3 Management of Distal Femoral Fractures (Extra-articular)

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Abstract

Extra-articular distal femur fractures are challenging orthopedic injuries that occur less commonly than proximal and diaphyseal femur fractures. As implant design and technology improve, the rate of fracture healing and complication rate have both improved. Currently, these injuries are most commonly treated with lateral locking plates or intramedullary nail fixation, but have yet to show uniformly good results. Considerations to direct the appropriate implant choice include degree of comminution, distance above the joint line, and intra-articular extension. Complications of distal femur fixation include nonunion, implant failure, and malalignment. These complications may have severe impact on functional and radiographic outcomes, and strategies to achieve appropriate alignment and fixation of femur fractures must be carefully considered to achieve optimal results.

3.1 Epidemiology

Like many traumatic fractures, distal femur fractures occur in a bimodal distribution, with high-energy injuries seen in young patients and low-energy injuries in osteoporotic elderly patients. These fractures represent less than 1 % of all fractures and are less common than femoral shaft and proximal femur fractures, making up only about 5 % of femur fractures [1]. Five to ten percent of distal femur fractures have been reported to be open fractures [2], though other studies have demonstrated higher rates [2, 13].

3.2 Traumatic Mechanism

Mechanism of injury may involve axial loading, bending forces, rotation, or any combination therein. The fracture pattern may reflect the mechanism of injury (i.e., spiral fracture in setting of rotational injury or comminution in high-energy

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axial loading). High-energy mechanisms also result in a relatively large degree of soft tissue stripping from the bone and may ultimately result in open fractures. The open wounds associated with fractures are typically anterior and involve injury to the quadriceps tendon to a variable degree. The high-energy injuries are commonly reported to occur through motor vehicle or motorcycle crash, whereas the low-energy injuries often result from a fall from standing height.

3.3 Clinical Examination

Clinical exam begins with advanced trauma life support (ATLS) protocol, especially for higher-energy mechanism of injury. Limb-specific evaluation first involves the neurovascular exam to detail perfusion or nerve compromise. The skin must also be inspected for evidence of open fracture. The resting position of the lower extremity is examined for gross deformity, and the hip, thigh, and knee are evaluated for instability. Swelling and bruising are often seen at the level of injury. Compartment syndrome must be considered and ruled out at the time of initial exam. Ligamentous examination of the knee may be difficult due to proximity of the femur fracture, but should be considered.

3.4 Imaging and Preoperative Workup

Plain radiographs with orthogonal views of the entire length of the femur must be obtained to fully evaluate the distal femur fracture and to rule out ipsilateral femur fractures at other levels. The distance from the joint is measured, as this is important when considering implant choice.

CT scan is helpful to evaluate comminution, intercondylar extension (covered in the intra-articular distal femur chapter), and coronal plane fractures (Hoffa fracture).

Any concern for vascular injury would be an indication to obtain an ankle-brachial index (ABI). Any patient with a suspected vascular injury and ABI less than 0.9 should be evaluated by vascular surgery and have lower extremity angiography performed.

3.5 Classification

For practical purposes, many orthopedists use a descriptive classification of distal femur fracture patterns. However, the AO/OTA classification is the most commonly applied to the distal femur. AO/OTA classification for extra-articular distal femur fractures is denoted 33A. The extra-articular fractures are further divided into 33A-1, 33A-2, and 33A-3, indicating simple, metaphyseal wedge, or comminuted fracture pattern, respectively (Fig. 3.1). 33B and 33C (partial articular and complete articular, respectively) fractures will be covered in a separate chapter.

3.6 Indications

Most fractures of the distal femur require reduction and stable internal fixation to restore alignment and allow early range of motion. Nonoperative management is typically only appropriate for stable, nondisplaced fractures, or it is reserved for those patients who are nonambulatory or too medically unstable to tolerate surgery.

Fractures of the femoral shaft distal to the midshaft of the bone (infraisthmal) are good indications for an intramedullary (IM) nail. Extra-articular distal femur (supracondylar) fractures are amenable to a retrograde nail as well, but the surgeon must be sure that at least two screws, preferably out of plane to each other, can be inserted into the distal fracture segment. A simple coronal split in the articular cartilage can be fixed with a cancellous screw, and then a retrograde IM nail can be inserted as long as careful pre-op planning assures that the implants will not interfere with each other. Coronal fractures of the condyles can easily be managed with screw fixation remote from the IM nail insertion site and can be done before or after the IM nail procedure. With the increased incidence of both total knee replacements and osteoporosis, retrograde IM nailing of periprosthetic fractures can lead to a stable construct that may even allow some partial weight bearing due to the load-sharing properties of the IM nail. With all very distal femur fractures, it is incumbent upon the surgeon to examine the x-rays for intra-articular fracture lines and also to deter-

