Acta Scientific Orthopaedics (ISSN: 2581-8635)

Volume 6 Issue 9 September 2023

Review Article

Femoral Malrotation Following Intramedullary Nailing of Femoral Shaft Fractures

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DOI: 10.31080/ASOR.2023.06.0827

Received: August 21, 2023

Published: August 29, 2023

Abstract

Femoral malrotation represents one of the common causes of deformity following intramedullary nailing of femoral shaft fractures that can lead to cosmetic and functional consequences. Femoral malrotation is often underrecognized because femoral rotation is variable amongst the population and even variable within a patient comparing one's own lower extremities. Moreover, femoral malrotation is difficult to measure. Clinical examination, ultrasonography, radiography, and computed tomography have all been described to measure femoral malrotation. In this review, we discuss the IMN complication of femoral malrotation with respect to its definition, functional significance, how to measure it, and treatment.

Keywords: Femoral Malrotation; Femoral Torsion; Intramedullary Nailing; Femoral Shaft Fractures

Abbreviations

IMN: Intramedullary Nail; CT: Computed Tomography; AP: Anterior-Posterior

Introduction

The worldwide incidence of femoral shaft fractures ranges between 10-21 per 100,000 per year and represent one of the most common fractures treated by orthopedic surgeons. These fractures follow a bimodal distribution either occurring from high energy mechanisms in the youthful population or low energy mechanism in the elderly population. Other less common causes of femoral shaft fractures include atypical fractures resulting from bisphosphonate use, pathologic fractures through lesions, insufficiency fractures due to osteoporosis, stress fractures due to overuse in the athletic and military population. Femoral shaft fractures also can be associated with an ipsilateral femoral neck fracture, which must be assessed. Moreover, femoral shaft fractures can occur bilaterally in a high energy trauma, and 80% of patients with bilateral femoral shaft fractures have associated injuries, which necessitates a thorough systemic work-up [1].

Over the last few decades intramedullary nailing (IMN) has become the standard of treatment for femoral shaft fractures in physiologically stable patients. Initially described by Dr. Gerhard Küntscher for the treatment of femoral fractures in the 1940s during World War 2, IMN offers the major advantages of reduced soft tissue damage, early mobilization, preserved periosteum and hematoma around the fracture site, and high union rates [1,2].

Despite these advantages, one common complication that can arise from IMN is femoral malrotation. Femoral malrotation is the most common cause of deformity following a femoral IMN and can lead to functional and cosmetic complaints, although its consequences are not completely understood. Femoral malrotation has been described to occur in up to 27.6% of femoral IMNs; however, the complication is often underrecognized, as there is variation regarding normal anatomy in addition to the fact that femoral malrotation is difficult to measure [1-3]. In this review, we discuss the IMN complication of femoral malrotation with respect to its definition, functional significance, how to measure it, and treatment.

Definition of femoral malrotation and functional significance

To determine femoral malrotation, one first measures the femoral anterversion of both femurs, which is defined as the angle between a line through the femoral neck and a line through the posterior aspect of posterior femoral condyles. Then the difference between these femoral anteversion angles of each femur constitutes the femoral malrotation for the side of interest [4]. It should be noted that the amount of femoral anteversion a person possesses is highly variable and patient-specific, which makes a defined abnormal value for femoral malrotation difficult to confirm [3]. Even in normal patient controls, the femoral rotation difference between femurs within a patient can be variable, as one study found a femoral anterversion difference of 11.8° [5]. While debated, rotational differences <10° are generally considered normal, whereas >15° are considered to be malrotated with respect to most authors [6-9]. This leaves the 10-14° range as a "grey area", which needs to be correlated with the patient's clinical picture [6]. However, it again must be emphasized that defining malrotation with a specific cutoff is difficult, as some authors even claim that patients can tolerate 15°-30° of rotational difference, and really >30° is when serious complaints of malrotation start to affect the patient clinically, whereas other authors support that >10° can lead to a significant effect [6,10-13].

