Fractures of the Distal Femur

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Contents

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G. Bentley (ed.), *European Surgical Orthopaedics and Traumatology*,
DOI 10.1007/978-3-642-34746-7_135, © EFORT 2014

Abstract

Distal femur fractures occur following high-energy impact in young patients often resulting in comminuted and open fractures, whereas low-energy injury is sufficient to cause distal femoral fractures in elderly patients with osteopaenic or osteoporotic bone. The treatment of distal femoral fractures was for a long-time associated with high complication rates. Although implants and surgical techniques were improved in the past decades, plate osteosynthesis and intramedullary nailing suffered from considerable rates of infection, non-union und mal-alignment. Attention to the soft tissue envelope by "biological" osteosynthesis and minimally-invasive approaches resulted in decreased complication rates. In the 1990s out of this movement grew the concept of minimally-invasive plating with locking plates and the retrograde nailing concept.

However, both concepts require precise pre-operative planning and advanced surgical experience to reduce the risk of revision surgery.

Keywords

Aetiology • Anatomy • Classification • Diagnosis • Distal fractures • Femur • Imaging • Rehabilitation • Surgical techniques

Introduction

Distal femoral fractures occur with an incidence of 12 per 100,000 population, mainly affecting young (patients between 20 and 35 years of age) and patients in advanced age, affected by osteoporosis. Distal femoral fractures represent a small proportion of all fractures, between 6 % and 7 % [1].

The goal of past surgical treatment was high primary stability and anatomical reconstruction of metaphyseal fragments, including the transition area. This was achieved by a generous exposure of the operative field, often excessive periosteal stripping and the use of multiple lag screws to achieve high primary stability. Later on it was recognized that extensive exposure could lead to diminished blood supply to the fracture zone with the consequence of delayed union or non-union. As a result in the late 1980s it was almost mandatory to perform a primary bone graft when dealing with a distal femur fracture [2].

In the mid-1990s it became gradually accepted that a minimall- invasive procedure could be performed and still achieve anatomical alignment and length. This became possible with the advent of advanced implants and improved intra-operative imaging. The "re-discovered" importance of iatrogenic soft tissue trauma and the vascularity of the fragments led to several new "minimally-invasive plate osteosynthesis" (MIPO) techniques for distal femoral fractures: minimally-invasive percutaneous plate osteosynthesis (MIPPO) for extra-articular fractures and a trans articular approach and percutaneous plate osteosynthesis (TARPO) for intra-articular fractures [3, 4]. These techniques avoid direct exposure of the metaphyseal fracture site, use the conventional plate as an extramedullary internal splint or using a retrograde intramedullary nail, and do not depend on compression or lag screw application. It was shown experimentally that this more "biological" approach lead to less iatrogenic disturbance of the bone vascularity [5] and resulted in a higher strength, bone vitality and earlier fragment callus bridging [6–10].

Due to the shift in surgical techniques towards minimally-invasive procedures the mechanical benefits of secondary bone callus with bridging callus of the metaphyseal zone became an accepted outcome (as compared to previous decades where it was seen as a disadvantage) [11].

Aetiology

Young male patients suffer a distal femur fracture mostly in the context of multi-trauma, usually by car or motorcycle high-speed accidents. The fracture occurs as a result of direct force to the flexed knee. These road traffic accidents account for over 50 % of distal femur fractures in this age group [12, 13]. About 30 % of these patients are polytraumatized, with additional injuries of the

Table 1 Injuries and associated injuries of distal femoral fractures

Injury	Incidence
Polytrauma	44 %
Closed soft tissue injuries	20 %
Open fractures	24–40 %
Nerve and vascular injuries	3 %
Ligament injuries	10 –19 %
Meniscal damage	4 %
Cartilage injuries (flake fractures)	7 %
Patella fracture	4–19 %
Associated ipsilateral extremity injuries	17–27 %
Injury of the contralateral limb	10–13 %

trunk and the skull. According to the literature and our own observations, 10–15 % of patients with a distal femur fracture have an accompanying patellar fracture. Knee ligament instability requiring treatment occurred in 20–30 % of cases. In a total of 20–25 % of cases a further bony lesion of the ipsilateral leg was also observed (Table 1).

A particular pattern of injury is the "floating knee". This combination of a distal femoral fracture with a proximal tibial fracture is reported as about 5 % of distal femoral fractures [12, 13]. Related concomitant vascular or nerve injuries, although rare, must always be excluded first in these cases. A common pathogenic mechanism in traffic accidents is the so-called "dashboard injury", in which the patella is driven by the impact of the knee like a wedge between the femoral condyles. This also explains the combination of injury between intra-articular distal femur fractures and patellar fractures. If trauma occurs to the longitudinal axis of a leg fully extended at the knee, the tibial plateau is driven against the condyles. This leads to a supracondylar femoral fracture, followed by impaction of the condyles through the femoral shaft. This accident mechanism can be seen in a fall from height, but also in traffic accidents.

The second peak age is found in mostly female patients elder than 65 years. This increases the incidence of distal femur fractures up to 170 per 100,000 population for the over 85-year-old [14]. The causes of accidents found in this population are predominantly low-energy trauma. Favourable to this fracture origin is an osteoporotic bone structure.

Anatomy

The femoral condyles, together with the tibial plateau and the patella, are a functional unit (Fig. 1). They are all contained within the capsular ligaments, which are crucial for the function of the knee and located on the inner and outer condylar regions. Within the intercondylar notch the anterior cruciate ligament inserts in the dorso-medial aspect of the lateral condyle and the posterior cruciate ligament in the ventro-lateral region of the medial condyle. On the posterior epiphyseal surface of the distal femur arises the medial and lateral heads of gastrocnemius from their respective condyles. These heads can avulse after a fracture the distal fragment in hyperextension. Adductor magnus inserts on the medial condyle and a portion of popliteus inserts on the lateral condyle. In a dorso-ventral direction, the outer condylar shoulder converges trapezoidally, which must be considered when implanting metalware. In the frontal plane the condyle surfaces run at an angle of about 7° to the femoral shaft. In particular, axial deviation in this plane, and joint steps associated with intra-articular fractures lead to post-traumatic osteoarthritis. The range of motion is primarily dependent on the articular defects and post-traumatic adhesions, which restrict the mobility. Decisive preventive measures include early functional exercises of the knee joint.

