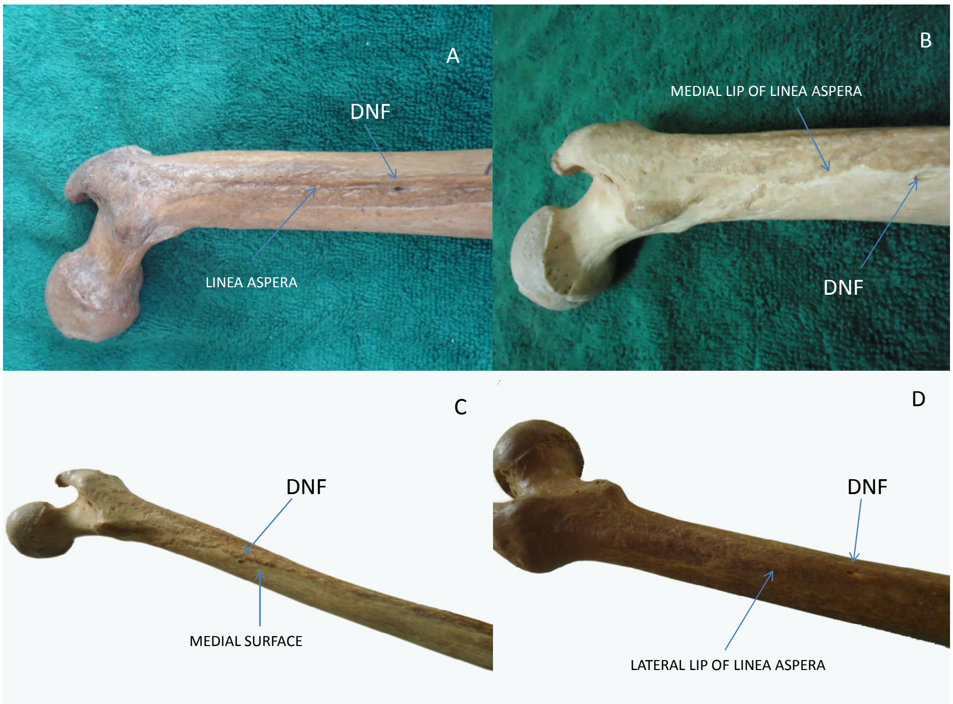

Fig 1: Photographs of femurs with single diaphyseal nutrient foramen located on linea aspera (A), medial lip (B), medial surface (C) and lateral lip (D).
DFN- Diaphyseal Nutrient Foramen.

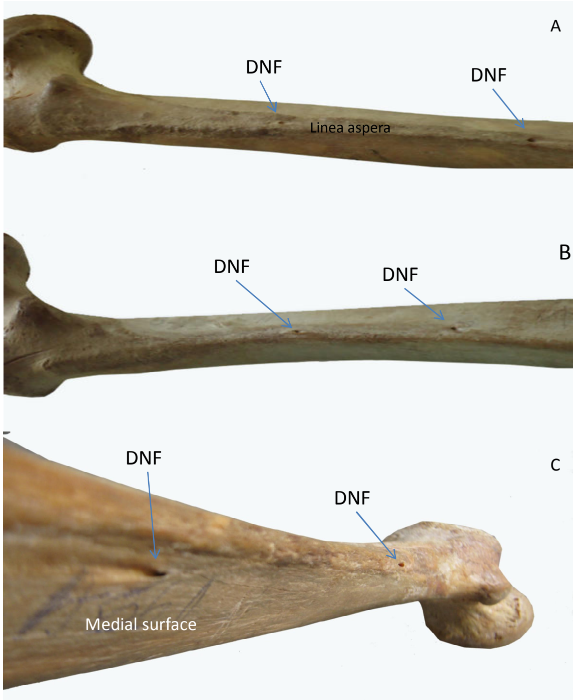

Fig 2: Photographs of femurs with double diaphyseal nutrient foramen located on Linea aspera (A); Medial lip and medial surface (B); linea aspera and medial surface. (C).

DFN- Diaphyseal Nutrient Foramen.

Table 1: Occurrence of Single and double DNFs in the right and left femurs.

Side	Single DNF	Double DNF	Total
Right	31 (32.63%)	12 (12.63%)	43(45.26%)
Left	43 (45.26%)	9 (9.47%)	52(54.74%)
Total	74 (77. 89%)	21 (22.10%)	95 (100%)

Table 2: Occurrence of DNF in the vertical zones of the femur.

SIDE	LA	ML	LL	MS	LS	TOTAL
Right	23(24.21%)	9 (9.47%)	7(7.37%)	11 (11.58%)	2(2.11%)	43(45.26%)
Left	23 (24.21%)	8 (8.42%)	5 (5.26%)	7(7.37%)	0 (0%)	52(54.74%)
Total	46 (48.42%)	17(17.89%)	12 (12.63%)	18 (18.95%)	2 (2.11%)	95(100%)

Table 3: Occurrence and location of dual DNF in femurs with double DNF.

Site	Frequency	Percentage
MS, LA	7	33.33%
LA, LA	4	19.06%
ML, MS	2	9.52%
MS, MS	2	9.52%
LA, ML	2	9.52%
LA, LL	2	9.52%
ML, ML	1	4.76%
LL, MS	1	4.76%
Total	21	22.10%

LA- Linea Aspera, ML- Medial Lip of Linea Aspera, LL- Lateral Lip Of Linea aspera, MS- Medial Surface , and . LS – Lateral Surface.

Table 4: Comparison of results of studies on Diaphysial Nutrient Foramen of Femur.

Investigators	Population	Sample size	Single DNF	Double DNF
Mysoreks (1962)	Indian (Hindus)	180	49 %	51%
Forriol compos(1987)	Spanish	31	40%	60%
Sendemir (1991)	Turkey	102	54%	46%
Prashanth(2011)	Indian	86	47.7%	42.2%
Anusha (2013)	Indian	50	46%	52%
Present study	Nigerian	95	77.9%	22.1%