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Morphometry and Indices of Tibia and Their Importance

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Abstract: The tibia is the strong weight bearing bone of the leg. It has usually a single nutrient foramen. Of late, tibia is gaining importance in determining the stature, sex and race of individuals and in the identification of missing persons. The dry bone specimens were obtained from the department of anatomy of our institution. A total of seven morphometric parameters were obtained for the study. The number of nutrient foramen present and their location were recorded. The cross sectional index, cnemicus index, length-thickness index, and the proximal - distal surface index were arrived from the data obtained. A single nutrient foramen was observed in the study; located in the upper one third of tibia in its posterior surface. The results are presented as descriptive statistics (mean ± SD); and standard errors of estimate (SEE) for right and left tibia and total tibia. The mean differences obtained are not statistically significant. The confidence interval of SD or SEM is less than 1. The two – tailed P value equals less than 1and is not statistically significant. Tibia has a single nutrient foramen in the upper one third of tibia in its posterior surface. The morphometric parameters obtained and the indices derived differed widely among the different studies. The differences may be due delicate variations in the measurements. There is a need for defining the parameters by further studies for the better utilization of morphometry of tibia.
Keywords: Cnemicus index; nutrient foramen; indices.

INTRODUCTION

All human beings on this globe belong to the species Homo sapiens [1]. But no one is similar to other individual including identical twins; in respect of his or her bodily and skeletal traits.

The bodily and skeletal traits develop and get differentiated by the inter play of genes which one inherits; and the environment in which he or she lives. Hence, there is abundance of variation in the stature and skeletal remains in the populations across the globe [2].

The morphometric measurements are an important step in assessing health and general body size trends in the given populations [3]. The long bones such as tibia and femur of the lower limb collectively remain the best for the assessment of the living stature of the individual [4].

The tibia is the strong and the only weight bearing bone of the leg [5]. Its proximal and distal ends are widened to receive and transmit the weight of the body [6]; and help in maintaining the erect posture [7]. It has three named parts and they are the upper and lower ends and a middle shaft.

The tibial nutrient foramen is situated obliquely at the superior end of the vertical line on the posterior surface [8]. Classically tibia usually has a single nutrient foramen in comparison with the number of nutrient foramina in other long bones [9]. Recent identification of the nutrient foramen on the proximal tibia as the ideal harvest site for the surgical reconstruction and restoration of chronic and acute pathological defects, has accounted for the global incidence of approximately one million bone graft procedures annually [10, 11].

The morphologic and morphometric differences of the tibia may be related to racial and individual variations [12]. Sexual dimorphism is greater in Black individuals than in Caucasians and thus dependent on race [13]. The females appeared to have longer tibia than males in Japanese population; the study suggested that for the determination of sex of the tibia there is a need to take into consideration the demographic factor of the population in question [14].

The present study is aimed to investigate the morphologic and morphometric parameters of the dry tibia and to analyse the obtained morphometric data to estimate the bilateral differences between the right and the left tibiae and to obtain various indices and compare the results with other studies.

MATERIALS AND METHODS

The study was done on a total of 37 (19 right sided and 18 left sided) tibia; obtained from the anatomy department of NRI institute of Medical sciences, Visakhapatnam. The tibia which were incomplete and deformed were not included in the study. The ethical clearance was obtained from our institutional ethics committee.

As a part study the number of nutrient foramina in each tibia was noted with their location and details were recorded.

The standard indexical formulae as mentioned by Pradeep Bokariya *et al.*, were adopted in the study except for the following: 1. the measurement of the maximum diameter in the middle of tibia (MDMT) was measured in the present study from anterior crest of the tibia to its medial border; 2.the sagittal diameter at the level of nutrient foramen (SDNF) - was measured from anterior crest of tibia to its medial border; 3.the mid shaft circumference (MSC) was measured as the maximum circumference at the mid length of the shaft of tibia. These changes were adopted in the present study as the posterior surface of tibia is not defined and the maximum girth of tibia is also variable. To eliminate the subjectivity of the observer while taking measurements the changes mentioned are adopted in the present study.

MTL (maximum tibia length) was measured using the Osteometric board. Measuring tape was used to measure circumference at the mid shaft of tibia. Digital vernier caliper which provides precision readings from 0.01 mm and 0.0005 mm, through a clear liquid crystal display is used to measure the distance between two bony landmarks. Each reading is taken thrice and averaged and the mean was noted.