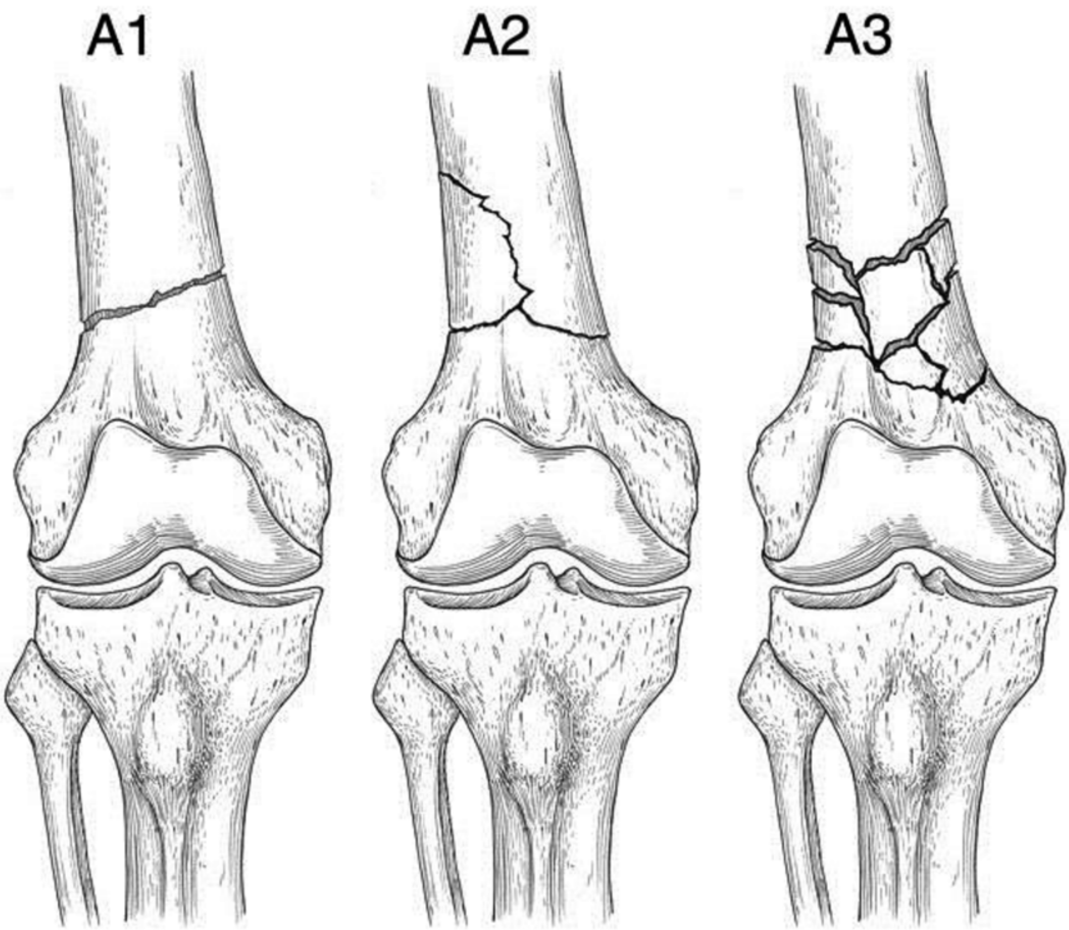

Fig. 3.1 AO/OTA diagram for 33A fractures (Reprinted with permission from FW Gwathmey [16])

mine the total amount of distal femur available for screw fixation. Remembering that the IM nail will be inserted just proximal to the intercondylar notch and knowing the location of the screw holes in the IM nail for distal interlocking will allow the surgeon to stabilize distal fractures with an IM nail when these parameters are met.

When a fracture is too distal to allow adequate fixation with the distal interlock screws of an IM nail, a lateral distal femur locking plate may provide a better option. The plate can be positioned quite distally if needed, with multiple screws available for fixation at the level of the condyles and metaphysis. Newer, variable angle locking plates are also now available that may provide the surgeon with improved ability to stabilize a wider range of fracture patterns.

3.7 Surgical Techniques (Anesthesia, Patient Positioning, Surgical Approaches, Reduction, and Fixation Techniques)

3.7.1 Anesthesia

For any patient requiring surgical stabilization of a distal femur fracture, clearance or optimization for surgery by the primary medicine or trauma service is obtained. Thorough evaluation by the anesthesia team should also be undertaken, and general anesthesia is routinely used for the procedure. If the surgeon believes that the reduction might be difficult or that gaining length may be a challenge, then it is incumbent for the surgeon to discuss the matter with the anesthesiologist and recommend general endotracheal anesthesia with complete muscle paralysis. In cases where the surgeon does not require paralysis, an effective spinal or epidural block may work as well, and these techniques have the added benefit of postoperative pain control. Regional anesthesia with a femoral nerve block may be a useful adjunct.

3.7.2 Patient Positioning

For all procedures, patients are placed in the supine position, with consideration of a blanket bump under the ipsilateral hip to neutralize lower extremity rotation.

For retrograde IM nailing of distal femur fractures, the patient is placed supine on a radiolucent table with the knee placed over a radiolucent sterile triangle. The use of a bolster under the ipsilateral buttocks is optional; however, if the surgeon uses a bump, then care must be taken to assess rotation of the femur. If no bolster is used, the patella can typically be placed straight anterior to allow for proper rational alignment of the limb. The leg is then prepped and draped in the usual sterile fashion making sure that the drapes go up to the pelvis to allow room for proximal screw insertion, anterior to posterior, for a full-length IM nail.

