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Lesser Trochanter Morphometry: A Novel Morphological Classification System

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ABSTRACT

Every orthopedic procedure requires the restoration of normal limb anatomy, function, and prevention of rotational malalignment. This can be predicted using indices on the lesser trochanter (LT), as it shows geographical and racial variations. No unified morphological classification system for LT exists in literature, and information on LT morphology in Nigerians is scanty. This study aimed to fill this gap and develop a morphological classification system with groups I, II, III, IV, and V representing oval, round, triangular, shield-like like and irregular LT shapes, respectively. Using 100 dry adult femurs, lesser trochanter height (LTH), lesser trochanter width (LTW), LT-Fovea distance (LT-F) and greater to lesser trochanter (GT-LT) distance were measured with digital vernier calipers. The LT shape and presence of retrotrochanteric groove were noted. The mean LTH, LTW, LT-F and GT-LT were 1.42 ± 0.32 cm, 2.15±0.39 cm, 7.2 ± 0.75 cm and 6.03 ± 0.76 cm, respectively. We observed a groove behind the LT in 85 femurs - shallow in 63 and deep in 22. The LT shapes observed were oval (54%), round (19%), triangular (5%), shield-like (21%) and irregular (1%). Following our novel classification system, class Ib was the most frequent (35%), followed by class IVb (16%), while others were absent. The various LT shapes reflect varying patterns, force and direction of pull exerted by ligaments in pre- and post-natal development, which depend on human occupational activities. Introduction of a unified morphological classification system provides a common standard for comparing the LT morphology in different populations.

Keywords: Lesser trochanter, femur, classification, morphometry

INTRODUCTION

Lesser trochanter (LT) is a minute bulge of bone projecting from the posterior part of the femur, inferomedially at the lower part of the femoral neck. Landmarks of LT have been utilized in assessing rotational alignment. The extent of LT symmetry between limbs, whether the LT profile varies because of age, sex and the efficacy of the LT profile technique, remains unknown[1]. Previous studies on the proximal femur have identified the LT as an excellent tool in forecasting femoral rotational mal-alignment intraoperatively[2]. It can also be used to develop angular references to determine clinically important malrotation of the limb[3,4].

As a cone-shaped projection on the posteromedial aspect of the proximal femur at the junction between the neck and the shaft[4], the summit of LT receives the insertion of the psoas major muscle while the base receives the insertion of the iliacus anteriorly and adductor magnus muscle posteriorly[5]. In addition to its importance in orthopedics, LT morphology has attracted the attention of anthropologists as it shows geographical and racial variations. In spite of the above-stated importance of LT, there is a paucity of information on its detailed morphological characterization. Previous attempts focused on the changes in shape of LT with limb rotation as observed at magnetic resonance imaging[2]. Past studies also failed to characterize the LT into detailed morphological categories, nor do they show its location in relation to constant bony landmarks.

To evaluate femoral alignment during and after surgery, the LT is a crucial anatomical structure of the femur, which could be used as a landmark to predict femoral mal-alignment, as the relationship between the height and width of the LT and femoral rotation at different angles has been investigated[2]. This cross-sectional study on the LT involving the analysis of the size, shape or other parameters in a group of bones in the Departments of Anatomy in both the University of Ibadan and Bowen University was done to assess the activity level, presence of hip joint pathologies and to investigate the variations in the LT as might relate to hip function or a potential for injury risk in Nigerian population. We developed a 5-class morphological classification system for the LT with groups I, II, III, IV and V representing oval, round, triangular, shield-like and irregular LT shapes, respectively and Subgroup a, b, and c representing absent groove, shallow groove and deep groove, respectively.

MATERIALS AND METHODS

A total of 100 dried cadaver femurs of unknown gender and age were randomly selected from the Bone Libraries of the University of Ibadan and Bowen University, Nigeria. The sample size was determined by using this formula:

$$N = \frac{Z^2 [P(1-P)]}{d^2}$$

The Institutional Review Board and Ethical Committee approval was obtained from Bowen University Teaching Hospital Ethical Committee (Ethical approval number BUTH/REC-446). The study period was determined as the time period between January and May 2022, during which the measurements of all dry bones that met the inclusion criteria were taken. Bones with bony tissue erosion, deformities, fractures in the proximal femur and callus formation were excluded from the study.

