6 Nail Osteosynthesis of Distal Femur Fractures

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6.1 Introduction

Fractures of the distal femur comprise approximately 4–5% of femoral fractures [1]. As with many fractures, they have a bimodal distribution with peaks in young patients who sustain high-energy injuries and in elderly patients who sustain fragility fractures. In addition, periprosthetic fractures around the knee following total knee arthroplasty (TKA) are becoming increasingly common and most commonly involve the distal femur [2]. The vast majority of distal femur fractures are treated operatively, with nonoperative treatment reserved for undisplaced fractures or non-ambulatory patients.

Fractures of the distal femur should be treated according to general fracture principles. Intra-articular fractures require an anatomic reduction performed via a direct, open approach with the goal of absolute stability and primary bone healing. In contrast, the metaphyseal and diaphyseal portions of the fracture are often reduced indirectly with the aim of restoring length, alignment, and rotation while achieving relative stability and healing by bridging callus (secondary bone healing).

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These goals are most commonly achieved using internal fixation with either an intramedullary nail or a distal femoral locking plate used as a bridge plating construct. This chapter focuses on the use of intramedullary nails to treat fractures of the distal femur. Indications, approaches, and techniques are discussed, along with appropriate postoperative management and the recognized advantages and disadvantages of this technique.

6.2 Indications

Nailing can be indicated for most OTA/AO type A (extra-articular) and type C (complete articular) fractures of the distal femur, including periprosthetic fractures above a TKA [3]. These indications are similar to those for locked plating, with a few exceptions. Nails may be contraindicated in specific settings such as the presence of hardware in the ipsilateral proximal femur (e.g., a total hip arthroplasty or proximal femoral nail), fractures with extensive articular comminution (type C3), fractures with too small a condylar segment to allow nailing (less than 6–7 cm), and, finally, periprosthetic distal femur fractures with a closed femoral box or stemmed femoral component.

In contrast, there are a number of situations where nailing of distal femur fractures may offer specific advantages including fractures with substantial shaft extension (Fig. 6.1), fractures associated with an ipsilateral fracture of the femoral

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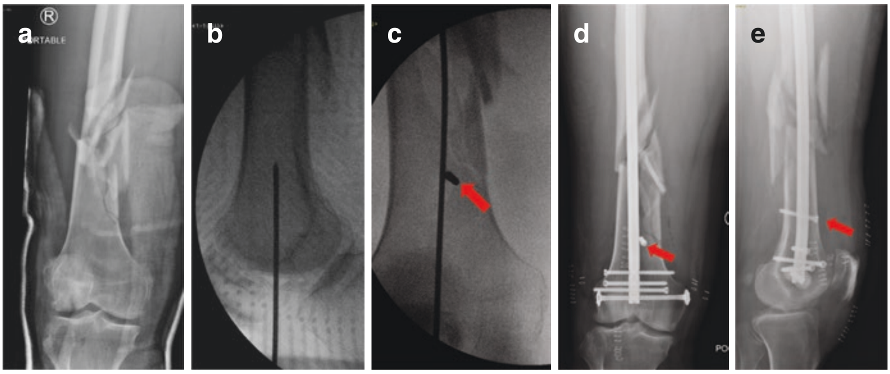

Fig. 6.1 (**a**) Preoperative radiograph demonstrating a comminuted extra-articular fracture of the distal femur in a 64-year-old male involved in a high-speed motorcycle accident. (**b** and **c**) Intraoperative photographs demonstrating closed reduction of the fracture, starting guidewire insertion and placement of a 5 mm blocking screw (red arrow) to correct coronal alignment. (**d** and **e**) Postoperative radiographs demonstrating anatomic alignment. Note the use of four multi-planar distal locking screws (including one locking condylar bolt) and a blocking screw (red arrows)

