Quantitative assessment of changes in lesser trochanter shapes in relation to femoral rotations

Ali Turgut, Anıl Koca, Melişah Uzakgider, Sertan Hancıoğlu, Serkan Erkuş, Önder Kalenderer

Department of Orthopaedics and Traumatology, Tepecik Training and Research Hospital, İzmir, Turkey

ABSTRACT

Objective: The aim of this study was to evaluate changes in lesser trochanter shapes in relation to femoral rotations and to develop a reference value for the determination of clinically relevant malrotation of the femur.

Methods: Patients who underwent computed tomography angiography between January 2009 and July 2018 were identified based on a review of their institutional medical records. Thereafter, three-dimensional (3D) images of the whole femur for a total of 860 patients were obtained from their tomographic sections. The distance between the lateral outer cortex of the femur and the most medial point of the lesser trochanter with the femur in neutral rotation was measured and set as the reference value. Then, the same distance was measured at 5°, 10°, 15°, and 20° of femoral internal rotation and at 5°, 10°, 15°, 20°, and 25° of femoral external rotation. To avoid magnification errors, the reference values were divided by each measured value at these different rotation angles and then multiplied by 100.

Results: The mean distances between the lateral cortex of the femur and the most medial point of the lesser trochanter at 5°, 10°, 15°, and 20° of femoral internal rotation were 97%, 95%, 90%, and 88%, respectively, of those measured with the femur in neutral rotation. The same distances at 5°, 10°, 15°, 20°, and 25° of femoral external rotation were 102%, 104%, 106%, 107%, and 108%, respectively, of those measured with the femur in neutral rotation. There was no statistically significant difference between the measured distances in males and females (p>0.05). However, significant differences were observed among each measured distance at different angles of femoral rotation (p<0.01).

Conclusion: The surgeon should be aware of the possible femoral malrotation if the distance between the lateral cortex of the femur and the most medial point of the lesser trochanter on the operated side is more than 106% or less than 90% of that measured with the femur in neutral rotation on the healthy side.

Level of Evidence: Level IV, Diagnostic study

Femoral shaft fractures are commonly seen among all age groups after high-energy injuries (1, 2). Intramedullary nailing is the treatment of choice for a majority of such fractures (3). Formerly, fractures were treated by the open technique; however, in the recent years, closed reduction is the preferred method for treating femoral shaft fractures; it allows faster healing in a minimally invasive manner, leading to the preservation of femoral shaft biology. After the closed reduction of fractures, the probability of malreduction (e.g., malrotation) increases in comparison with open reduction techniques. The reason for this higher probability is that the surgeon is unable to directly visualize the key points for anatomic reduction as opposed to that with open reduction (4). The incidence of clinically relevant malrotation of at least 15° after femoral shaft fractures has been reported to be between 17% and 35% (5-8). To overcome this complication, several clinical and radiological methods have been described. Clinically, malrotation can be observed by comparing the range of movements during external and internal rotations of both the hip joints (7). Radiologically, rotational deformity can be assessed by comparing femoral neck anteversions (9). Ultrasonography and computed tomography (CT) have also been used (10, 11). Cortical step sign and diameter difference sign have been described in detail (12). The lesser trochanter shape sign was described in 1998 by Krettek et al.; thereafter, Kim et al. used it to predict the rotational malalignment in femoral shaft fracture treatment (4, 13). Malrotation of more than 15° may lead to early arthritis of the hip and knee joints; therefore, it is of clinical importance (8, 14). It becomes more difficult to overwhelm the resultant deformity after the union of the fracture (4). In order to prevent possible complications, as
mentioned earlier, one should be aware of the amount of rotational deformity and should make every effort to correct it, preferably intraoperatively. In this study, we aimed to create a reference on the amount of rotational deformity by measuring the femoral width at the level of lesser trochanter at different degrees of internal and external rotations.

