Distal Femoral Fractures: Current Concepts

Abstract

The diversity of surgical options for the management of distal femoral fractures reflects the challenges inherent in these injuries. These fractures are frequently comminuted and intra-articular, and they often involve osteoporotic bone, which makes it difficult to reduce and hold them while maintaining joint function and overall limb alignment. Surgery has become the standard of care for displaced fractures and for patients who must obtain rapid return of knee function. The goal of surgical management is to promote early knee motion while restoring the articular surface, maintaining limb length and alignment, and preserving the soft-tissue envelope with a durable fixation that allows functional recovery during bone healing. A variety of surgical exposures, techniques, and implants has been developed to meet these objectives, including intramedullary nailing, screw fixation, and periarticular locked plating, possibly augmented with bone fillers. Recognition of the indications and applications of the principles of modern implants and techniques is fundamental in achieving optimal outcomes.

Distal femoral fractures currently account for <1% of all fractures and about 3% to 6% of all femoral fractures; however, the incidence likely will increase as the population ages. An elderly patient with poor bone quality may sustain a distal femoral fracture in a simple fall, whereas a high-energy mechanism, such as a motor vehicle crash, is generally required to produce such injury in a younger patient with good bone quality. Epidemiologic studies reflect these injury patterns, showing peaks in incidence in elderly women and young males. These fractures are frequently comminuted and intra-articular, and they often involve osteoporotic bone. Understanding the inherent characteristics of distal femoral fracture as well as the principles and challenges of management is important in optimizing outcomes.

Anatomy

The distal femur includes the supracondylar and intercondylar region of the femur extending from the metaphyseal-diaphyseal junction to the articular surface of the knee. The femoral shaft is oriented in 7° to 11° of valgus in relation to the knee joint. Maintaining this alignment is critical to the function and durability of the limb. In distal femoral fracture, the thigh musculature shortens and displaces the fracture into either varus or valgus, depending on the location of the fracture relative to the adductor tubercle. The gastrocnemius muscle causes apex posterior angulation of the fracture, and the two heads of the muscle may separate and rotate the femoral condyles in the event of an intercondylar split.
Classification

Fracture of the distal femur may be broadly classified as extra-articular, intra-articular unicondylar, or intra-articular bicondylar, with subclassifications for specific patterns and degrees of comminution. The AO/OTA fracture classification system is the most universally used4 (Figure 1). The fracture patterns are classified as type A (extra-articular), type B (partial articular/unicondylar), and type C (complete articular/bicondylar). Subclassification within fracture types A and C reflects the degree of comminution and instability. Type A2, A3, and C2 fractures involve metaphyseal comminution, whereas type C3 fractures are characterized by metaphyseal and intra-articular comminution. Type B fractures are subclassified based on the involved condyle; the lateral condyle is designated as B1 and the medial condyle as B2. Coronal plane partial articular fractures (ie, Hoffa) are designated as type B3. Type C fractures also may have condylar fracture lines in the coronal plane.

Clinical Evaluation

Distal femoral fractures typically manifest as severe thigh or knee pain, with an inability to bear weight on the injured extremity. Obvious swelling and deformity are often present, although these findings may be less evident in the obese patient. Initially, plain radiographs should be obtained for suspected fracture of the distal femur. In more complex fractures, CT is used to delineate intra-articular extension, degree of comminution, and fracture lines in the coronal plane. A recent study reported coronal plane fracture in 38.1% of all distal femoral fractures, with the lateral condyle most frequently involved.5 In that study, plain radiography missed 31% of coronal plane fractures.

A thorough neurovascular examination of the affected extremity before and after reduction is essential. Open fracture occurs in 5% to 10% of supracondylar fractures; thus, the skin should be meticulously examined for wounds.4 The anterior thigh proximal to the patella is a common location for an open wound caused by penetration of the proximal spike through the quadriceps on axial load. After reduction, provisional management entails immobilization with a well-padded splint or knee immobilizer. Skeletal traction is useful for unstable fractures with shortening and in patients with other injuries or conditions that preclude early surgical intervention.