A total of seven morphometric tibial parameters were studied for this study. The parameters studied were:

- Maximum tibial distance (MTL) was measured as the maximum distance from the highest point of the upper part of the tibia to the lowest point of the tibia using osteometric board (Fig-1).
- Bi condylar tibial width (BTW) was measured as the maximum transverse distance of the superior surface of tibia, from the lateral side of the lateral condyle to the medial side of the medial condyle, using the digital vernier caliper (Fig-2).
- Midshaft circumference (MSC) was measured as the maximum circumference at the mid length of the shaft of tibia by a measuring tape (Fig-3).
- Distal articular surface length (DASL) was measured as the maximum transverse distance of the inferior articular surface of the lower end tibia, up to the tip of the medial malleolus (Fig-4).
- Transverse diameter at the level of nutrient foramen (TDNF) – was measured from medial tibial border to its interosseous border, at the level of nutrient foramen (Fig-5).
- Maximum diameter in the middle of tibia (MDMT)–was measured from anterior crest of the tibia to its medial border, in the middle length of shaft of tibia (Fig-6).
- Sagittal diameter at the level of nutrient foramen (SDNF) - was measured from anterior crest of tibia to its medial border, at the level of nutrient foramen (Fig-7).

Further the following formulae were used for calculating various indices as mentioned by Pradeep Bokariya *et al.*, [15] with the changes adopted in this study as mentioned above:

a) Cross-Section index in middle= (Transverse diameter at the level of the nutrient foramen /Maximum Diameter in the middle of tibia) X 100

TDNF/MDMT X100

b) Cnemicus Index= (Transverse Diameter at level of Nutrient Foramen/ Sagittal Diameter at level of Nutrient Foramen) X100

TDNF/SDNF X100

c) Length - Thickness Index = (Mid shaft circumference of tibia /Maximum tibial length) X100

MSC/MTL X100

d) Proximal – distal articular surface index = (Distal articular surface length / Bi condylar tibial width) X100

DASL/BTWX100

STATISTICAL ANALYSIS

The data obtained in the study was analysed by descriptive statistics and is expressed as mean ± standard deviation (SD) and SEM. The statistical comparison of differences between right and left tibia were done with help of t -test for unpaired .The Statistical significances were noted at $P < 0.05$. The GraphPad, statistical online software was used for the analysis.

RESULTS

In our study, we observed that all the tibias had only one nutrient foramen; located in the posterior surface; in the upper one third of tibia, except for in three specimens. In one specimen it was located in the medial surface. In another specimen it was located in the lateral surface, on the interosseous border and in one another specimen it was located on the soleal line (Fig 8 & 9).

The results are presented as descriptive statistics (mean ± SD); and standard errors of estimate (SEE) for both right and left tibia in the Table-1. The mean differences of all the measured parameters are not statistically significant. The confidence interval of SD or SEM is less than 1.The two – tailed P value equals for the right and left sides of tibia is 0.20, 0.11, 0.75, 0.97, 0.77, 0.51, 0.98, and 0.97 respectively for the above parameters. By the conventional criteria this difference is considered to be not statistically significant.

The Table-2 shows the morphometric values of the total tibia the mean ± SD and SEE. The confidence interval of SD or SEM is less than 1.

The Table-3 shows the index values for the right and left tibia and total tibia. The indexical results given in the Table 3 show that the length- thickness index is in the ratio of 1:4.8; the cross section index is in the ratio of 1:1.10; cnemicus index is in the ratio of 1:1.03; and the proximal and distal articulating surface index is in the ratio of 1: 1.71.