**Materials and Methods**

This study was performed in a tertiary-care training and research hospital after obtaining local ethics committee approval (number: 2018/16-14). Patients who underwent CT angiography (CTA) between January 2009 and July 2018 were searched from our institutional medical records. Patients older than 18 years who underwent the whole lower extremity CTA were included in this study. Patients who underwent CTA for different body parts, those who were younger than 18 years, those with a previous lower extremity injury, or those who had undergone arthroplasty and did not have an appropriate view of the femur were excluded. Finally, 860 patients were included in this study (Figure 1).

**Method of measurement**

Using a RadiANT DICOM Viewer 2.2.9° (Medixant, Poznan, Poland), obtained DICOM-type axial CT images were reconstructed into three-dimensional (3D) images of the entire femur and patella. Vascular and other structures interfering with the femoral images were cut from the created 3D images. 3D images with the patella facing forward were accepted as neutral views. The distances between the lateral outer cortex of the femur and the most medial point of the lesser trochanter were measured and noted as reference values. Thereafter, the same distance was measured at 5°, 10°, 15°, and 20° of femoral internal rotation and at 5°, 10°, 15°, 20°, and 25° of femoral external rotation (Figure 2. a–j). To avoid magnification errors, the reference values were divided by each measured value at different rotations and multiplied by 100. The obtained percentages were also noted. The measurements were performed by three of the authors (AK, MU, and SH), and a mean value of these three measurements was calculated.

**Statistical analysis**

The Statistical Package for the Social Sciences version 17.0 (SPSS Inc.; Chicago, IL, USA) was used to calculate the mean, standard deviation, and minimum and maximum values as percentages. 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**

Among all the study patients, 112 (13.02%) were female, and the average patient age was 59.5±17.9 years (range: 18–96 years). The mean distances between the lateral cortex and the most medial point of the lesser trochanter at 5°, 10°, 15°, and 20° of femoral internal rotation were 97%, 93%, 90%, and 88%, respectively, of those measured with a neutrally rotated femur. The same distances at 5°, 10°, 15°, 20°, and 25° of femoral external rotation were 102%, 104%, 106%, 107%, and 108%, respectively, of those measured with a neutrally rotated femur (Table 1). The mean cutoff values for a clinically relevant malrotation of 15° during internal and external rotations were found to be 90% and 106%, respectively (Table 1, Figure 3). The measured distance decreased with internal rotation and increased with external rotation. Because of the importance of the outlier values, box and whisker plots were constructed (Figure 4, 5). For 15° of internal and external rotations, there were 14 and 3 measured outliers, respectively. There was no statistically significant difference in the calculated values between males and females (Table 2). A statistically significant difference was observed among all the groups of internal and external rotation percentages after performing ANOVA with post hoc testing (p<0.01). Similarly, there was a statistically significant difference among all the groups regarding both internal and external rotation percentages (Table 3).

**Discussion**

Minimally invasive nailing of the femur is the most preferred treatment for femur fractures in adults (3). The complication of...
Malrotation can be observed after closed treatment of such fractures, particularly if the fracture is transverse, comminuted, or segmental (7). Intraoperatively, the lesser trochanter shape sign is a useful tool to detect rotational malalignment, but the amount of deformity cannot be determined using this method (4, 13). In this study, we observed that if the quotient of the distances measured between the lateral cortex and the most medial point of the lesser trochanter at various angles divided by the distance at a neutrally rotated femur (forward-facing patella) decreases to a value less than or equal to 90% or increases to 106% or higher, malrotation can be observed after closed treatment of such fractures, particularly if the fracture is transverse, comminuted, or segmental (7). Intraoperatively, the lesser trochanter shape sign is a useful tool to detect rotational malalignment, but the amount of deformity cannot be determined using this method (4, 13).