Prior to the surgery, the alignment and reduction of the limb can be assessed under fluoroscopic guidance, and by moving the triangle and a roll of towels posterior to the distal femur and applying traction, an acceptable reduction prior can be obtained (Fig. 3.2a).

3.7.3 External Fixation

External fixation is used as a temporizing measure when definitive fixation is not appropriate, such as in the setting of severe soft tissue injury or damage control orthopedics (DCO) scenario.

Two 5.0-mm Schanz pins are placed in the femur shaft (proximal to the intended proximal extent of the definitive fixation if a plate will be used). The authors' preferred technique is to predrill with a 3.5-mm drill. In the tibia, two Schanz pins are placed using the same technique. 175-mm half-pins and 150-mm half-pins typically work well in the femur and tibia, respectively, for most nonobese patients. Longer pins may be required for very obese patients.

The knee may then be stabilized with a spanning construct consisting of either pin banks placed at the pins and a "diamond" frame with bars and connectors between pin banks or pin-to-bar connectors used to place multiple bars directly between proximal and distal pins (Fig. 3.3). Applying longitudinal traction while maintaining appropriate alignment of the limb will typically bring the fracture into acceptable alignment for tightening the external fixation construct. The knee is typically placed at 15–20° of flexion, though this may be adjusted to accommodate fracture characteristics.

3.7.4 Intramedullary Devices

For the majority of extra-articular fractures, a small medial parapatellar tendon incision from the inferior pole of the patella to the tibial tubercle with either a medial or patellar tendon splitting incision will be sufficient to gain access to the insertion site. The knee on the triangle should be flexed between 30° and 45° to allow for passage of the reamers and IM nail. Too much flexion can bring the patella inferior and block the insertion site and too little flexion could possibly damage the tibial plateau. The synovium is spread, and a guide pin inserted into the distal femur and centered on both the AP and lateral fluoroscopic views. On the lateral view, with both femoral condyles superimposed on each other, the starting point should be 6 mm proximal to the convergence of Blumensaat's line and the femoral groove [3] (Fig. 3.2b, c). The AP view should show the pin centered in the distal femur, not perpendicular to the articular surface. A starting rigid reamer can be used over the guide pin while protecting the tendon and surrounding cartilage.

A ball-tipped long guide rod is then inserted across the fracture site up to the level at or above

