### 6.6.2 Femur, shaft (incl. subtrochanteric fractures)

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6.6.2 Femur, shaft (incl. subtrochanteric fractures)

1 Introduction

1.1 Evaluation of the fracture

The soft tissues should be assessed to ensure that there is no open wound, and the neurovascular status of limb must be checked as well.

- Since the thigh has an extensive soft-tissue envelope, a high-energy injury may present with marked bone comminution, but without visible external wounds. However, a considerable muscle injury can be assumed.

The x-ray examination should consist of x-rays in two orthogonal planes. The x-rays must include the joint above and below the fracture to exclude other fractures. As femoral shaft fractures can be associated with fractures of the femoral neck, the latter must be scrutinized for the presence of such a neck fracture, which is often nondisplaced. The femoral neck is best judged in 15º of internal rotation, taking into account that the proximal femur is typically externally rotated. The femoral neck should also be checked on the initial pelvic x-rays or CT scan. After fixation of the femoral shaft fracture the femoral neck should again be evaluated by image intensifier before leaving the operating room.

1.2 Evaluation of the patient

In young patients, femoral shaft fractures are often a marker for a high-energy injury with associated lesions. Patients with bilateral femoral shaft fractures have a higher mortality rate due to the presence of other systemic injuries (5.6% versus 1.5%) [1]. All patients must be systematically assessed to ensure that other injuries are not missed.

A closed femoral shaft fracture can cause considerable bleeding into the thigh (0.5–1.5 L). However, hypotension must never be assumed to be the result of the femoral fracture. Other sources of blood loss must be sought in the abdomen, thorax, or retroperitoneum.

2 Fracture and soft-tissue classification

The Müller AO Classification classifies diaphyseal fractures (Fig 6.6.2-1) and fractures of the subtrochanteric segment as 32- (chapter 1.5). Fractures of the subtrochanteric region (proximal third of the shaft) are classified as 32-(A–C)(1–3).1 depending on the fracture pattern. Categorizing fracture patterns helps in decision making and the choice of fixation method.

A b
Before the 1970s, stabilization of long-bone fractures—including the femur—was often performed after a delay of a few days. This was thought to be advantageous for the patient as a whole as well as the fracture. It has become clear that early stabilization of long-bone fractures reduces patient morbidity and mortality, especially in the severely injured patient (chapter 4.1).

- In patients with isolated femoral shaft fractures early stabilization will lessen pain and respiratory morbidity as well as hospitalization time and treatment costs [2, 3].

There is increasing evidence that patients need to be resuscitated and in a hemodynamically stable condition before definitive operative fixation of long-bone fractures. Definitive internal fixation can lead to additional blood loss and may further stimulate a systemic inflammatory response that has already been primed by the initial soft-tissue trauma and any reperfusion injury. Patients who need ongoing resuscitation will still benefit from early fracture stabilization, especially external fixation (damage-control surgery).

Temporary external fixation has been shown to lead to less blood loss and reduce operating time when compared to intramedullary nailing or plating. It can be safely converted into an intramedullary nail fixation within 2–3 weeks after injury [4–6]. Similar morbidity rates have been observed in patients treated with external fixation and those treated with a reamed intramedullary nail, although the former had been more severely injured [7]. Current guidelines recommend that patients at high risk (ISS > 40) be treated with temporary external fixation [7]. Every femoral fracture must be surgically stabilized early in the multiply injured patient, which means within 12–24 hours [8].

**Timing of fixation—orthopedic damage-control surgery**

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**Preoperative planning**

Good preoperative x-rays are essential for planning fracture stabilization.

For multifragmentary fractures, where x-ray evaluation of cortical landmarks cannot be used, it may be difficult to judge when the correct length has been restored. Typical errors are the application of too much force with a traction table (lengthening) or not enough force with manual pulling (shortening).

Several methods can be used to determine correct length and rotation (chapter 3.3.1). They all use the intact opposite femur as a guide:

- A formal scanogram can be obtained in the x-ray department with a ruler imaged over the hip and knee.
- Femoral nails in their original packaging can be imaged over the opposite femur until a nail of correct length is found.
- A ruler can be imaged over the opposite leg in the operating room.