Fig-1: Showing measurement of maximum tibial length

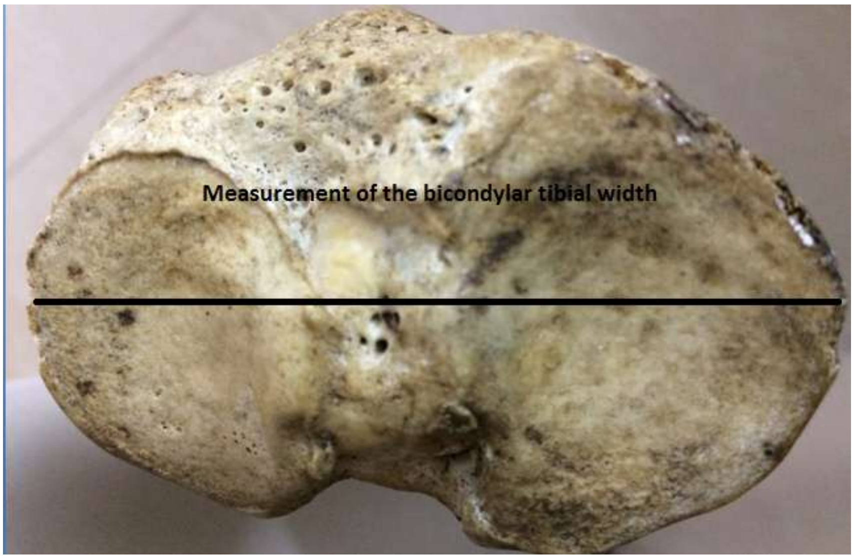

Fig-2: Showing measurement of Bicondylar tibial width

Fig-3: Showing measurement of mid shaft circumference of tibia

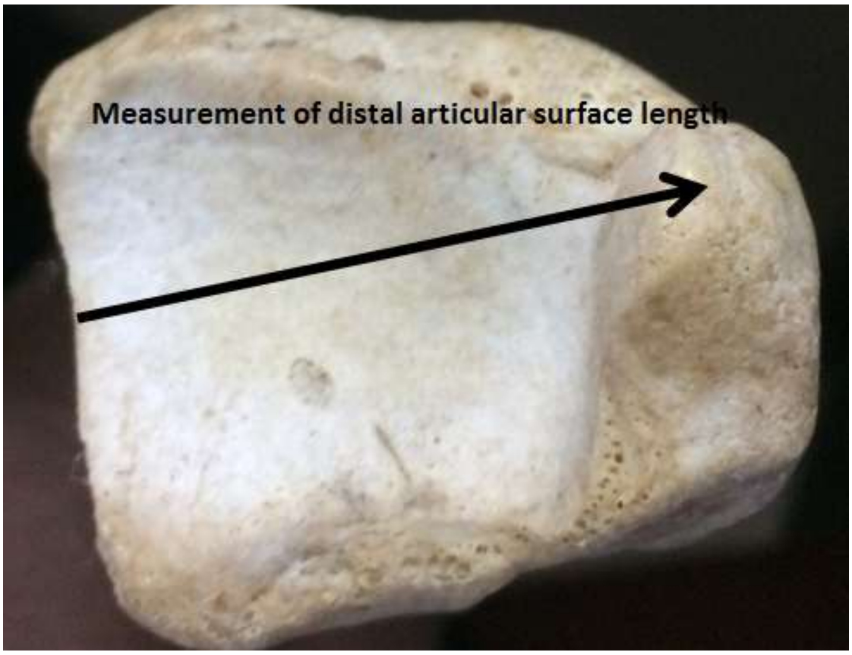

Fig-4: Showing measurement of distal articular surface length of tibia

Fig-5: Showing measurement of transverse diameter of tibia at the level of nutrient foramen