Management

Definitive management of distal femoral fractures requires maintenance or restoration of distal femoral alignment to preserve the function of the extremity. Coronal plane alignment has been shown to be the most difficult factor to control and the most crucial to overall outcome.7 Posttraumatic arthritis has been reported to develop in fractures that heal with >15° of valgus or any degree of varus at the knee.5 Malalignment in the axial and sagittal planes also affects knee kinematics and range of motion (ROM), and articular incongruity further contributes to the development of degenerative arthritis. Early knee motion is central to the management of distal femoral fracture. Knee stiffness and loss of ROM may develop with immobilization, and these often contribute to poor outcome.9

Theoretically, these principles support surgical reduction and fixation of distal femoral fracture. However, one study showed that early surgical techniques failed to obtain sufficient stability and that they were associated with unacceptably high rates of nonunion and infection.10 These poor results led orthopaedic sur-

The AO/OTA classification of supracondylar femur fractures.
Type A, extra-articular. Type B, partial articular/unicondylar. Type C, complete articular/bicondylar. The fractures may be subclassified based on the location of the fracture lines and degree of comminution.
gions to manage most distal femoral fractures with skeletal traction and casting. The development of a fixed-angle blade plate in the early 1960s allowed rigid internal fixation and ushered in a new era of management. This fixed-angle design served as the foundation for future developments such as the locking plate. Nonsurgical management has largely fallen out of favor as the result of further advances in technique and implants.

Surgical fixation has consistently demonstrated better outcomes than has nonsurgical management, including improved alignment, union, knee motion, and functional outcome.11,12 Butt et al12 reported good or excellent results in 53% of patients treated surgically and in 31% of patients treated nonsurgically in a prospective, randomized controlled trial comparing surgical with nonsurgical management of displaced distal femoral fractures in elderly persons. The nonsurgical group had a higher rate of complications.

Nonsurgical management is reserved for stable, minimally displaced fractures. Management generally consists of restricted weight bearing in a hinged knee brace. Early knee motion is encouraged to avoid stiffness. Radiographs should be obtained throughout the recovery process to ensure appropriate healing and to monitor for displacement. Weight bearing should be protected until there is radiographic evidence of union.

Relative contraindications to surgery include nonambulatory status, medical unsuitability, severe osteoporosis, and severe comminuted fractures that cannot be reconstructed. In these cases, nonsurgical management may involve splinting or bracing, although severely comminuted fractures with axial instability may require traction to prevent excessive shortening of the limb. Complications are typically related to immobilization and include decubitus ulcers, thromboembolic disease, and loss of knee function. Recent literature supports surgical intervention in nonambulatory patients to avoid such complications.13

Surgical

A complete trauma or medical evaluation may be required before surgical treatment, particularly in young persons involved in high-energy accidents and in elderly persons. Early definitive fixation may not be suitable for the polytraumatized or under-resuscitated patient. In these cases, it may be appropriate to use damage-control orthopaedics with spanning external fixation to restore length and stabilize the extremity to allow systemic stabilization. Proximal external fixation also may be used for high-energy fractures with excessive soft-tissue injury and periostal stripping as well as for open fractures with devitalized tissue and contamination. Such fixation allows the soft-tissue envelope to stabilize before internal fixation.

A variety of surgical methods is available for definitive fixation. Selection is based on the characteristics of the fracture and patient status. External fixation may be used definitively in some severely comminuted fractures, in severe open fractures, and in patients who are unsuitable for additional surgery. Fixed-angle side plates, including blade plates, condylar plates with a sliding barrel, and locking plates, provide greater versatility in managing intra-articular and osteoporotic fractures. These plates may be used for a variety of fracture configurations, from simple extra-articular (AO/OTA type A1) to comminuted intra-articular (AO/OTA type C3). Intramedullary (IM) nailing is commonly used for extra-articular (AO/OTA type A) and simple or minimally comminuted intra-articular (AO/OTA types C1 and C2) fractures. Buttress plates and screws are used in certain circumstances, such as relatively stable fracture configurations and partial articular fractures (AO/OTA type B). They also may be used to augment other constructs. Total knee arthroplasty (TKA) is an option for acute fracture in select osteoporotic elderly patients with preexisting arthritis or severely comminuted fracture.14

Surgical Principles

Distal femoral fractures require reduction and fixation of the articular segment to the remainder of the femur. With intra-articular type C fractures, restoration of the congruity of the articular surface should be a priority, and intercondylar fractures should be addressed initially. Reduction clamps, Kirschner wires, or interfragmentary screws may be used to stabilize the articular block, taking care to ensure that they will not interfere with subsequent implant placement. Following reconstruction of the articular block, the extra-articular component of the fracture is addressed. Length, alignment, and rotation should be evaluated clinically and fluoroscopically after reduction and before the implant is secured. Communion, osteoporosis, and bone loss are frequently encountered, and it may be necessary to augment cortical defects with primary bone grafting or bone cement.