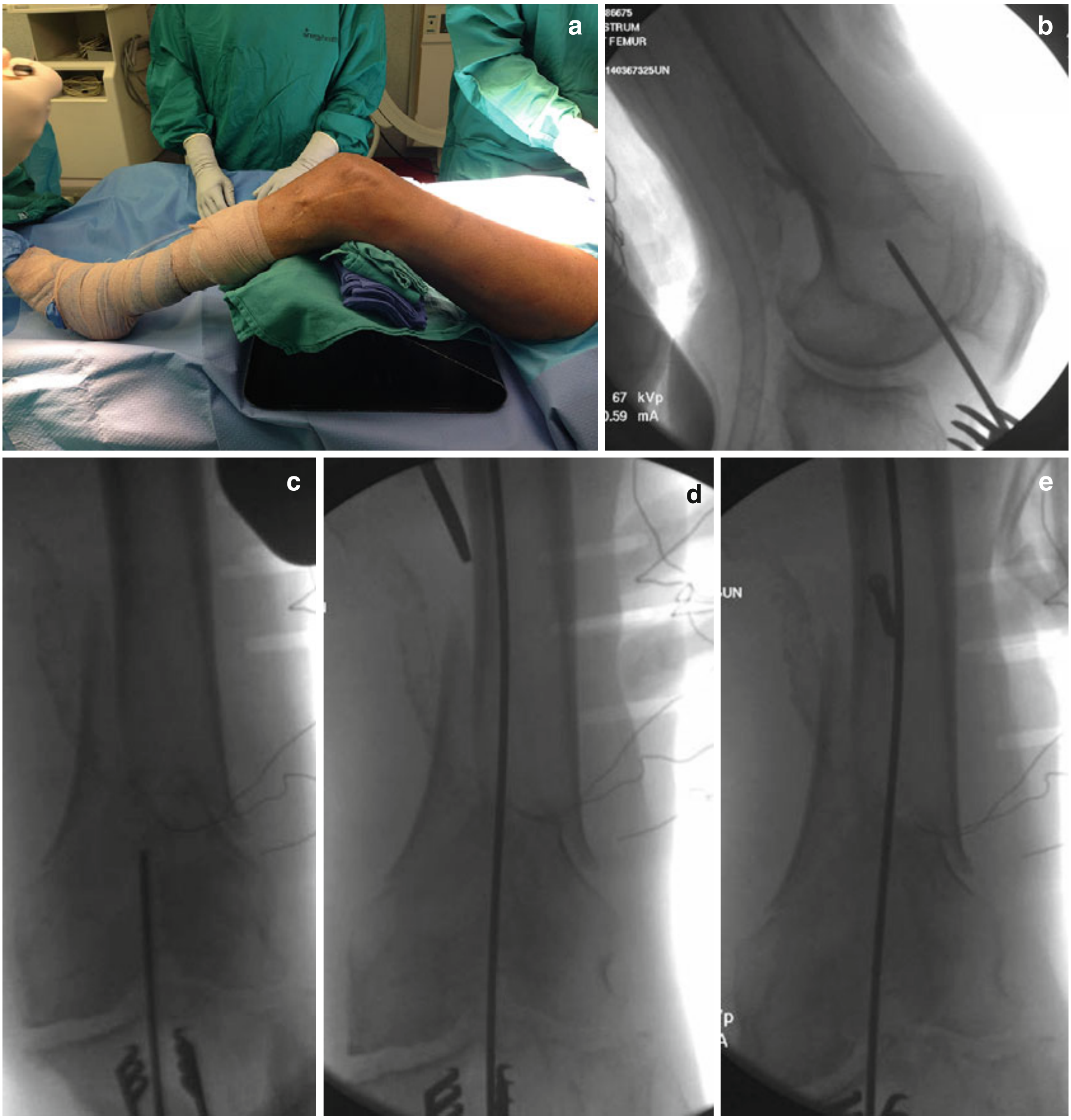

Fig. 3.2 (**a**) Lateral view showing distal femur fracture positioning over radiolucent triangle with bolsters behind the distal femur to correct apex posterior angulation. (**b**, **c**) A 90-year-old male with asymptomatic arthritis of the knee and supracondylar femur fracture. (**b**) Shows proper placement for retrograde IM nail on the lateral view just a few millimeters proximal to Blumensaat's line. (**c**) Shows anterior-posterior fluoroscopic view with guide pin centered in the distal femoral metaphysis. (**d**, **e**) – **d** Demonstrates medial translation of the distal femur after guide rod insertion. Note the guide rod centered in the distal femur but hugging the medial cortex at the infraisthmal femoral flare. (**e**) A blocking screw has been placed to block the IM nail from going along the medial cortex of the femur and thereby translating the distal femur laterally. (**f**, **g**) Final anterior-posterior x-rays showing excellent final alignment without translation or angulation of the distal femur. Due to the patient's age and osteoporosis, multiple screws with minimal purchase were used off-axis for distal femoral fixation. (**g**) Shows lateral radiograph and alignment. The blocking screw backed up slightly on IM nail insertion but is doing its job and should not be removed after IM nail insertion. The retrograde IM nail is not prominent at the level of the cartilage of the knee, and the alignment is satisfactory

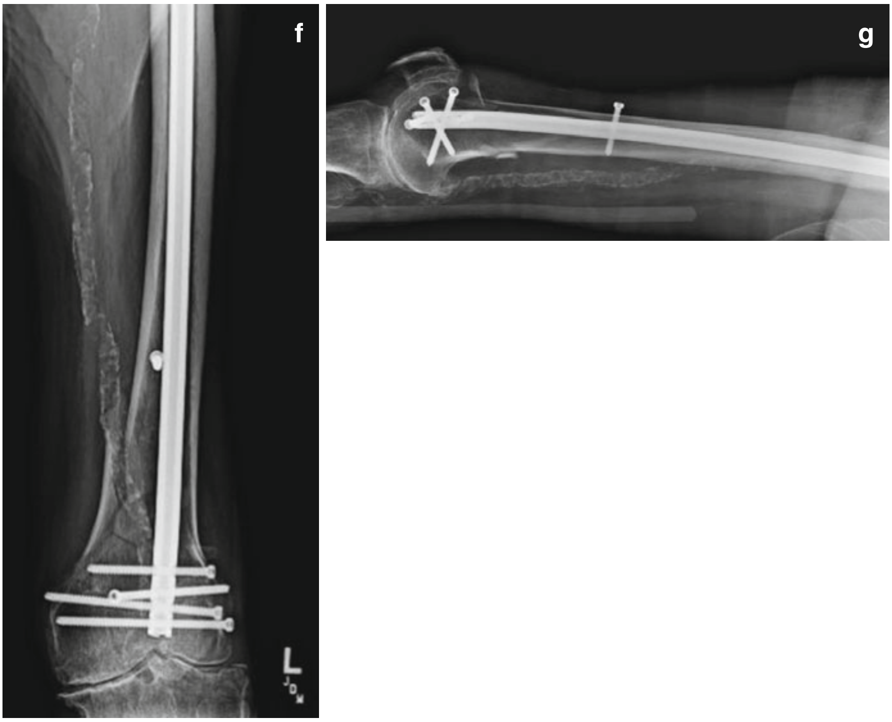

Fig. 3.2 (continued)

the lesser trochanter. For supracondylar fractures, it is imperative to maintain reduction while inserting the guide rod and during reaming. Reaming the intramedullary canal with the femoral fracture reduced will lead to better alignment once the IM nail is inserted, as it will not follow an aberrant track. The nail length is then determined using a ruler, and the proximal tip of the IM nail should be above the bottom of the lesser trochanter. Reaming is performed assuring that the reduction is maintained during this process. The intramedullary canal is reamed to 1 mm to 1.5 mm greater than the canal diameter that has been determined by the first reamer that contacted the cortex and caused audible "chatter." The retrograde IM nail is then inserted with the fracture reduction maintained. Close attention should be paid when the IM nail is crossing the fracture site as an eccentric entry into the proximal fragment can cause comminution. Using anterior-posterior and lateral fluoroscopy, visualization of the proximal end (insertion end) of the IM nail must be identified and its relationship to the intercondylar notch is imperative. The nail must be at least flushed with the articular cartilage or even inserted deep to the cartilage by a few millimeters; it cannot be prominent as that will cause damage to the cartilage of the patella [4].