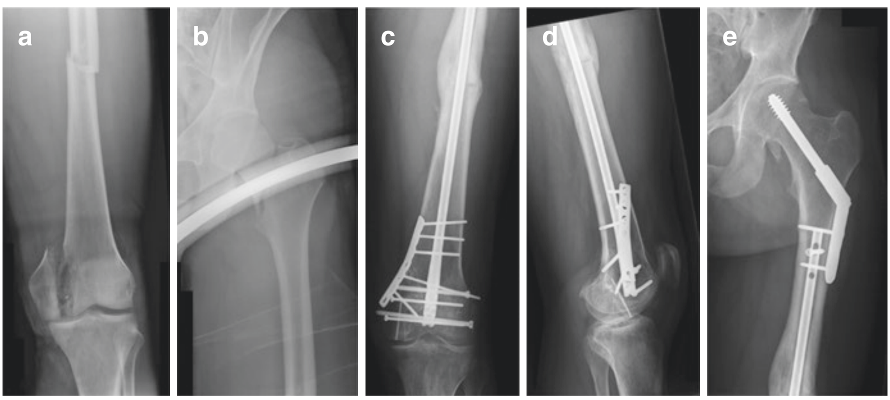

Fig. 6. 2 (**a** and **b**) Preoperative radiographs demonstrating a distal femoral shaft fracture, an intra-articular medial femoral condyle fracture, and an ipsilateral displaced femoral neck fracture in a 26-year-old male involved in a high-speed motorcycle accident. (**c**, **d** and **e**) Long-term follow-up radiographs demonstrating healing of all three fractures. The patient was treated with provisional lag screw fixation of the medial femoral condyle via a medial parapatellar approach, followed by RIMN, further plate fixation of the medial femoral condyle, and finally, closed reduction and sliding hip screw fixation of the femoral neck fracture. Note the RIMN was ended below the lesser trochanter to allow passage of the proximal sliding hip screw into the femoral neck

neck (Fig. 6.2), floating knee injuries where distal femur fractures are combined with fractures of the ipsilateral tibia (see Fig. 6.3), open fractures (see Fig. 6.4), and situations where early weight-bearing is desired (see Fig. 6.5).

Recent evolutions in the design of modern nails have allowed the indications for nailing of distal femur fractures to expand substantially. These include increasing the number of distal locking screws, employing the use of oblique/multi-planar distal locking screws, clustering of distal locking screws in the distal aspect of the nail, and the inclusion of locking condylar bolts (see Figs. 6.1, 6.3 and 6.4) or fixed angle locking screws. All of these modern design evolutions have served to improve fixation in small condylar segments or osteoporotic bone, thereby substantially expanding the indications for which a nail

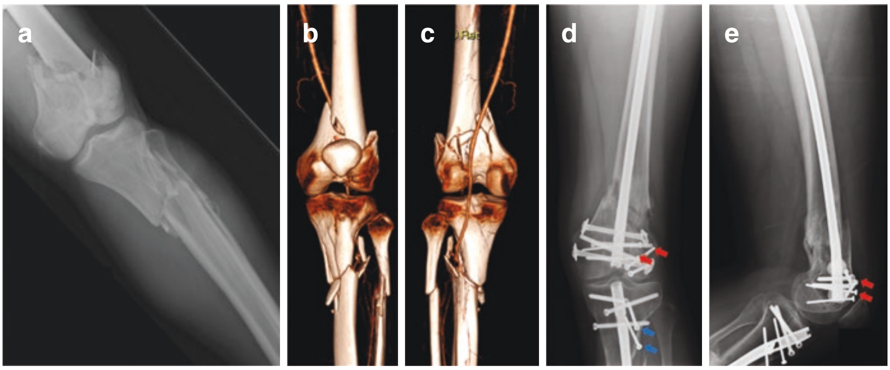

Fig. 6.3 (**a**, **b** and **c**) Preoperative radiographs and 3D CT scan reconstructions demonstrating a comminuted, intra-articular distal femur fracture and a proximal tibial shaft fracture (floating knee injury) in a 23-year-old male involved in a high-speed motorcycle accident. The distal femur fracture was an open injury (Gustilo grade 2). (**d** and **e**) Six-month postoperative radiographs demonstrating healing in anatomic alignment following RIMN of the femur fracture and antegrade nailing of the tibia fracture. Note the use of multiple anteroposterior and lateral to medial lag screws in the distal femur (red arrows), locking condylar bolts in the RIMN, and blocking screws in the proximal tibia (blue arrows)

