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Research Article

Diaphyseal Nutrient Foramina

A Study Of The Diaphyseal Nutrient Foramina Of Dried Bangladeshi Fibulae

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Context: The fibula serves crucial functions in lower limb biomechanics and is frequently used in reconstructive surgery. Understanding its nutrient foraminal patterns is essential for surgical success and forensic applications. However, population-specific data for Bangladeshi fibulae has been lacking.

Objectives: To determine the morphometric characteristics of diaphyseal nutrient foramina in dried Bangladeshi fibulae.

Methods: This cross-sectional analytical study examined 120 dry fully ossified left human fibulae (68 male, 52 female) at Dhaka Medical College. Measurements included total length, diaphyseal dimensions, nutrient foraminal characteristics (number, position, direction), and talar facet parameters. Sexual dimorphism was assessed using unpaired Student's t-test and chi-square test.

Results: Significant sexual dimorphism was observed in total length (male: 35.41 ± 1.67 cm, female: 32.72 ± 1.28 cm, $p<0.001$), midshaft diameter (male: 14.01 ± 1.07 mm, female: 13.21 ± 0.85 mm, $p<0.001$), and nutrient foraminal measurements. Single nutrient foramen predominated in both sexes (male: 95.6%, female: 92.3%), with primarily downward direction (male: 95.6%, female: 100%). Type-2 Foraminal Index was most common (male: 98.5%, female: 98.1%). Nutrient foramina was predominantly located on the posterior surface in males (42.6%) and medial crest in females (32.7%).

Conclusion: This study establishes baseline morphometric data for Bangladeshi fibulae, demonstrating significant sexual dimorphism and consistent nutrient foraminal patterns. These findings have immediate applications in surgical planning, particularly for fibular grafting procedures, and provide valuable reference data for forensic sex determination in the Bangladeshi population.

Keywords: Fibula, Nutrient foramen, Sexual dimorphism, Morphometry, Bangladesh, Forensic anthropology

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Introduction

The fibula, though often considered a minor weight-bearing bone, serves crucial functions in lower limb biomechanics and skeletal architecture. It provides essential muscle attachments, contributes to ankle joint stability, and participates in load sharing during standing and gait, bearing up to 16% of the lower limb load [1].

The bone's blood supply, primarily delivered through nutrient foramina, is fundamental to its development, healing, and surgical outcomes. Nutrient foramina are specialized openings in bones that allow passage of nutrient arteries, which are critical for bone viability and healing. These foraminal characteristics - their number, position, direction, and distance from bone landmarks - have significant clinical implications, particularly in orthopedic surgery and bone grafting procedures [2]. The fibula is frequently used as a source for vascularized bone grafts, especially in mandibular reconstruction, making detailed knowledge of its nutrient foramina essential for surgical success [3].

Beyond surgical applications, fibular morphometry, including nutrient foraminal patterns, has forensic significance. The bone demonstrates sexual dimorphism, making it valuable for gender determination in forensic anthropology. Specific dimensions around the nutrient foramen are sexually dimorphic, aiding in the biological profiling of skeletal remains [4].

While studies have examined fibular nutrient foramina in various populations, including South African [5], Indian [6], and Kenyan populations [7], there is a notable absence of data specific to the Bangladeshi population. Given that morphometric variations exist across different geographical and ethnic groups, population-specific data is crucial for both clinical and forensic applications.

The present study aims to document the morphometric characteristics of nutrient foramina in dried Bangladeshi fibulae, specifically examining their number, position, direction, and foraminal index. Additionally, we investigate sexual dimorphism in these parameters to enhance their forensic utility. This research seeks to establish baseline data for the Bangladeshi population, contributing to both clinical practice and forensic anthropology in the region.

Materials and Methods

Study Design and Sample Collection: This cross-sectional, analytical study was conducted in the Department of Anatomy at Dhaka Medical College, Dhaka, from January 2021 to December 2021. A total of 120 dry, fully ossified left human fibulae were studied using purposive, convenient sampling. The sample size was calculated using the formula for comparing two means with 99.99% confidence level and 99% power [8].

Inclusion and Exclusion Criteria: Only fully ossified left human fibulae were included in the study, considering that complete ossification occurs by the fifteenth year in females and the seventeenth year in males [9].