Distal interlocking is performed with an outrigger jig attached to the insertion handle of the IM nail. One screw is probably sufficient for stable, transverse fractures with greater than 50 % cortical contact. Two screws may be used when there is cortical comminution at the fracture site and oblique screws should be considered with small distal fragments in an attempt to get orthogonal screw placement. After distal interlocking, the length of the femur must be assessed. If the fracture does not have axial stability, the leg will shorten with IM nail insertion. When shortening is identified, following distal interlocking, the IM nail is "backslapped" to regain length and the fracture alignment is reassessed by fluoroscopy.

The insertion handle can then be removed and the leg can be placed flat on the OR table. If no bolster under the torso was used (author's

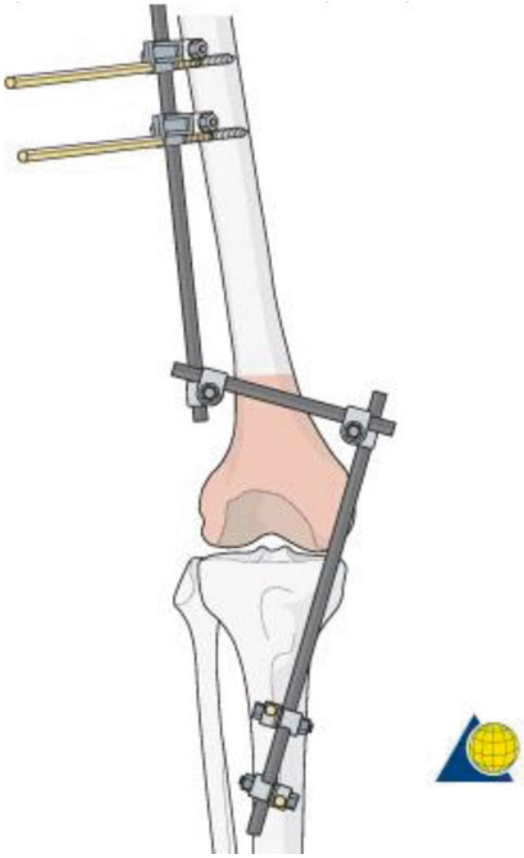

Fig. 3.3 "Z" configuration for knee spanning external fixator. Note that this construct does not require pin banks and can be planned to allow access to the distal femur so that it may remain in place at the time of definitive internal fixation (Reprinted with permission from AO Trauma)

preference), then the patella can be placed in a straight anterior direction during nail insertion and for proximal interlocking. The anterior to posterior proximal interlocking screws are placed using a "free-hand" technique and "perfect circles." The C-arm is positioned in an anterior to posterior position and an image of the proximal locking screws is obtained. The direction of the fluoroscopic image is changed until the anterior and posterior holes in the IM nail are collinear and appear as a "perfect circle." A small anterior incision is made over the proximal screw hole through the skin, quadriceps fascia, and the muscle down to the anterior cortex. The bayonet tip drill bit is then laid on the anterior cortex obliquely until the tip of the drill point is centered in the proximal interlocking hole. The surgeon's arm is then brought to a position parallel to the direction of the C-arm, and the drill is inserted through the anterior cortex. Most commonly after this, the drill bit remains in the cortex but the drill is removed from the bit. The fluoroscopic view will determine the exact position that the drill bit has to go to make its way through the hole, and adjustments on the drill bit and its tip with gentle mallet blows can assist in getting the drill through the interlocking hole. The posterior cortex is drilled being careful not to over penetrate the posterior cortex and possibly injure the sciatic nerve. Utilizing a locking screwdriver, the screw is inserted after measuring with a depth gauge. Two proximal screws may be used for comminuted fractures. A full-length IM nail extending proximal to the bottom of the lesser trochanter should be used to prevent coronal plane motion and stress at the proximal end of the IM nail.

For supracondylar fractures, occasionally the alignment of the distal femur is not acceptable despite all of the "tricks" used for reduction, reaming, and insertion. In these cases, a blocking screw can be used to guide the IM nail into the desired position. Oftentimes, the IM nail must be removed, the long guidewire replaced into the femur, and using the short drill bit for the proximal interlocking screws, a hole is drilled next to the guide rod on the concave side of the deformity (Fig. 3.2d, e). The screw must block the IM nail's trajectory but allow enough room for the IM nail to pass. The screws utilized are those employed for interlocking the IM nail [5]. The retrograde nail is then reinserted and should "bounce" off of the blocking screw for this technique to work (Fig. 3.2f, g). Sometimes, the limb deformity must be exaggerated to allow the nail to proceed past the blocking screw. Proximal and distal interlocking is then performed as previously discussed, and the blocking screw is left in place to maintain the reduction.