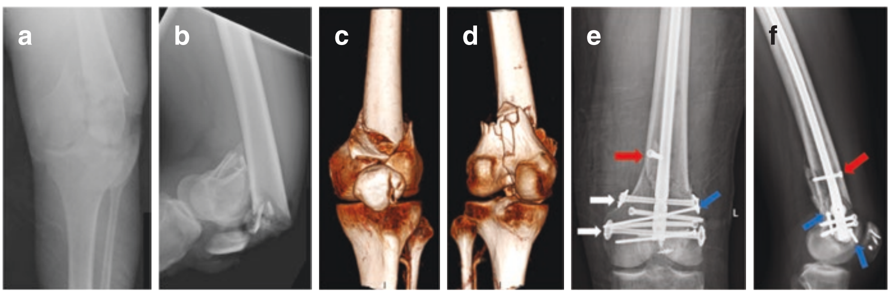

Fig. 6.4 (**a**, **b**, **c** and **d**) Preoperative radiographs and 3D CT scan reconstructions demonstrating a comminuted, intra-articular distal femur fracture in a 32-year-old male involved in a high-speed motorcycle accident. The distal femur fracture was an open injury (Gustilo grade 3). (**e** and **f**) Postoperative radiographs demonstrating anatomic reduction following RIMN. Note the use of two lateral to medial lag screws in the distal femur placed anterior and posterior to the nail (blue arrows), locking condylar bolts in the RIMN (white arrows), and a blocking screw to aid in coronal alignment reduction (red arrow)

can be used. These modern nails have offered improved biomechanics [4] and clinical outcomes [5].

6.3 Antegrade vs Retrograde Nailing

While it is technically possible to use an antegrade nail for distal femur fractures and recent series have described the use of specially designed antegrade nails for this purpose [6], we recommend the use of a retrograde nail for several reasons. First, the use of a retrograde nail allows direct access to guidewire placement in the distal fragment which dramatically improves reduction and control of the distal fragment. Second, the use of retrograde nail is advantageous for intra-articular fractures, as articular reduction and nail start point can be achieved through the same approach. Third, retrograde nailing is performed with the patient supine and the leg placed over a radiolucent triangle which substantially improves the ability to perform a

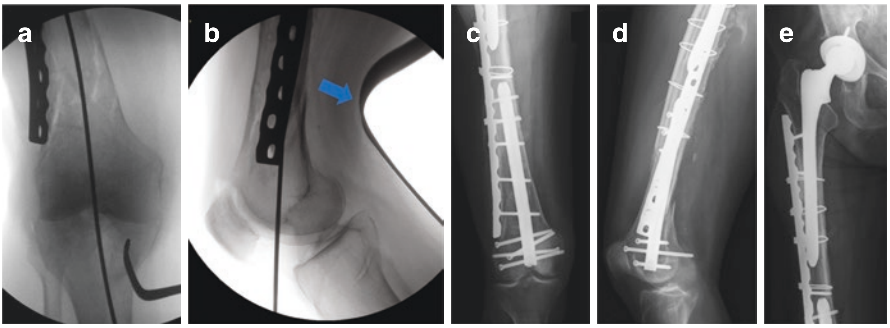

Fig. 6.5 (**a** and **b**) Intraoperative radiographs demonstrating an extra-articular distal femur fracture in a 72-year-old female following a low-energy fall. This patient had previously undergone fixation of a periprosthetic fracture of the proximal femur several years prior and had well-fixed hardware in situ. A short RIMN was chosen for treatment as it allowed for removal of the least amount of pre-existing hardware and facilitated early weight-bearing. Note the placement of the radiolucent triangle at the apex of the fracture to correct extension of the distal fragment (blue arrow) and the ideal positioning of the starting guidewire (center of the intercondylar notch on the AP view and anterior to Blumensaat's line on the lateral view). In addition, on the lateral intraoperative view, flexion of the knee to approximately 40 degrees to facilitate safe reamer passage can be appreciated. (**c**, **d** and **e**) Six-month postoperative radiographs demonstrating healing in anatomic alignment

closed reduction of the distal femur over antegrade nailing. Fourth, there is widespread availability of retrograde nails with the modern distal fixation options described above. Finally, retrograde nailing has a much stronger track record in the literature on the treatment of distal femur fractures [1, 3, 7, 8].

6.4 Retrograde Nailing Versus Locked Plating of Distal Femur Fractures

There remains at the present time relative controversy with respect to the use of retrograde nailing versus locked plating for the management of distal femur fractures. As described above, the indications for both implants are generally similar. Locked plating likely has more versatility with respect to small distal fragments and accommodating pre-existing hardware [9]. In addition, reduction may be more difficult to achieve with retrograde nailing. However, retrograde nailing has several potential advantages. First, retrograde nailing has been shown to be biomechanically superior when modern nail implants are compared to locked plating constructs [4]. Second, nails function as a load-sharing device that facilitates early weight-bearing. Third, nails can be inserted using smaller, more minimally invasive incisions that better preserve fracture biology. Finally, locked plating has often resulted in constructs that are overly stiff and potentially impair secondary bone healing, leading to higher nonunion rates than nails [2, 7]. However, recent evolutions in surgical technique and implant design have sought to address this issue with locked plating [10–12].

