6.6.3 Femur, distal

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Fractures of the distal femur represent about 6% of all femoral fractures.

- **Distal femur fractures typically occur after high-energy trauma in younger patients, or after low-energy trauma in the elderly with osteoporotic bone.**

One third of the younger patients have multiple injuries and only a fifth of cases occur as an isolated injury. There is usually considerable soft-tissue damage and almost 50% of intraarticular distal femur fractures are open injuries. With the increasing number of patients with knee joint replacement, the incidence of periprosthetic fractures will rise in the future.

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**Surgical anatomy**

In addition to the articular capsule, the insertions of tendons and ligaments at the femoral condyles and the cruciate ligaments contribute to the function and stability of the knee joint as a complex system of force transmission.

The gastrocnemius muscle originates from the back of both femoral condyles; the cruciate ligaments are located in the central notch, and the tendon of the popliteus muscle inserts at the lateral condyle. The joint capsule and the strong collateral ligaments originate from the femoral condyles.

Due to the close proximity of neurovascular structures, vascular lesions are found in about 3%, and nerve injuries in about 1% of distal femoral fractures.

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**Clinical examination and diagnostic tools**

The diagnosis of a distal femoral fracture can often be made clinically. Careful examination of the neurovascular status is essential. It may be necessary to verify that the popliteal artery is unharmed by a Doppler ultrasound or more accurately by angiography. If compartment syndrome due to a crush injury is suspected, early pressure measurement of the different compartments is advisable. Examination of the stability of ligamentous structures prior to osteosynthesis is usually quite painful and not reliable. It should be done under anesthesia prior to surgery, and again after the fracture has been stabilized. If multiple injuries of the lower extremity are suspected, AP and lateral x-rays of both femur and tibia, including the adjacent joints, must be taken as well as well centered views of the knee joint. CT scans including 3-D reconstructions or MRI offer additional information, but are not generally essential in treating acute injuries.

**Classification of fractures**

The fractures are classified as (Fig 6.6.3-1):

<table>
<thead>
<tr>
<th>Type</th>
<th>Fractures</th>
</tr>
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<tbody>
<tr>
<td>Type A</td>
<td>Extraarticular fractures</td>
</tr>
<tr>
<td>Type B</td>
<td>Partial articular fractures</td>
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<tr>
<td>Type C</td>
<td>Complete articular fractures</td>
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Fig 6.6.3-1 Müller AO Classification.
A2 Extraarticular fracture, metaphyseal wedge.
B3 Partial articular fracture, coronal ("Hoffa" fracture).
C2 Complete simple articular fracture with multifragmented metaphysis.

4 Principles of operative treatment

- Standard treatment consists of open reduction and internal fixation of the fracture.

Conservative treatment is only justified in impacted nondisplaced extraarticular (type A) distal femoral fractures or in patients who are deemed inoperable and nonambulatory.

The aims of operative treatment are:
- anatomical reconstruction of the articular surfaces;
- restoration of rotational and axial alignment;
- stable fixation of the condyles to the shaft of the femur;
- repair of injured ligamentous structures;

The traditional concept of open reduction and internal fixation, which requires an extended approach to the knee joint and fracture zone, is changing towards a more biological and atraumatic approach, with careful handling of the soft-tissue envelope.

- It is still mandatory to perform a precise reconstruction of the anatomy of the condyles and articular surface.

This usually requires a direct view into the knee joint through an appropriate surgical exposure.

4.1 Timing of the operation

In distal femur fractures definitive treatment is indicated as soon as clinically feasible.

In some polytrauma patients, open fractures with severe soft-tissue damage, vascular injuries, or under conditions that prevent an early definitive operation (eg, inexperienced staff), damage-control surgery will be necessary. In such cases, a joint-bridging external fixator is a quick and effective method of stabilization.

4.2 Operative technique

4.2.1 Positioning and reduction
Anatomical reduction of the articular block with adequate restoration of length, alignment, and rotation must be achieved before internal fixation of the condyles to the femoral shaft is performed.

- When the knee joint is fully extended, the pull of the gastrocnemius muscle on the one hand, and of the adductor magnus muscle on the other hand, leads to genu recurvatum and shortening.
With the knee flexed at approximately 60° over a knee support this malalignment of the distal fragments can easily be corrected (Fig 6.6.3-2). The shortening is best approached by manual traction or with a distractor. In cases of extensive fragmentation, restoration of anatomy may be extremely difficult. Careful preoperative planning, using the contralateral side as a template, is helpful.

