Malreductions Following Intramedullary Nail Fixation of Femur Shaft Fractures

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Funding The authors received no financial report for the research, authorship, or publication of this article.

Conflict of Interest The authors report no conflicts of interest.

ABSTRACT

Femur shaft fractures are common injuries frequently treated with intramedullary fixation. Although satisfactory alignment is usually achieved, malreductions can happen in sagittal and coronal planes, as well as along the longitude axis. The causes of malposition with femoral nailing include fracture location, comminution, and suboptimal technique. We identify the most common patterns of malreduction of nailed femur shaft fractures as well as how to avoid and treat them.

Keywords: Femur Shaft Fracture, Intramedullary Nail, Malunion, Surgical Complications

INTRODUCTION

Femoral shaft fractures are common injuries encountered by orthopaedic surgeons, and intramedullary nailing has become the standard of care for management.[1] Despite many excellent outcomes, intramedullary nailing can lead to malreduction of the femur if the surgeon is not vigilant. The goal with intramedullary nailing of femoral shaft fractures is to restore length, rotation, and alignment and provide relative stability to achieve healing by callus.[2] These factors allow the patient to mobilize quickly, often within 1 day of fracture fixation.

It is not necessary to obtain a perfect anatomic reduction of all fracture fragments for an acceptable outcome, in contrast to articular fractures. The nail acts as a strut to align the medullary canals of the proximal and distal fragments so translation deformities can be spontaneously corrected by placement of the nail, especially if the nail fits tightly within the medullary canal.[3] When the fracture is transverse in the mid-shaft, there is also spontaneous correction of coronal and sagittal plane translation and angulation. However, there are several instances in which passage of the intramedullary nail does not cause a serendipitous global reduction. This paper describes common scenarios in which additional steps must be taken to ensure adequate alignment for femur shaft fractures treated with intramedullary nail fixation.

The incidence of malunion is estimated to be 30%, although the true incidence is unknown because there is not universal agreement on the amount of deformity necessary to constitute a clinically significant amount of deformity and hence "malunion."[4] The frequency of malreduction is high enough to be a clinical problem but low enough to preclude high-quality randomized controlled studies. Therefore, our recommendations are generally based on best available evidence, which is often senior author experience consistent with existing literature. The topic is particularly important to young surgeons as it is one of the American Board of Orthopaedic Surgery assessment milestones for treatment of long bones and a common topic of Part II Board Examination.

Fracture Comminution

When comminution is present, there may be sufficient distance between the nail and the endosteal cortical bone that sagittal and coronal plane angulation or displacement are not spontaneously corrected. Blocking screws are an effective technique to prevent these types of malunions. Blocking screws placed across the medullary canal effectively reduce the internal diameter of the canal to more closely match the external diameter of the straight nail and effect reduction of the fracture. If a fracture malreduces with nail placement (angulation or displacement), the nail will not be in the center of at least one of the bone fragments (proximal or distal). One or more blocking screws across the medullary canal positioned to force the nail into the center of the fragment will correct the deformity (Figure 1).

Metaphyseal Location

Similar to fracture comminution, when the fracture occurs in meta-diaphyseal bone or severely osteoporotic bone with a very wide medullary canal, there is no contact of the nail with the endosteal cortex of the bone. When the nail is not in contact with the cortical bone in both the proximal and distal fragments, significant angulation is possible. Several techniques can address this problem. The nail diameter can be increased if the isthmus of the canal will permit.

Another option is to use a blocking screw as mentioned above (Figure 1). A third option is to make a "mini-open" approach, directly reduce the fracture, and place fixation to hold reduction during nailing and inter-lock screw placement.[5] This can be done with temporary clamps, permanent or temporary cerclage wire, or a unicortical locking plate (Figure 2).