Diagnosis

In severe trauma with the potential for multiple injuries, the first priority is to diagnose injuries of the torso and visceral cavities and treat any that are an immediate threat to life. For most of the acute distal femoral fractures the diagnosis can often be made already clinically. The vascular and sensorimotor status of the patient must always be assessed. A doppler ultrasound should be used immediately if the flow status of a vessel is

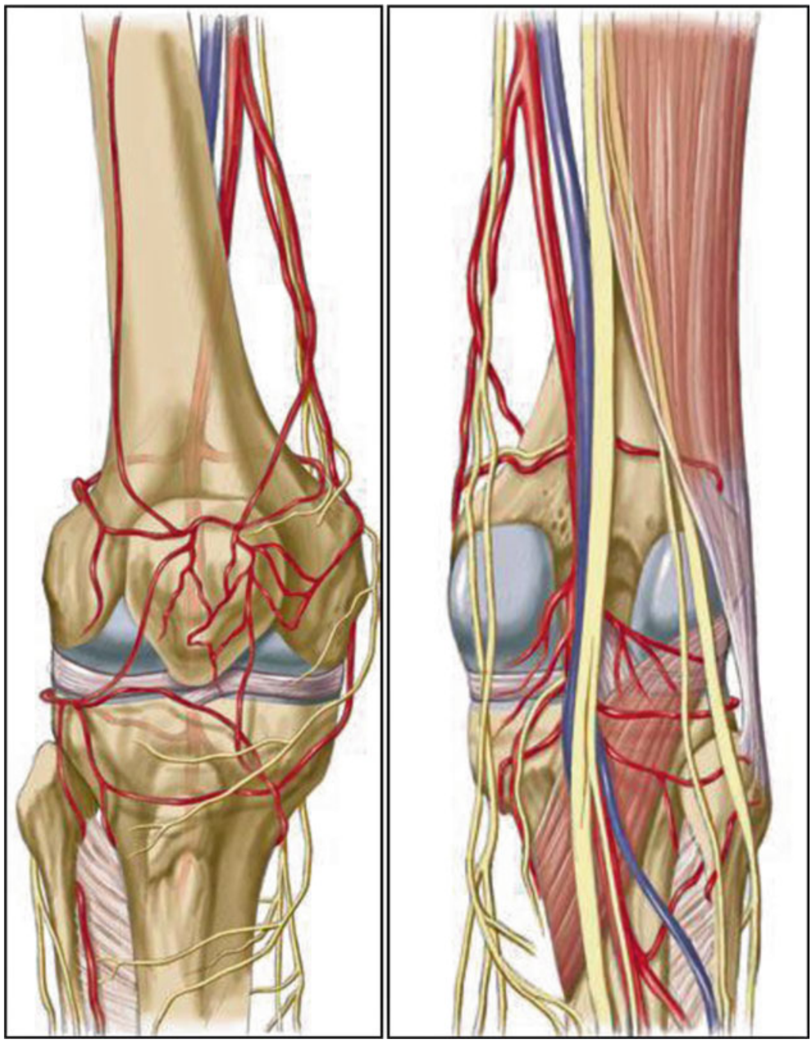

Fig. 1 Distal femoral anatomy highlighting the popliteal vessels, the popliteal artery and vein, and the sciatic (*anterior* & *posterior* view) (From : M. Schütz, M.J. Kääb (2012) Distale Femurfrakturen. Tscherne Unfallchirurgie, p. 359, Springer-Verlag Berlin Heidelberg. With permission of Springer-Verlag)

unclear. If no examination of the peripheral nerves can be performed, this must be specifically stated in the examination form. During the examination it is important to pay attention to axial deviations and soft tissue injuries. The investigation of internal knee injuries is to be omitted in the initial diagnosis due to unnecessary pain provocation and the risk of fracture dislocation, vascular and nerve damage. The capsule-ligament stability needs to be necessarily judged by surgical treatment and subsequent clinical course.

The severity of the accompanying soft tissue damage is critical to decisions regarding surgical approaches and definitive treatment. Therefore, the assessment should be made by an experienced surgeon. In the case of an open fracture and soft tissue injury, the principles of open fracture management are applied. High energy fractures have a higher risk of associated neurovascular complications and highlight the importance of surveying the entire limb at the time of initial assessment. The possible development of compartment syndrome must be considered. After the first clinical examination, the basic radiological diagnostics should be performed including conventional X-ray images of the entire femur and possibly a sufficiently objective radiograph of the distal femur. For intra-articular fractures or where articular involvement is questionable, additional knee views in two planes are also required. In the presence of fracture it is important to take a pelvic radiograph to rule out pelvic injuries.

Depending on the type of fracture (particularly for intra-articular comminuted fractures) and the overall condition of the patient a computed tomography (CT) with two-and three-dimensional reconstruction should be performed for surgical planning. If the articulation is involved, a CT scan is mandatory. The indications for MRI examination include the diagnosis of internal knee lesions in the presence of pathological fractures or intra-articular shear fractures. Angiography is required in cases of suspected vascular lesions or negative abnormal Doppler findings.

Classification

Various different classification systems are available for distal femoral fractures however, the AO classification over the last decade has become more widely used in clinical, education and research purposes (Fig. 2). The advantage of the AO classification is that it allows comparison with other classifications along with more precise mapping of the fracture types and a forecast of therapeutic approach and prognosis [15, 16]. The five-digit alphanumeric code, based on extensive evaluation of a fracture, comprises the fracture location and type. The classification incorporates the division into extra-articular (type A), partially or uni-condylar articular (type B) and articular fractures (type C). From A to C, the severity of the fracture increases with worsening of the prognosis for uncomplicated healing, this is true of 1-3 in the sub-groups.