**Positioning and reduction**

Historically, the gold standard for positioning and reduction for intramedullary nailing had been to use a traction table. The advantages of a traction table include both familiarity and availability. Because the table holds the reduction, the procedure can be done without assistants, although an unscrubbed surgical assistant may be required for fracture reduction. The disadvantages include additional set-up time, positioning problems for patients with unstable spine and/or pelvic fractures, and the risk of pudendal nerve injury. There is limited access to the patient for anesthesia and other specialists, and
it is impossible to prepare and drape the ipsilateral lower leg or the contralateral lower extremity in patients with multiple extremity fractures. Furthermore, compartment syndrome of the uninjured leg can occur.

The femoral distractor for fracture reduction may be helpful as it is safe and effective, but it is technically demanding [9]. Manual traction on a radiolucent table has been shown to lead to a statistically significant reduction in operating time, and less table changes for patients with multiple injuries [10]. The advantages of manual traction also include improved postoperative length and rotation (CT proven) and the ability to perform multiple procedures using the same operating room table (Fig 6.6.2-2) [11].

For manual traction the fracture must be fresh (less than 24 hours old) or must have been held out to length with an external fixator or exceptionally held in traction prior to surgery. Otherwise the mechanical advantage of a traction table or a femoral distractor will be needed to regain the appropriate length.

When using a traction table, traction and abduction or adduction of the leg is used for reduction, while a crutch will help to correct sagging in the sagittal plane. With proximal fractures, the proximal fragment will displace with flexion, abduction, and external rotation, which may be difficult to correct. A reduction tool (eg, a joystick) can be inserted into the proximal fragment and used to steer it (Fig 6.6.2-3).

![Fig 6.6.2-2a–d](image-url) Positioning options for fixation of femoral shaft and subtrochanteric fractures. Viewing the normal limb permits comparison and helps to overcome difficulties with length, rotation, and axial displacements.

a Normal supine position.

b Lateral decubitus position on the normal table for intramedullary nailing.
Specific fractures
6.6 Femur

Fig 6.6.2-2a–d (cont) Positioning options for fixation of femoral shaft and subtrochanteric fractures.

c Traction table for intramedullary nailing of femoral shaft and proximal femoral fractures in the supine position.

d Position on the traction table for nailing in lateral decubitus position (more complicated).

Fig 6.6.2-3 “Dummy nail” with a handle for joystick reduction maneuvers or for mounting an aiming device for Schanz screw insertion.
When using a radiolucent table and manual traction, adequate pharmacologically induced relaxation is essential. The distal fragment can be freely manipulated to line up with the proximal fragment. Bumps placed beneath the thigh can be used to correct deformities in the sagittal plane (Fig 6.6.2-4). A femoral or tibial traction pin and bow can be used to steer the distal fragment. A femoral distractor or a temporary external fixator may also be helpful (Fig 6.6.2-5), or a percutaneous bone hook or Schanz screw may help to steer the guide wire into the distal fragment (Fig 6.6.2-6) [9]. The fractures that are hardest to reduce with manual traction are isthmus fractures in young adults with large thigh muscles and a small medullary canal. When treating proximal third fractures, positioning patients in the lateral decubitus or “floppy lateral” position will allow correction of the deforming forces on the proximal segment.

Fig 6.6.2-4a–b  Bump(s) beneath the thigh are used for fracture reduction.
Specific fractures
6.6 Femur

Fig 6.6.2-6a–c A minimal incision and a technique using a bone hook to obtain reduction.

Fig 6.6.2-5a–b Application of the distractor in femoral shaft fractures with well placed Schanz screws, especially on the distal and proximal sides.

a The proximal Schanz screw is inserted with the help of a special aiming device, so as not to interfere with the intramedullary nail.

b The two Schanz screws for the distractor may be placed in the coronal plane.

The cross section demonstrates that this technique does not violate the femoral neurovascular structures.