With the femur oriented in a position such that its long axis lies vertically, the lesser trochanter height (LTH) was measured as the distance between the superior-most and inferior-most part of the LT base. The lesser trochanter width (LTW) was measured as the transverse dimension between the midpoint of the base of the LT to its apex. All the above measurements were taken in cm using the digital Vernier caliper and tape rule.

The shape of the LT, as viewed from the top of the apex, was observed and classified into oval, round, triangular and shield-like types. The posterior surface of the LT was inspected for the presence of grooves, which were thereafter ranked into deep and shallow.

The LT-fovea (LT-F) distance was measured as the distance between the superior-most border of LT to the superior border of the fovea, while the "Greater to lesser trochanter (GT-LT) distance" was measured as the distance between the superior-most parts of both trochanters. The measurement was done in centimeters using a meter rule.

The femoral neck length (FNL) was measured in cm, as the distance between the base of the femoral head and to intertrochanteric line. At the midway point down the FNL, the tape rule was thrown around the neck of the femur to measure the femoral neck circumference (FNC) in cm.

The distance (in cm) from the most proximal point of the head to the most distal point of the medial condyle was measured as the Maximum femoral length (MFL) using the meter rule. The sides of the femurs were noted and recorded. All measurements were taken independently by two observers.

The statistical package for the social sciences version (17.0 SPSS Chicago, IL, USA) was used to calculate the mean, standard deviation and minimum and maximum values. Confidence intervals (CIs) 95% were also calculated as the lower and upper bounds for continuous data. Student's T-test was used to compare these continuous data. One-way analysis of ±variance (ANOVA) was used to compare more than two groups. A p-value < 0.05 was considered to be statistically significant.

RESULTS

One hundred dried femurs (52 right and 48 left) were used for the study, after excluding the femurs that did not meet the inclusion criteria. Quantitative analysis of the LT revealed the mean height (LTH) and mean width (LTW) to be (1.42 ± 0.32 cm) and (2.15±0.39 cm), respectively (Table 1).

To define the specific location of the LT, we measured its distance from two constant bony landmarks (the fovea and greater trochanter). The mean "lesser trochanter-fovea distance" and "greater trochanter-lesser trochanter distance" were 7.20 ± 0.75 cm and 6.03 ± 0.76 cm, respectively.

Table 1: Range, mean and standard deviation of osteometric parameters of the lesser trochanter.

	Minimum	Maximum	Mean	Std Dev	SEM
LTH (cm)	100	0.80	2.30	1.42	0.32
LTW (cm)	100	1.20	3.50	2.15	0.39
LT-F (cm)	100	5.30	9.10	7.20	0.75
GT- LT (cm)	100	4.50	8.30	6.03	0.76
FNL (cm)	100	1.70	5.50	3.07	0.75
MFL (cm)	100	38.00	52.70	46.02	2.99
FNC (cm)	100	8.40	12.20	10.32	0.77

Lesser trochanter height - LTH, Lesser trochanter width - LTW, Lesser trochanter- Fovea - LT-F distance, Greater trochanter - Lesser trochanter distance - GT-LT, Femoral neck length - FNL, Maximum femur length - MFL, Femoral neck circumference - FNC.

The distribution of the various shapes of LT observed in our study is presented in Fig.1.