In some instances it may be useful to accept some shortening of the femur, particularly in osteopenic bone and complex fractures where impacted metaphyseal fragments are preferred over exact length. To facilitate reduction, Schanz screws can be fixed in larger fragments (joystick technique) or integrated into the large distractor [1].

4.2.2 Approaches
The standard lateral approach to the distal femur (Fig 6.6.3-3) allows anatomical reduction of the shaft and the metaphyseal area, with the disadvantage of extensive soft-tissue exposure and stripping of fragments. In the case of intraarticular fragmentation, where exact reconstruction of the joint congruity

Fig 6.6.3-2  Patient position for surgery on distal femoral fracture.

Fig 6.6.3-3  Lateral approach to the distal femur. Incision of skin and fascia. There should be minimal detachment of the vastus lateralis muscle. Avoid stripping the periosteum from the bone!
is mandatory, the lateral parapatellar approach is recommended (Fig 6.6.3-4) [2]. By pulling the patella medially, the reconstruction of the condylar components is facilitated. This incision may also be used for the submuscular insertion of a long bridging side plate, ie, a condylar blade plate, a condylar buttress plate or LISS (less invasive stabilization system) plate. The approach with detachment of the patellar ligament at the tibial tuberosity or with a patellar tendon Z-plasty should only be used in exceptional cases as it has a high complication rate.

Open fractures often have insufficient soft-tissue cover. If a tension-free closure of the skin is not feasible, secondary contamination of the wound must be avoided by using a skin substitute, the vacuum sealing technique, an early local flap, or (very rarely) free flap (chapter 4.2; 4.3).

Fig 6.6.3-4a–b  Lateral parapatellar approach.
a  Skin incision.
b  Exposure of the femoral condyles by retracting the patella medially.

Fig 6.6.3-5a–e  Dynamic condylar screw—technique.
a  Intraarticular distal femoral fracture (33-C1).
b  Reduction and temporary fixation with K-wires.
4.3 Special fixation techniques and implants

The basic principle in treating intraarticular distal femur fractures is based on the reduction of the articular fragments under direct visual control [2, 3] (chapter 2.3). After temporary stabilization with K-wires (Fig 6.6.3-5a–b), fixation is achieved either by compressing the fragments with lag screws or by bridging the articular defect with fully threaded cortical screws without lagging, functioning as position screws. The subsequent fixation of the articular block to the distal femur is done with additional implants, depending on the type of fracture.
4.3.1 Screw fixation
Large and small (partially threaded) cancellous bone screws—standard or cannulated—are used for the reconstruction of the articular block of the condyles. For type B fractures, the stability of the fixation may be augmented by a plate with buttress function (Fig 6.6.3-6). In type B fractures it may be possible to insert the screws through small stab incisions or under arthroscopic control. For any other reconstruction of complex intraarticular fractures, a formal arthrotomy using the lateral parapatellar approach is recommended.

4.3.2 Condylar blade plate/dynamic condylar screw
- In the treatment of complex extraarticular fractures (33-A3 fractures), and simple intraarticular fractures (33-C1.2) the 95° condylar blade plate and the dynamic condylar screw have proven to be reliable and effective implants.

These 95° fixed-angle devices provide angular stability to maintain alignment and prevent secondary collapse in varus.

**Condylar blade plate**
The first step is reduction of the articular fragments and stabilizing with lag screws. Placing these screws in relation to the final position of the blade has to be considered. The condylar blade plate position is defined using K-wires (Fig 6.6.3-7). After widening the entry and hammering in the chisel, the blade can be inserted and fixed to the femur (Video 6.6.3-1).

It is possible, but more demanding, to insert the condylar blade plate by a minimal incision technique using shorter incisions and reflecting the vastus lateralis muscle. After the implant is inserted with the blade parallel to the joint line, it is fixed to the distal femur, maintaining correct alignment. Additional stability of the blade can be achieved if cancellous bone screws are inserted through the plate into the condyles (Fig 6.6.3-7c).