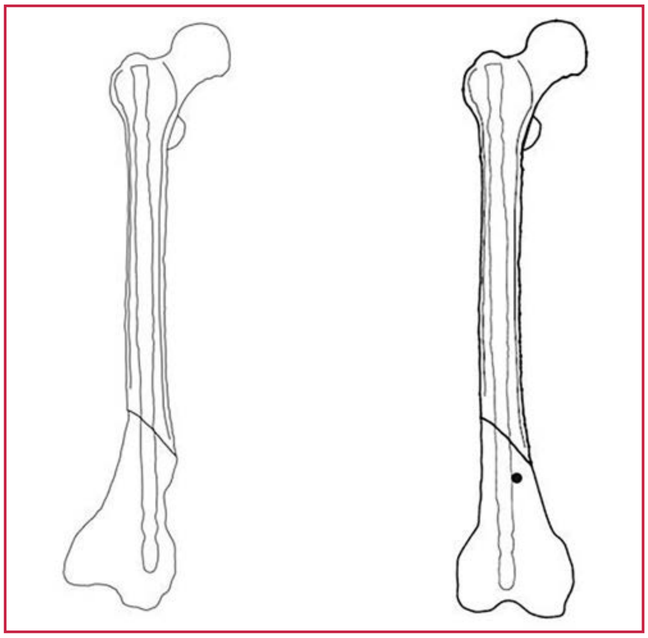

Figure 1. *Blocking screw is placed anterior to posterior medially in the proximal aspect of the distal fragment to create an artificial "endosteum." The lateral aspect of the nail contacts the blocking screw, forcing the nail into the center of the distal fragment correcting the tendency toward lateral displacement malreduction.*

When the fracture is metaphyseal (subtrochanteric or supracondylar), the fracture should be reduced prior to obtaining the starting point and this reduction should be maintained while reaming to avoid malunion.

Starting Point

Femoral nail entry points can be either proximal or distal depending on antegrade or retrograde technique. There are three different proximal entry points for antegrade femoral nails (piriformis, trochanteric, or "trochaformis"), depending on nail design (Figures 3A and 3B). The piriformis fossa was traditionally used for straight nails. For easier insertion, nails were designed for insertion through the tip of the greater trochanter. Some authors suggested an intermediate entry point (so called "trochaformis").[6] For antegrade nails, an excessively anterior entry point will cause an apex anterior angulation at the fracture site in the sagittal plane (Figures 4A and 4B). Similarly, a lateral entry point will cause an apex lateral angulation at the fracture site in the coronal plane. Using a trochanteric entry point for a nail designed for piriformis entry will produce apex medial angulation.

Retrograde nails are placed through a distal femur entry point that is centered in the coronal and sagittal plane (Figure 5).[7] The entry point is in line with the femoral shaft in all planes. Entry points are typically made percutaneously under fluoroscopic guidance, and when an entry point is incorrect, passage of the nail will force a malreduction at the fracture site even if good alignment was achieved before nail placement. For retrograde nails, an entry point made with residual apex posterior angulation at the fracture site will result in an apex posterior angulation at the fracture site when the nail is inserted, even if good alignment is achieved