### Table 1. Percentages of values that were measured at different rotational angles with respect to the value measured for neutral rotation

| Amount of rotation       | Mean percentage ± standard deviation (minimum–maximum) | 95% CI (lower–upper bounds) |
|--------------------------|--------------------------------------------------------|-----------------------------|
| 20° internal rotation    | 88%±4% (80%–99%)                                       | 87.7%–88.3%                 |
| 15° internal rotation    | 90%±3% (84%–99%)                                       | 89.8%–90.2%                 |
| 10° internal rotation    | 93%±2% (87%–100%)                                      | 92.9%–93.1%                 |
| 5° internal rotation     | 97%±2% (88%–103%)                                      | 96.9%–97.1%                 |
| 5° external rotation     | 102%±2% (95%–110%)                                     | 101.8%–102.2%               |
| 10° external rotation    | 104%±2% (97%–107%)                                     | 103.8%–104.2%               |
| 15° external rotation    | 106%±3% (97%–121%)                                     | 105.8%–106.2%               |
| 20° external rotation    | 107%±4% (100%–122%)                                    | 106.7%–107.3%               |
| 25° external rotation    | 108%±5% (101%–129%)                                    | 107.7%–108.3%               |

### Table 2. Comparison of the values between females and males

| Amount of rotation       | Female (n=112) Mean (%)±standard deviation (minimum–maximum)/95% CI (lower–upper bounds) | Male (n=748) | p* |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-------------|----|
| 20° internal rotation    | 87%±4% (80%–92%)/(86.3%–87.7%)                                                                                           | 88%±4% (80%–99%)/(88.7%–8.3%) | 0.17 |
| 15° internal rotation    | 90%±3% (84%–94%)/(89.4%–90.6%)                                                                                           | 90%±3% (86%–99%)/(89.8%–90.2%) | 0.47 |
| 10° internal rotation    | 93%±2% (90%–98%)/(92.6%–93.4%)                                                                                           | 93%±2% (87%–100%)/(92.9%–93.1%) | 0.20 |
| 5° internal rotation     | 96%±2% (88%–98%)/(95.6%–96.4%)                                                                                           | 97%±2% (91%–103%)/(96.9%–97.1%) | 0.39 |
| 5° external rotation     | 101%±2% (95%–104%)/(100.7%–103.3%)                                                                                       | 102%±2% (97%–110%)/(101.9%–102.1%) | 0.35 |
| 10° external rotation    | 102%±2% (97%–106%)/(101.6%–102.4%)                                                                                       | 104%±2% (99%–107%)/(103.9%–104.1%) | 0.12 |
| 15° external rotation    | 105%±3% (100%–110%)/(104%–106%)                                                                                          | 106%±3% (97%–122%)/(105.8%–106.2%) | 0.38 |
| 20° external rotation    | 105%±3% (100%–122%)/(104%–106%)                                                                                          | 107%±4% (100%–121%)/(106.7%–107.3%) | 0.08 |
| 25° external rotation    | 107%±4% (102%–122%)/(106%–108%)                                                                                          | 108%±5% (101%–129%)/(107.6%–108.4%) | 0.26 |

*p* Student’s *t*-test

Figure 2. a–j. Measurements performed at 20° (a), 15° (b), 10° (c), and 5° (d) of internal rotations; neutral rotation (e); and 5° (f), 10° (g), 15° (h), 20° (i), and 25° (j) of external rotations; ir: internal rotation; er: external rotation.
15° of internal or external malrotation, respectively, should be carefully considered.

CT imaging has been accepted as the most reliable method to determine the rotational malalignment of the femur. However, besides being expensive, CT imaging poses a high radiation risk to patients (15). The ability to assess the rotational deformity from a single plain radiography would be very advantageous to avoid such undesirable consequences. Therefore, we believe that creating a reference will be very convenient, and the present study can be appropriate for this purpose (because 860 femoral images were assessed).

Recently, Marchand et al. have studied the accuracy of the lesser trochanter shape for determining the rotational status of the femur (16). The authors evaluated CT scans of 152 consecutive patients. As a conclusion, no difference between the sexes was reported, which is similar to the results obtained in the present study. The accuracy of the lesser trochanter shape sign was confirmed.

