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Morphometric Analysis of the Femur: A Comprehensive Study of the Linea Aspera, Popliteal Surface, and Metaphyseal Vessel Foramina

Femurun Morfometrik Analizi: Linea Aspera, Popliteal Yüzey ve Metafizyal Damar Foramenlerinin Kapsamlı İncelenmesi

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ABSTRACT

Objective: This study aims to analyze the morphometric characteristics of key anatomical structures on the posterior surface of the femur, particularly the linea aspera and the popliteal triangle.

Methods: The study was conducted on 52 adult human femurs from the dry bone archive of the department of anatomy. Measurements of total femur length, linea aspera length, gluteal tuberosity, and the dimensions of the popliteal triangle, including its height, base width, and distances between vascular foramina, were obtained using digital calipers and osteometric boards.

Results: The mean femur length was 43.90±2.57 cm. The linea aspera length was recorded as 10.03±1.79 cm, while the height of the popliteal triangle measured 13.13±1.86 cm. The base width of the popliteal triangle was 6.22±0.55 cm, and its midpoint width was 2.17±0.36 cm. A moderate negative correlation was found between linea aspera length and popliteal triangle height, whereas a positive correlation was observed between linea aspera length and popliteal triangle width.

Conclusion: The morphometric properties of the posterior femur are crucial for surgical planning. The findings of this study may contribute to the development of anatomy-based surgical strategies in distal femoral procedures, minimizing vascular injuries and improving clinical outcomes.

Keywords: Anatomy, arteries, popliteal, femur, morphometry, orthopedic surgeries

ÖZ

Amaç: Bu çalışma, femurun arka yüzeyindeki önemli anatomik yapıları, özellikle linea aspera ve popliteal üçgenin morfometrik özelliklerini analiz etmeyi amaçlamaktadır.

Yöntem: Çalışma, anatomi anabilim dalı kuru kemik arşivinde bulunan 52 yetişkin insan femuru üzerinde gerçekleştirildi. Femurların total uzunluğu, linea aspera uzunluğu, gluteal tüberosite ve popliteal üçgenin yüksekliği, genişliği ve damar foraminaları arasındaki mesafeler dijital kumpas ve osteometrik tahtalar kullanılarak ölçüldü.

Bulgular: Ortalama femur uzunluğu 43,90±2,57 cm olarak bulundu. Linea aspera uzunluğu 10,03±1,79 cm iken, popliteal üçgenin yüksekliği 13,13±1,86 cm olarak ölçüldü. Popliteal üçgenin taban genişliği 6,22±0,55 cm ve orta nokta genişliği 2,17±0,36 cm olarak belirlendi. Linea aspera uzunluğu ile popliteal üçgen yüksekliği arasında orta derecede negatif korelasyon gözlenirken, linea aspera uzunluğu ile popliteal üçgen genişliği arasında pozitif korelasyon bulundu.

Sonuç: Femurun arka yüzeyindeki morfometrik özellikler cerrahi planlama açısından büyük önem taşımaktadır. Çalışmanın bulguları, distal femur cerrahisinde anatomik yapılara dayalı stratejilerin geliştirilmesine katkıda bulunabilir ve vasküler yaralanmaların en aza indirilmesini sağlayabilir.

Anahtar Kelimeler: Anatomi, arterler, popliteal, femur, morfometri, ortopedik cerrahiler

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INTRODUCTION

The femur, the largest bone in the human body, has a shaft region that contains several important anatomical structures on its posterior surface. Among these, the linea aspera is one of the most prominent features, extending along the diaphyseal axis. It serves as an attachment site for several muscles, including the adductor longus, adductor brevis, adductor magnus, vastus medialis, vastus lateralis, and the short head of the biceps femoris, as well as for the intermuscular septa, which partially continues as the fascia lata of the thigh.[1] The linea aspera is generally recognized as a confluence of medial and lateral ridges; however, in certain instances, these ridges may remain separate.[2] At its proximal and distal ends, the linea aspera becomes more distinct, with its lateral ridge continuing as the gluteal tuberosity and its medial ridge as the pectineal line. Distally, these ridges further separate into the medial and lateral supracondylar lines, which enclose the popliteal surface of the femur. The adductor canal opens onto the popliteal surface of the distal femur.[3]