Following international agreements on paired bilateral structures, left-sided measurements were preferred [10]. Bones showing evidence of fracture, deformity, or pathological changes were excluded from the study.

Sex Determination: The collected bones were segregated into male and female groups using the discriminant function analysis technique [4].

This yielded 68 male and 52 female specimens. The technique utilized the maximum length of the fibula and distance of nutrient foramen from the upper end as variables for sex determination.

Morphometric Measurements: All measurements were taken using standardized equipment including:

- A digital vernier calliper (accuracy ±0.01 mm)
- Osteometric board
- Flexible metallic wire
- Protractor
- Digital camera for documentation

The following parameters were measured:

Nutrient Foramina Characteristics:

- Number of foramina
- Direction (determined using hypodermic needle insertion)
- Position relative to surfaces and borders
- Foraminal Index (FI) calculated using the formula [11]: FI = (DNF/TL) × 100 where DNF = Distance of nutrient foramen from upper-end TL = Total length of fibula

Linear Measurements:

- The total length of the fibula
- Maximum midshaft diameter
- Circumference at various levels (midshaft, nutrient foramen level)
- Antero-posterior and mediolateral diameters at nutrient foramen level
- Distance of nutrient foramen from upper and lower ends

Angular Measurements:

- Angles between various aspects of the talar facet using a protractor

Statistical Analysis: Data were analyzed using Statistical Package for Social Sciences (SPSS) version 25.0. Descriptive statistics including mean, standard deviation, and ranges were calculated for all measurements. Unpaired Student's t-test was used to compare measurements between male and female specimens. A chi-square test was applied for categorical variables. Statistical significance was set at $p<0.05$.

Documentation: All measurements were recorded in standardized data collection forms.

Digital photographs were taken using standardized positioning and lighting conditions. Each bone was assigned a unique identification number to ensure accurate documentation and prevent the mixing of data.

Results

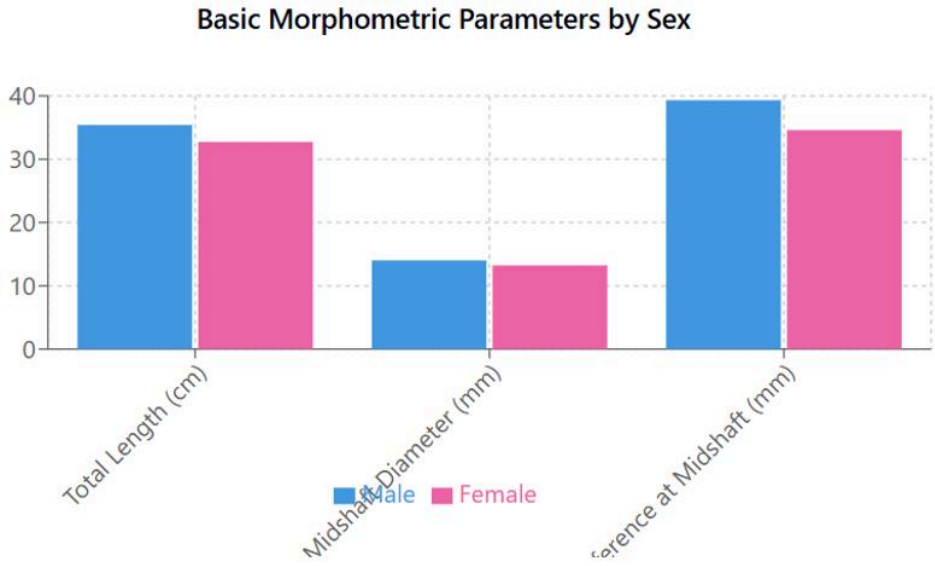
A total of 120 dry fully ossified left fibulae (68 male, 52 female) were analyzed. The findings are presented in the following categories:

Basic Morphometric Parameters The mean total length of the fibula showed significant sexual dimorphism ($p<0.001$), being greater in males than females (Table 1).