Although partial articular AO/OTA type B fractures are not exposed to the same deforming forces as supracondylar and complete articular fractures, proper reduction and adequate fixation are necessary for the integrity of the knee joint. In most such fractures, well-positioned
Surgical Approach

Exposure is dictated by fracture configuration, implant, and surgeon experience. For side-plate constructs, a lateral approach centered over the distal femur is used for type A and C1 fractures. The iliotibial band is split in line with the skin incision, and the vastus lateralis muscle is reflected anteriorly to expose the distal femur. A swashbuckler approach, which uses a more anterior distal skin incision to allow lateral parapatellar arthrotomy, facilitates exposure of the articular surface for type C2 and C3 fractures (Figure 2). Minimally invasive and indirect reduction techniques also may be used with a limited skin incision and percutaneous insertion of proximal screws.

Medial exposure may be needed for isolated medial condylar fractures and in severely comminuted bicondylar fractures in which medial fixation is required. A straight medial approach centered over the fracture is extended distally anterior to the adductor tubercle. The fascia should be divided in line with the skin incision, and the vastus medialis muscle should be elevated to expose the distal femur. For articular exposure, an anteromedial approach with a medial parapatellar arthrotomy may be used.

Retrograde IM nail insertion requires the ability to flex the knee to ≥70°. A longitudinal anterior incision medial to the patellar tendon allows access to the intercondylar notch. Starting the incision in the center of the notch anterior to the posterior cruciate ligament ensures proper position of the nail within the medullary canal. A soft-tissue protector should be used to shield the cruciate ligaments and articular surface. The starting point at the superior margin of the Blumensaat line should be confirmed on a true lateral fluoroscopic image before reaming.

Surgical Techniques and Implants

External Fixation

External fixation is an invaluable management option for distal femoral fractures because it offers rapid stabilization and restoration of length with minimal soft-tissue disruption. Half-pin, hybrid, and circular wire frame constructs provide relative stability, with the advantage of shorter operating time, minimal blood loss, and minimal periosteal stripping. External fixation should be considered in patients with open wounds, poor skin healing potential, and multiple injuries as well as in fractures that cannot be reconstructed with open reduction and internal fixation. Limited internal fixation involving reconstruction of the articular block with concurrent external fixation of the extra-articular fracture has been advocated. Several authors report acceptable overall results with external fixation, de-
scribing union rates ranging from 92.3% to 100% at an average of 4 to 6 months postoperatively. Nonetheless, the cumbersome nature of the frame, in addition to complications such as pin-tract infection, deep infection, loss of reduction, malunion, and knee stiffness, discourage routine use except in fractures that are unsuitable for internal fixation.

**Fixed-angle Blade Plate and Sliding Barrel Condylar Plate**

The fixed-angle blade plate revolutionized the surgical management of distal femoral fractures with its ability to provide stable fixation and control alignment in multiple planes (Figure 3). The plate consists of a rigid condylar blade fixed to a precontoured lateral side plate that mirrors the valgus relationship between the distal femur and the knee joint. The construct requires precise initial implantation of the blade into the distal fragment to ensure proper alignment of the fracture in the coronal, sagittal, and axial planes.

Drawing on the successful design of the fixed-angle blade plate, the sliding barrel condylar plate employs a similar fixed-angle concept in an implant that is technically more forgiving. The key advantage of the sliding barrel condylar plate is its two-piece construction, which allows easier implantation as well as improved capability for less invasive insertion. The lag screw may be positioned over a guidewire and can generate compression of an intercondylar split.

Inherent disadvantages of these devices include poor fixation in osteoporotic bone and an inability to control coronal plane fracture. Interfragmentary screws used to secure comminuted fracture fragments may create obstacles for insertion. In addition, insertion of the lag screw of the sliding barrel plate requires the removal of a large amount of bone from the femoral condyles.