The transition zone between the distal femoral shaft and the condylar region is located close to the transverse line passing through the superior border of the condyles, forming a popliteal triangular surface. It contains several foramina, which accommodate metaphyseal vessels critical for the vascular supply of the distal femur and knee joint structures.[4] Morphometric data regarding the femoral length, linea aspera, and the popliteal triangular surface are relatively scarce in the literature, despite their clinical relevance. The location of metaphyseal vessels should be well known in terms of complications such as bleeding, hematoma, necrosis, delayed healing or inadequate treatment response that may develop during or after the treatment of supracondylar, intercondylar, and condylar fractures and other surgical procedures (e.g., tumor-related bone resection).[5,6] Intramedullary nailing and distal locking screw placement, which are common treatment methods for distal femur fractures, can also directly affect the triangular popliteal surface and the vascular structures within its borders, during surgical interventions.[7,8] Improper anatomical orientation can lead to malalignment or malrotation, which in turn affects knee and hip biomechanics, potentially resulting in recurrent surgical interventions.[9-12]

The morphometric properties of the triangular popliteal surface, including its height, base width, and midpoint width, are essential for preoperative planning and surgical decision-making. This study aims to provide a detailed analysis of the morphometric characteristics of the triangular popliteal surface and its relationship with the linea aspera and total femur length. The findings may contribute to improving anatomical-based surgical strategies in distal femoral procedures, minimizing vascular injuries, and optimizing implant positioning. Understanding the distribution of the foraminae within the popliteal triangular surface can help guide the placement of stabilization devices, reducing the risk of vascular damage-related complications, thereby enhancing fracture healing outcomes.

METHODS

The current study was conducted on 52 adult human femurs from the dry bone archive of the department of anatomy, faculty of medicine, to analyze the morphometric characteristics of the linea aspera and the triangular popliteal surface. The study included 25 right-sided and 27 left-sided femurs, excluding bones with fractures, significant osteophyte formation, or severe surface damage. Measurements were performed using digital calipers (precision: 0.01 mm) and osteometric boards for accuracy.

The following parameters were recorded (Figure 1):

Total femur length (L1): Measured from the highest point of the femoral head to the lowest point of the condyles.

Gluteal tuberosity to linea aspera length (L2): The oblique distance from the beginning of the gluteal tuberosity to the start of the linea aspera.

Linea aspera length (L3): Measured from the point where the medial and lateral lips of the linea aspera converge proximally to its distal termination at the apex of the triangular popliteal surface.

Height of the triangular popliteal surface (L4): The distance from the bifurcation point of the linea aspera into the medial and lateral supracondylar lines to the superior margin of the femoral condyles.

Metaphyseal vessel foramina distance (L5): The distance from the upper margin of the region containing vascular foramina, adjacent to the base of the triangular popliteal surface, to the base of the triangle.

Base width of the triangular popliteal surface (W1): The transverse distance between the junctions where the medial and lateral supracondylar lines meet their respective condyles.

Midpoint width of the triangular popliteal surface (W2): The width at the longitudinal midpoint of the triangular popliteal surface.

Statistical Analysis

All measurements were taken three times, and the average value was recorded to minimize measurement error. All data were analyzed using SPSS software (version 21, IBM Corp.,

Armonk, NY, USA). Descriptive statistics, including mean, standard deviation, minimum, maximum, and median values, were calculated for all morphometric parameters.