Hoskins et al. recently published a retrospective review of locked plating versus retrograde intramedullary nailing (RIMN) for the treatment of distal femur fractures based on Australian registry data in 2016 [1]. They were able to analyze outcomes for 297 patients (195 treated with locked plating and 102 treated with RIMN). Their primary finding was a clinically relevant and statistically significant improvement in general health outcomes, on the basis of EuroQol-5 Dimensions (EQ-5D) scores at 6 months with RIMN being superior to locked plating. There was a trend toward improved EQ-5D scores at 1 year in the RIMN group as well, although the difference was no longer statistically significant. They also reported a significant reduction in angular deformity in the RIMN group. The authors concluded that RIMN may be a superior treatment to locked plating for fractures of the distal femur, although their study had several limitations based on its retrospective nature, and this diminished the strength of their conclusions. However, the authors did feel that their results strongly supported the need for a randomized trial comparing RIMN to locked plating.

In 2013, Tornetta et al. presented the results of a prospective randomized trial comparing 156 patients with extra or intra-articular fractures of the distal femur randomized to either locked plating (80) or RIMN (76) [13]. Treatment with a RIMN demonstrated trends toward improved functional outcomes and quality of life, although the observed differences failed to reach statistical significance, despite being above the threshold for clinical relevance. They also found that malunion in valgus >5° was more common with plate fixation. The results of this study, which represent the only level I evidence at present, suggest that overall there may be an advantage to RIMN over locked plating for the treatment of extra-articular or simple intra-articular fractures of the distal femur.

In a recent meta-analysis from 2018, Koso et al. reported on the issue of plating versus retrograde nailing of distal femur fractures [8]. They combined the results from 11 studies, including a total of 505 patients (376 treated with plate fixation and 129 treated with RIMN). The authors found no significant differences in nonunion, malunion, complications, or revision surgery rate between the two groups. The authors concluded that based on their findings, both treatments were acceptable for distal femur fractures and the choice of implant could be based upon surgeon preference, patient factors, and specific fracture characteristics.

In 2014, Ristevski et al. completed a systematic review on the treatment of periprosthetic distal femur fractures [2]. The authors compared locked plating to RIMN in 418 patients (308 treated with locked plating ant 110 treated with RIMN). There were no significant differences in nonunion or secondary surgical procedures, although there was a trend toward increased rates of nonunion with locked plating (8.8% with locked plating versus 3.6% with RIMN). In contrast, the rate of malunion was significantly lower with locked plating (7.6% with locked plating versus 16.4% with RIMN). The authors concluded that results failed to indicate which was the preferred technique overall, and they felt there was a strong need for a prospective randomized trial comparing locked plating to RIMN for the treatment of periprosthetic distal femur fractures.

Overall, the current evidence does not strongly support one technique over the other with respect to the use of RIMN versus locked plating for the management of distal femur fractures. On this basis, the selection of a nail versus a plate can be made at the discretion of the surgeon, while taking into account specific fracture pattern, surgical experience, and patient factors.

6.5 Surgical Approaches and Reduction Techniques

The patient positioning for retrograde nailing is supine with the use of a radiolucent table or radiolucent extension. Often a bump or sandbag under the ipsilateral buttock or a side support is helpful to prevent external rotation of the limb. In select cases where obtaining appropriate length and rotation may be particularly challenging (i.e., a highly comminuted and/or segmental fracture), we will often position the patient completely flat and prepare and drape both limbs to allow length and rotation to be matched directly to the intact limb intraoperatively. A radiolucent triangle or gown pack is placed under the knee to allow knee flexion for nail entry and also to relax the gastrocnemius, which in combination with the pull of the extensor mechanism commonly results in extension of the distal fragment. The surgeon should check that appropriate fluoroscopic views can be obtained prior to prepping the patient.

Surgical approach is dependent upon fracture characteristics. For extra-articular fractures (see Figs. 6.1 and 6.5), a 3 cm midline incision is created just below the inferior pole of the patella. The patellar tendon can subsequently be split or a medial parapatellar incision can be used. Often a portion of the fat pad is excised. This allows access to the distal femur for insertion of the starting guidewire. For intra-articular fractures where reduction and fixation of intra-articular fracture lines must be performed (see Figs. 6.2, 6.3 and 6.4), a formal medial parapatellar or lateral parapatellar approach is used to allow visualization and fixation of the articular surface. The remainder of the approach generally consists of percutaneous incisions for placement of locking screws and/or bolts in addition to percutaneous reduction aids.