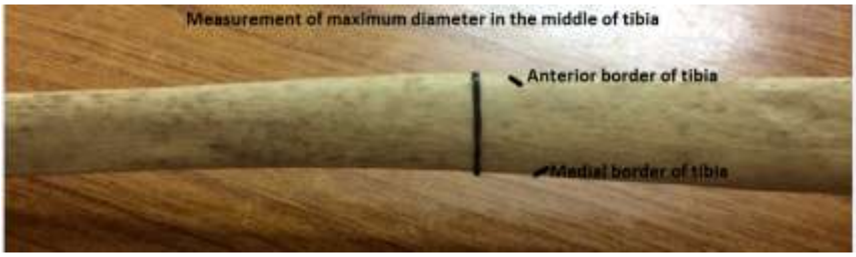

Fig-6: Showing measurement of maximum diameter in the middle of tibia

Fig-7: Showing measurement of sagittal diameter at the level nutrient foramen

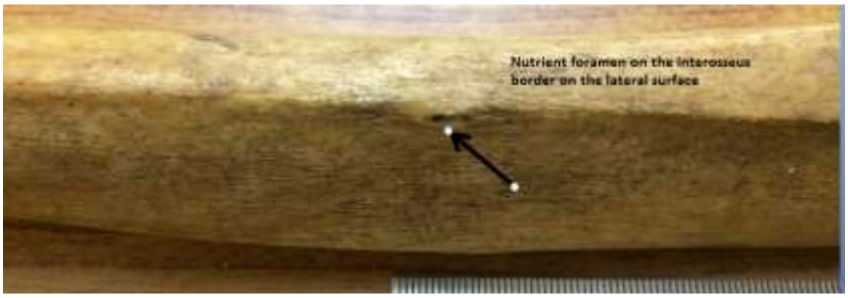

Fig-8: Showing nutrient foramen in the lateral surface on the interosseous border of tibia

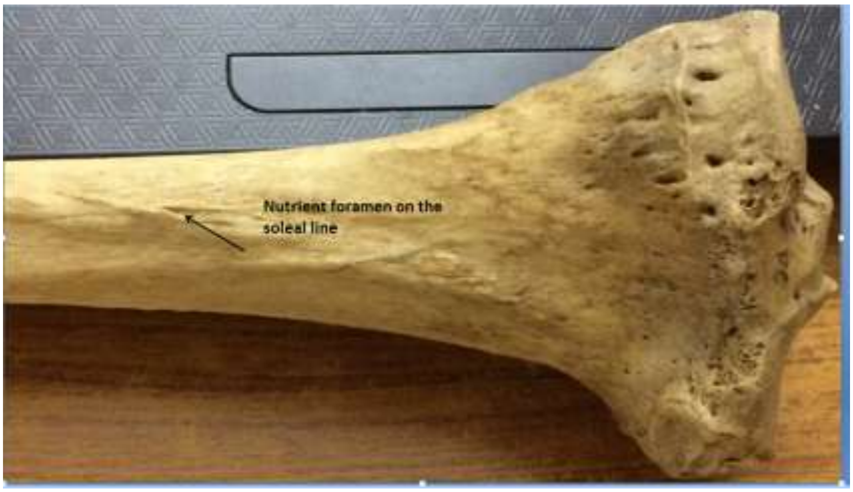

Fig-9: Showing nutrient foramen on the soleal line of tibia

Table-1: Showing the mean, SD and SEM in respect of right and left Tibia

Sl No	Parameters	Right mean ±SD	SEM	Left mean ±SD	SEM
1	Transverse diameter at the level of nutrient foramen (TDNF)	21.84±2.14 mm	0.49	20.61±3.53 mm	0.83
2	Maximum diameter in the middle of tibia (MDMT)	24.52±2.77 mm	0.63	23.00±3.00 mm	0.7
3	Sagittal diameter at the level of nutrient foramen (SDNF)	23.05±4.55 mm	1.044	22.61±3.80 mm	0.89
4	Mid shaft circumference (MSC)	7.76±0.68 mm	0.15	7.71±0.82 mm	0.19
5	Maximum tibial length (MTL)	37.34±3.03cm	0.69	37.05±3.12 cm	0.73
6	Bicondylar tibial width (BTW)	67.15±5.45 mm	1.25	67.38±6.32 mm	1.49
7	Distal articular surface length (DASL)	39.22±3.76 mm	0.84	39.22±4.09 mm	0.96

Table-2: Showing the mean, SD and SEM for total tibia

Sl No	Parameters	Total	SEM
1	Transverse diameter at the level of nutrient foramen (TDNF)	21.24±2.92 mm	0.48
2	Maximum diameter in the middle of tibia (MDMT)	23.78±2.95 mm	0.48
3	Sagittal diameter at the level of nutrient foramen (SDNF)	22.83±4.15 mm	0.68
4	Mid shaft circumference (MSC)	7.74±0.74 mm	0.12
5	Maximum tibial length (MTL)	37.20±3.03cm	0.49
6	Bicondylar tibial width (BTW)	67.27±5.81 mm	0.95
7	Distal articular surface length (DASL)	39.08±3.91 mm	0.64