After a layered closure, the leg is wrapped with a long elastic bandage from toes to groin. Immediate knee range of motion is stressed early in the rehabilitation process. Active motion is encouraged in cooperative, alert patients, and continuous passive motion (CPM) machines can be used for patients who are intubated or unable to comply with the therapy regimen. Transverse fractures with greater than 50 % cortical contact can start some immediate weight bearing and progress to full weight bearing as tolerated. Those patients with comminuted, length unstable fractures should start early partial weight bearing but refrain from full weight bearing until callus is visible on x-ray. By 6 weeks following surgery, most patients will have at least 90° of knee flexion, and by 3 months all patients should have near normal flexion.

3.7.5 Plate Fixation

Open reduction internal fixation with anatomically precontoured lateral plate is perhaps the current gold standard for distal femur fixation. Distal femur fractures involving the articular surface are addressed in a separate chapter.

The approach for distal femur plating will depend on the fracture pattern and exposure required to adequately address the injury. Minimally invasive plate osteosynthesis (MIPO) incisions are appropriate for simple fracture patterns or extra-articular patterns amenable to indirect reduction and bridge plating. However, this approach can be extended into a longer lateral incision for more extensive fractures that require direct reduction. Lastly, those fractures with intra-articular involvement that require access to the anterior distal femur may be approached through a lateral parapatellar arthrotomy that extends proximally to the lateral femur (termed "swashbuckler" approach). This approach is covered in the intra-articular distal femur chapter.

For lateral exposure, direct reduction, and plate application, a lateral incision is marked out from the lateral epicondyle and extended proximally in line with the femoral shaft. The incision may be extended further distally if required to allow mobilization of the skin without excessive tension. Skin incision is made with a #10 blade and carried down to the IT band. IT band is divided in line with its fibers, and the vastus lateralis is visualized. The vastus lateralis is retracted anteriorly and elevated from the lateral intermuscular septum. Perforating vessels are encountered proximally and hemostasis achieved with electrocautery. The dissection is carried distally to expose the distal lateral femur (at this point the dissection can be adjusted more anterior to include lateral arthrotomy if intra-articular exposure is required).

If a direct reduction is undertaken, the fracture site is debrided of interposed fragments for simple fracture patterns where absolute stability can be achieved. For comminuted fractures where bridge plating is most appropriate, the fracture site is not routinely debrided.

With paralysis in place, length can usually be achieved with manual traction. If achieving adequate length proves challenging, a femoral distractor may be used to achieve length. A bump is placed under the femur at the level of the fracture functions to relax the deforming pull of the gastrocnemius on the distal fragment and maintain the alignment of the shaft and metaphysis once achieved. For simple fracture patterns, periarticular reduction clamps (such as "King Tong" clamp) may assist with reduction and can be applied safely to the medial side of the femur with a small percutaneous stab incision or a folded OR towel to avoid injury to the skin [19]. Provisional fixation is then achieved with Kirschner wires.

Plate application is performed by sliding the plate under the vastus lateralis along the femoral shaft. Plate length can be determined by preoperative templating or by estimation during surgery followed by fluoroscopic confirmation of appropriate length. We recommend a minimum of four bicortical screws above the fracture site, taking into consideration adequate working length for bridge plate applications – typically a minimum of three empty holes remain at the level of the fracture for bridge plating, though this number may be greater for extensive comminution.

Stepwise, once appropriate plate length is established:

1. Provisional fixation of the plate at the distal femur using a k-wire, based on perfect lateral view (Fig. 3.4).

Fig. 3.4 Lateral view of the distal femur with appropriate plate position. Note that the distal/posterior most screw is posterior to Blumensaat's line, and a unicondylar screw was used in this position

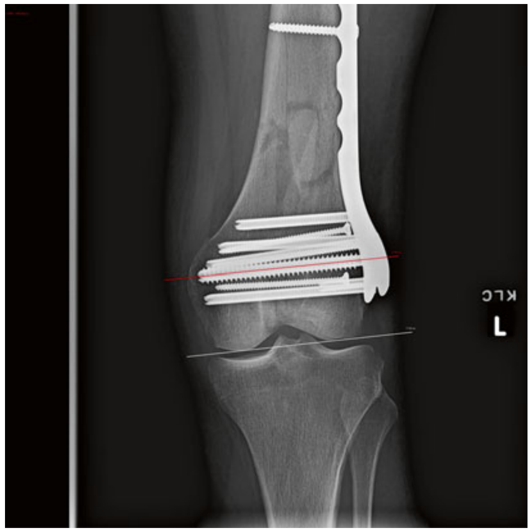

Fig. 3.5 Anatomically precontoured lateral locking plates are designed to recreate the normal valgus angle of the distal femur and should be placed parallel to the distal articular surface

2. Provisional fixation of the plate proximally with a k-wire. The plate should be centered on the shaft in the lateral view. This step avoids unrecognized plate malposition on the shaft.
3. On AP view, confirmation of appropriate varus/valgus alignment. Guidewire for first distal locking screw should be aligned with distal articular surface (Fig. 3.5).
4. Secure the shaft with 4.5-mm cortical screw.
5. Correct any remaining extension deformities of distal fragment with direct reduction prior to placing subsequent distal locking screws.
6. Place remaining shaft screws.