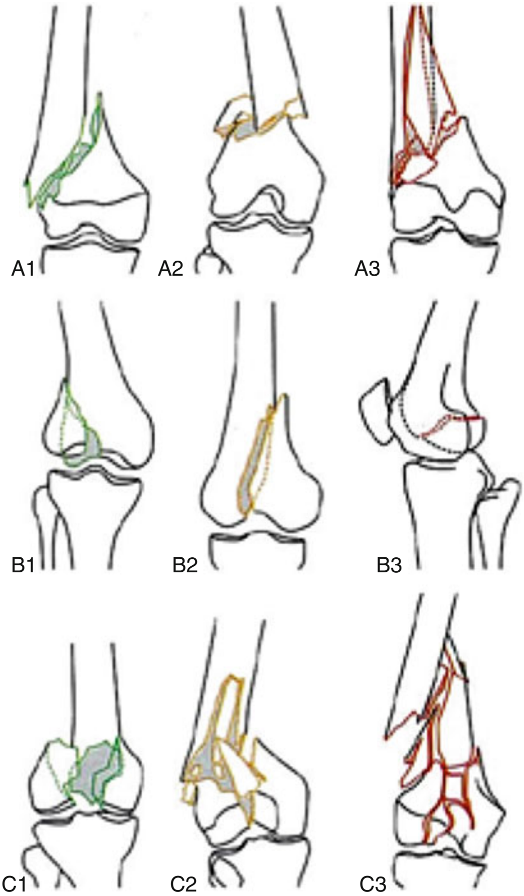

Fig. 2 AO-Classification of distal femur fractures [From AO Manual of fracture management, Thieme Verlag (Copyright by AO Foundation, Switzerland. www.aosurgery.org)]

Indications for Surgery

Nowadays most of distal femoral fractures are managed surgically due to the better clinical outcomes. The conservative treatment of distal femur fractures is an absolute exception and only indicated in patients with non-dislocated fractures, very severe osteoporosis or with an extreme high general anesthetic risk or certain undisplaced paediatric fractures. Various implants are available for the surgical treatment of distal femur fractures. Nevertheless the treatment goal remains always the same, regardless of the surgical technique and the implant used. The aim is to achieve anatomical reconstruction of the articular surface, correct axial alignment and restoration of length of the distal fragment to the shaft to allow early functional, plaster-free treatment of the injured limb.

Through applying these AO principles the post-surgical outcomes published in several studies have significantly improved. Already in the 1960’s. nearly 75 % of cases the result obtained was considered as good to very good [17].

Pre-Operative Preparation and Planning

Surgical treatment of distal femur fractures should only be performed by surgeons with an adequate understanding of the fracture and a wide experience of the different treatment methods. The patient's clinical situation should be stable, otherwise an external joint bridging fixator can provide an excellent temporary device to stabilize the limb. When selecting the appropriate surgical procedure the surgeon is influenced by a variety of factors: the type of fracture, associated injuries, bone quality, overall condition of the patient, the surgeon's own experience and that of the surgical team, and logistic requirements. During the pre-operative preparation and planning, the drawing is still an essential part in the planning of reduction, implant selection and implant size and to gain an understanding of the fracture characteristics. At this stage we also need to anticipate possible problems and to consider options and alternative withdrawal operations. Furthermore, it must be ensured before surgery, that the desired implants (also the alternative methods) are present.

Extra-articular distal femoral fractures can be managed with either extra- or intramedullary implants. In both processes the fracture is reduced and stabilized indirectly preferably by minimally-invasive techniques. In extramedullary fixation angular stable implants (condylar plate, DCS or pre-contoured locked plates) are applied. On the other hand for intramedullary fixation the antero-grade and retrograde intramedullary nailing systems are available.

Partial intra-articular fractures are usually stabilized with screw fixation. In cases of particularly poor quality bone, however, a supportive plate fixation may be necessary. Also, for completely intra-articular fractures extramedullary and intramedullary stabilization is used. The key to deciding which technique to apply is it the implant can be anchored in the distal fragment. Plating technique is certainly the choice when the intra-articular fracture is characterized by high grade comminution and multiple small fragments (Table 2).

Operative Techniques

Patient Positioning

The length of the leg and the rotational profile of the contralateral extremity is examined pre-operatively to ascertain the correct rotational profile and length of the injured femur. The patient should be placed in supine position on a radiolucent table to allow complete radiograhic

Table 2 Possible implants for the final fracture treatment of distal femur fractures ([b]an additive to the screw fixation in severe osteoporosis possible), Locked Plate System, *DCS* Dynamic Compression System; [a]AO classification of distal femur

AO[a]	Screws	Plate	Internal Fixator	Intramedullary
A1-A3		Condylar blade plate, DCS	Locked plates	Retrograde Femoral Nail, antegrade femoral nail
B1, B2	3.5 mm. Small fragment screws, 6.5 mm. cancellous screws, partially threaded screws	Condylar blade plate[b]	Locked plate[b]	
B3	3.5 mm. small fragment screws, Partially threaded screws			
C1, C2		Condylar plate, DCS	Locked plate	Retrograde femoral nail
C3			Locked plate	

imaging of the lower leg up to the hip joint during the surgical procedure. The operated leg should be freely movable. Preparation and draping should allow complete exposure of the operated femur up to the hip joint, especially in cases where a longer plate is to be used. The knee joint line should be placed slightly distal to the hinged part of the table to allow flexion of the knee joint during the surgery. A fully extended knee should be avoided, because the force of the gastrocnemius muscle would pull the distal fragment into recurvatum, which makes the reduction of the fracture more difficult.