Clinical studies have generally shown good results with these devices. A recent long-term study with an average follow-up of 9.5 years reported satisfactory to excellent results in 82% of fractures managed with the condylar plate.

**Locking Plate**

Locking plates offer several new options in the management of periarticular fractures as well as in fractures in osteoporotic bone (Figure 4). This technology transformed conventional plates into fixed-angle devices with the capacity to capture fracture fragments and maintain rigid reduction of comminuted fractures. Lateral plates are exposed to severe bending forces in the distal femur. Nonlocking plates have been shown to allow >5° varus collapse in 42% of comminuted distal femoral fractures. Locked screws augment the stability of the construct because they secure the plate at multiple points, thereby eliminating motion at the plate-bone interface and bestowing greater strength to resist pullout. Locking plates have been shown to be biomechanically superior to blade plates in both cyclic loading and ultimate strength. The application of these plates is similar to that of other fixed-angle devices, with the added versatility of multiple distal screw hole options combined with the ability to lock or compress, as needed. Locking plates achieve fixation...
with less invasive insertion and less soft-tissue disruption. One such device is the Less Invasive Surgical Stabilization (LISS) plate (Synthes, Paoli, PA). This plate is precontoured to the lateral border of the distal femur, and it is inserted through a minimally invasive incision. Proximal percutaneous screw placement is guided by an attached outrigger. In a biomechanical cadaver study, Zlowodzki et al\textsuperscript{25} demonstrated greater fixation strength in axial loading but less strength in torsional loading with the LISS plate compared with angled blade plating and IM nailing. Early clinical results with the LISS plate have been promising, with union rates ranging from 93% to 100%, an average time to union from 12 to 13 weeks, and infection rates of zero to 3.2%; however, these studies lack a comparison group.\textsuperscript{26-28} Later-generation locking plates offer the option of insertion through either a conventional open technique or a minimally invasive incision with proximal percutaneous screw placement.

The recently introduced polyaxial locking plates possess even greater versatility in screw positioning. These plates appear to be ideal for managing comminuted intra-articular fractures in which conventional locking plates fail to capture all fracture fragments and in which multiple interfragmentary lag screws pose traffic obstacles. A recent biomechanical study comparing a polyaxial locking plate with a conventional locking plate demonstrated greater axial and torsional stiffness with the former as well as less irrevers-

AP (A) and lateral (B) radiographs demonstrating a distal femoral fracture with intra-articular extension (AO type C3). Coronal reconstruction (C), sagittal reconstruction (D), and axial CT slice (E) demonstrating the intra-articular extension, which can be helpful in preoperative planning. Postoperative AP (F) and lateral (G) radiographs demonstrating fracture fixation with a periarticular locked plate. Oblique interfragmentary screws were required to secure the intercondylar component.
ible deformation and higher load to failure. Haidukewych et al examined the use of polyaxial locked plating in periarticular fractures of the knee in a retrospective clinical study. No evidence of implant fixation failure was observed in the 25 distal femoral fractures managed with this technique. One nonunion and one infection were observed. These authors concluded that polyaxial plating offers excellent periarticular control with no loss of strength and no increase in complications.

Despite the improved biomechanical properties of periarticular locked plate fixation, failure with varus collapse has been shown to occur, with proximal screw failure or breakage of the locked screws at the plate interface frequently implicated. Causes of fixation failure include high-energy fracture with extensive metaphyseal comminution, poor reduction, poor plate position or fixation, and early weight bearing before radiographic evidence of union. Techniques that may prevent collapse and malunion include bicortical proximal screw fixation, medial augmentation with primary bone grafting or plating for large metaphyseal defects, protected weight bearing, and early surgical intervention with bone grafting for delayed union. Management of failed fixation often involves malunion take-down with grafting and revision to a blade plate or another fixed-angle device.

Intramedullary Nailing

IM fixation allows fracture stabilization with minimal disruption of the soft tissue and periosteum around the fracture site (Figure 5). Historically, IM fixation was reserved for extra-articular fractures, but improvements in design have expanded the indications. Newer implants offer multiple distal screw position options that allow articular reconstruction and sturdy fixation even in intra-articular fractures.