6.6.2  Femur, shaft (incl. subtrochanteric fractures)

6  Approaches

6.1  Intramedullary nailing

Depending upon nail design, the entry point for antegrade intramedullary nailing will vary. The entry point is either the piriformis fossa in line with the medullary canal on the AP view (Fig 6.6.2-7) or the tip of the greater trochanter. Identifying the correct entry point is essential. This will help to prevent malreduction and decrease the incidence of malalignment and the occurrence of bursting stresses in the proximal fragment when the nail is inserted.

The skin incision is typically made 2–4 cm proximal to the greater trochanter. The piriformis fossa is a posterior structure overhung by the anterior cortex of the proximal femur (Fig 6.6.2-8). Therefore, a properly placed initial guide wire

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**Fig 6.6.2-7a–b**

- a  AP view: Guide wire in line with the intramedullary canal.
- b  Lateral view: Guide wire in line with the posterior third of the femur.

**Fig 6.6.2-8a–c**  Correct entry points for various nails.
- Red = UFN.
- Blue = PFNA.
- Green = R/AFN.
will appear to be inside the bone before it actually enters the cortex (Fig 6.6.2-9).

The entry point for a retrograde nail is in line with the medullary canal on the AP view and anterior to Blumensaat’s line on the lateral x-ray (Fig 6.6.2-10). A formal medial parapatellar arthrotomy can be made, or a small percutaneous incision can be used, if intraarticular injuries have to be addressed. Splitting the patella tendon does not seem to increase the incidence of postoperative knee pain.

6.2 Plating
If open plating is performed, the incision is made on the lateral aspect of the thigh (Fig 6.6.2-11). The fascia lata is split and the vastus lateralis muscle is elevated off of the intramuscular

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Fig 6.6.2-9 Proximal femur, AP view. The guide wire appears to be inside the femur because of the posterior location of the piriformis fossa.

Fig 6.6.2-10a–b Distal femur, AP and lateral view. The entry point for retrograde femoral nails is in line with the medullary canal on the AP and lateral views.
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septum. The perforating vessels run across the operative field and are usually ligated.

Submuscular plating is used for fixation of femoral fractures extending into the metaphyseal area. One or two incisions are made proximal and/or distal to the fracture site and a plate is tunneled using a submuscular, extraperiosteal method. The periosteal blood supply at the level of the fracture is better preserved, especially when plates with locking head screws are used, e.g., LISS or LCP (Fig 6.6.2-12) [12].

Fig 6.6.2-11a–b
a The standard approach to the femoral shaft is by a straight incision on the lateral side of the thigh.

b Deep dissection follows the intermuscular septum down to the linea aspera. Expose as little bone as is required for plate placement in order to preserve the vascularity of the fragments.

Fig 6.6.2-12a–b Example of a submuscular, percutaneous approach. Plating with incisions proximal and distal to the fracture site and submuscular tunneling past the fracture site.
7 Choice of implants

7.1 Intramedullary nailing

7.1.1 Retrograde/antegrade nailing

Intramedullary nails can be introduced in an antegrade or retrograde manner. The new expert nail system provides the cannulated retrograde/antegrade femoral nail (R/AFN), which can be inserted in both directions with the same instruments. While antegrade nailing remains to be the gold standard (chapter 3.3.3), retrograde nailing has gained popularity in spite of potential drawbacks resulting from the intraarticular entry point in the knee.

Indications for retrograde nails include:
- obesity (it is very difficult to find the correct antegrade entry point);
- ipsilateral femoral neck and shaft fractures;
- ipsilateral femoral and tibial shaft fractures (one incision for both intramedullary nails) (Fig 6.6.2-13);
- multiple injuries (the surgeon can prepare and drape the opposite leg and arm, abdomen and chest on the radiolucent table);
- unstable spine injuries;
- pregnancy (minimization of the fetus’ exposure to radiation);
- an uncontaminated knee arthroscopy;
- ipsilateral pelvic and/or acetabular fractures (antegrade nail incision might interfere with subsequent incisions);
- severe soft-tissue injuries or burns at the antegrade nail starting site;
- preexisting proximal femoral hardware (Fig 6.6.2-14);
- patients with “through-knee” amputations.

Fig 6.6.2-13a–b Ipsilateral femoral and tibial fractures treated with a retrograde femoral nail and an antegrade tibial nail.