Surgical Approaches

The surgical procedure and therefore the approach depends on the type of fracture (extra-articular vs. intra-articular) and whether an intra-articular fracture requires open reduction. In extra- articular fractures and in fractures with simple articular involvement (AO Classification C1), a lateral approach to the distal femur is used (Fig. 3a, b), when choosing a plate. A lateral incision approximately 8 cm. long is made from Gerdy's tubercle and extended in a proximal direction to expose the lower margin of the vastus lateralis. The incision should be made in the line of the shaft. After sharp dissection of the subcutaneous tissue, the iliotibial tract is split in the direction of its fibres. There is no need to open the joint capsule in extra- articular fractures, but visualization or palpation of the anterior femoral condyle might be helpful for positioning of the plates. This approach is only appropriate for extra-articular or undisplaced articular fractures. For all displaced articular fractures of the distal femur, a lateral parapatellar approach should be used to ensure an optimal overview of the articulation to judge the appropriate reduction (Fig. 3c, d). The skin incision of approximately 10–15 cm. is made parapatellar on the lateral side. The joint capsule can then be divided in line with the split in the iliotibial ligament. A medial dislocation of the patella ensures an optimal overview of the articulation.

Screw Fixation

The isolated screw fixation is the preferred method in uni-condylar fractures (B-fractures). One disadvantage of screw fixation is that the strength in osteoporotic bone may not be enough. In these cases additional internal fixation with a plate is necessary.

Plating

Access to extra-articular fractures are usually via a short lateral approach. The reduction is performed indirectly. Individual larger fragments can optionally be reduced with a Kirschner wire. Especially with multi-fragmentary A3 fractures, the temporary use of an external fixator or distractor to correct axial alignment and to control the rotation may be required. The stabilization is preferably with angle-stable implants: condylar blade-plate, DCS or locking plates. The non-angular stable plates are hardly used anymore on the distal femur.

A meta-analysis of 624 distal femur fractures demonstrated a 6.4 % infection rate, a rate of delayed union of 5.3–3.4 % and an incidence of non-union and implant failure of 5.9 % [19–21].

Condylar Blade-Plate

The condylar blade-plate (95° angle-plate, blade-plate) is an angle-stable implant. Indications are supracondylar fractures, and as additional stabilization for uni-condylar fractures and simple intra-articular fractures. The condylar plate carries a high primary stability and is a frequently used and appropriate implant. Due to the rigid connection of the blade with the drive shaft it is important to ensure the proper insertion of the blade into the condyle at all levels because the position of the implant cannot be corrected. Furthermore, a minimally-invasive fixation with the condylar plate is not possible, since access to the length of the implant is required. When breaking the blade must be a previously reconstructed