A standard-length retrograde nail should extend to the level of the lesser trochanter to minimize stress on the subtrochanteric region. Short supracondylar nails are also available. These should be long enough to...
allow placement of two interlocking screws in the proximal fragment. An antegrade nail may be used in proximal supracondylar fractures. Regardless of nail type, multiple distal locking screws are required to control sagittal alignment of the distal fragment. Reaming of the canal has been proposed to stimulate a healing response.33

Biomechanical studies have demonstrated that IM nailing and side-plate constructs have similar axial strength.21,33 However, a recent cadaver study of supracondylar fracture fixation showed that IM nailing had 47.5% greater axial stiffness than a dynamic condylar screw and 77% greater axial stiffness than a locking condylar plate.34 Nailing was also associated with less micromotion than were the other constructs. Another cadaver study demonstrated that IM nailing may fail by loss of distal fixation during axial loading, resulting in nail penetration of the knee joint.25 In a clinical situation, such penetration can have catastrophic consequences on knee joint function.

Insufficient fracture reduction, a poor starting point, or eccentric reaming may lead to fracture malalignment. The fracture should be adequately reduced before passage of the nail because often very little cortical contact is present in the metaphysis or in osteoporotic bone. Blocking screws placed in the distal or proximal fragment to guide the trajectory of the nail as it is passed may be helpful in achieving satisfactory reduction. A notable disadvantage of retrograde IM nailing is violation of the knee joint. Careful insertion is required to protect the articular cartilage. Impingement or notching of the patella has also been shown to be a possible complication of nails that back out or that are inadequately seated.32

Papadokostakis et al35 performed a systemic review of the literature on retrograde nailing of femoral fractures. An analysis of 544 distal femoral fractures demonstrated an overall union rate of 96.9% at a mean time to union of 3.4 months. Average knee ROM was 104.6°. Reported complications included knee pain (16.5%), infection (1.4%), and malunion (5.2%). Reoperation was performed in 17% of patients, most commonly for screw-related problems or nail revision or removal, or to promote union. A recent long-term study with a mean follow-up of 80 months showed a significantly reduced rate of bone grafting and malunion following retrograde IM nailing compared with conventional open reduction and internal fixation (67% versus 9% and 42% versus zero, respectively).36 IM nailing also demonstrated a trend toward fewer infections and nonunions.

**Periprosthetic Fracture of the Distal Femur**

The incidence of periprosthetic distal femoral fracture has been reported to be 0.9% after primary TKA and 1.6% after revision TKA.37 Risk factors include advanced age, osteoporosis, rheumatoid arthritis, chronic steroid use, and neurologic disease. Anterior notching of the femur is thought to be a risk factor, but a recent study has called this into question.38 With the exception of nondisplaced, stable fractures and patients who are unsuitable for surgery, surgical intervention is indicated to restore alignment, knee motion, and implant stability. Even modest malalignment may jeopardize the function and durability of a previously well-performing arthroplasty.

Revision arthroplasty with a long-stemmed component should be considered for fractures that compromise the stability of the femoral component. Distal femoral replacement may be indicated in fractures with massive bone loss. For supracondylar fracture proximal to a stable femoral component, the implant and fracture configuration dictate surgical management. The exact type of implant should be investigated to determine whether the intercondylar notch can accommodate the passage of a retrograde nail. An opening ≥1 mm larger than the size of the intended nail is recommended, and the component position must allow appropriate passage and seating of the nail within the medullary canal. Fixed-angle side-plate devices are useful in osteoporotic bone, more distal fractures, and situations in which the femoral component does not allow passage of a nail. A blade plate inserted just proximal to a well-fixed femoral component can provide excellent angular stability. Locking plates afford versatility in screw placement for comminuted or osteoporotic fractures (Figure 6).

**Postoperative Management**

Depending on the perceived stability of the fracture construct intraoperatively, postoperative motion should be initiated immediately to prevent stiffness and loss of function. Early physical therapy for knee ROM as well as quadriceps and hamstring strengthening are helpful in maximizing functional recovery. A hinged knee brace may be used to protect the fracture from varus and valgus stresses. Some surgeons use a continuous passive motion machine to facilitate gradual advancement in knee flexion. Achieving full extension of the knee during therapy should be emphasized to avoid contracture. Toe-touch or non-weight-bearing restrictions should be implemented for ≥12 weeks or until fracture healing
is visible radiographically. Management of underlying osteoporosis may prevent subsequent fragility fracture, and involvement of the primary care provider or an endocrinologist is essential in providing comprehensive care.