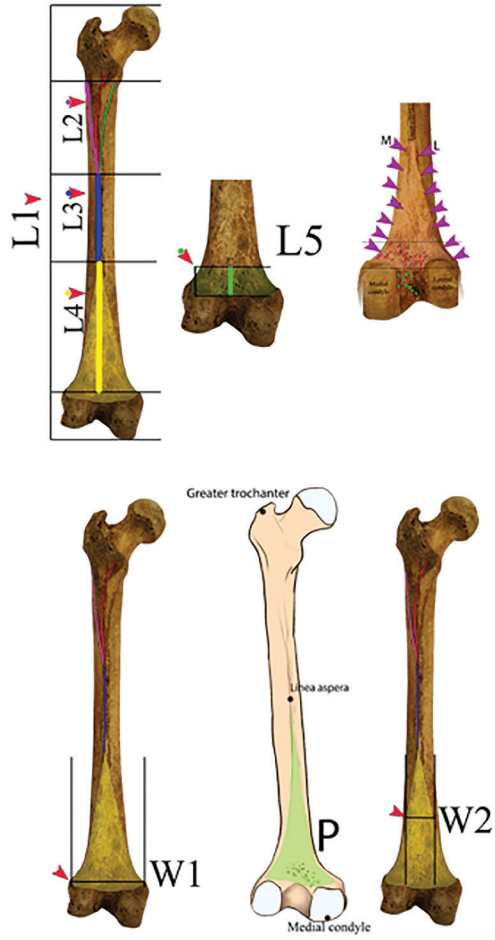

Figure 1. The figure illustrates the parameters that constitute the main subject of the study. In the figure, the femur length between the most proximal and distal ends is represented as L1, the length between the gluteal tuberosity and the beginning of the linea aspera as L2, the length of the linea aspera as L3, the height of the triangular popliteal surface as L4, and the average distance of the upper boundary of the metaphyseal vascular foramina located at the base of the triangular popliteal surface as L5.

The metaphyseal vascular foramina (small red arrowheads) located at the base of the triangular popliteal surface (P) increase in number along the width of the intercondylar notch and towards the posterior edge of the medial condyle. Nutritional foramina (small green arrow heads) are also observed within the intercondylar fossa. The supracondylar lateral line (purple arrowhead, L) generally maintains its prominence towards the lateral condyle corner, whereas the supracondylar medial line (purple arrowhead, M) merges with the lateral surface near the level of the adductor tubercle and disappears

The normality of data distribution was assessed using the Shapiro-Wilk test. Comparisons between right and left femurs were performed using the independent samples t-test for normally distributed data and the Mann-Whitney U test for non-normally distributed variables. Pearson's correlation test or Spearman rho correlation test was used to evaluate the relationships among continuous variables, as appropriate. A p value less than 0.05 was considered statistically significant. The study was approved by the Non-Interventional Research Ethics Committee of Buca Seyfi Demirsoy Training and Research Hospital (decision no: 2023/216, date: 27.12.2023). The study was conducted retrospectively.

RESULTS

The descriptive statistical analysis of femur parameters provided the following results: the mean total femur length (L1) was 43.90±2.57 cm, ranging from 37.7 to 47.6 cm. The distance from the gluteal tuberosity to the linea aspera (L2) measured 10.85±1.48 cm, with a range of 8.0 to 14.5 cm. The linea aspera length (L3) was recorded at 10.03±1.79 cm, varying between 6.9 and 15.0 cm. The height of the triangular popliteal surface (L4) averaged 13.13±1.86 cm, spanning from 9.5 to 16.8 cm. The distance from the uppermost metaphyseal vessel foramina to the base of the popliteal surface (L5) was 2.29±0.47 cm, with values ranging from 1.4 to 3.5 cm. Additionally, the base width of the triangular popliteal surface (W1) measured 6.22±0.55 cm (range: 5.1-7.5 cm), while the midpoint width of the popliteal surface (W2) was 2.17±0.36 cm, ranging from 1.3 to 3.0 cm (Table 1).

No statistically significant differences were observed between sides for any of the measured parameters ($p>0.05$ for all) (Table 1). A moderate negative correlation was found between the length of the linea aspera and the height of the triangular popliteal surface, while a moderate positive correlation was observed between the linea aspera length and the triangular popliteal surface width (Table 2).

DISCUSSION

This study analyzed the morphometric features of certain anatomical structures on the posterior surface of the femur, including the length of the linea aspera, gluteal tuberosity, triangular popliteal surface, and the mid and base width . No significant differences were found between right and left femurs. Although the femurs examined in this study exhibited a wide range of lengths (37.7 cm to 47.6 cm), no correlation was found between femur length and the other measured parameters. However, some measured parameters showed either positive or negative correlations with each other. A shorter triangular popliteal surface was associated with a relatively longer linea aspera.