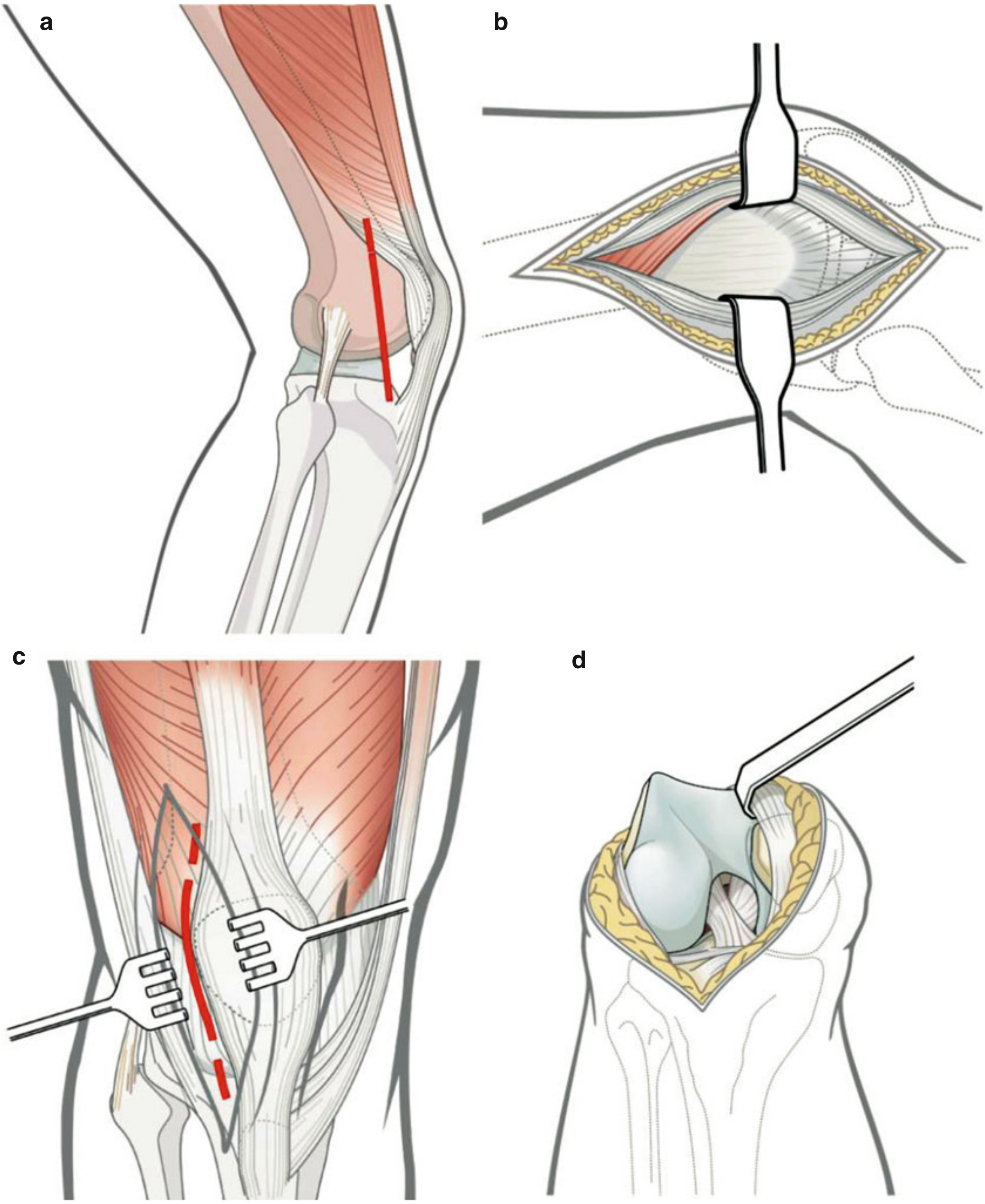

Fig. 3 The surgical approaches for plate insertion depends whether or not an articular fracture requires open reduction. In non-articular fractures and fractures with simple articular involvement, a lateral approach to the distal femur is used (**a**, **b**). For displaced intra-articular fractures or multiplane articular involvement a parapatellar approach is recommended (**c**, **d**). The medial dislocation of the patella ensures an optimal overview of the articulation (**d**). Both approaches allow, precutaneous plating. [From, AO Manual for fracture fixation, Thieme Verlag (Copyright by AO Foundation, Switzerland. www.aosurgery.org]

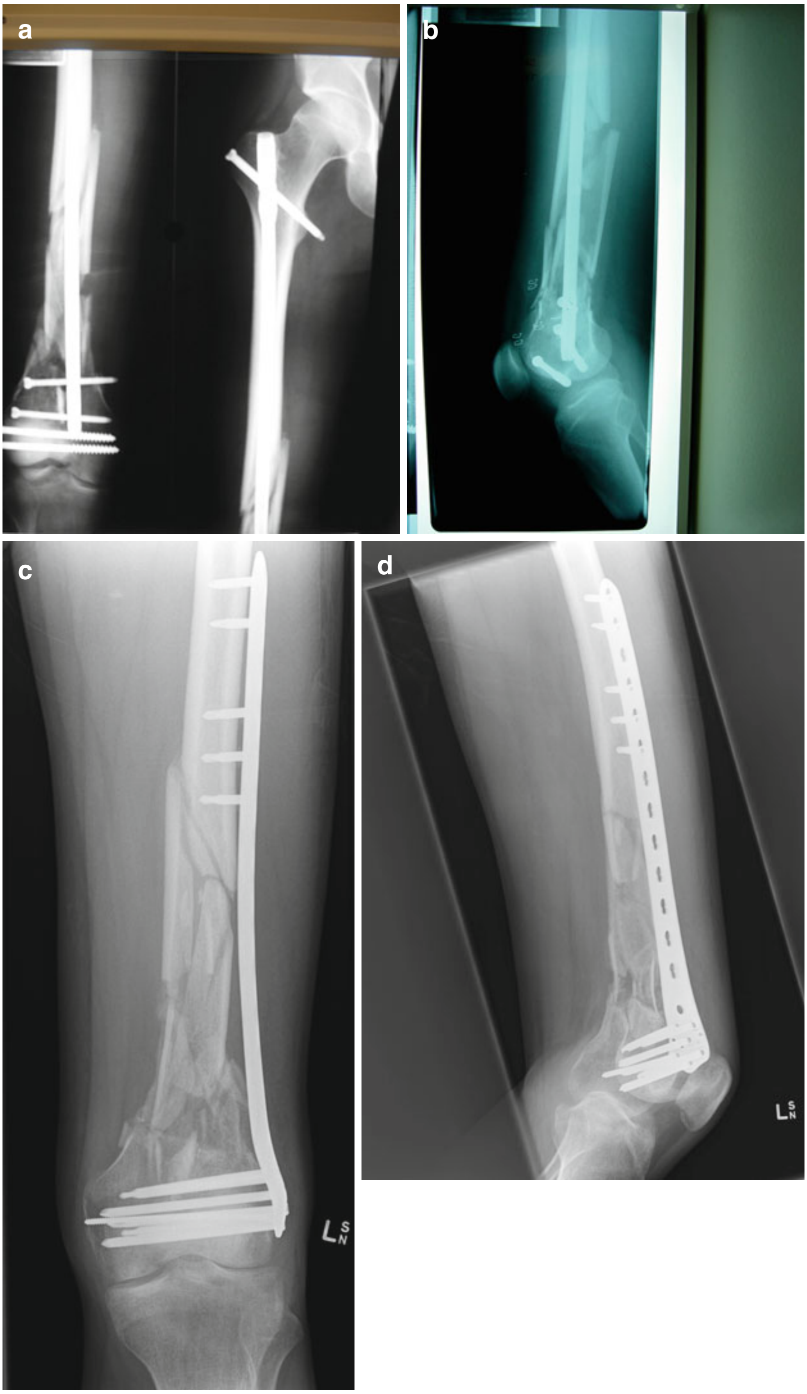

Fig. 4 (continued)