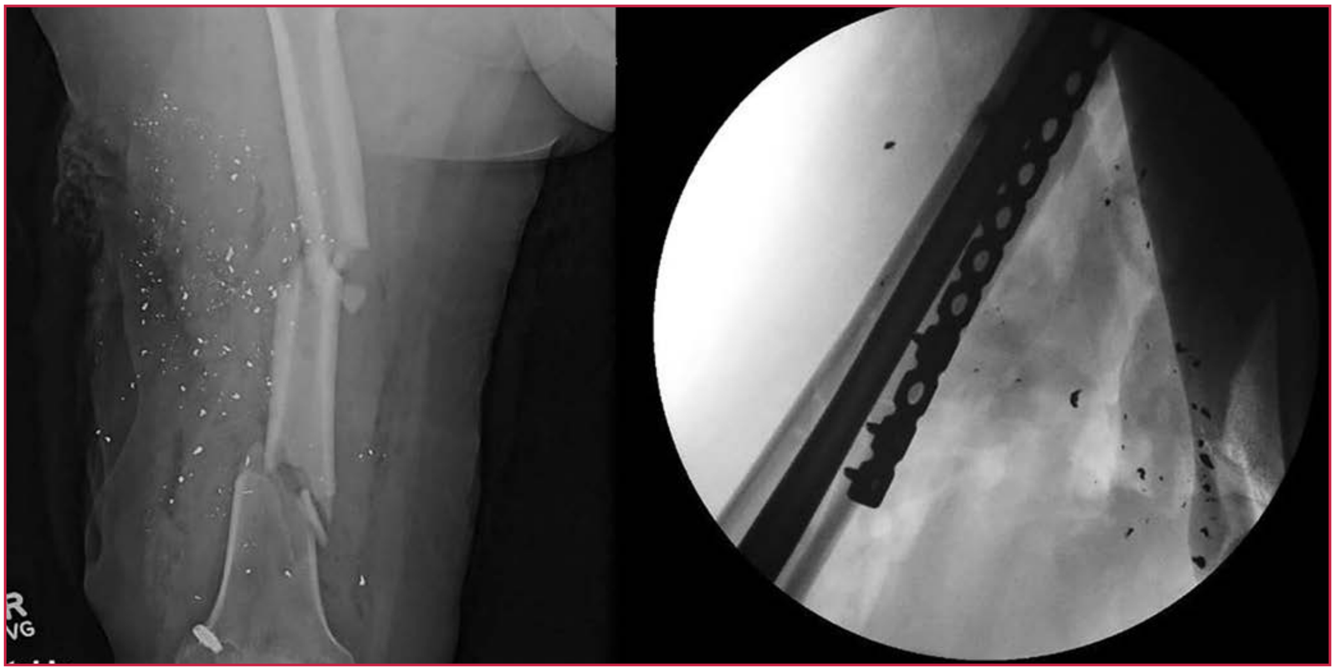

Figure 2. *A segmental femur shaft fracture treated with augmented fixation. A unicortical plate was placed before reaming to help with fracture reduction. Additionally, the plate protects the bone from devitalization during reaming.*

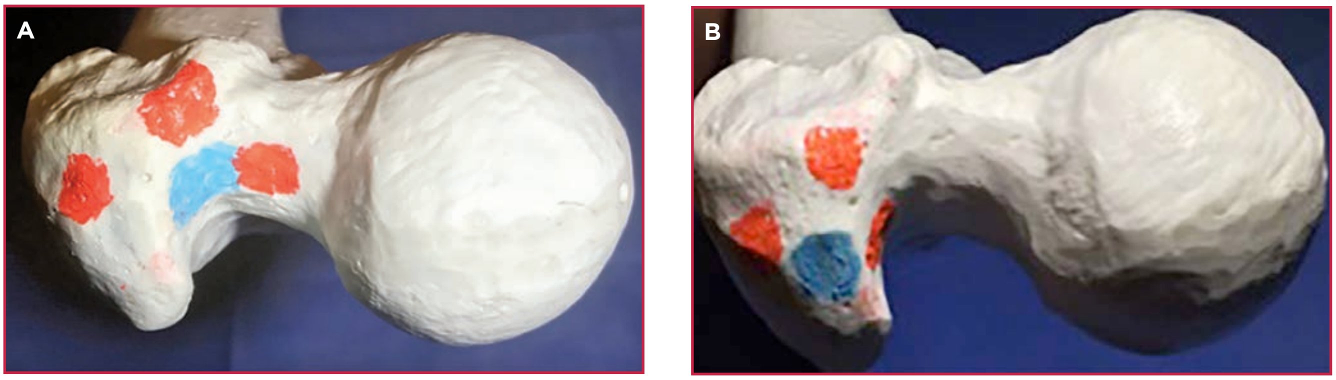

Figure 3. *Correct starting point (blue) and common entry point errors (red) for A) piriformis entry and B) trochanteric entry. In the piriformis entry, the most medial red entry increases the risk of damage to the medial femoral circumflex artery and likely avascular necrosis. The anterior and lateral red areas will result in apex anterior and lateral deformities, respectively.*

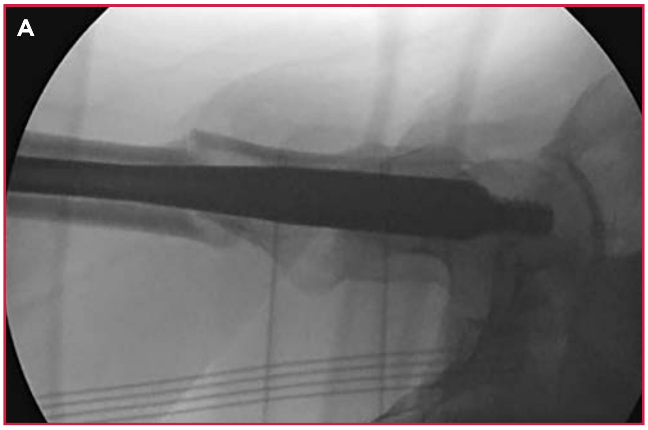

Figure 4. *Radiographs of a femur after antegrade nailing. A) Lateral view shows starting point that is too anterior, resulting in an apex anterior deformity. B) Anteroposterior view shows starting point that is too lateral, resulting in an apex lateral deformity.*