6.5.1 Reduction and Nail Insertion (Extra-articular Fractures)

In the case of extra-articular fractures, the fracture can frequently be reduced in closed fashion. We begin the procedure by obtaining a provisional reduction of the fracture. This generally consists of traction on the limb with flexion of the knee over a radiolucent triangle. It is critical to place the radiolucent triangle directly at the apex of the fracture to correct the extension of the distal fragment that commonly occurs due to the pull of the gastrocnemius (see Fig. 6.5). Varus/valgus alignment can then be corrected with direct manipulation of the distal limb. An appropriate start point for the retrograde nail is then obtained. In the setting of distal femur fracture, the start point is **critical** and often dictates the quality of the reduction that is subsequently obtained. The guidewire should be placed in the center of the intercondylar notch on the AP view and just anterior to Blumensaat's line on the lateral view (see Fig. 6.5). The trajectory of the starting guidewire should then match the alignment of the distal femur on both views. Once optimal guidewire position is confirmed, reaming over top of the guidewire is then performed with a starting reamer. A soft tissue protector should be used to protect the patellar tendon and patellar cartilage. Flexion of the knee to approximately 30–40 degrees facilitates this (see Fig. 6.5). Once the starting point has been reamed, a ball-tipped guidewire is placed into the distal femur and across the fracture, to the level of the lesser trochanter. At this point reduction of the fracture should be confirmed with anatomic restoration of length and alignment. If the closed techniques described above are insufficient to achieve this, further reduction aids are required. In our experience, this is often the case, particularly with more distal and comminuted fractures. A variety of *percutaneous strategies* that maintain the biological advantages of nailing can be employed including [14]:

1. Percutaneous application of bone hooks or ball spiked pushers
2. Schanz pins in the distal fragment and/or proximal fragment
3. Blocking or Poller screws (see Figs. 6.1 and 6.4)
4. Percutaneous reduction clamp placement

We find the use of blocking screws to be an excellent method for aiding reduction when nailing distal femur fractures (see Figs. 6.1 and 6.4). These screws can be placed in either the proximal or distal fragment and should be positioned in such a fashion to direct the path of the nail and correct any malreduction (most commonly in the coronal plane for distal femur fractures). Their utility and application has been well described in the literature [15, 16]. It is critical that reaming is done (or redone) after placement of the blocking screw(s) (see Fig. 6.1). Our preference is to use the 5 mm screws that accompany the nail set, as they are more robust for reaming around, more reliable for aiding fracture reduction, and this precludes the need to open an additional set.

Once reduction is achieved and confirmed, reaming over the ball-tipped guidewire is carried out in 0.5 mm increments until cortical fit ("chatter") is achieved. We typically over-ream by 1.5 mm. Nail length is selected based on measurement for a nail that will end at or above the lesser trochanter. The exception of this would be when a femoral neck fracture is present, in which case we end the nail distal to the lesser trochanter to allow for the placement of fixation in the femoral neck with a sliding hip screw (see Fig. 6.2). The nail is then passed over the guidewire and impacted into position with care taken to ensure that the nail is countersunk at least 3–5 mm below the articular surface of the distal femur. Fluoroscopic assessment is once again used to confirm anatomic restoration of length and alignment in both planes with the nail in position. In our experience, it is not uncommon to require some adjustment of fracture reduction at this stage, despite a good initial reduction and a satisfactory starting point, particularly in more complex (distal and/or comminuted) fractures. This most commonly occurs in the coronal plane and is often best addressed with the aid of blocking screws (see Figs. 6.1 and 6.4). This requires removal of the nail, insertion of a well-positioned blocking screw, and repeat reaming, prior to re-insertion of the nail. Once satisfactory reduction is achieved, distal locking screw insertion is performed using a targeting guide, with screws placed through percutaneous incisions. In the setting of distal femur fractures, multiple distal locking screws (ideally 3–4 multiplanar screws) should be placed [5]. We find the use of locking condylar bolts to be advantageous, particularly in very distal or intra-articular fractures where compression and optimal fixation in the condyles is desired (see Figs. 6.1, 6.3 and 6.4). There is both biomechanical and clinical literature supporting the use of locking condylar bolts in this setting [4, 17]. Once distal locking is complete, final confirmation of both rotation and length should be confirmed prior to proximal locking. Removal of the targeting guide at this stage facilitates this, as it allows the leg to be placed in full extension on the table. Confirmation of length and rotation can be confirmed by visualization of fracture reduction in more simple fracture patterns (see Figs. 6.4 and 6.5). However, in more comminuted fractures, ancillary techniques such as comparison of the lesser trochanter profile with the contralateral limb or free draping of the contralateral limb to allow direct intraoperative clinical comparison may be required (see Fig. 6.1). Once this is confirmed, proximal locking is done anterior to posterior using fluoroscopic guidance through a small anterior incision and blunt dissection through the rectus femoris. In our experience, these screws generally measure 35 mm in women and 40 mm in men [18]. The use of 1 versus 2 proximal locking screws can be done at the discretion of the surgeon based on fracture pattern and bone quality.