Table 1. Descriptive statistics and comparison of right and left femoral parameters (cm)								
		L1	**L2**	**L3**	**L4**	**L5**	**W1**	**W2**
Right (n=25)	Mean	44.58	10.50	10.24	13.17	2.22	6.31	2.20
	SD	2.12	1.30	1.64	1.90	0.42	0.57	0.38
	Minimum	40.50	8.00	6.90	9.50	1.40	5.40	1.30
	Maximum	47.60	14.00	12.80	16.80	3.40	7.50	3.00
	Median	44.60	10.00	10.50	13.20	2.20	6.30	2.30
Left (n=27)	Mean	43.26	11.17	9.84	13.09	2.37	6.13	2.14
	SD	2.82	1.58	1.93	1.86	0.51	0.53	0.34
	Minimum	37.70	8.00	7.20	10.50	1.50	5.10	1.60
	Maximum	47.50	14.50	15.00	16.50	3.50	7.00	2.80
	Median	43.50	11.30	9.60	12.70	2.40	6.20	2.20
	p value	0.11	0.08	0.39	0.70	0.19	0.27	0.45
Total (n=52)	Mean	43.90	10.85	10.03	13.13	2.29	6.22	2.17
	SD	2.57	1.48	1.79	1.86	0.47	0.55	0.36
	Minimum	37.70	8.00	6.90	9.50	1.40	5.10	1.30
	Maximum	47.60	14.50	15.00	16.80	3.50	7.50	3.00
	Median	44.00	10.75	9.75	12.80	2.25	6.20	2.20

p<0.05 is statistically significant. All morphometric values are presented in centimeters (cm), n: Number of case, SD: Standard deviation

Table 2. Correlation matrix of femoral morphometric parameters							
	L1	**L2**	**L3**	**L4**	**L5**	**W1**	**W2**
L1 p (r)	-						
L2 p (r)	0.191 (-0.183)	-					
L3 p (r)	0.225 (0.170)	0.207 (-0.176)	-				
L4 p (r)	0.758 (0.043)	0.969 (-0.006)	**0.008*** (-0.360)	-			
L5 p (r)	0.659 (0.062)	0.248 (0.161)	0.457 (0.104)	0.923 (0.014)	-		
W1 p (r)	0.925 (-0.013)	0.098 (0.229)	0.231 (0.167)	**0.001*** (0.431)	0.052 (0.269)	-	
W2 p (r)	0.401 (-0.118)	0.223 (0.170)	**0.009*** (0.356)	0.729 (0.049)	0.432 (0.110)	**0.028*** (0.303)	-

p<0.05 is statistically significant, r: Correlation coefficient. Statistically significant correlations are marked with an asterisk (*), indicating p<0.05. r=0.01-0.29 low level relationship, r=0.30-0.70 medium level relationship, 0.71-0.99 high level relationship

Conversely, as the linea aspera length decreased, the triangular popliteal surface height increased. This trend also extended to the middle and base widths of the triangular area, which increased proportionally. Notably, a longer femur does not necessarily correspond to a longer linea aspera or a wider distribution of metaphyseal vascular foramina.

The linea aspera is a prominent longitudinal anatomical structure extending along the posterior surface of the femoral shaft. It becomes more defined as an individual approaches adulthood and plays a critical role in the balanced distribution of mechanical loads on the bone. Through adaptive bone remodeling, the linea aspera forms a typical linea aspera-pilaster complex, which appears as a characteristic radiographic feature resembling railway tracks.[12-14] A practitioner must be aware of this normal anatomical formation to avoid misinterpreting it as a pathological flare sign indicating Paget's disease.[14]

In fractures affecting the midshaft of the femur, the proximal portion of the linea aspera is exerted by flexion and abduction force vectors, whereas the distal segment is exerted by superior and medial force vectors. When surgically aligning fractures involving the linea aspera, tracking this distinct anatomical landmark on the posterior midline of the femur serves as a crucial guide.[10] Morphometric features of the posterior femur vary across different populations and even within the same population. Aksu et al.[15] studied dry femurs from the Turkish population, reporting an average femur length of 42.3 cm and a linea aspera length of 14.4 cm. Although their definition of the linea aspera was similar to that used in this study, they reported significantly higher values for its length. Similarly, Polguj et al.[2] examined femurs from different sexes, reporting average femur lengths of 42.1 cm in females and 45.6 cm in males. They classified the linea aspera morphology into four types-parallel, concave, convex, and variform-reporting corresponding lengths of approximately 18.1 cm, 19.5 cm, 18.5 cm, and 19 cm. Meanwhile, Solan and Kulkarni[16] reported a linea aspera length of approximately 10.3 cm in a South Indian population, closely aligning with our findings. Variations in reported values across studies may stem from differences in genetic background, age, and sex-dependent bone remodeling processes.