Table 1: Basic Morphometric Parameters of Fibula by Sex

Parameter	Male (n=68)	Female (n=52)	p-value
Total length (cm)	35.41 ± 1.67	32.72 ± 1.28	<0.001*
Maximum midshaft diameter (mm)	14.01 ± 1.07	13.21 ± 0.85	<0.001*
Circumference at midshaft (mm)	39.32 ± 3.35	34.60 ± 2.65	<0.001*

Values presented as Mean ± SD; *Statistically significant

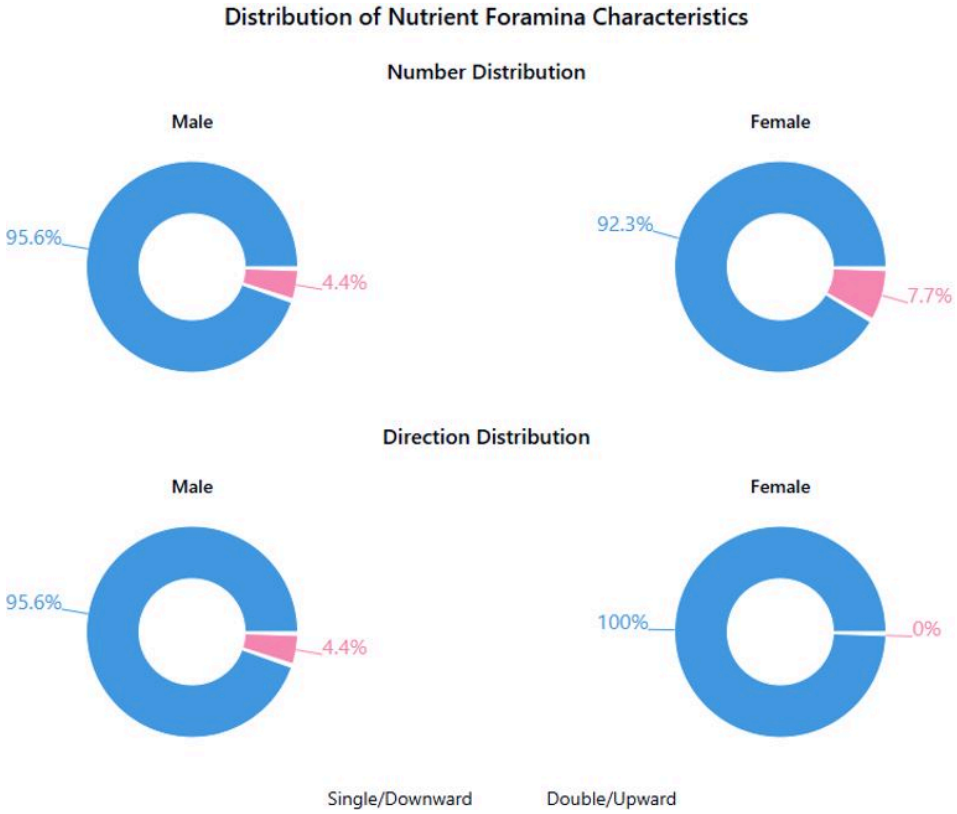


Graph 1: Grouped bar chart comparing these three parameters between males and females

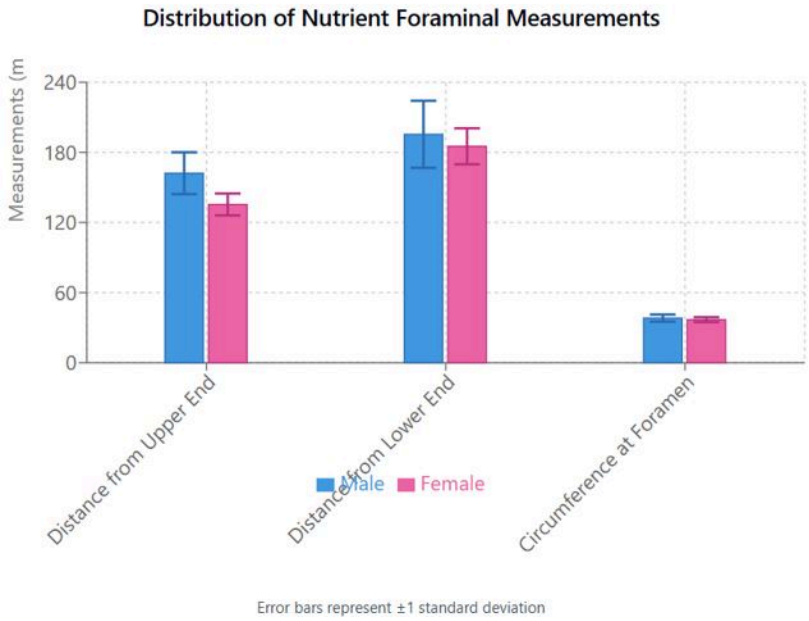
Nutrient Foramina Characteristics The majority of specimens showed a single nutrient foramen in both sexes (Table 2).

