6.6.1 Femur, proximal

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1 Introduction

According to the Müller AO Classification (Fig 6.6.1-1) fractures of the proximal femur are divided into three types:

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Fig 6.6.1-1   Müller AO Classification.

2 Trochanteric fractures (31-A)

2.1 General considerations

Trochanteric fractures make up 55% of fractures of the proximal femur and occur predominantly in elderly patients with osteoporosis. The early perioperative mortality is high. Trochanteric fractures in young patients are usually associated with high-energy trauma and/or other injuries. Trochanteric fractures by definition are extracapsular and the vascularity of the femoral head is rarely compromised. Operative treatment is generally indicated and leads to a good clinical result in the majority of cases.

The Müller AO Classification subdivides trochanteric fractures into three groups. A1 fractures are simple two-part fractures with good bony support at the medial cortex. A2 fractures are multifragmentary with the medial and dorsal cortices (lesser trochanter) broken at several levels, but with an intact lateral cortex. In A3 fractures the lateral cortex is also broken (reverse oblique fracture type). A horizontal line at the level of the lesser trochanter indicates the inferior limit of the trochanteric region. If the center of the fracture is distal to this line, it is classified as a subtrochanteric fracture (32-A).

2.2 Surgical treatment

Standard AP and lateral x-rays of the proximal femur are required for evaluation of the fracture. If an intramedullary device like the proximal femur nail (PFNA) or trochanter femoral nail (TFN) is planned, imaging of the femoral shaft must be included for measurement of the width of the medullary cavity and assessment of diaphyseal morphology. With excessive anterior bowing of the femur it may be impossible to insert a screw/nail device because the tip of the intramedullary nail might perforate the anterior cortex of the femoral shaft or cause a fracture.

- **A full orthopedic and medical assessment of the patient is essential and surgery should be performed, without delay, once the patient is considered fit for surgery.**

With the patient supine, the fracture is usually treated by closed reduction on a radiolucent or fracture table (Fig 6.6.1-2). This is achieved by longitudinal fraction and internal rotation, which usually corrects the deformity. Intraoperative image intensification in two planes is mandatory. The classical approach is a straight lateral incison, splitting the iliotibial tract, and gently elevating the vastus lateralis muscle (Fig 6.6.1-3).
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Fig 6.6.1-2 Positioning on a fracture table. Alternatively, a radiolucent table with simple supine positioning may be used.

Fig 6.6.1-3a–b
a Lateral approach to proximal femur.
b The vastus lateralis muscle (1) may be split or elevated. Here it is shown elevated from the posterior intermuscular septum (2). Perforating vessels (3) must be ligated.
Successful treatment of trochanteric fractures requires mechanically stable fixation based on careful planning and the correct use of implants and instruments. Fixation devices have evolved greatly in recent years and many different concepts of fixation provide good results.

- **Intramedullary fixation** may be associated with shorter operation time, less blood loss, and earlier weight bearing, but the method has not yet proven to be superior to extramedullary fixation of trochanteric fractures [1–6].

The dynamic hip screw (DHS) is the implant of choice for stable fractures (31-A1, 31-A2.1). It allows secondary impaction of the fracture along the axis of the gliding hip screw (Fig 6.6.1-4), which must be placed correctly in the center of the femoral head [7]. A positioning in the superior quadrant may lead to failure by cutout, particularly in osteoporotic bone. To avoid malpositioning of the DHS, central placement of the guide wire is essential and has to be checked carefully with the use of x-rays in two planes (Video 6.6.1-1).

**Video 6.6.1-1** Technique for the insertion of the dynamic hip screw. The guide wire for the hip screw must be placed centrally in the head on both the AP and lateral x-rays.

**Video 6.6.1-2** Technique for the insertion of the proximal femoral nail antirotation (PFNA).
Due to their biomechanical characteristics, the new PFNA and TFN are recommended for unstable multifragmentary fractures (31-A2.3, 31-A3) (Fig 6.6.1-5). Distal locking should be static (Video 6.6.1-2).

The dynamic condylar screw and condylar blade plate as well as the DHS in combination with the trochanter stabilizing plate (Fig 6.6.1-6) [8, 9] may be valid alternative options for selected cases of unstable fractures. Of the three, the dynamic condylar screw is considered the easiest to insert.