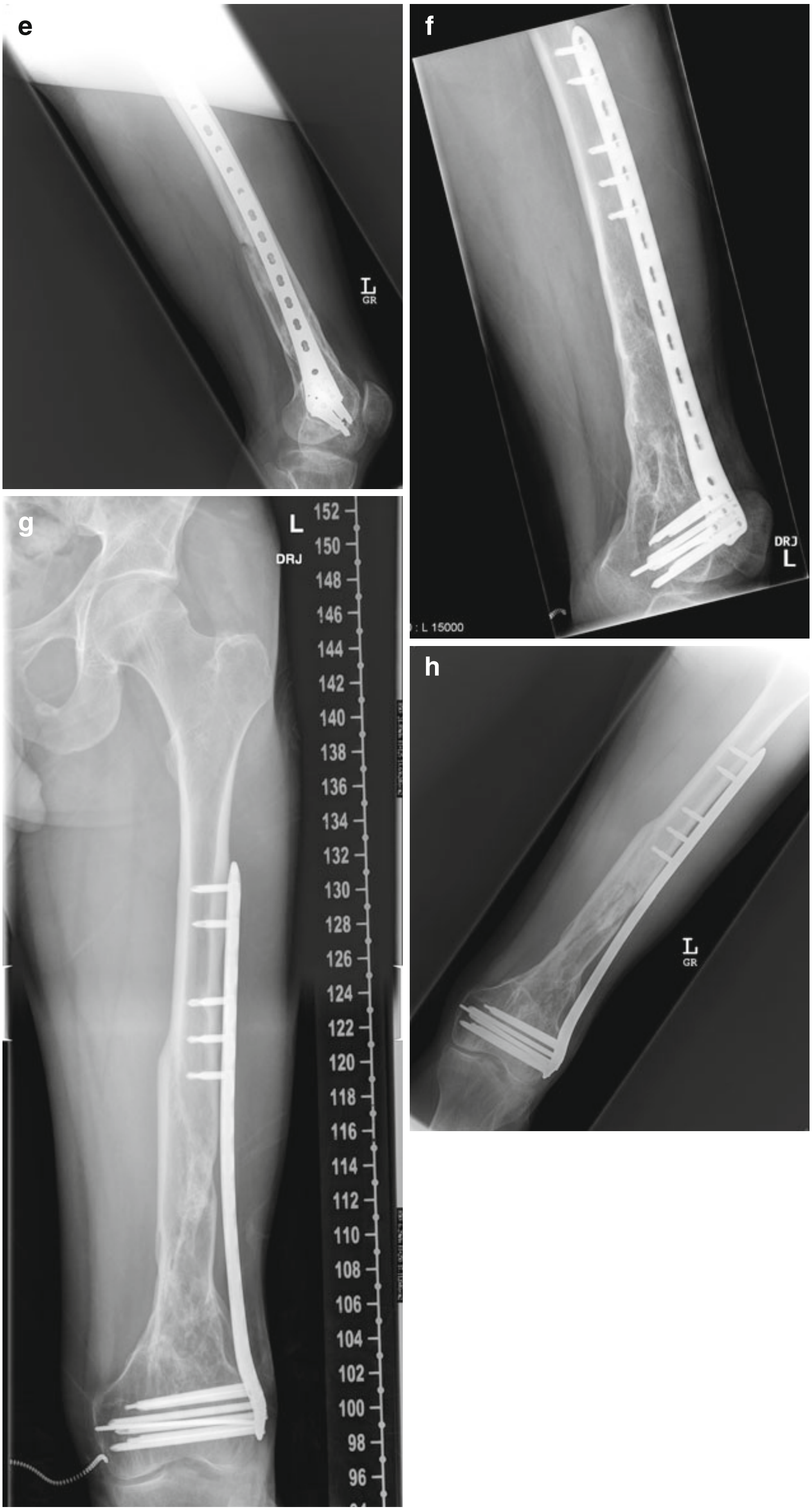

Fig. 4 (continued)

joint block special attention should be given as possible, especially with good bone quality is its detonation. Furthermore, another indication for the condylar plate is fractures reduced with a very short distal fragment. In the recent literature, the number of complications with the condylar plate included: 11.2 % infection rate, rate of delayed healing of bone fractures 10.4 %, 7.1 % pseudarthrosis and implant failure rate of 3.2 % [22, 23].

DCS

The dynamic condylar screw (DCS) is, also, an angle-stable implant, and the indications are similar to those of the condylar plate. Advantages of DCS compared to the condylar plate are:

- Easier implant placement / adjustment to the femoral shaft
- Reduced risk of losing reduction of the reconstructed condyle due to using finer drilling techniques and screws as opposed to the hammering of the chisel blade
- Possibility of using minimally-invasive techniques by the two-piece implant design.

A possible disadvantage to the condylar plate is the greater loss of bone mass and a slight decreased rotational stability in the sagittal fracture plane [24]. The average complication rate of internal fixation with DCS is: infection 3.2 %, 5.7 % nonunion and an implant failure rate of 2.5 % [16, 21].

Locked Plates (Internal Fixators)

Locked plates are angular-stable systems that differ fundamentally from conventional extramedullary angular stable systems (condylar plate or DCS). The indications for locked plating covers all distal femur fractures, except fractures, which can be stabilized with the sole lag screw fixation. The advantage of locked plating is the permanent angle stability, which prevents a secondary loss of reduction, the preservation of cortical perfusion and the possibility of minimally-invasive surgical technique. The angular stability is guaranteed by the precisely fitting threaded connection between screw head and plate hole [18, 25, 26].

In the conventional plate fixation the stability of the plate-bone contact point is generated by friction under the plate. The friction force depends on the friction coefficient of the plate pressure, caused by the screw force acting in an axial direction. Thus, in conventional plate fixation with axial extension, a cross-loading of the bone and a longitudinal stress on the screws will occur. With locked plating the longitudinal forces are transferred through the angle screws as shear forces on the bones and a friction fit is no longer necessary. The result is that most of the cortical blood flow remains undisturbed [27].

Nowadays specially developed locked plate systems for the distal femur are broadly available combining angular stability and options for percutaneous plating / screw placement. The LISS (Less Invasive Stabilization System), as the first available system, consists of the basic support which is pre-formed according to the anatomy of the distal femur and is specific for the right and left side ranging up to 16 holes in plate length. Using an adaptive aiming device the LISS can be implanted minimally-invasively. The targetting device also acts together with a trocar system as a target device for percutaneous insertion of the self-drilling and tapping locking screws (Figs. 4 and 5).