Table 2: Distribution of Nutrient Foramina Characteristics

Characteristic	Male (n=68)	Female (n=52)
Single foramen	65 (95.6%)	48 (92.3%)
Double foramina	3 (4.4%)	4 (7.7%)
Direction downward	65 (95.6%)	52 (100%)
Direction upward	3 (4.4%)	0 (0%)



Graph 2: Pie charts showing the distribution of nutrient foramina number and direction for each sex



Graph 3: Box plots showing the distribution of these measurements by sex

Table 3: Nutrient Foraminal Measurements

Parameter	Male (n=68)	Female (n=52)	p-value
Distance from the upper end (mm)	162.17 ± 17.90	135.45 ± 9.35	<0.001*
Distance from lower end (mm)	195.47 ± 28.69	185.21 ± 15.41	0.022*
Circumference at foramen level (mm)	38.19 ± 3.05	36.87 ± 2.09	0.008*

Foraminal Measurements Measurements related to nutrient foramina showed significant sexual dimorphism (Table 3).

Position of Nutrient Foramina The distribution of nutrient foramina positions varied between sexes (Table 4).

Table 4: Position of Nutrient Foramina

Position	Male (n=68)	Female (n=52)
Posterior surface	29 (42.6%)	16 (30.8%)
Medial surface	10 (14.7%)	6 (11.5%)
Medial crest	20 (29.4%)	17 (32.7%)
Interosseous border	6 (8.8%)	9 (17.3%)
Other locations	3 (4.5%)	4 (7.7%)

Talar Facet Measurements Measurements of the talar facet showed sexual dimorphism in certain parameters (Table 5).

Table 5: Talar Facet Measurements

Parameter	Male (n=68)	Female (n=52)	p-value
Maximum height (mm)	21.29 ± 2.30	19.90 ± 1.60	<0.001*
Antero-medial distance (mm)	19.97 ± 1.85	18.61 ± 1.78	<0.001*
Postero-medial distance (mm)	20.64 ± 1.54	19.22 ± 1.76	<0.001*

Foraminal Index Analysis Type-2 Foraminal Index (33.34% - 66.66%) was most prevalent in both sexes:

- Male: 67 specimens (98.5%)
- Female: 51 specimens (98.1%) Type-1 (<33.33%) was found in only one specimen of each sex, and no specimens showed Type-3 (>66.66%).

All measurements showed good reproducibility with minimal inter-observer variation.

Statistical significance was particularly strong in parameters related to total length, midshaft measurements, and nutrient foramen positioning. The findings demonstrate clear sexual dimorphism in multiple parameters, with males generally showing larger values than females. The position and number of nutrient foramina showed consistent patterns within the Bangladeshi population studied.

Discussion

The present study provides comprehensive morphometric data on nutrient foramina of Bangladeshi fibulae, revealing several significant findings with clinical, forensic, and anthropological implications.

Morphometric Sexual Dimorphism: The observed sexual dimorphism in fibular measurements aligns with established biological patterns. Males consistently demonstrated larger dimensions than females across multiple parameters, particularly in total length (35.41 ± 1.67 cm vs 32.72 ± 1.28 cm, p<0.001).

This finding corresponds with studies by Mazengenya and Billings [10] in South African populations (35.88 ± 2.09 cm in males, 33.11 ± 2.22 cm in females) and Vedapriya and Rajasree [11] in Indian populations (37.1 cm in males, 33.3 cm in females). The consistency across populations suggests reliable applicability in forensic sex determination.