Percutaneous insertion of fixation devices for hip fractures has recently been advocated. However, implant failure and reoperations appear to occur more often than compared to open hip screw fixations [10]. In cases of preexisting symptomatic osteoarthritis of the hip, a pertrochanteric fracture may be managed by a total hip replacement. Primary arthroplasty in such circumstances is difficult and associated with a high rate of complications. In most of these cases, initial internal fixation seems more appropriate. If the patient remains symptomatic after the fracture has healed, an arthroplasty can be performed more easily than in a fresh fracture.

2.3 Postoperative management

- After internal fixation, mobilization of a compliant and otherwise healthy patient starts on the first postoperative day using a walking frame or crutches.

The fixation construction should allow full weight bearing since most elderly patients are not able to adjust to partial weight bearing. Fracture healing should be completed within 3 months. If the implant has been applied correctly, it will provide adequate fixation even in the presence of marked osteoporosis [7]. In case of failure of fixation or loss of reduction, the choice of how to proceed depends on the type of failure, the bone quality as well as the age, the requirements and expectations of the patient. In younger patients revision of the internal fixation is considered if the femoral head still has good bone stock, intact cartilage, and good blood supply. In elderly patients a revision arthroplasty implant is usually more appropriate.

Fig 6.6.1-5a–b
a Multifragmentary trochanteric fracture (31-A2.3).
b Unstable fracture treated with the PFNA. The shaft of the nail prevents lateral displacement of the fragments.
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Fig 6.6.1-6a–e

a  Reverse oblique intertrochanteric fracture (31-A3.3).
b  This fracture is preferably fixed with an intramedullary device (PFNA, TFN, etc).
c  Alternatively, the DHS with an additional trochanter stabilizing plate and a tension band wire can be used.
d–e  The fracture can also be fixed with the dynamic condylar screw or a condylar blade plate. The dynamic condylar screw or the blade is placed high in the proximal fragment. The plates have to be put under tension. Patients cannot fully bear weight immediately after surgery.
Fractures of the femoral neck (31-B)

3.1 General considerations

Vertigo, dementia, malignancy, and cardiopulmonary disease in the elderly and high-energy injuries in the younger patient are associated with an increased risk of femoral neck fracture. These fractures lie within the joint capsule, which adversely affects the blood supply to the femoral head (Fig 6.6.1-7). The severity of the damage to the blood supply mainly depends on the extent of displacement of the femoral head and fragmentation of the neck. Early anatomical reduction and stable internal fixation of the fracture is associated with a lower rate of avascular necrosis (AVN) of the femoral head [11, 12]. The increased intracapsular pressure from the fracture hematoma may occlude venous return of the capsular vessels and decrease the arterial flow in the femoral neck. The intracapsular pressure and hematoma may be released via capsulotomy [12, 13]. Open reduction and anterior capsulotomy also facilitate anatomical reduction under direct vision (Fig 6.6.1-8). The capsule should be left open.

Fig 6.6.1-7a–b The blood supply of the femoral head, anterior (a) and posterior (b) view. The vascular anatomy varies, but in 60% of patients the medial and lateral femoral circumflex arteries originate from the profunda femoris artery (1). Most of the blood supply of the femoral head comes from the lateral femoral circumflex artery (2), which gives rise to three or four branches, the retinacular vessels. These run posteriorly and superiorly along the femoral neck in a synovial reflection until they reach the cartilaginous border of the head. The obturator artery gives rise to the vessels within the ligamentum teres (3). An ascending branch of the medial femoral circumflex artery (4) supplies the greater trochanter and anastomoses with the lateral femoral circumflex artery.
In young patients with displaced fractures, internal fixation must be carried out without delay in order to preserve the femoral head. Anatomical reduction is essential and this usually requires an open surgical approach and stable internal fixation.

To enable follow-up MRI studies of the femoral head vitality, the use of titanium screws/implants is advisable.

In cases where immediate intervention is not possible, needle aspiration of the intraarticular hematoma is recommended.

The hip should be kept in a semi-flexed and externally rotated position. Lateral or mediocervical femoral neck fractures (31-B2.1) in children or elderly adults are partially extracapsular and the femoral head vitality may be jeopardized by the intracapsular hematoma rather than by the disruption of the blood supply to the head.

### 3.2 Surgical treatment

X-rays in two planes must be obtained in all cases. Retroversion of the head and posterior comminution can easily be evaluated by a cross-table lateral view. Nondisplaced or valgus impacted subcapital fractures (31–B1), also known as abduction...
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Femur fracture, may be stable enough for nonoperative treatment. The stability of the fracture should be checked under image intensification and regularly monitored. As secondary displacement does occur, especially in the presence of even slight retroversion of the femoral head (which increases the risk of AVN), internal fixation is strongly recommended for most of these fractures, particularly in younger individuals and active elderly patients. Percutaneous fixation with cannulated screws adequately prevents secondary displacement of these impacted fractures.