Fig 6.6.2-14a–b Fracture distal to an old sliding hip screw. It was stabilized with a retrograde nail.
The potential complications of retrograde nails result from the intraarticular entry point. So far, outcome studies have not demonstrated an increase in knee degenerative disease or limited range of motion after retrograde nailing, as long as the nail is countersunk beneath the articular surface. There have been case reports of septic knees after retrograde nailing of open femoral shaft fractures (the knee is now communicating with the open fracture site). Knee pain is more common after retrograde nailing, while hip pain and heterotopic ossification about the proximal entry point are more common after antegrade nailing [13].

Initial studies of retrograde nailing showed a lower union rate when compared to antegrade nailing. However, the nails used had not been matched to the size of the medullary canal. Prospective randomized trials revealed that more secondary procedures were needed to gain union in the retrograde group, but that overall union rates were the same [13, 14].

7.1.2 Reamed versus unreamed procedure
Femoral nails can be inserted either after reaming of the medullary canal or without reaming (“reamed” or “unreamed” intramedullary nails) (chapter 3.3.1). The union rate after insertion of nonreamed nails is lower than after using reamed nails [15, 16]. Originally, reaming was considered responsible for lethal pulmonary embolism after intramedullary nailing in severely injured patients. Recent studies have shown that the severity of the pulmonary injury and the quality of resuscitation are probably more decisive for the development of posttraumatic pulmonary dysfunction than the fixation device or insertion technique (chapter 4.1) [17].

7.2 Plating

7.2.1 Open procedure
The method of plate fixation in a femoral shaft fracture using an open technique is more than a century old. It is indicated when
- a contraindication to the use of an intramedullary nail exists (eg, the presence of a femoral neck fracture);
- there is a large traumatic open wound;
- there is a compartment syndrome;
- the surgeon lacks an image intensifier;
- the surgeon is more familiar with plating than with intramedullary nailing.

The advantages comprise debridement and evacuation of hematoma, direct inspection of major fracture fragments, and accurate alignment.

Disadvantages include increased blood loss and the risk of devascularization of bone fragments leading to an increased rate of nonunion and/or infection. Plates are load-bearing devices as compared to nails, which are load sharing. Because the femur is subjected to high stresses, there is an increased risk of hardware failure when a plate is used, as compared to an intramedullary nail.

7.2.2 Minimally invasive surgical procedures
Recently, there has been enthusiasm for plate fixation of comminuted fractures extending into the metaphysis using an indirect reduction and percutaneous, submuscular plate insertion technique through small incisions proximal and distal to the fracture focus. Experimentally this leads to less damage to perforator vessels and periosteal blood supply [12]. The advantage of the percutaneous bridge plating technique is a better preservation of blood supply to the fracture fragments with early callus formation due to relative stability. The disadvantage is a higher risk of malunion [18]. The plate generation of the LISS and LCP based on the internal fixator principle is especially suited for minimally invasive osteosynthesis (MIO) (chapter 3.1.3).
### 7.3 External fixation

In the femoral shaft, external fixation is increasingly being used for temporary stabilization in high-risk patients (damage-control surgery) [3, 6]. Because these frames are temporary, they should be placed simply and quickly. Pins may be placed through the quadriceps muscle from anterior to posterior and should be kept as far away from the fracture site as possible (Fig 6.6.2-15). As the large femoral soft-tissue envelope promotes pin-track infection, and the thigh muscles cause large deforming forces, external fixation is typically not used for definitive treatment of femoral shaft fractures. Definitive fixation by an internal device should occur within 14 days. Ring fixators are useful in special situations such as deformity correction, bone transport, or femoral lengthening. Schanz screws placed for definitive fixation should be inserted laterally along the intramuscular septum to pass through the smallest amount of muscle possible (Fig 6.6.2-16).
7.4  Neck/shaft fractures

- Femoral neck fractures are associated with femoral shaft fractures in about 2.5–6% of cases [18, 19]. These neck fractures are often nondisplaced and more vertical than isolated ones (Fig 6.6.2-17). They are often missed initially for a variety of reasons.