In the setting of severe bone loss or defect, Masquelet technique may be used. This technique is a two-stage strategy for the reconstruction of long bone segmental diaphyseal defects and utilizes induced membranes with nonvascularized bone autograft [17, 18]. The first stage involves placement of a polymethyl methacrylate (PMMA) cement spacer into the defect, with closure or soft tissue coverage of the area. Approximately 6 weeks later, the second stage consists of spacer removal with care taken to not disrupt the membrane around the defect. This cavity is filled with cancellous autograft bone that can be combined with demineralized bone matrix or allograft if additional volume is required. The technique relies on the theory that the biological membrane induced by the PMMA cement has a protective and positive effect on the cancellous autograft.

3.7.5.1 Tips

If shortening is accepted to improve bony apposition and excessive medial translation of the distal fragment is encountered, one may apply cortical screws in the proximal portion of the shaft, followed by locking screws for distal fixation of the shaft, which will appropriately secure the position of the distal fragment in the coronal plane (Fig. 3.6). This will avoid excessive medial translation of the condyle portion of the fracture.

For osteoporotic bone or very distal fractures, a more distal plate position may be chosen. The most distal posterior locking screw may still be

Fig. 3.6 This fracture demonstrated severe comminution, and shortening was accepted to improve contact at the fracture site. Locking screws in the distal portion of the shaft are an effective way to control its position, avoiding excessive medialization of the condylar fragment

placed across both condyles, accepting that the screw is intra-articular in the femoral notch (evaluated on the notch view of the knee). To avoid this scenario with a distal plate position, use a shorter screw that only traverses the lateral condyle.

3.8 Postoperative Regimen

Following placement of external fixator, patients are non-weight bearing until the time of definitive internal fixation. Low molecular weight heparin (LMWH) or other chemoprophylaxis is typically used for deep vein thrombosis (DVT) prophylaxis because of the considerable immobilization. Routine pin care is performed.

After plate fixation, patients are typically toe touch weight bearing (TTWB) for 6–8 weeks, using a walker or crutches to mobilize. DVT prophylaxis at our institution consists of 2 weeks of LMWH 40 mg subcutaneous (SC) daily, then four additional weeks of 325 mg aspirin (ASA) by mouth daily. Antibiotics are continued postoperatively for two additional doses not to exceed 24 h after surgery.

Following IM nail fixation, activity level varies depending on factors including bone quality, amount of fixation, and degree of comminution, though earlier motion may be considered based on the load-sharing properties of the IM nail.

3.8.1 Rehabilitation

Immediate knee range of motion is stressed early in the rehabilitation process. Active motion is encouraged in cooperative, alert patients, and continuous passive motion (CPM) machines can be used for patients who are intubated or unable to comply with the therapy regimen. Since these fractures are infraisthmal, there is no good cortical contact, and for the majority of patients, limited initial weight bearing is usually recommended. Those patients with comminuted, length unstable fractures should start early partial weight bearing but refrain from full weight bearing until callus is visible on x-ray. By 6 weeks following surgery, most patients will have at least 90° of knee flexion, and by 3 months all patients should have near normal flexion.

3.9 Complications

1. *Coronal plane malalignment* – Anatomically precontoured lateral locking plates are designed to recreate the normal valgus angle of the distal femur, and certain implant-specific screws should be placed parallel to the distal articular surface (Fig. 3.5). Coronal plane malalignment will result in excessive loading of the medial or lateral compartment of the knee.

   With retrograde IM nailing of distal femur fractures, malalignment and malunion are possible due to the fact that there is no cortex to guide the nail. Varus and valgus are both possible and often the concavity of the deformity is on the more comminuted side. Blocking screws do act as an artificial cortex and can guide the IM nail into position, reduce the fracture, and decrease the incidence of malalignment.

2. *Incorrect implant position* – Placing the plate too anterior or posterior may result in intra-articular screws that violate the trochlea or notch, respectively. The distal femur has a trapezoidal shape, which must be considered to achieve safe implant placement. Posterior plate placement on the distal condylar fragment will lead to medial displacement or golf club deformity of the femur [14, 15]. Further, the proximal portion of the plate has a tendency to shift too anterior relative to the shaft. In this instance, the proximal locking screws may not engage the bone or only have unicortical purchase. This problem can be addressed by placing a percutaneous k-wire through the most proximal hole to maintain appropriate position during placement of the distal screws.

   Even for supracondylar fractures, a full-length retrograde femoral IM nail should be used to take advantage of the isthmus to prevent excessive movement of the implant in the femur. It is imperative with retrograde IM nailing to be absolutely sure that the distal tip of the IM nail is not prominent at the level of the articular cartilage.

3. *Prominent screws at medial cortex* – If distal screws are too long, they may encroach on the medial collateral ligament (MCL). This complication is likely to be symptomatic for patients and may require implant revision or removal. An internal rotation view along the medial aspect of the distal femur (approximately 25° rotated) will allow the surgeon to evaluate for prominent screws.

   The distal screws placed through the femoral condyles and through the IM nail can be symptomatic. A prominent screw head on the lateral condyle may be palpable and cause friction with knee motion as the iliotibial band rubs over it. Additionally, when the screws are a little too long, the medial tip of the screw often causes pain as it is prominent, and with knee flexion, the quadriceps rubs over the screw tip causing pain. Removal of screws is possible after 12 months when the fracture appears to have remodeled callus surrounding the fracture site.