The effect of femoral malrotation on patient outcome and function depends on the amount of femoral malrotation as well as individual patient thresholds to tolerating the malrotation. Bråten et al. measured femoral malrotation after IMN in 110 patients, and found that of the 21 patients that had malrotation 15°, only 8 had complaints of malrotation. Moreover, of the 26 patients that had femoral malrotation in the 10-14° range, only 3 patients had complaints [14]. Gugala., *et al*. also performed a study on 16 patients with healed femoral fracture treated with IMN and found that patients could tolerate and compensate for femoral malrotation to a great extent [15]. On the other hand, Karaman et al. assessed 24 patients who underwent IMN and found that 10/24 (41.7%) of patients had 10° of femoral malrotation and these patients had significantly decreased Western Ontario and McMaster University osteoarthritic index (WOMAC) knee scores, WOMAC hip scores, and Lysholm knee scale scores compared to those patients without malrotation. Moreover, the patients with femoral malrotation 10° had significantly more difficulty climbing stairs and complained of anterior knee pain [12]. Thus, Bråten et al. and Karaman et al. found different effects regarding the "grey area" of 10-14° of rotation [12,14]. One explanation for the variability in how femoral malrotation affects patient outcome may derive from the baseline amount of normal hip rotation, direction of the malrotation, and patient activities as well as patient expectations, but more investigation is needed [3].

Jaarsma., *et al*. assessed femoral malrotation in 76 IMN cases and found that 21/76 (28%) had femoral malrotation >15°. Moreover, these malrotation patients in their study had difficulties with running, climbing stairs, and other sporting activity. The authors found that external malrotation led to more functional problems than internal malrotation [8]. In a different study performed by Jaarsma et al., the authors found again that external malrotation led to more patients complaints. In this study, the authors analyzed the foot-progression angles during gait with a device as well as clinical complaints and functional outcome scores and related it to the femoral malrotation based off computed tomography (CT). They found that patients with external malrotation had more difficulty compensating with their foot poot progression angle compared to internal malrotation, and patients with 20° of external malrotation had significantly worse Oxford 12-item and WOMAC functional outcome scores in addition to having more clinical complaints with regard to climbing stairs [16]. In general, the literature tends to lean towards external malrotation having more of a functional impact when comparing the functional effect of external malrotation versus internal malrotation [3].

On a biomechanical level, Gugenheim et al. performed a computer model study assessing the effect of femoral malrotation, where they assessed the effect of rotation in 15° increments from 60° internal rotation to 60° external rotation at different levels of the femoral shaft, including the proximal femur, midshaft femur, and distal femur. The authors found that any external rotation at any level of the femur resulted in a posterior displacement of the weightbearing axis in the sagittal plane. Femoral malrotation of >30° internal rotation in the proximal femur, >45° internal rotation in the midshaft, and >30° external rotation in the proximal femur caused frontal plane malalignment. External rotation >45° caused knee joint malorientation. Overall, Gugenheim et al. concluded that femoral malrotation is not just a cosmetic problem but can cause malalignment and malorientation leading to functional difficulty [11].

Gugenheim's study raises concern for the long-term effects of femoral malrotation beyond cosmesis, but the exact long-term effects of femoral malrotation still remain elusive. Lee., *et al*. conducted a study on cadaveric lower extremities and found that a rotational deformity of 30° in either internal rotation or external rotation caused significantly increased tension of the quadriceps tendon and joint contact pressures in the patellofemoral joint. More specifically, external rotation resulted in increased pressures on the medial patellar facet, whereas internal rotation caused increased pressures on the lateral patellar facet. These joint contact pressures were further increased by 30° and 60° of knee flexion [17]. Yildirim., *et al*. also studied the impact of femoral malrotation on the patellofemoral joint and found that patients with >10° external rotation led to significantly decreased patella scores and medial patellar tilt compared to patients with less than 10° of rotation in either direction as well as patients with >10° internal rotation [13]. Overall, the effects of femoral malrotation lead to changes in the patellofemoral joint, which further supports the need to avoid malrotation as a complication during IMNing.

Methods to Measure Femoral Malrotation

To measure femoral rotation, one can utilize a clinical examination, ultrasound, radiographic and fluoroscopic measures, or CT [3].

Clinical examination

To measure the femoral rotation in the clinic, one performs Craig's test, which begins by positioning the patient prone on an examination table and flexing the knee to 90°. Next the examiner palpates the greater trochanter and rotates the hip until the greater trochanter reaches its most prominent lateral position. In this position, the femoral rotation can be obtained by measuring the angle between the tibial shaft and a line perpendicular to the examination table [18]. While Craig's test in the prone position is generally the mainstay clinical examination, one can also measure femoral anteversion following the same steps in the supine position and the hip flexed to 90° [3]. The hip range of motion can also be correlated with malrotation, as a difference between hip internal rotation and external rotation of 20° is indicative of malrotation [19].