**Dynamic condylar screw**
The advantages of the dynamic condylar screw are its two components, which allow insertion with minimal exposure (Fig 6.6.3-5). It is technically easier to insert than the condylar blade plate (Video 6.6.3-2), but the main drawbacks are the large bone defect caused by the large diameter of the condylar screw and the fact that it cannot be placed as far distal in the femur.
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**Fig 6.6.3-7a–c** 95° Condylar blade plate—technique.

**a** Insertion of the seating chisel parallel to the joint line and to the correctly orientated K-wire. The intraarticular fracture must be fixed prior to this by one or two lag screws.

**b** Position of the lag screws and the chisel in the femoral condyles. The blade can be inserted more distally than the dynamic condylar screw.

**c** The supracondylar fracture has been reduced to the plate. In transverse supracondylar fractures and nonunions, axial compression should be applied using the tension device.

**Video 6.6.3-1** Technique of insertion of the 95° condylar blade plate for fractures of the proximal femur.

**Video 6.6.3-2** Technique of application of the dynamic condylar screw for fractures of the distal femur.
4.3.3  Locking plates

- The locking condylar buttress plate for complex fractures (33-C3) with additional fracture lines in the coronal plane is not available in all regions of the world [4–6].

Compared to the condylar blade plate, this plate offers the advantages of individual placement of screws over a wide area and buttressing of the lateral femoral condyle. If the correct level is chosen for fixation of the plate to the distal femur, the large tongue-shaped and prebent head of the plate usually does not need additional contouring. There is angular stability between the screws and the plate (locking head screws), which prevents secondary varus malalignment if the medial bony buttress is absent. The use of a medial plate is no longer required. The LCP distal femur has recently been introduced and is based on the same mechanical principles, allowing fracture reduction using the plate and conventional 4.5 mm screws through the combination holes.

The angular stability produced by these newly designed locking plates allows the option of using the minimally invasive submuscular insertion technique. With the latter technique, it is recommended to fix the plate to the femoral shaft first and reduce the condyle area to the plate thereafter.

4.3.4  LISS (less invasive stabilization system)

- The LISS-DF is an implant based on the internal fixator principle (chapter 3.3.4).

The LISS (Fig 6.6.3-8) uses monocortical or bicortical locking head screws and is inserted percutaneously with an aiming device. The plate is not pressed to the bone, therefore the periosteal blood supply is not damaged any further [7–9].

The operative procedure using the less invasive stabilization system (chapter 3.3.4) starts with reduction and K-wire or screw stabilization of the articular components using a lateral or medial parapatellar incision required for the exposure of the intraarticular fracture. Having rebuilt the condylar block the LISS can be applied to the femur taking into account the correct length and rotation (Fig 6.6.3-9). The stabilization is completed with the LISS once it is introduced with the aiming device and aligned to the femur in the AP and lateral views (Video 3.3.4-1). For temporary fixation of the LISS plate, K-wires are used. After preliminary fixation of the plate proximally and distally, the length and rotation of the femur must be checked. This can be done using image intensification and/or the electrocoagulation cable technique [10]. The screws are inserted using the special screw-on drill sleeves, usually starting at the femoral shaft. A reduction device that is affixed to the bone and can pull bone to the LISS plate can be used. The LCP-DF has the shape of the LISS-DF, but combination holes in the shaft.

4.3.5  Retrograde intramedullary nailing

Retrograde intramedullary nailing is suitable for extraarticular fractures (33-A) and sometimes also for simple articular fractures (33-C1, 33-C2) [2, 11–13]. The articular fractures need fixation of the fragments first. Lag screws are used, but the later position of the intramedullary nail always has to be taken into consideration.

Closed intramedullary nailing uses an infrapatellar arthroscopy avoiding the patellar ligament medially. The decision on the approach is dictated by the fracture type. Under guidance of an image intensifier in both planes, with the knee flexed, the central guide wire is inserted into the medullary canal [14]. The medullary canal is opened just anterior to the notch (Fig 6.6.3-10), respecting the origin of the posterior cruciate...
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Fig 6.6.3-9a–b Bilateral femoral fractures.

a Left: simple transverse shaft fracture (32-A3); right: complex articular fracture (33-C3).

b Reconstruction with a DFN on the left side and the LISS system on the right side with additional screws for reconstruction of the condyles.