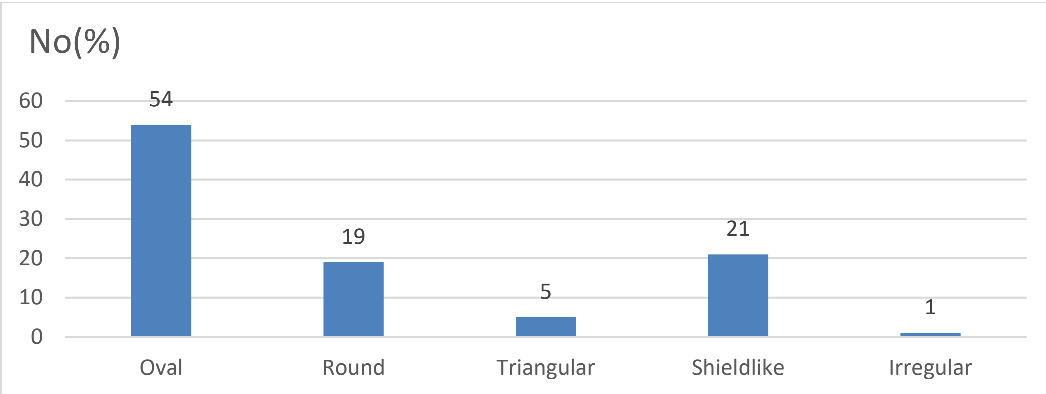

Fig 1: Distribution of the lesser trochanter based on shape

The most frequently observed shape was oval (56%), while the least was irregular (1%). Other shapes observed were round, triangular and shield-like, respectively (Fig. 2).

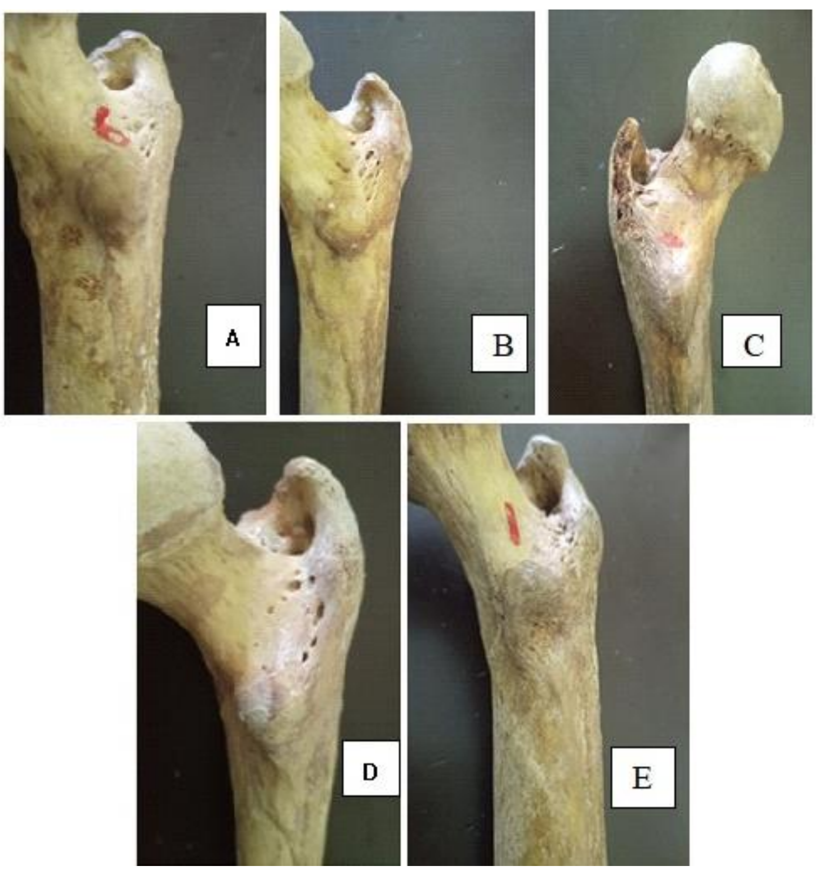

Fig 2: Photographs of the lesser trochanter showing the characterization of the various shapes (A-E). (A): Lesser trochanter showing an oval shape; (B): Lesser trochanter showing a round shape; (C): Lesser trochanter showing a triangular shape; (D): Lesser trochanter showing a shield-like shape; (E): Lesser trochanter showing an irregular shape.

Of the 100 femurs studied, we observed a groove behind the LT in 85 femurs (85%). These grooves were shallow in 63 (63%) and deep in 22 (22%). (Fig. 3).

Table 2 summarized the morphological parameters of the lesser trochanter using our recommended classification system. Class Ib was the most frequent (35%), followed by class IVb (16%), while classes IIIa, IIb, Vb & Vc were absent.