Patients may not complain of hip pain because of the distracting femoral shaft fracture or an altered level of consciousness. The fracture may not be obvious on the x-ray since the best image of the proximal femur is taken with 15° of internal rotation but the initial trauma AP pelvis frequently has the proximal femur in external rotation. In addition, the fracture is often nondisplaced or minimally displaced. Therefore, it is essential to properly evaluate the femoral neck by imaging and scrutinizing the proximal femur before going to the operating room, checking any CT cuts that include the femoral neck (Fig 6.6.2-18), and imaging the femoral neck in internal rotation in the operating room after fixation of the femoral shaft fracture.

- Treatment of the femoral neck takes precedence over the treatment of the shaft fracture, because of the potential complications of the femoral neck fracture.

The incidence of avascular necrosis and nonunion after ipsilateral femoral neck and shaft fractures is not known. Avoidance of nonunion is dependent on obtaining and maintaining an anatomical reduction and stable internal fixation. If an anatomical reduction cannot be obtained with closed reduction, an open reduction should be performed. The incidence of avascular necrosis may be lower than in isolated neck fractures because some of the energy of the injury is thought to dissipate through the shaft fracture and many of the fractures are nondisplaced.

Fig 6.6.2-17a–b  Minimally displaced vertical femoral neck fracture associated with a femoral shaft fracture.

Fig 6.6.2-18  CT of the pelvis that includes the femoral neck and demonstrates a proximal femoral fracture.
The decision of which fixation device to use partly depends on whether the femoral neck fracture is found before or after fixation of the femoral shaft. Currently, the use of separate fixation devices for each fracture is recommended [20]. Options for the femoral neck include screw fixation of nondisplaced 31-B2 (transcervical) neck fractures and sliding hip screw fixation for the base of neck fractures (Fig 6.6.2-19). Devices for stabilization of the femoral shaft fracture include...

Fig 6.6.2-19a–f  Displaced femoral neck fracture with complex (C3) shaft fracture extending into the knee (A3). Open reduction and lag screws to the femoral neck, LISS for the femoral shaft.
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retrograde femoral intramedullary nails or submuscular plates. Although devices that stabilize both fractures—such as an intramedullary nail that allows fixation into the femoral head and neck—can be used, it may be difficult to reduce and stabilize two fractures at once [20]. If the femoral neck fracture is detected after intramedullary nailing, additional lag screws to stabilize the neck fracture should be inserted, preferably anterior to the nail (Fig 6.6.2-20).

Whether or not to perform a hip capsulotomy is controversial. If the capsule has not been torn it is hypothesized that an intracapsular hematoma can limit venous outflow and affect perfusion to the femoral head. At the time of surgery a capsulotomy can be performed by sliding a scalpel blade anteriorly along the femoral neck.

Fig 6.6.2-20a–b Screws for stabilization of a femoral neck fracture placed around an intramedullary nail. The screws are placed anterior to the nail.

8 Subtrochanteric fractures

Subtrochanteric fractures occur in the region between the lesser trochanter and 3 cm distal to it. The medial cortex is subjected to large compressive forces and the lateral cortex to tensile stresses. This region is also the transition from cancellous bone of the intertrochanteric region to cortical bone of the femoral diaphysis.

- There are a number of techniques available to stabilize subtrochanteric fractures (Fig 6.6.2-21), and fixation devices for this region need to be strong enough to withstand high forces until the fracture has consolidated.

Intramedullary nailing has been used very successfully for the treatment of subtrochanteric fractures resulting in high union rates. Because of the large medullary canal diameter in the proximal femur, nail insertion will not reduce the fracture. An acceptable reduction needs to be obtained prior to nail insertion. If the lesser trochanter is still attached to the proximal fragment, a standard nail can be used (Fig 6.6.2-22). If the lesser trochanter is fractured, a nail with fixation into the head and neck should be used. If there are fractures that extend into the piriformis fossa, displacement and/or propagation can occur during reduction, manipulation, reaming, or insertion of the intramedullary nail. As in femoral neck fractures associated with femoral shaft fractures, a CT scan of the proximal femur can be useful to delineate the exact fracture pathology in the subtrochanteric region.