6.5.2 Reduction and Nail Insertion (Intra-articular Fractures)

Distal femur fractures with intra-articular extension that are treated with RIMN fixation require open and anatomic reduction of the joint surface with rigid fixation. We generally begin with reducing and fixing any coronally oriented fractures (“Hoffa fragment”) with anterior to posterior screws (see Fig. 6.3). We typically use 3.5 mm or 2.7 mm screws for this to minimize hardware crowding. We then reduce the two condyles together in an anatomic fashion with the aid of k-wires to manipulate the individual condyles and the placement of a large pointed reduction clamp. The condyles are then secured together with 3.5 mm lag screws placed from lateral to medial. Care must be taken to avoid the desired path of the retrograde nail when placing these screws, which can be technically demanding. We generally find there is sufficient room for at least one lag screw anterior and one posterior to the nail. Two lag screws are most often sufficient, particularly when locking condylar bolts are subsequently placed in the nail (see Fig. 6.4). Once the intra-articular fractures are anatomically reduced and rigidly fixed with lag screws, RIMN proceeds as outlined above.

At the conclusion of retrograde nailing, the femoral neck should be screened radiographically to ensure there are no fractures. We always obtain a preoperative CT scan to look for any evidence of a femoral neck fracture in all young patients with high-energy femur fractures prior to operative planning for a RIMN. Despite this, it remains imperative to screen the femoral neck at the conclusion of the nailing procedure. In addition, the limb should be examined to compare length, alignment, and rotation to the contralateral limb once all the drapes are removed and prior to waking up the patient. Finally, both distal pulse palpation and a ligamentous examination of the knee should be carried out.

6.6 Postoperative Treatment

Analgesia, antibiotic prophylaxis, and deep vein thrombosis prophylaxis are all done as per standard of care following nailing of distal femur fractures. Postoperative weight-bearing is dependent upon fracture pattern and fixation. For extra-articular fractures (including periprosthetic fractures above a total knee arthroplasty), we generally allow immediate weight-bearing as tolerated (WBAT). This is especially important in geriatric patients with fractures of the distal femur. If there is intra-articular involvement of the weight-bearing surface, then we generally restrict weight-bearing to toe-touch for the first 6 weeks and then progress to WBAT. Irrespective of fracture pattern, immediate active and passive ROM of the knee is allowed without restriction.

Routine clinical and radiographic follow-up is carried out at 6 weeks, 12 weeks, 6 months, and 1 year, with continued follow-up until complete clinical and radiographic healing. On occasion, patients develop symptoms at the site of locking screw insertion due to prominence. Once fracture healing is complete, these screws can be removed in the clinic under local anesthetic (for one or two simple screws) or as an outpatient surgical procedure (for multiple symptomatic screws or for locking condylar bolts). Nail removal is rarely required unless it is for revision surgery in the setting of non-union or infection.

6.7 Conclusions

Retrograde nailing represents an excellent option for the treatment of extra-articular and simple intra-articular fractures of the distal femur. In more complex and more distal fractures, retrograde nailing can be technically demanding, and advanced techniques to both obtain and maintain reduction are often required. However, nailing offers substantial benefits with regard to minimally invasive insertion, biomechanical strength, early weight-bearing, and the potential to improve union rates and decrease complications. For these reasons, retrograde nailing is our treatment of choice for the treatment of most distal femur fractures. Further research further defining indications and comparing treatment outcomes between RIMN and locked plating is warranted.

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