Jaarsma et al. reported an in vitro study with 10 intact human femora that deals with the avoidance of rotational malalignment in the femoral shaft fracture treatment by using the lesser trochanter shape (17). The authors evaluated three methods to determine such a rotation. As a conclusion, they stated that using a reference view, lesser trochanter shape measurement yielded a nearly excellent evaluation of rotation. This study also confirms the accuracy of the lesser trochanter sign for assessing the rotational alignment of the femur. Although the aforementioned

---

**Table 3.** Statistical comparison of the values for external and internal rotation groups*

| External rotation | 5°   | 10°  | 15°  | 20°  | 25°  | Internal rotation | 5°   | 10°  | 15°  | 20°  |
|-------------------|------|------|------|------|------|-------------------|------|------|------|------|
| 5°                | X    | p<0.01| p<0.01| p<0.01| p<0.01| 5°                | X    | p<0.01| p<0.01| p<0.01|
| 10°               | p<0.01| X    | p<0.01| p<0.01| p<0.01| 10°               | p<0.01| X    | p<0.01| p<0.01|
| 15°               | p<0.01| p<0.01| X    | p<0.01| p<0.01| 15°               | p<0.01| p<0.01| X    | p<0.01|
| 20°               | p<0.01| p<0.01| p<0.01| X    | 0.02| 20°               | p<0.01| p<0.01| p<0.01| X    |
| 25°               | p<0.01| p<0.01| p<0.01| 0.02| X    | 25°               | X    | X    | X    | X    |

*Student’s t-test
study was of significance, it did not contribute toward estimating the amount of rotation.

Zhang et al. are the only group to study the lesser trochanter shape sign by performing measurements at different angles (18). Conventional radiographic views of the proximal femurs of 50 healthy adult volunteers were evaluated at the neutral position as well as at 5°, 10°, 15°, and 20° of both internal and external rotations. The measurements were performed using a baseline and the highest point of the lesser trochanter. In contrast to the results reported by these authors, we mentioned the percentages as well. The mean values of the measured distances at 15° of internal and external rotations were 79% and 118%, respectively, of the distance at neutral rotation for the left femurs of men; the corresponding values were similar for the right femurs (78% and 119%, respectively). The mean values of the measured distances at 15° of internal and external rotations were 76% and 120%, respectively, of the distance at neutral rotation for the left femurs of women; the corresponding values were similar for the right femurs (75% and 118%, respectively). We believe that this is also a critical study that can serve as a reference for the detection of the amount of rotational deformity. However, the strength of our study is that we calculated the percentages and have taken them into account. Values were not evaluated in millimeters or centimeters; therefore, we believe that the magnification error—a critical issue otherwise—was not an issue in our study. The percentage values reported in the abovementioned studies and the present study are different from each other; this is attributable to the fact that the reference points for the measurements were different.

This study has several limitations. The measurements of the contralateral femurs were not performed and compared. Performing this comparison would have facilitated the evaluation of the accuracy of the lesser trochanter shape sign. Another important limitation is that it can be difficult to prevent magnification errors when using this method intraoperatively. In this case, we recommend the use of a scalpel handle, using which the length can be determined. Another limitation is that the intra- and inter-rater reliabilities of the measurements were not assessed. This study also has certain strengths. Performing evaluation in percentages instead of measurement units prevented possible magnification errors, which is very important for such studies. Another advantage is the crowded population.

In conclusion, we recommend to pull out the distal interlocking screws or plate screws when performing intramedullary nail or plate-screw fixation for femur fractures and to correct the rotational malalignment if the distance between the lateral cortex of the femur and the most medial point of the lesser trochanter is more than 106% or less than 90% of the distance with neutrally rotated femur on the healthy side.

Ethics Committee Approval: Ethics committee approval was received for this study from the Local Ethics Committee of Tepecik Training and Research Hospital (number: 2018/16-14).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Author Contributions: Concept - A.T., Ö.K.; Design - A.T., A.K., S.H.; Supervision - Ö.K.; Materials - A.T., A.K., M.U., S.H., S.E.; Data Collection and/or Processing - M.U., S.H., S.E.; Analysis and/or Interpretation - A.K., M.U., S.H.; Literature Search - A.T., A.K., M.U.; Writing Manuscript - A.T., A.K.; Critical Review - A.T., Ö.K.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declare that this study has received no financial support.