- In unstable and displaced fractures of the femoral neck the choice of treatment mainly depends on the general and biological conditions of the patient.

A reasonable treatment algorithm should address the age and the level of activity, the bone density, additional diseases, the estimated life expectancy, and the compliance of the patient [12]. Internal fixation is the treatment of choice for patients with high functional demands and good bone stock. Patients who are less than 65 years old and do not have a chronic illness should have urgent open reduction and internal fixation. In patients over 75 years of age, prosthetic replacement is recommended. In those who have low functional demands, chronic illness or severe osteoporosis, or who are noncompliant, hemi or total hip arthroplasty is preferred. Patients of any age with severe chronic illness or a limited life expectancy should be managed with a prosthesis. When there is a life expectancy of less than one year a unipolar prosthesis can be used.

- In general, the biological rather than the chronological age should determine the management.

There is no strong evidence in favor of either internal fixation or arthroplasty with regard to mortality. However, the literature does suggest a higher rate of reoperations in those who had internal fixation compared with those with arthroplasty [14–16]. When prosthetic replacement is indicated, it can be done within the first 24 hours after stabilizing the patient’s general condition to reduce postoperative morbidity. The same principles apply for polytrauma patients, where fixation of a displaced femoral neck fracture must have high priority in the management protocol. Closed reduction can usually be obtained with gentle traction and internal rotation under anesthesia and with x-ray control. The Leadbetter maneuver can also be used. The leg is abducted with lateral traction and external rotation. The leg is then gently returned to the neutral position and internally rotated. Traction is then reduced to allow impaction of the fragments. In cases that do not reduce easily, repeated and vigorous attempts must be avoided and open reduction is indicated. With the patient in the supine position, an anterolateral approach to the hip is chosen and an anterior capsulotomy is performed (Fig 6.6.1-9). The femoral head, which is usually displaced posteriorly and inferiorly, is carefully disimpacted by additional abduction of the leg or by lateral traction with a bone hook. It may be helpful to place two temporary 2.0 mm K-wires into the femoral head fragment. They act as joysticks and aid reduction, as rotational deformity can be difficult to correct and control. Reduction is then secured with one or two 2.0 mm K-wires. In young patients, the surgeon aims for anatomical alignment of the fragments; in elderly patients with osteoporosis, however, the fractures may be impacted in a slight valgus position. Correct reduction is verified with the image intensifier in two planes.
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The crucial element for the choice of fracture fixation and implant is the quality of bone. Any fixation method used in osteoporotic fractures should be safe and easy to apply. With regard to complications and outcome, the DHS has proved to be superior to fixation by screws alone or by angled blade plates [17] (Fig 6.6.1-10). To achieve rotational stability and good buttressing at the fracture site, an additional screw cranial to the DHS should be inserted, especially in case of marked posterior fragmentation. An angled blade plate 130° may also be used, but the technique is more demanding because good fragment contact has to be obtained and fracture distraction must be avoided especially in young patients with dense cancellous bone. With good bone quality, two, preferably three, 7.0 or 7.3 mm cannulated cancellous bone screws can be used to achieve compression of fragments (Fig 6.6.1-11). These screws should be inserted parallel to each other with the help of the aiming device to allow for gliding and secondary impaction of the fracture. The screws should run peripherally in the neck. Care must be taken that the threads of all three screws are positioned well within the head fragment and do not cross the fracture line, as only then compression can be achieved. The screws must be tightened carefully and repeatedly during the procedure (Video 6.6.1-3). If a fracture table is used, traction must be released. This procedure can also be performed percutaneously through stab incisions. AP, lateral, and 45° oblique views must be taken with the image intensifier to ensure the screws do not penetrate the hip joint. In the rare instance of a vertical shear fracture that may be difficult to reduce, a valgus osteotomy and fixation with a 120° angled blade plate may be considered (Fig 6.6.1-12).

For patients with limited life expectancy, in debilitated patients or those with minimum activity, the use of a unipolar prosthesis is recommended. For very active patients with pre-existing osteoarthritis a total hip replacement is more appropriate (Fig 6.6.1-13) [16].