The femur is a critical bone in paleoanthropology and forensic research due to its considerable size and distinctive anatomical landmarks. Various anatomical structures, including the femur length, greater and lesser trochanters, and linea aspera, can be used to estimate age[17], sex[18], stature[16], and activity-related bone adaptations.[19] Moreover, certain morphometric parameters allow for accurate estimation of total femur length based on fragmented remains.[20] Therefore, studying population-specific morphometric data and interrelationships among femoral parameters is essential. Gidna and Domínguez-Rodrigo[17] developed a method using linea aspera length to estimate femur shaft dimensions, reporting that linea aspera-to-femur length ratios were 28.24% in females and 29.09% in males. However, in this study, the linea aspera-to-femur length ratio was approximately 21.8%, with no significant correlation found between these two parameters. The discrepancy in findings across studies may be attributed to differences in age, sex, and ethnic composition of the sample populations.

To the best of our knowledge, this is the first study to provide morphometric data on gluteal tuberosity. This roughened surface, serving as the attachment site for the gluteus maximus muscle, is located between the posterior surface of the greater trochanter and the linea aspera. In some cases, its superior margin forms a distinct bony prominence known as the third trochanter, with a reported prevalence of 6.1%.[18] In our sample, no third trochanter was observed, but the gluteal tuberosity exhibited a varying degree of surface roughness, extending obliquely from the superolateral to inferomedially. Notably, no correlation was found between the gluteal tuberosity length and other femoral parameters.

The triangular popliteal surface is a key structure forming the superior portion of the diamond-shaped popliteal fossa. It extends distally from the divergence of the medial and lateral lips of the linea aspera to the superior border of the femoral condyles. This region accommodates critical vascular and neural structures, including the popliteal opening of the subsartorial canal (adductor hiatus), which allows the passage of femoral vessels into the popliteal fossa. The precise location of the adductor hiatus is of great importance for surgical procedures involving the distal femur and knee joint. Olson and Holt[3], in their study of 24 adult cadavers, reported that the adductor hiatus was located approximately 10 cm (right: 10 cm, left: 9.9 cm) proximally from the adductor tubercle. Kale et al.[19] measured femur length from the superior border of the greater trochanter to the intercondylar transverse line, reporting an average length of 36.92 cm (range: 33.4-44.5 cm). They determined the mean distance from the midpoint of the intercondylar line to the superior margin of the adductor hiatus to be 11.96 cm. The results of our study, combined with previous findings, suggest that the apex of the triangular popliteal surface approximately aligns with the adductor hiatus.

In our study, the mean width of the triangular popliteal surface was 6.22 cm. This measurement is comparable to the intercondylar width measured by Kale et al.[19], who

reported an average width of 8.85 cm (range: 7.63-9.47 cm). The discrepancy between these values may be attributed to differences in measurement methods, as our study measured the posterior surface of the femur, whereas Kale measured the external condylar width.

The popliteal artery, formed from the femoral artery within the triangular popliteal surface, gives rise to several branches supplying the knee and distal thigh. The metaphyseal arteries, which nourish the distal femur, form an intricate network with other nutrient foraminae within the medullary cavity. Understanding the distribution of these vascular structures is crucial for fracture management, healing, and minimizing preoperative and postoperative complications.[20,21] In this study, the foramina within the triangular popliteal surface were predominantly clustered between the medial and lateral condyles, extending towards the posterior surface of the medial condyle. Bhat et al.[4] also reported that nutrient foramina were most accumulated within the triangular popliteal surface, particularly near the medial condyle. They noted that foramina with a diameter exceeding 2 mm were more common in this region, emphasizing the clinical significance of potential hemorrhage and necrosis complications.

Study Limitations

This study has several limitations. The age, sex, and ethnic origin of the femoral specimens could not be determined, which may influence morphometric variations and limit the generalizability of the findings. Additionally, the relatively modest sample size and the exclusive use of dry bones without accompanying clinical data restrict the ability to correlate anatomical features with functional or demographic parameters. Future studies involving larger and more diverse populations, including radiological and intraoperative assessments, would provide more comprehensive insights.

CONCLUSION

This study provides new morphometric insights into the posterior surface of the femur, emphasizing the significance of the linea aspera and the triangular popliteal region in surgical planning. The findings highlight the anatomical variations that may influence distal femoral procedures, particularly in fracture fixation and vascular preservation. Understanding these structures is essential for orthopedic surgeons to optimize surgical approaches, minimize complications, and improve patient outcomes. Future studies with larger and more diverse samples will further refine these anatomical correlations and their clinical relevance.