Fig 6.6.3-10a–c Retrograde intramedullary nailing with the DFN—technique.

a The entry point is identified in two planes using x-ray control. The medullary canal is opened anterior to the condylar notch and reamed over a guide wire.

b Insertion of the retrograde intramedullary nail (DFN), using the insertion handle, over the guide wire.

c Drilling of the hole for the distal interlocking screw with fixed aiming device.
ligament, and the slightly bent solid distal femoral nail (DFN) or the new expert R/AFN (chapter 3.3.1) is inserted into the medullary cavity with the aiming device mounted (Video 6.6.3-3).

To prevent misplacement of the interlocking screws, locking is done from lateral to medial using the aiming device either for the interlocking screws or the spiral blade. If necessary, it is possible to reduce the length of the fracture by careful axial compression. Proximal locking is done using the special radiolucent drill attachment. Due to its axial and bending stability, the locked intramedullary nail, unlike the blade plate, provides adequate long-term stability without additional bone grafting, even in multifragmentary supracondylar fractures [15, 16]. However, the correct alignment of intraarticular fragments may be difficult to achieve with this implant.

4.3.6 External fixation
The indications for temporary joint-bridging external fixation are polytrauma patients, open fractures or dislocations, or closed fractures with severe soft-tissue trauma or vascular damage. If possible, the articular block is reconstructed with minimal internal fixation using conventional or cannulated lag screws. Then, the joint-bridging external fixator is mounted with Schanz screws far from the zone of injury, which are inserted laterally or anteriorly in the femur and anteromedially in the tibia. Both elements are then connected in a tube-to-tube technique (Fig 6.6.3-11), thus providing sufficient stability until definitive treatment is feasible.
4.3.7 Periprosthetic fracture
With an increasing incidence of total knee replacements the number of periprosthetic fractures in osteoporotic bone will rise. To address these fractures, systems based on the internal fixator principle (locking buttress plate, LISS) are recommended (Fig 6.6.3-12).

The use of the DFN (Fig 6.6.3-13) depends on the design of the femur component. The notch must be wide enough to allow access to the correct insertion point.

5 Additional treatment
Cancellous bone grafting is rarely necessary as long as the metaphyseal fracture has not been exposed and devitalized during surgery (indirect reduction technique and biological bridge plating). However, bone grafting is indicated to stimulate new bone formation in larger defects or to provide stability within a comminuted condyle. Exceptionally, bone cement may be applied to provide better implant purchase in very osteoporotic bone. Concomitant lesions of the medial, lateral, and cruciate ligaments are less often encountered. If present, they should be treated primarily, because secondary interventions to the ligamentous structures seldom yield good results in this situation.

6 Complications
Axial and rotational malalignment are typical problems observed while treating distal femoral fractures [17]. Due to the pull of the gastrocnemius and the adductor magnus muscles there is a risk of genu recurvatum with subsequent hyperextension and laxity of the knee joint. A knee flexion of 60° during surgery can help to prevent this.

Varus malalignment and malrotation appears to occur more frequently after fixation with the condylar blade plate than with locking buttress plates. If the insertion point of the blade is too far posterior, the condylar block is shifted medially, which invariably produces a varus deformity.

The less invasive stabilization system needs careful alignment at the femur shaft in the AP as well as in the lateral view, as proximal pull out of the monocortical screws in malaligned plates has been described [8]. Insertion of the LISS plate too far distally can cause soft-tissue problems.

The use of the retrograde intramedullary nail seems to cause fewer axial malalignments, because insertion of the implant requires the knee to be flexed with the lower leg hanging down. This positioning can lead to a partial self-reduction of the fracture. However, malrotation may occur as there is no control of the rotation of the proximal fragment [17]. The retrograde nailing may also cause intraarticular cartilage damage.

If malunion develops, the decision for a corrective osteotomy depends on the degree of malalignment and the severity of symptoms. Valgus/varus malalignment greater than 10° and/or rotational deformity greater than 15° should be corrected.
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Fig 6.6.3-12a–d Periprosthetic distal femoral fracture; preexisting long-stem total hip replacement.

a–b Severely displaced fracture. The femoral prosthesis is not loose or infected.
c–d Stabilization with a LISS. Bone cement was used for augmentation.

Fig 6.6.3-13a–d Periprosthetic distal femoral fracture in a 82-year-old female.

a–b Preoperative x-rays of the severely displaced fracture.
c–d Postoperative control after stabilization with a DFN.
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7 Bibliography