Plate fixation is a valid alternative (Fig 6.6.2-23). Historically, when open reduction with exposure of all fracture fragments and extensive stripping was carried out, delayed unions, nonunions, and hardware failure were common in these fractures. With the use of indirect reduction techniques and minimal exposure the incidence of nonunions and the need for bone
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Fig 6.6.2-21a–e Five options for stabilizing subtrochanteric fractures.

a 95° angled blade plate, with anatomical reconstruction and absolute stability.
b Dynamic condylar screw bridging the complex fracture area. The side plate can be introduced with a tunneling technique.
c Femoral nail with spiral blade (UFN).
d Proximal femoral nail (PFNA) introduced from the tip of the trochanter gives a very stable construct. For more complex 32-B3.1 configurations, especially with a more distal segmentation, the long PFNA offers an alternative to the UFN with spiral blade.
e LCP proximal femur/femoral shaft.
6.6.2 Femur, shaft (incl. subtrochanteric fractures)

**Fig 6.6.2-22a–b**  Subtrochanteric fracture with an intact lesser trochanter. A standard intramedullary nail can be used to treat this fracture pattern.

**Fig 6.6.2-23a–c**  Complex subtrochanteric fracture 32-C3.3 (a) fixed with a dynamic condylar screw bridging plate with MIPO technique (b). Uneventful healing and return to full function (c).

Grafts have been markedly reduced [21]. These techniques are particularly applicable for more comminuted fractures where bridge plating techniques can be used. The goal is to restore overall axial alignment, length and rotation, rather than absolute stability of all fracture fragments.

9 Postoperative management

Postoperative mobilization and range of motion exercises of the knee and hip are started as soon as possible. Patients with fractures of the femoral diaphysis that have been stabilized with a tightly fitting nail and two interlocking screws on either end, are allowed to bear as much weight as tolerated immediately after surgery, regardless of the amount of comminution present [22]. Prophylaxis of deep vein thrombosis should be considered because of the significant incidence of pelvic vein thrombosis [23]. Patients with subtrochanteric fractures that have been stabilized with a plate should not fully bear weight for the first 6–8 weeks.

10 Complications

10.1 Nonunion

Femoral shaft fractures treated with antegrade reamed nailing have a union rate of 95–99% [24]. Unreamed and relatively smaller diameter intramedullary nails have been shown to have statistically higher nonunion rates as compared to reamed
intramedullary nails (7.5% versus 1.6%) [16]. When non-unions occur, treatment is individual and based on the type of nonunion, the type of hardware present, and on the presence or absence of bone loss (chapter 5.2).

10.2 Infection

Superficial infections can be treated with oral or intravenous antibiotics. Deep infections that respond to antibiotics should be revised, debrided, and repeatedly washed out. Provided that the hardware is providing stability, it may be left in situ until bony union occurs. Antibiotics should be administered for at least 6 weeks (chapter 4.5). Once the fracture has healed, hardware can be removed, the medullary canal reamed, and antibiotics can be administered as needed in an attempt to eradicate the infection. More aggressive deep infection with loosening of hardware will require debridement, antibiotics, hardware removal, and stabilization with an external fixator until the infection is under control. At that time, definitive reconstruction can be carried out (chapter 5.3).

10.3 Malunion

Axial malunion most commonly occurs in the proximal or distal thirds of the femur. A study using CT scan to evaluate rotation revealed that rotational malalignments greater than 15° occur in up to 28% of patients and can affect axial alignment if the rotation is severe enough [25]. Patients may have trouble with vigorous activities such as stair climbing, sports, and running. Internal rotation seems to be better tolerated than external rotation [25]. If it is detected early, the interlocking screws can be removed from one end of the nail, the femur derotated and the nail relocked in correct orientation. If it is detected after healing has taken place, a formal osteotomy will be needed (chapter 5.1).

11 Bibliography

6.6.2  Femur, shaft (incl. subtrochanteric fractures)


9  Acknowledgment

We wish to thank Dankward Höntzsch for his contribution to this chapter in the first edition of the AO Principles of Fracture Management.