In the pre-operative planning the implant length is determined, and following the biomechanical principles the aim should be a rather long implant. The length of metaphyseal screws as well as

Fig. 4 32 yo male with a closed distal multifragmentary femoral fracture (AO 33-C 2) after MVA. The initial management was done with lag screws and antegrade femoral nailing (elsewhere). After returning to Australia, the distal screws had already loosened and the fixation had to be revised (**a**, **b**). Revision surgery was performed with a locking plate in a bridging technique (**b**, **c**). Anatomic precontoured plates are facilitating the indirect reduction, when knowing that the distal locking screws should be parallel, when the plate shaft is adequately place to the femur shaft. X-ray follow-up after 1 years (**e**, **f**) and after 5 years (**g**, **h**) showed a good healing of the fracture

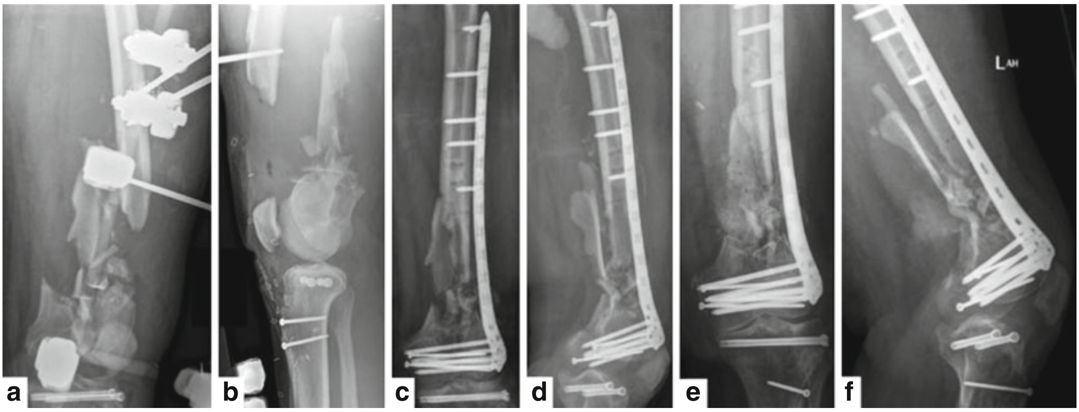

Fig. 5 34yo polytraumatized male after MBA(Motor Cycle Accident) with an III B open distal femur fracture (AO 33-C3) in combination with a proximal tibia fracture (floating knee injury). Initial treatment was performed in the receiving hospital with an external fixator (**a**, **b**) before transferring the patient to a tertiary facility for further management. Definitive fixation with a 3.5 mm. lag screws and a locking plate system (**c**, **d**). Due to the fact of initial bone lost, further bone grafting was required after 6 month. One year follow up showed increasing healing of the fracture with no dislocation of the implant (**e**/**f**)

bi-cortical screws in the shaft is directly measured. In cases (young patients) with strong cortical bone mono-cortical shaft screws can be used. In contrast, a bi-cortical screw fixation remains recommended in cases when in doubt and clearly with more osteoporotic bone structures.

The average infection rate of locked plates is 3.3 % (meta-analysis of 268 fractures), the rate of delayed fracture healing and non-union 2.4 % and the rate of implant failure 5.9 % [25, 28, 29]. It should be noted that most implant failure is related to proximal screw pull-out that occurred due to the minimally-invasive and non-central placement of the implant to the femoral shaft in the early days of percutanous plating.

Intramedullary Nails

Antegrade and retrograde femoral nails can be used for the treatment of distal femoral fractures depending on the size of the distal fragment. One advantage of nailing in comparison to extramedullary fixation is the biomechanical concept of a support beam in the main loading axis. Another advantage is the less frequent irritation of the iliotibial band in contrast to extramedullary devices. The fixation properties of retrograde nails compared to a condylar blade-plate are a much higher axial stiffness and a comparable bending stiffness [30]. A biomechanical disadvantage is the lower rotational stability of nails compared with extramedullary angular stable implants. Nevertheless the lower rotational stability appears to be sufficient for post-operative neutralization of torsional forces considering the good clinical experience with intramedullary stabilization of femoral shaft fractures [31].

Most interlocking nails, by design, achieve rotational stability in the sagittal plane by introducing two distal locking screws, or special locking options like spiral blades in retrograde nails. However stabilization can be quite challenging in short distal fragments.

Antegrade Technique

The antegrade intramedullary nailing of distal femoral fractures is a rare indication. Standard implants are used, and the indication for extra-articular fractures is limited to those in which the fracture line is at least 4–5 cm. proximal to the former growth-plate [32]. The indication for antegrade nailing was extended by some authors to intra-articular fractures of the distal femur [33, 34]. Intra-articular fractures are reconstructed anatomically according to the articular surface and stabilized with lag screws and a nail placed by a standard antegrade technique. The known general problems of antegrade nailing such as Trendelenburg limp and heterotopic ossification at the insertion site, joins the problematic alignment of the distal fragment. In an analysis of 57 cases of antegrade intramedullary nailing of distal femoral fractures, the infection rate was 0 %, the delayed healing of bone fractures 3.5 %, non union 0 % and the rate of implant failure 3.5 % [33, 34].

Retrograde Technique

The current standard procedure when intramedullary nailing distal femoral fractures is to use the retrograde femoral nail [35] (Fig. 6). For retrograde nailing today a multitude of different implants are available differing in material and design (especially regarding the locking options).

The retrograde intramedullary nailing can be performed minimally- invasively and

Fig. 6 18 yo male after MBA with a fracture distal to the femur isthmus. After initial treatment with an external fixator, a distal femoral nail was choosen due to massive abrasions over the hip area. The X-Rays on the right demonstrate the healing progress after 6 and 18 months

allows, the direct visualization of the articular surface. Indications for retrograde nailing are extra-articular distal femur fractures and simple (C1 or C2) intra-articular fractures of the femur, allowing a double distal locking. One problem is the retaining force of the distal locking screws, which can lead to a loosening in osteoporotic bone. This loosening occurs in about 8 % of cases [31, 36]. The holding force of the distal locking screws could be increased by a modified geometric arrangement of the screws, through the introduction of a spiral blade and the fixed angle distal clamping [37]. Other problems occurring with the retrograde femoral nailing technique may be heterotopic ossification, fractures of the locking pin, adhesion-related limitations of range of motion swelling of the knee joint and symptomatic, prominent distal locking bolts [31, 37, 38].