3.3 Postoperative management

Depending upon the stability of fixation achieved and the reliability of the patient, the patient may be mobilized within 24 hours. Young patients should manage partial weight bearing,
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Fig 6.6.1-10a–c
a Displaced femoral neck fracture (31-B2.2).
b The fragments have been reduced and impacted with slight overcorrection into valgus and without retroversion. Fixation with the DHS 135° and 2-hole side plate. Alternatively, a 4-hole plate could have been used. An additional cancellous bone screw was inserted in parallel to prevent rotation of the head fragment. The thread of this screw should engage fully in the head fragment. As some impaction of the fracture may occur during weight bearing, some backing out of the screws is possible.
c The same fracture can also be treated with an angled blade plate 130° with one or two screws. An additional cancellous bone screw may be inserted to increase the initial stability of the fixation, to close the fracture gap, and to put it under compression intraoperatively. The blade of the plate should be inserted into the lower half of the head.

Fig 6.6.1-11 A similar fracture as in Fig 6.6.1-10, treated with three large 7.0 or 7.3 mm cancellous bone screws. The screws should run parallel and peripherally in the neck and the inferior screw should abut on the inferior cortex of the femoral neck (calcar). The threads of all screws must engage completely in the head fragment. Cannulated screws facilitate correct placement and may even be inserted percutaneously if closed reduction can be obtained.
but with elderly patients, partial weight bearing may be impossible. They need reliable internal fixation or a prosthetic replacement that allows for immediate full weight bearing.

If failure of fixation or loss of reduction should occur, the choice of how to proceed depends on the type of failure, the bone quality, the age, and the requirements of the patient. In younger patients, revision of the internal fixation is considered if the head appears viable. With a nonunion or varus deformity a valgus osteotomy may be indicated. In patients with poor bone quality and limited functional demands a bipolar or total hip arthroplasty is the procedure of choice. If femoral head necrosis develops in younger patients and the area of head collapse involves less than 50% of the head, an intertrochanteric osteotomy may provide relief of pain and relatively good function. Hip fusion is an alternative, but is technically more difficult in the presence of avascular bone; total hip replacement may be the best option.

Video 6.6.1-3 Technique for the insertion of 7.3 mm cannulated screws for a subcapital fracture. The guide is used to ensure that the screws are parallel.

Fig 6.6.1-12a–b In the presence of a vertical fracture plane, the shearing forces can be transformed into compressive forces by performing an intertrochanteric valgus osteotomy of some 30–40° and fixation with the 120° double angled blade plate. This is technically demanding and careful preoperative planning is essential.

Fig 6.6.1-13 In elderly patients with displaced femoral neck fractures and limited life expectancy, a femoral head prosthesis, or a total hip prosthesis are preferred treatment options.
4 Fractures of the femoral head (31-C)

4.1 General considerations

Substantial force is required to produce a fracture of the femoral head which is often associated with traumatic hip joint dislocation or fracture dislocation. Femoral head or “Pipkin” fractures commonly represent just one aspect of a combined and serious injury of the hip joint [18]. Associated fractures of the femoral neck and acetabulum are frequent. The injury most commonly occurs in motor vehicle collisions and may be accompanied by multiple traumas, in particular to the lower extremity. An AP x-ray of the pelvis is mandatory to rule out dislocation or fracture of the hip.

- A dislocated femoral head must be reduced urgently and kept in the reduced position. This is best achieved under general anesthesia with muscle relaxation.

After reduction, joint stability must be examined and a standard AP view of the pelvis is taken under some axial load with the legs slightly abducted. The width and congruity of the joint space are compared with the opposite side. On the injured side, interposed fragments, a torn and inverted labrum, or a folded ligamentum teres may cause the joint space to appear wider. CT scan of the hip will permit assessment of impaction and fractures of the femoral head. Simultaneously, the reduction can be checked, loose fragments localized, and the acetabulum may be evaluated for precise classification. Sagittal and coronal CT scan reconstructions can be especially helpful in demonstrating the femoral head alignment in the weight-bearing area and may reveal prognostically important bone bruises that cannot be diagnosed otherwise.

In case of a “Pipkin” fracture and dependent on the position of the fragment within the femoral head, internal fixation is usually mandatory. Furthermore, any loose or interposed fragment must be removed to restore joint congruity.