Clinical Results

Despite the abundance of literature describing distal femoral fracture fixation, there is a relative dearth of recent comparative clinical studies. The available literature reports on relatively small groups. In a prospective study, Markmiller et al\(^39\) compared the functional and radiographic outcomes of 16 patients who underwent LISS plating with 16 patients who underwent IM nailing. No difference was found between devices for any outcome measure, and good or excellent results were reported in 87.5% of patients in both groups.

In a prospective controlled trial, Hartin et al\(^40\) compared IM nailing with condylar blade plating. Twelve patients were randomized to the IM nail group, and 11 were available for follow-up at an average of 21.1 months. Eleven patients were assigned to the blade plate group, 8 of whom returned for complete follow-up at an average of 18.8 months. No significant difference in operating time, knee ROM, or functional scores was found between the groups. Three patients in the IM group required reoperation.

Zlowodzki et al\(^41\) collected information on the surgical fixation of 1,670 distal femoral fractures from 48 series over 16 years. The fixation techniques analyzed included IM nailing (ie, antegrade, retrograde), locked internal fixation (ie, LISS), compression plating (eg, blade plate, dynamic condylar screw, condylar buttress plate), and external fixation. The authors reported an overall nonunion rate of 6.0%, fixation failure rate of 3.3%, deep infection rate of 2.7%, and secondary surgical procedure rate of 16.8%. Specifically, the authors reported a nonunion rate of 5.3% with retrograde IM nailing, 8.3% with antegrade IM nailing, 5.5% with LISS plating, 6.3% with compression plating, and 7.2% with external fixation. Fixation failure was reported in 3.2% with retrograde nailing, 3.7% with antegrade nailing, 4.9% with LISS plating, 2.6% with compression plating, and 1.5% with external fixation. Deep infection rates were 0.4% with retrograde IM nailing, 0.9% with antegrade IM nailing, 2.1% with LISS, 4.8% with compression plating, and 4.3% with external fixation. Secondary surgical procedures were required in 24.2% managed with retrograde
nailing, 23.1% managed with antegrade IM nailing, 16.2% managed with LISS, 12.7% managed with compression plating, and 30.6% managed with external fixation.

The broad range of fracture and injury characteristics prevented detailed meaningful comparative statistical analysis of all groups. However, the outcomes of locked internal fixation plating and conventional compression plating were compared. A statistically nonsignificant relative risk reduction of 55% in deep infection was seen in open fractures managed with locked internal fixation compared with traditional compression plating technique (P = 0.056). Conversely, a relative risk increase was noted in fixation failure of 89% (P = 0.062) and in reoperation of 28% (P = 0.145) with compression plating versus locked internal fixation. Nonetheless, the authors of this study recommended that the results be interpreted with caution because of the lack of randomization and control groups.

Summary

Fractures of the distal femur present treatment challenges because of the inherent complexity of the injury as well as the internal and external deforming forces that act on fixation. Careful patient evaluation and fracture characterization is critical when choosing a treatment plan. Unstable or displaced fractures should be managed surgically unless contraindicated. Management priorities include restoration of the articular surface as well as length, rotation, and alignment of the distal femur. Locked plating and IM nailing are mainstays of surgical treatment because of their ability to obtain sturdy fixation, even in osteoporotic bone, and their resistance to inherent deforming forces. Prospective research comparing these two types of implant is needed to elucidate their respective roles in surgical management of distal femoral fracture.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, reference 40 is a level I study. Level II studies include references 5, 12, 24, 25, 29, 33, 34, and 41. Level III studies include references 11, 36, and 38. References 1-3, 7-10, 13, 14, 16-23, 26-28, 30-32, 35, and 37 are level IV studies. References 15 and 37 are level V expert opinion.

Citation numbers printed in bold type indicate references published within the past 5 years.

20. Araz Mi, Memik R, Ogun TC, Yel M: Ilizarov external fixation for severely comminuted supracondylar and intercondylar fractures of the distal