Table 2: Classification system on the lesser trochanter morphology based on shape and degree of grooving

CLASSES	a (Non-grooved)	b (Shallow groove)	c (Deep groove)
I	6	35	13
II	5	7	7
III	0	5	0
IV	3	16	2
V	1	0	0

Figure 3: Photographs (A - C) of the lesser trochanter showing the graduation of grooving. (A): Lesser trochanter showing no groove; (B): Lesser trochanter showing shallow groove. (C) Lesser trochanter showing a deep groove. The arrow indicates the LT groove.

Table 3 showed the comparison of the lesser trochanter height (LTH), lesser trochanter width (LTW), lesser trochanter to fovea distance (LT-F), and greater trochanter-lesser trochanter distance (GT-LT) of the right with that of the left. Femur neck length (FNL) and femur neck. There was no significant difference between the mean values of each parameter between the bone sides.

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Table 3: Comparison of Osteometric parameters on both sides of the lesser trochanter.

Side	N	Mean	Std Deviation	P value
LTH (cm)				
Left	48	1.43	0.34	
Right	52	1.41	0.31	0.29
LTW (cm)				
Left	48	2.09	0.43	
Right	52	2.21	0.34	0.39
LT-F (cm)				
Left	48	7.19	0.78	
Right	52	7.21	0.73	0.65
GT-LT (cm)				
Left	48	6.01	0.74	
Right	52	6.04	0.79	0.70

Lesser trochanter height - LTH, Lesser trochanter width - LTW, Lesser trochanter - Fovea distance - LT-F, Greater trochanter - Lesser trochanter distance - GT-LT.

DISCUSSION

The lesser trochanter is an important tool for predicting the rotational status of the femur, and the lesser trochanter sign has been affirmed by many studies[10]. The shape and size of the femur exhibit racial and geographical variation. The LT is more of a triangular or conical eminence that arises at the inferior aspect of the junction of the femoral neck and the proximal femur and projects posteriorly[11]. The mean LT height in our study is higher than that observed in the neutral limb position of the Chinese population[2]. However, our observed mean LT width is less than the value recorded in Zhang's study[2]. The difference in the values from these two studies may be attributed to the different modes of measurement employed. We used direct measurement of cadaveric bones while Zhang *et al*[2] used digital radiological estimation. The height and width of the lesser trochanter exhibit a linear correlation with femoral rotation when viewed on radiographs. The height and width of the lesser trochanter increase with external rotation of the limb and decrease with internal rotation[2].

The LT is an apophysis which provides attachment to the tendon and ligament which exert a pull on it. This forms the basis for naming them 'traction epiphysis.' The various shapes (oval, round, shield and irregular) observed reflect varying patterns, force and direction of pull exerted by ligaments in the course of pre- and post-natal development. In a previous study, only conical or triangular shapes were observed[11]; however, our study revealed other forms of shapes of the lesser trochanter. This force is also responsible for the difference in the orientation of the LT in the medieval and modern age femur. It reflects the changes in occupational activities in the various populations over the years[8]. We hypothesize that the oval LT shape is the result of greater traction along the vertical axis relative to the traction along the transverse axis. However, the round shape may result from equal traction along all axes. The majority of childhood activities in Africa involve squatting, which results in greater traction along the vertical axis of the LT. This may explain the occurrence of the oval shape as the predominant LT shape-type in the current study.

The distance between LT and Fovea is higher than that reported in Chinese volunteers[9]. The disparity in these values may be attributed to the geographical variation in land activities in the two populations. It may also be due to differences in the study design employed in the two studies. The

Mean distance between LT & GT in our study is similar to that reported in the Turkish population[4].

CONCLUSION

Since measurements from LT have been a useful guide in assessing rotational deficiency in the femur, providing a unified morphological classification system will allow a common standard for comparing the various findings in the different populations. It may also serve as a prognostic tool in the various orthopedic conditions and could be used as a landmark to avoid femoral mal-alignment during surgery.

Conflict of Interests

No conflict of interest declared.

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Authors' contributions

OSO: Conceptualization; methodology; writing (original draft); visualization; supervision; endorsement. OAB: Methodology; writing (original draft); writing (review and editing); visualization; endorsement.

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