The sexual dimorphism observed can be attributed to multiple factors including hormonal influences, mechanical loading patterns, and genetic factors [12]. These differences become particularly relevant in forensic anthropology and prosthesis design. Nutrient Foramina Characteristics: The predominance of single nutrient foramina (95.6% in males, 92.3% in females) aligns with previous studies. Sinha et al. [13] reported similar findings in Indian populations, though with slightly different percentages. The consistent downward direction of nutrient foramina (95.6% in males, 100% in females) follows the general principle that nutrient foramina are directed away from the growing end of long bones [14].

Position and Distribution: The preferential location of nutrient foramina on the posterior surface in males (42.6%) and medial crest in females (32.7%) represents a notable finding.

This differs somewhat from Majid et al. [9], who reported predominantly posterior surface locations in their Indian population study. These variations could have evolutionary and developmental implications, possibly related to population-specific adaptations.

Foraminal Index: The overwhelming prevalence of Type-2 Foraminal Index (98.5% in males, 98.1% in females) indicates a consistent middle-third location of nutrient foramina. This pattern differs slightly from Mazengenya and Fasemore's findings [12], suggesting possible population-specific variations. The practical implications of this consistency are significant for surgical approaches and bone grafting procedures.

Clinical Implications: The predictable patterns of nutrient foramina location and direction have important surgical implications, particularly for:

1. Fibular grafting procedures: The consistent middle-third location (Type-2 Foraminal Index) provides reliable guidance for harvest site selection [15].

2. Vascular preservation: Understanding the predominant posterior surface and medial crest locations helps in surgical planning to preserve blood supply [16].

Forensic Applications: The significant sexual dimorphism observed in multiple parameters enhances the utility of the fibula in forensic sex determination. The combination of:

- Total length
- Midshaft measurements
- Nutrient foraminal distances provide multiple reliable criteria for sex estimation, supporting previous findings by Fasemore et al. [2].

Population-Specific Considerations: This study provides the first comprehensive dataset for the Bangladeshi population. The observed variations from other population studies [17,18,19,20] emphasize the importance of population-specific standards in both clinical and forensic applications. Limitations and Future Directions: While this study provides valuable baseline data, certain limitations should be noted:

1. Age-related changes could not be assessed due to the nature of the specimens
2. Bilateral asymmetry could not be evaluated as only left-sided bones were studied

3. Soft tissue relationships could not be analyzed in dry bones

Future studies should consider:

1. Bilateral comparison of nutrient foramina patterns
2. Age-related changes in foraminal characteristics
3. Correlation with soft tissue structures using radiological studies

Conclusion

This comprehensive morphometric study of nutrient foramina in Bangladeshi fibulae has yielded several significant findings. The study demonstrated clear sexual dimorphism in multiple parameters, including total length, midshaft measurements, and nutrient foraminal characteristics. The predominance of single nutrient foramina (>92% in both sexes), their consistent downward direction, and preferential location in the middle third of the bone (Type-2 Foraminal Index >98%) establish a reliable anatomical pattern specific to the Bangladeshi population.

Key findings with practical implications include:

Surgical Relevance:

- Predictable nutrient foramina locations, predominantly on the posterior surface in males (42.6%) and medial crest in females (32.7%)
- Consistent middle-third positioning, crucial for fibular graft harvesting
- Reliable vascular patterns for preserving blood supply during surgical procedures

Forensic Applications:

- Significant sexual dimorphism in multiple parameters provides reliable criteria for sex determination
- Population-specific baseline data enhances forensic anthropological accuracy
- Quantifiable measurements with statistical significance support forensic applications

Anthropological Significance:

- First comprehensive morphometric database for Bangladeshi fibulae
- Contribution to understanding population-specific variations
- Baseline data for comparative anthropological studies

These findings contribute substantially to the existing knowledge base and have immediate practical applications in surgical planning, forensic analysis, and anthropological studies.

The established morphometric standards specific to the Bangladeshi population will serve as valuable reference data for both clinical practice and forensic investigations. Further research building on these findings, particularly investigating age-related changes and bilateral variations, would further enhance our understanding of fibular morphometry in the Bangladeshi population.

The results of this study provide a solid foundation for such future investigations while offering immediate practical applications in clinical and forensic settings.

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