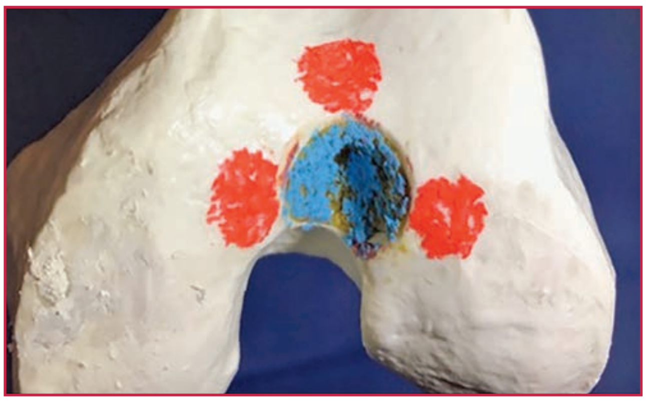

Figure 5. *Distal femur with the correct retrograde entry site in blue and common mistakes in red. Starting lateral, anterior, or medial will cause apex lateral, anterior, and medial deformities, respectively.*

Figures 3, 4, and 5 *reprinted with permission from Thomas A. DeCoster (DeCoster TA, Bozorgnia S, Kakish S. Antegrade nailing of femur shaft fractures: a review. Univ N M Orthop Res J. 2017;6:37-45).*

before nail passage. In contrast to most antegrade nails, retrograde nailing requires reduction of the fracture before establishing the entry point to avoid subsequent sagittal plan malangulation. Fracture reduction before entry site is important with antegrade nailing when the fracture is subtrochanteric and muscle tone pulls the proximal fragment away from the anatomic position.

Sub-Optimal Reaming

After the entry point is chosen and the femur accessed with the entry reamer, the guide wire is placed. It is imperative to ensure adequate reduction of the fracture site before reaming.[8] Reaming of a malreduced fracture site will result in eccentric reaming, meaning the opposing ends of the fracture site are reamed along the opposite cortices.[9] This will prevent the correct endosteal contact with the intramedullary nail at the fracture site; in other words, the improperly reamed position will be maintained after the nail has been placed. Eccentric medullary reaming can be prevented by manually holding reduction while reaming. Reaming can caused fragment displacement. A technique used to prevent displacement of comminution is a "push-past" technique, in which the reamer is stopped before the fracture site, advanced without spinning, then re-started after the cutting flutes are beyond the fracture site.[10] When dealing with intercalary segments, reaming of a segment of bone that is not rotationally stabilized can also cause catastrophic consequences and segment devitalization. This fragment of bone must be controlled by either direct clamping or temporary fixation while reaming (Figure 2).

Matching Nail Design to Femoral Anatomy

The femur has an anterior bow that is inversely measured as "radius of curvature" (ROC). The smaller the ROC, the greater the bow; the larger the ROC, the straighter the femur. Nails are manufactured with various ROCs by different companies. Most nails in current use have an ROC between 1 and 2 meters. Femoral ROC averages 2 meters in patients aged 20 years and 1 meter in those aged 65 years (increased femoral bow with age). With metabolic bone disease, the femoral bow can be even greater. Small amounts of mis-match between ROC of the broken femur and nail are not clinically significant. However, large mis-match between ROC of broken femur and nail will create clinical problems, including iatrogenic comminution, nail protrusion through the bone or malreduction at the fracture site.[11] Placing a nail that is straighter (larger ROC) than the ROC of the bone (smaller ROC) will result in apex posterior angulation at the fracture site when the nail is placed. Patients over 50 years old with femur shaft fractures often have increased bow which is important for the surgeon to identify preoperatively. The surgeon should know the ROC of available nails and either select a nail with smaller ROC or adjust the bow of the chosen nail in the operating room by gently bending it with a large plate bender.