The literature demonstrates that clinical measurement represents an inconsistent means of measuring femoral malrotation. Jaarsma et al. found that clinical measurement misses femoral malrotation >20° in 42% of patients measured supine and 25% of patients prone [8]. Moreover, when compared with CT scans, the 95% confidence interval of clinical measurement of femoral malrotation is ±21° with the patient supine and ±19° with the patient prone [20]. With these statistics, improved techniques should be utilized to assess femoral rotation.

Ultrasonography

Ultrasonography can also be utilized to measure femoral rotation. First described by Terjesen et al. in 1990, an ultrasound probe with an attached goniometer is utilized to measure the angle between the femoral neck and the distal femoral condyles. Ehrenstein et al. found that the femoral rotation measured by ultrasound had a median difference of ±3° compared to measurements taken by CT scans in the same 32 patients [22]. With these results, the use of ultrasound has been advocated for, especially in the postoperative setting after a IMN procedure [14].

Radiographs/Fluoroscopy

Intraoperatively, basic technique to assess for malrotation involves indirect means, such as assessing patella orientation, skin fold thickness, cortical bone thickness, or femoral alignment after reduction [9,23,24]. However, the narrow field of fluoroscopic view with the inability to see the entire full-length femur limits the ability to assess femoral alignment accurately [3]. Thus, more advanced fluoroscopic measures can be utilized for achieving proper femoral rotation.

Tornetta., *et al*. described a technique for measuring femoral anteversion. First, with the patient supine, one obtains a true lateral of the proximal femur of the uninjured side. The C-arm's angle position to obtain this view is then marked. Next a true lateral of the ipsilateral knee is obtained and again the C-arm's angle position is recorded. The difference in the C-arm angles between the two views represents the femoral anteversion. The same technique is performed on the injured side after placement of the proximal interlocking screws in the IMN. The femoral anteversion is then reduced until it matches the uninjured contralateral side and then the distal interlocking screws are placed. Tornetta et al. then performed a study assessing the outcome of femoral rotation utilizing this technique. Using a postoperative CT scan, the authors found that this technique led to a mean rotational discrepancy of 5° (range, 0° to 8°) in 12 patients between the injured and uninjured sides. These results were then compared to 22 patients that underwent IMN without the technique. Of the 22 patients without the technique, 12/22 (55%) had femoral malrotation >10°, 13/22 (59%) patients had external rotation with an average malrotation of 18° (range, 5° to 61°), and 9/22 (41%) patients had internal rotation with an average malrotation of 12° (range, 4° to 37°) [9].

Deshmukh., *et al*. described utilizing the less trochanter profile to assess for femoral malrotation. First, with the patient supine, a true lateral of the knee on the fractured side is obtained. Then the C-arm is rotated 90° without moving the lower extremity and another fluoroscopic image is taken. This anterior-posterior (AP) image is utilized to assess the less trochanter's profile. This image is then moved to the opposite side of the double screen of the fluoroscopic monitor, and then the technique is repeated on the contralateral uninjured side. The lesser trochanters' profiles are then matched to account for the rotational reduction. Theoretically, one can perform the technique on the uninjured side or the injured side in any order. Deshmukh et al. also assessed this technique utilizing a postoperative CT scan and found that all 5 patients who underwent the technique had <10° of malrotation and 4/5 had <5° of malrotation. In the control group of 5 patients that had their rotation reduced by the traditional methods of fracture alignment and a skin fold assessment, 3/5 patients had malrotation >10° and 2/5 patients had malrotation >15° [24].

Finally, a method using only lateral images can be utilized to account for femoral rotation intraoperatively. First, on the uninjured side, a true lateral of the knee. Then, with the limb stabilized and held in position, the C-arm is moved proximal to take an image proximal femur with the C-arm in the same angle as it was when obtaining the true lateral of the knee. From this view, one can measure two angles, which include the neck-femoral angle (the angle between a line down the axis of the femoral neck and a line down the axis of the femoral shaft) and the neck-horizontal angle (the angle between a line down the axis of the femoral neck and a line horizontal with the monitor). The surgeon can compare these angles to the contralateral side to obtain adequate reduction of femoral rotation [3]. Bråten., *et al*. performed this technique on 10 patients and found that all 10 patients had femoral rotation within <10° of the uninjured contralateral side when assessing them postoperatively with ultrasound [25].