Ethics

Ethics Committee Approval: The study was approved by the Non-Interventional Research Ethics Committee of Buca Seyfi Demirsoy Training and Research Hospital (decision no: 2023/216, date: 27.12.2023).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Concept: İ.Ç., F.Y., Design İ.Ç., F.Y., Data Collection or Processing: İ.Ç., G.D.A., Analysis or Interpretation: İ.Ç., G.D.A., Literature Search: İ.Ç., G.D.A., F.Y., Writing: İ.Ç., G.D.A., F.Y.

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REFERENCES

1. Standring S. Gray's Anatomy The Anatomical Basis of Clinical Practice 42nd ed. Elsevier Health Sciences; 2021.
2. Polguj M, Bliźniewska K, Jędrzejewski K, Majos A, Topol M. Morphological study of linea aspera variations - proposal of classification and sexual dimorphism. Folia Morphol (Warsz). 2013;72:72-7.
3. Olson SA, Holt BT. Anatomy of the medial distal femur: a study of the adductor hiatus. J Orthop Trauma. 1995;9:63-5.
4. Bhat D, Doddaiah S, Murugesh P, Pushpa NB. Vascular anatomy of distal end of femur and its clinical implications. J. Anat. Soc. India. 2021;70:30-4.
5. Martinet O, Cordey J, Harder Y, Maier A, Bühler M, Barraud GE. The epidemiology of fractures of the distal femur. Injury. 2000;31(Suppl 3):62-94.
6. Henderson CE, Kuhl LL, Fitzpatrick DC, Marsh JL. Locking plates for distal femur fractures: is there a problem with fracture healing? J Orthop Trauma. 2011;25 (Suppl 1):8-14.
7. Nester M, Borrelli J Jr. Distal femur fractures management and evolution in the last century. Int Orthop. 2023;47:2125-35.
8. Aggarwal S, Rajnish RK, Kumar P, Srivastava A, Rathor K, Haq RU. Comparison of outcomes of retrograde intramedullary nailing versus locking plate fixation in distal femur fractures: a systematic review and meta-analysis of 936 patients in 16 studies. J Orthop. 2022;36:36-48.
9. Gangavalli AK, Nwachuku CO. Management of distal femur fractures in adults: an overview of options. Orthop Clin North Am. 2016;47:85-96.
10. Abdelaal AH, Yamamoto N, Hayashi K, et al. The linea aspera as a guide for femoral rotation after tumor resection: is it directly posterior? A technical note. J Orthop Traumatol. 2016;17:255-9.
11. Peschiera V, Staletti L, Cavanna M, Saporito M, Berlusconi M. Predicting the failure in distal femur fractures. Injury. 2018;49 (Suppl 3):2-7.

12. Jang SJ, Kunze KN, Casey JC, et al. Variability of the femoral mechanical-anatomical axis angle and its implications in primary and revision total knee arthroplasty. Bone Jt Open. 2024;5:101-8.
13. Pitt MJ. Radiology of the femoral linea aspera-pilaster complex: the track sign. Radiology. 1982;142:66.
14. Gheorghiu D, Leinenkugel A. The linea aspera-pilaster complex as a possible cause of confusion with the 'flame sign': a case report. Acta Orthop Traumatol Turc. 2010;44:254-6.
15. Aksu F, Akkoç RF, Biçer A, Aras O, Kavaklı A, Ögetürk M. Femur kuru kemiklerinde linea aspera'nın morfometrik Öözellikleri. Firat Med J. 2023;28:220-5.
16. Solan S, Kulkarni R. Estimation of total length of femur from its fragments in south indian population. J Clin Diagn Res. 2013;7:2111-5.
17. Gidna AO, Domínguez-Rodrigo M. A method for reconstructing human femoral length from fragmented shaft specimens. Homo. 2013;64:29-41.
18. Bolanowski W, Smiszkiewicz-Skwarska A, Polguj M, Jedrzejewski KS. The occurrence of the third trochanter and its correlation to certain anthropometric parameters of the human femur. Folia Morphol (Warsz). 2005;64:168-75.
19. Kale A, Gayretli O, Oztürk A, et al. Classification and localization of the adductor hiatus: a cadaver study. Balkan Med J. 2012;29:395-400.
20. Reddy AS, Frederick RW. Evaluation of the intraosseous and extraosseous blood supply to the distal femoral condyles. Am J Sports Med. 1998;26:415-9.
21. Chen MJ, Goodnough LH, Salazar BP, Gardner MJ. Impact on periosteal vasculature after dual plating of the distal femur: a cadaveric study. OTA Int. 2021;4:e131.