Length Deformity

Another challenge with femoral nailing is Z-axis deformity, comprising length and rotational alignment. Unlike coronal and sagittal plane translation and angulation, which often spontaneously reduce with nail placement, Z-axis deformities do not usually spontaneously correct. Distraction can occur with any fracture pattern and can be the result of excessive traction, inadequate distal reaming, or inattention to detail. Shortening is more common in the presence of oblique fracture lines or extensive comminution.[12,13]

To avoid length problems (distraction or shortening), the surgeon must assess both direct and indirect radiographic signs. The intraoperative technique includes releasing traction before interlock screw placement and longitudinal manual tamping to avoid lengthening or correct distraction at the fracture site. Length should be assessed in the operating room using external references, although these can be unreliable owing to draping and patient positioning. Described techniques involve preoperative imaging of the contralateral limb with objective reference, like a Bovie cord or metallic ruler, that can then be referenced during the procedure.[14] If shortening is present, then additional traction can be provided to dis-impact the fracture and restore proper length before placement of a second set of locking screws.

Length should also be assessed immediately after completion of the procedure, in the operating room while the patient is still intubated. This can be performed by holding both lower extremities in a symmetric position and manually assessing limb length by either palpating the medial malleolus with knees and hips in full extension or palpating the medial femoral condyle. The earlier a limb length difference can be recognized, the easier it is to correct. Small length differences less than 20 mm in the femur are not typically clinically significant and are well tolerated.[15] As with other non-anatomic reductions, the exact amount of shortening or lengthening that may cause some clinical problem is not well defined nor universally accepted. Length restoration back to pre-fracture status should be the goal.

Rotational Deformity

Malrotation is probably the most common deformity after nailing of femur shaft fractures, but it is under recognized. This is due to the difficulty in accurately assessing rotation as well as the variation that exists in normal anatomy. One study identified a 22% incidence of malrotation more than 15°.[16] The clinical consequences of femoral malrotation are not completely understood. Biomechanical studies suggest that it causes a substantial change in load bearing in the affected extremity.[17] Malrotation will cause gait abnormality with in-toeing or out-toeing. Techniques including clinical examination and fluoroscopy are useful in measuring femoral rotational alignment intraoperatively. Postoperatively, computed tomography (CT) is useful in identifying the magnitude of malrotation and is very helpful in planning corrective de-rotation surgery.

Various techniques exist to recognize and avoid rotational malreductions. In general, the surgeon needs to identify the rotation of the proximal fragment relative to anatomic position, adjust the rotation of the distal fragment to match, and maintain that reduction until placement of the statically locked nail. The proximal radiographic landmarks include the greater and lesser trochanters. The distal radiographic landmarks include the position of the patella relative to the femur on anteroposterior (AP) view and the overlap of the medial and lateral femoral condyles on the lateral. One preferred technique involves fluoroscopy of the uninjured limb, then comparison of the fractured limb to the image before performing rotational reduction. The initial fluoroscopic step is to obtain a perfect AP of the knee with the patella exactly in the center of the distal femoral condyles, then hold that rotation on the fluoroscope and take an AP at the hip. The profile of the lesser trochanter is used to assess the degree of rotation of the proximal femur. The images are reversed (to make the right look like the left) and saved until the rotation of the fractured limb is reduced. The final rotationally reduced fracture images are compared and matched to the preoperative images of the contralateral femur (a variation of described technique by Deshmukh et al[18]).

At completion of the case, while the patient is still asleep, rotation should always be assessed by physical examination. Limbs should be compared for symmetry, particularly hip range of motion in internal and external rotation. A gunsight CT scan is the most objective measure of femoral rotation.[19] This can be obtained if there is postoperative concern for rotational malreduction. When identified early, rotational malunions can be corrected by removal of locking screws, de-rotation at the fracture site by manual manipulation in the operating room, and replacement of locking screws along a new path. If rotational malunion is found late, the fracture should be allowed to heal completely and then a de-rotation osteotomy and nail revision should be performed. Small rotational differences of less than 20° are often well tolerated by hip range of motion and do not require treatment.[20]

It is also important that the nail be placed in correct rotational relationship relative to both the proximal and distal femoral fragments so that the inherent geometry of the nail corresponds to the femoral anatomy and allows for proper interlocking screw placement.

CONCLUSION

Despite reduction difficulties often encountered during femoral nailing, knowledge of common pitfalls will allow for excellent outcomes including avoidance of malreductions.[1,21,22] It is important to identify and correct malreductions if they occur. Special operative techniques include appropriately selected and precisely placed entry sites and blocking screws. Understanding bow, ROC, and execution of rotation and length protocols can help avoid the problem of mal-reduction of nailed femur shaft fractures. When clinically significant malalignments occur in patients, they should generally undergo correction of the deformity with revision fixation.

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