Computed tomography

CT has been the mainstay for accurately measuring the femoral rotation. Jeanmart., *et al*. described their technique to measure femoral rotation on a CT. First, to draw the line down the axis of the femoral neck, one should utilize the axial cut slightly below the femoral head where the full thickness of the femoral neck can be visualized. Next, the sum of angles of anterior and posterior distal femoral condyles is obtained, although for simplicity, one can just utilize a line drawn tangent to the posterior femoral condyles. The angle between the femoral neck and the posterior femoral condyles represents femoral malrotation [26]. An alternative method proposed by Dugdale et al. involves comparing the femoral neckline and the posterior femoral condylar line to the horizontal in their respective CT scan cut as opposed to comparing the lines directly [27]. While CT scan remains the mainstay, one should note that there is some variability as Jaarsma et al. found an intraobserver variance of 3.9° and an interobserver variance of 4.1° [28].

Treatment

As discussed, there is no universally defined value for femoral malrotation where it becomes significant. Thus, a keen investigation is needed to determine when intervention is needed relying on measuring the amount of femoral malrotation and correlating it with the patient's clinical picture. Despite its shortfalls, a CT rotational profile should be conducted to best determine the degree of femoral malrotation and determine if a corrective procedure is warranted [3].

A revision IMN is easier to conduct if performed before fracture union as one can remove the IMN, reduce the malrotation, and then reinsert the IMN. However, if bony union has occurred, a derotational osteotomy is needed to correct the malrotation deformity. For this procedure, one can utilize the CT rotational profile to determine the exact amount of malrotation and how many degrees are needed to reduce the malrotation to the uninjured side. Two stout Steinmann pins (3.8mm) can be placed spanning the fracture site, with one pin place in the trochanteric region and the other pin in the distal femoral region. These pins are placed either posterior or anterior to the IMN. Moreover, these pins should be placed using a goniometer to create the angle of desired rotational correction, so when the reduction occurs, the pins will be parallel to confirm adequate reduction. Or alternatively, the pins can be placed initially in parallel and then the reduction can occur to place the pins at the desired angle of rotational correction [3].

The IMN is then removed, and a transverse osteotomy is performed with an intramedullary saw or through an open technique via multiple drill perforations. Next the intramedullary canal is reamed an additional 1.5mm greater for the new IMN. After the osteotomy and reaming, the reduction can occur to correct the malrotation using the angle between the Steinmann pins and a goniometer. The IMN is then fixated with screws, and attention must be paid to the new drill hole sites as there can be a high potential for screw cut-out if the drill hole is placed too close in proximity to the previous drill hole. Depending on the specific IMN, techniques to account for this include using alternative locking holes through the IMN, using the IMN's dynamic locking slot, or simply advancing or retracting the IMN to avoid the previous drill hole [3,29].

Conclusion

Femoral malrotation is defined as the difference between these femoral anteversion angles of each femur and different thresholds have been described. While debated, the general consensus is that <10° constitutes normal rotation and >15° constitutes malrotation, which leaves a 10-14° range that needs to be correlated with a patient's clinical presentation as malrotation can lead to cosmetic and functional consequences, especially with regard to climbing stairs and patellofemoral contact pressures. Computed tomography represents the mainstay method to measuring femoral rotation, but clinical examination, ultrasound, and radiography can be utilized. Fluoroscopy methods are utilized intraoperatively to account for femoral rotation and achieve reduction. To treat femoral malrotation, one performs a revision intramedullary nail if the bone has not yet healed, or a derotational osteotomy with a revision intramedullary nail if the bone has healed.

Bibliography

1. Denisiuk M and Afsari A. "Femoral shaft fractures". *Musculoskeletal Science and Practice* 39 (2019): 115-122.
2. Mansouri-Tehrani Mohammad Masih., *et al*. "Evaluation of femoral malrotation after intramedullary nailing". *International Journal of Burns and Trauma* 11.5 (2021): 418.
3. Lindsey Joshua D and James C Krieg. "Femoral malrotation following intramedullary nail fixation". *JAAOS-Journal of the American Academy of Orthopaedic Surgeons* 19.1 (2011): 17-26.

4. Mesgarzadeh Mamed George Revesz and Akbar Bonakdarpour. "Femoral neck torsion angle measurement by computed tomography". *Journal of Computer Assisted Tomography* 11.5 (1987): 799-803.

5. Reikeras Olav., *et al*. "Femoral neck angles: a specimen study with special regard to bilateral differences". *Acta Orthopaedica Scandinavica* 53.5 (1982): 775-779.

6. Vergano Luigi Branca Gianluca Coviello and Mauro Monesi. "Rotational malalignment in femoral nailing: prevention, diagnosis and surgical correction". *Acta Bio Medica: Atenei Parmensis* 91.14 (2020).

7. Ricci William M., *et al*. "Retrograde versus antegrade nailing of femoral shaft fractures". *Journal of Orthopaedic Trauma* 15.3 (2001): 161-169.