References

1. Salminen ST, Pihlajamaki HK, Avikainen VJ, Böstman OM. Population based epidemiologic and morphologic study of femoral shaft fractures. Clin Orthop Relat Res 2000; 372: 241-9. [CrossRef]

2. Court-Brown CM, Rimmer S, Prakash U, McQueen MM. The epidemiology of open long bone fractures. Injury 1998; 29: 529-34. [CrossRef]

3. Ramme AJ, Egol J, Chang G, Davidovich RI, Konda S. Evaluation of malrotation following intramedullary nailing in a femoral shaft fracture model: Can a 3D c-arm improve accuracy? Injury 2017; 48: 1603-8. [CrossRef]

4. Krettek C, Miclau T, Gru O, Schandelmaier P, Tcherne H. Intraoperative control of axes, rotation and length in femoral and tibial fractures technical note. Injury 1998; 29: 29-39. [CrossRef]

5. Zeckey C, Bogusch M, Borkovec M, et al. Radiographic cortical thickness parameters as predictors of rotational alignment in proximal femur fractures: A cadaveric study. J Orthop Res 2019; 37: 69-76. [CrossRef]

6. Braten M, Terjesen T, Rossvoll. Torsional deformity after intramedullary nailing of femoral shaft fractures. Measurement of anteverision angles in 110 patients. J Bone Joint Surg Br 1993; 75: 799-803. [CrossRef]

7. Jaarsma RL, van Kampen A. Rotational malalignment after fractures of the femur. J Bone Joint Surg Br 2004; 86: 1100-4. [CrossRef]

8. Zeckey C, Monsell F, Jackson M, et al. Femoral malrotation after surgical treatment of femoral shaft fractures in children: a retrospective CT-based analysis. Eur J Orthop Surg Traumatol 2017; 27: 1157-62. [CrossRef]

9. Rippstein VJ. Zur bestimmung der antetorsion des schenkelhalses mittels zweier röntgenaufnahmen. Z Orthop 1995; 86: 345-60. [CrossRef]

10. Bräten M, Terjesen T, Rossvoll I. Femoral anteverision in normal adults: ultrasound measurements in 50 men and 50 women. Acta Orthop Scand 1992; 63: 29-32. [CrossRef]

11. Wissing H, Buddenbrock B. Determining rotational errors of the femur by axial computerized tomography in comparison with clinical and conventional radiologic determination. Unfallchirurgie 1993; 19: 145-57. [CrossRef]

12. Ruedi TP, Murphy WM. AO. Principles of Fracture Management. New York: Thieme; 2000: 210-4. [CrossRef]

13. Kim J, Kim E, Kim KY. Predicting the rotationally neutral state of the femur by comparing the shape of the contralateral lesser trochanter. Orthopedics 2001; 24: 1069-70. [CrossRef]

14. Karaman O, Ayhan E, Kesmezacar H, Seker A, Unlu MC, Aydingoz O. Rotational malalignment after closed intramedullary nailing of femoral shaft fractures and its influence on daily life. Eur J Orthop Surg Traumatol 2014; 24: 1243-7. [CrossRef]
15. Kuo TY, Skedros JG, Bloebaum RD. Measurement of femoral anteversion by biplane radiography and computed tomography imaging: comparison with anatomic reference. Invest Radiol 2003; 38: 221-9. [CrossRef]

16. Marchand LS, Todd DC, Kellam P, Adeyemi TF, Rothberg DL, Maak TG. Is the lesser trochanter profile a reliable means of restoring anatomic rotation after femur fracture fixation? Clin Orthop Relat Res 2018; 476: 1253-61. [CrossRef]

17. Jaarsma RL, Verdonschot N, Van der Venne R, Van Kampen A. Avoiding rotational malalignment after fractures of the femur by using the profile of the lesser trochanter: an in vitro study. Arch Orthop Trauma Surg 2005; 125: 184-7. [CrossRef]

18. Zhang Q, Liu H, Chen W, et al. Radiologic measurement of lesser trochanter and its clinical significance in Chinese. Skeletal Radiol 2009; 38: 1175-81. [CrossRef]