In the analysis of 344 distal femur fractures which were treated with retrograde nailing, the infection rate was 0.3 %, the rate of delayed healing 4.7 %, the rate of non-union 2 % and implant failure rate was 8.4 % [39–43]. Rotational deformities were found in 8.3 % and deformities in the frontal plane in 3.2 % of cases. The cause of implant failure is usually the loosening of the distal screws or screw breakage.

External Fixation

The definitive treatment of a distal femoral fracture with an external fixator is an exception. In most cases, the fixator is for primary care in severely injured patients who are not operatively fit to allow for complex, definitive fracture fixation. Other reasons may be the complexity of the fracture or severe soft tissue damage. In fractures with vascular injury requiring surgical therapy the rapid fixator assembly allows for urgent vascular repair and undisturbed re-vascularization. The advantages of external fixation are the comparatively low surgical trauma, short operation time and the simple installation, which can even be made in individual cases outside of regular operating rooms. In hardly any cases is an external fixation used for final fixation, while it is used for knee joint bridging in cases of distal femur fracture. Another disadvantage is the possibility of pin-tract infection, which can also delay the delivery of secondary definitive osteosynthesis. The application of external fixation to the distal femur is predominately done as a joint-bridging assembly (transarticular external fixation - TEF). For solely femoral stabilization 2 pins/screws are anchored in the distal fragment. The danger in the anchoring of Schanz screws in the distal fragment is the fixation of this fragment in the wrong position and the ability to cause a pin-tract infection in the future operative field. In the TEF, the Schanz screws are introduced a safe distance from the fracture. The trans-fixation of the joint is useful for the conditioning of the soft tissues and the protection of vascular reconstructions. In some cases (simple articular fractures), a limited extended surgery may be useful in protecting alignment of the articular fragments once they are screwed together. The restored articular surface is then connected to the secondary definitive osteosynthesis with the stock.

Post-Operative Care and Rehabilitation

The fracture care follow-up treatment needs to be adjusted to the individual fracture situation, the surgical treatment, the implants being used, the concomitant injuries and the co-operation of the patient. The wounds should be checked regularly and the suture materials should be removed after about 12 days post-operatively, pending normal progress. After every operation, an x-ray examination should be performed for the purposes of documentation and legal formality. The surgeon should keep records about the maximum range of motion, the degree of weight- bearing and the need for additional support (e.g. orthoses). Special attention should be on thrombosis prophylaxis and sufficient pain medication to allow the post-operative rehabilitation. After the operation, the limb should be positioned in a soft splint with a slight flexion of the hip joint. But immediately after post-op. day one, the treatment with physiotherapy / and continuous passive motion (CPM – splint) should start, to reduce the risk of adhesions, support the cartilage healing and to help to reduce the swelling [44]. The CPM-treatment should be performed frequently, until the patient gets mobilized. Depending on the fracture type, the patients should partially weight-bear for 6–12 weeks. Extra- articular fractures need partial weight-bearing for 6–8 weeks, whereas complex intra-articular fractures might need partial weight-bearing for up to 12 weeks. Depending on the radiological signs of bone healing, the weight-bearing can be increased stepwise. If necessary, implant removal can be considered at the earliest after 18 months. In general, the post-operative management should take into account individual circumstances and must be well explained to the patient.

Complications

Complications that can occur during the surgical procedure include general risks of damaging vessels and / or nerves. The surgeon should pay special attention to the vascular bundle that runs closely posterior to the knee joint, especially when drilling in the antero–posterior direction. Particularly in complex fracture patterns a mal-alignment of the distal fragment can occur, if the implant is not placed correctly. The positioning of the implants and the intra-operative control of axis and length is even more important by using a minimally invasive method because of the reduced visibility of the fracture site.

Beside the general post-operative complications the loss of reduction and a reduced range of motion in the knee joint might occur after distal femur fractures. The infection rate after surgical treatment of distal femur fractures is about 3.9 %, depending on the surgical technique and the implant used [31, 36, 41]. Delayed union occurs in 5 %, but a non-union only in 2.2 % of the cases and implant failure was reported up to 6.4 %. Arthrosis is a common late complication, either due to mis-alignment of the axis with extra-articular fractures or because of cartilage damage with intra-articular fractures. Therefore the identification and an early treatment of mis-alignments have a high importance. Furthermore, the instability of the knee joint after distal femur fractures has an incidence of up to 39 %, and a limitation of the range of motion at the knee joint between 10–40 % [23, 45]. Beside intensive physiotherapy to achieve a better range of motion, an operative mobilization under general anesthesia should be considered in some cases.

Summary

Distal femur fractures occur following high-energy impact in young patients often resulting in comminuted and open fractures, whereas low-energy injury is sufficient to cause distal femoral fractures in elderly patients with osteoporotic bone. For the treatment of distal femoral fractures, mostly two fixation principles are used today: retrograde IM nailing or locking plating techniques. Both operative stabilizing systems follow the principle of biological osteosynthesis. The key factors of the operative treatment are the reconstruction of the articular surface and the biomechanical axis of the femur. The surgical management of distal femoral fractures remains challenging and requires accurate pre-operative planning. This means, if the articulation is involved, a compulsory CT scan should be performed before choosing an appropriate treatment / approach. Considering a good planning and the right treatment, good long-term results after open reduction and internal fixation can be achieved. The knee function increases through time, though the range of motion does not increase after 1 year. The presence of secondary osteoarthritis does not mean less favourable functional results in most patients [46].

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