Table-3: Showing the mean index values for right and left and total tibia

Index values in right left and total tibia			
Index values	Mean		
	Right	Left	Total
Length –thickness index	20.83	20.83	20.83
Cross section index	89.77	90.79	90.26
Cnemicus index	99.64	93.59	96.70
Proximal and distal articulating surface index	58.65	58.35	58.24

Table-4: Showing the comparison mean indexical values of right and left tibia

Indices	Bokariya *et al.*, [15]		Naidoo *et al.*, [19]		Gupta et al (2015)		Fozia Nazir *et al.*, [18]		Present study (2018)	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	left
Length – thickness index	24.21 ± 0.96	24.43 ± 1.78	28.86	27.99	22.21	22.01	31.95±2.12	31.34±2.08	20.83	20.83
Cross section index	102.90± 22.78	124.31± 25.06.	85.33	81.98	72.34	69.39	78.83 ±7.35	80.01±8.54	89.77	90.79
Cnemicus index	66.17 ± 10.68	67.31 ± 7.35.	76.93	74.92	70.55	66.98	68.19±5.23	68.02±7.48	99.64	93.59

DISCUSSION

In the study a single nutrient foramen was seen, located usually in the posterior surface of the upper one third of tibia. Pradeep Bokariya *et al.*, mentioned that only one right tibia possessed two nutrient foramina, else whole of the tibias studied were having single nutrient foramina [15]. The presence of single nutrient foramen throughout the samples studied is the remarkable difference compared to other long bones of human body [14]. Bhatnagar et al. mentioned that 95% of tibiae had single nutrient foramen and double nutrient foramina in 5%; in 90.47% of specimens the nutrient foramina were in the proximal third of the tibiae and in the rest of the tibiae examined (9.53%) nutrient foramina were located in the middle third [16]. Tejaswi *et al.*, mentioned 94.87% of tibiae had one foramen, 1.28% tibiae had two nutrient foramen and triple foramen in 3.85% of the tibiae; in 148 tibiae 94.9% had nutrient in the proximal third and in 8 tibias (5.1%) in the middle third of the bone [17]. There were no foramina in the distal third of tibia [16, 17]. Fozia Nazir *et al.*, mentioned that in all tibias, except one, there was only one nutrient foramen [18]. Difference in foramen number may be attributed to nutritional, genetic and growth factors [8, 14]. The single nutrient foramen was more prevalent in females (99.3%), while double nutrient foramina was recorded to be predominant in males (1.8%); which may indicate a degree of sexual dimorphism in the Black population group that is native to South Africa [19].

The tibial torsion commences during fetal development and continues until pubertal maturation; may account for the change in the classical location of the nutrient foramen in relation to the soleal line [20]. The degree and outcome of tibial torsion may be related to racial differences [20, 21].

The morphometric tibial parameters are considered to be of medico-legal importance due to the provision of stature-group-specific formulae for the determination of "personal identity" in circumstances of unknown and unclaimed human remains [22, 23]. All mean morphometric tibial parameters were higher in males than females [19]. The simultaneous process of growth and bone apposition that is specific to males only, may explain the increased tibial morphometry in males [24]. Agnihotri et al. recommended the combined use of tibial and ulnar lengths for the precise modeling of stature [25]. Iscan and Miller-Shaivitz postulated that sexual dimorphism was dependent on race [26].

The Cnemicus and Cross section indices showed statistical difference and this may be of value in medico legal issues where sometimes identity is to be established from part of bone only [27, 28]. Naidoo N *et al.*, observed that the indices presented with greater mean values in males; the indexical values could not be compared to any other study as it was not reported in the literature; they opined that for the purpose of comparison, further studies reporting on other race groups may be required; in addition, clinical studies may also be necessary in order to evaluate the exact hypothesis regarding tibial indices [19]. Table-4 gives the comparison mean index values for the right and left tibia. The differences observed in respect of indices may be because of delicate differences in respect of measurement of various parameters.

CONCLUSIONS

The tibia usually has a single nutrient foramen located in the upper one third of tibia in its posterior surface. This informed knowledge is useful for orthopedic surgeons in the undertaking harvesting surgical reconstruction of bone grafts and in the surgical repair of fractures.

The morphometric parameters obtained and the indices derived differed among the different studies. The differences may be due delicate variations in the measurements. There is a need for defining the parameters by further studies for the better utilization of indices of tibia.

CONFLICT OF INTEREST: NIL

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