8. Jaarsma RL., *et al*. "Rotational malalignment after intramedullary nailing of femoral fractures". *Journal of Orthopaedic trauma* 18.7 (2004): 403-409.

9. Tornetta Paul George Ritz and Alan Kantor. "Femoral torsion after interlocked nailing of unstable femoral fractures". *Journal of Trauma and Acute Care Surgery* 38.2 (1995): 213-219.

10. Kent Matthew E., *et al*. "Assessment and correction of femoral malrotation following intramedullary nailing of the femur". *Acta Orthopaedica Belgica* 76.5 (2010): 580-584.

11. Gugenheim Joseph J., *et al*. "The effects of femoral shaft malrotation on lower extremity anatomy". *Journal of Orthopaedic trauma* 18.10 (2004): 658-664.

12. Karaman Ozgur., *et al*. "Rotational malalignment after closed intramedullary nailing of femoral shaft fractures and its influence on daily life". *European Journal of Orthopaedic Surgery and Traumatology* 24 (2014): 1243-1247.

13. Yildirim Ahmet Ozgur., *et al*. "The effect of rotational deformity on patellofemoral parameters following the treatment of femoral shaft fracture". *Archives of Orthopaedic and Trauma Surgery* 133 (2013): 641-648.

14. Braten, Martinus., *et al*. "Torsional deformity after intramedullary nailing of femoral shaft fractures. Measurement of anteversion angles in 110 patients". *The Journal of Bone and Joint Surgery British Volume* 75.5 (1993): 799-803.

15. Gugala Zbigniew., *et al*. "Long-term functional implications of the iatrogenic rotational malalignment of healed diaphyseal femur fractures following intramedullary nailing". *Clinical Biomechanics* 26.3 (2011): 274-277.

16. Jaarsma RL., *et al*. "Compensation for rotational malalignment after intramedullary nailing for femoral shaft fractures: an analysis by plantar pressure measurements during gait". *Injury* 35.12 (2004): 1270-1278.

17. Lee Thay Q., *et al*. "The influence of fixed rotational deformities of the femur on the patellofemoral contact pressures in human cadaver knees". *Clinical Orthopaedics and Related Research®* 302 (1994): 69-74.

18. Ito Ikue., *et al*. "Differences between the Craig's test and computed tomography in measuring femoral anteversion in patients with anterior cruciate ligament injuries". *Journal of physical therapy science* 32.6 (2020): 365.

19. Uding Alexandria., *et al*. "Clinical tests to determine femoral version category in people with chronic hip joint pain and asymptomatic controls". *Musculoskeletal Science and Practice* 39 (2019): 115-122.

20. Jaarsma, Ruurd Lukas, and A. Van Kampen. "Rotational malalignment after fractures of the femur". *The Journal of Bone and Joint Surgery. British volume* 86.8 (2004): 1100-1104.

21. Terjesen Terje., *et al*. "Femoral anteversion in adolescents and adults measured by ultrasound". *Clinical Orthopaedics and Related Research (1976-2007)* 256 (1990): 274-279.

22. Ehrenstein T., *et al*. "A new ultrasound-based method for the assessment of torsional differences following closed intramedullary nailing of femoral fractures". *Skeletal radiology* 28 (1999): 336-341.

23. Langer Jakub S., *et al*. "The cortical step sign as a tool for assessing and correcting rotational deformity in femoral shaft fractures". *Journal of Orthopaedic Trauma* 24.2 (2010): 82-88.

24. Deshmukh RG., *et al*. "A technique to obtain correct rotational alignment during closed locked intramedullary nailing of the femur". *Injury* 29.3 (1998): 207-210.

25. Bråten M., *et al*. "The role of fluoroscopy in avoiding rotational deformity of treated femoral shaft fractures: an anatomical and clinical study". *Injury* 31.5 (2000): 311-315.

26. Jeanmart Louis., *et al*. "Computer tomography of neck, chest, spine, and limbs". *Principles of Computerized Tomographic Imaging* (1983).

27. Dugdale Thomas W., *et al*. "The use of computed tomographic scan to assess femoral malrotation after intramedullary nailing: a case report". *Clinical Orthopaedics and Related Research* 279 (1992): 258-262.

28. Jaarsma RL., *et al*. "Computed tomography determined femoral torsion is not accurate". *Archives of orthopaedic and trauma surgery* 124 (2004): 552-554.

29. Piper Kalman., *et al*. "Correcting rotational deformity following femoral nailing". *Injury* 40.6 (2009): 660-662.