4.2 Surgical treatment

Small fragments (< 1 cm²) distal to the round ligament usually do not need anatomical reduction unless they interfere with joint motion. If they do, small fragments may be removed while larger ones must be reduced and fixed with small-fragment screws (Fig 6.6.1-14). Even if reduced after closed reduction, fragments remain unstable. Thus, open reduction and internal fixation is indicated. Because these fragments are still attached to the inferior joint capsule, care must be taken to preserve this potential vascular supply during internal fixation. Surgery is clearly indicated in cases where loose fragments or soft tissues are interposed in the joint space, otherwise rapid joint destruction will follow. Special attention must be paid to CT scans as a small bone fragment usually lies within the fossa of the acetabulum. This fragment is firmly attached to the ligamentum teres, as it has been avulsed from the femoral head and does not displace into the true joint space. If no other indication for surgery exists, it may be left untouched. The position of this fragment in the fossa can easily be monitored by CT scan. Osteochondral fragments cranial to the ligamentum teres are part of the weight-bearing surface of the femoral head (C1.3, C3.1), which makes anatomical reduction mandatory. Taking care to preserve the vascular supply, the fragment is fixed with 3.5 or 2.7 mm small-fragment screws or with the 3.0 mm cannulated screw with a threaded washer system. The screw heads must be buried beneath the level of the cartilage. Biodegradable fracture pins may also be used for fixation of small osteochondral fragments. Any additional impacted area
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of the femoral head should be elevated and the defect filled with autogenous cancellous bone graft. The same procedure may be considered for fractures with significant impaction (C2.1–C2.3).

Split fractures combined with a femoral neck fracture (C3.2, C3.3) have the worst prognosis because in most of the cases the main fragment of the femoral head loses its vascular supply [18]. Some information about the vascularity of the main head fragment may be obtained by making drill holes, which may produce bleeding. This test is, however, unreliable. If there is hope that the vascular supply is still intact, the femoral neck fracture should be fixed with 7.0 or 7.3 mm cancellous bone screws before the head fracture is fixed. In young patients the bias should be towards preserving the joint, while in patients older than 40 years primary total joint replacement or in selected cases arthrodesis should be considered. Titanium implants should be used to facilitate MRI follow-up studies for femoral head vitality [19].

The presence of an acetabular fracture determines further management according to the established principles of treatment for such injuries (chapter 6.5). If the joint remains unstable after emergency reduction, or if loose fragments are trapped within the joint space but immediate surgery is not possible, the leg must be put in skeletal traction until surgery can be performed.

Isolated split fractures of the femoral head may be approached through an anterior or posterior incision depending on the fracture site. If a femoral neck or acetabular fracture must be fixed at the same time, this injury determines the surgical approach. The advantages of the anterior Smith-Petersen approach or the surgical hip dislocation (Berne approach) (Fig 6.5-13) are a significantly shorter operative time and less blood loss as well as an improved exposure of the fracture for the fixation of small fragments. Through the anterior approach, split fractures can be fixed directly with screws. The attachment of the fragments to the joint capsule or ligamentum

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Fig 6.6.1-14a–c Split-depression fracture of the femoral head (C2.3). Elevation of the impacted area, cancellous bone graft, and transchondral screw fixation of the split fragment. 2.7 mm cortex lag screws are countersunk to avoid any further chondral damage.
teres can be preserved. The increased risk of heterotopic ossification with this approach may be counteracted by limiting the stripping of gluteal muscle from the ilium. The direct head of the rectus femoris muscle can be detached from the anterior inferior iliac spine to assist exposure [20, 21]. With the posterior Kocher-Langenbeck approach visual control of exact reduction is difficult and the fixation of the fragment usually has to be done indirectly if the vascularity is to be preserved. Any attempt at an anatomical fragment fixation through the posterior approach demands redislocation of the femoral head and detachment of the fragment from its capsular or ligamentous attachments. This, of course, destroys the remaining direct blood supply of the fragment. Redislocation of the femoral head and joint restoration may be facilitated by a Ganz trochanteric osteotomy, especially in cases with additional posterior acetabular fractures [22].

### 4.3 Postoperative management

This includes early mobilization, partial weight bearing for 6–12 weeks, according to the type of injury, and possibly administration of indomethacin as prophylaxis against heterotopic ossification. In patients with a high risk of heterotopic ossification (e.g., a polytrauma patient with head injury plus anterior approach) an additional single dose of irradiation to the hip may be considered [19].

The outcome of these injuries remains unpredictable for the individual patient even after anatomical joint restoration. The incidence of posttraumatic arthrosis or avascular femoral head necrosis is determined by the initial damage to the cartilage and the subchondral bone due to the impact of trauma. In case of impaction of the femoral head, or if symptomatic partial head necrosis develops, intertrochanteric osteotomy may be indicated. In complete avascular head necrosis, or painful arthrosis, total joint replacement or hip arthrodesis are secondary treatment options.

### 5 Bibliography

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