4. *Sagittal plane deformity* – The force of the gastrocnemius muscle on the distal fragment results in extension. This deformity should be anticipated, and knee flexion will decrease the deforming force and facilitate reduction. Patients may have excessive extension and gait abnormalities related to the malalignment. Apex anterior malalignment is perhaps less well tolerated compared to recurvatum deformity due to the inability to regain full knee extension.

5. *Nonunion* – Due to the metadiaphyseal location and the closed reduction of the distal femur fracture for IM nailing, the union rates are very high, greater than 90 %. The ability to perform the nailing procedure without disrupting the muscle or blood supply or disruption of the healing factors has led to few fractures that do not heal. If nonunion is present, then a workup can be performed to rule out systemic causes like Vitamin D deficiency or the use of blood thinners or steroids or other factor-inhibiting drugs. Similar results can be obtained with minimally invasive plating if the medial soft tissues are respected and left intact.

   One critical aspect of considering options for the treatment of nonunions is to assess the fracture stability. In an atrophic nonunion, if the hardware is stable, then a bone graft can be added. If the hardware is not stable, then either an exchange IM nail or plating can be performed with adjunctive bone grafting. For hypertrophic nonunion that just want more stability, an exchange IM nail or plating can be performed without the addition of bone graft.

6. *Decreased range of motion* – Knee stiffness following these fractures is not uncommon in those patients immobilized for a period of time following surgery or those who do not start early knee motion. The quadriceps scars down to the fracture and its effective working length is decreased. Further, if the patella is not mobilized, then there are intra-articular contractures as well. Early range of motion (ROM) and

physical therapy are the hallmarks of early aggressive treatment. Should this fail to regain motion after several months, then a knee manipulation in the operating room or a quadricepsplasty may be required to regain knee flexion. Pillows behind the knee or prolonged sitting can lead to a flexion contracture of the knee, and patients are encouraged to get the knee to full extension while sitting or exercising.

7. *Infection* – Infection is rare following plating or retrograde IM nailing of distal femur fractures. Small nonhealing incisions can be treated expectantly with cleansing and possible antibiotics by mouth. If the knee joint shows evidence of infection following knee aspirate, then an arthrotomy is required to debride the synovium and active drain suction is recommended. Intravenous antibiotics may be necessary, and the IM nail or plate can be retained if the fracture has not healed yet and supplemented with suppressive antibiotic treatment. Hardware removal and local antibiotics may be employed as a definitive treatment once the surgeon is assured that the fracture is healed.

3.10 Results

Outcomes following fixation of distal femur fractures for both plate and IM nail fixation have been reported, and while modern implants have improved results compared to historical data, they have not resulted in uniformly good outcomes.

Early studies utilizing retrograde IM nails for distal femur fractures had good union rates, but malunions, shortening, painful and broken screws, as well as loss of reduction [6, 7]. Techniques improved as did the implants, and results with retrograde nails improved to be similar to those of plating. Three studies compared the results of plating versus retrograde I nailing of distal femur fractures. In 2004, Markmiller et al. found no difference in ROM in the less invasive stabilization system (LISS) plate versus retrograde groups and reported malunion in three plated femurs and two retrograde-nailed femurs [8]. At 1-year follow-up, nonunion and secondary surgical procedures were 10 % for both groups. A study comparing dynamic condylar screw (DCS) to retrograde nailing for distal femur fractures in elderly patients revealed a shorter OR time with less blood loss in the IM nail group, but complications were equal as were union rates and clinical results [9]. Hartin et al. reported on 23 patients randomized to plate versus IM nail and found that three patients in the retrograde IM nail group required revision surgery and this group had more pain on the SF-36 outcome score [10].

Clinical results after retrograde IM nailing of periprosthetic fractures around total knee replacements have been good. Recently, Pelfort published that 7/30 patients treated with an IM nail after total knee replacement had a mean extension deformity of 18° but at 6 year follow-up had no clinical symptoms [11]. To consider retrograde IM nailing for periprosthetic fractures, the surgeon must know the design and specifications of the femoral component as well as the characteristics of the IM nail being employed. Heckler et al. reported on the size of the femoral components, and this reference can be helpful if the surgeon is considering IM nailing through a total knee replacement [12].

Hoffmann et al. evaluated outcomes following plate fixation of distal femur fractures in a retrospective cohort and found a 74.8 % union rate after the index procedure [13]. They did have an 18 % nonunion rate, and 20 % of those in the nonunion group went on to recalcitrant nonunion. Submuscular plating had a lower nonunion rate than open reduction (80.0 % healed versus 61.3 %). It should be noted that 40.5 % of the injuries in this series were open fractures. Gardner et al. in a series of 335 patients treated with locked plating reported an 81 % union rate after the primary procedure and a 5 % overall infection rate. Diabetes and open fracture were both independent risk factors for needing reoperation and for deep infection. Implant failure was associated with open fracture, smoking, higher BMI, and shorter plate length [2].

Conclusions

Extra-articular distal femur fractures continue to be challenging injuries. Although implants have become more versatile and tailored to accommodate these specific fractures, care must be taken to avoid complications. Preoperative planning, implant selection, careful handling of soft tissue, restoration of alignment, and confirmation of appropriate implant position make up an important part of the approach required to maximize outcomes when treating this injury.

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