Surgical Techniques

Surgical Tips and Tricks for Distal Femur Plating

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ASSOCIATED VIDEO

ABSTRACT

Distal femur fractures are challenging fractures to treat, with nonunion rates as high as 22%. Precontoured locking plates have mitigated some earlier causes of failure, while introducing new challenges. The recognition of troublesome injury patterns and appropriate preoperative planning can avoid common pitfalls. Adjunctive techniques, including the use of a radiolucent triangle, an external fixator, unicortical plates, and crossing K-wires, can assist with fracture reduction and maintenance. It is important to understand the common pitfalls involved with distal femur plating and to consider a wide array of techniques to combat these challenges.

Distal femur fractures (Orthopaedic Trauma Association classification types 33A, 33B, and 33C) are relatively uncommon, with a prevalence of 0.5% of all fractures.[1] However, with an aging population that continues to grow, a corresponding increase in distal femur fractures has occurred, with the incidence most recently reported as 8.7/100,000/yr.[2] These fractures frequently occur in the presence of osteoporotic bone, with intraarticular extension common. Furthermore, with the ever-growing increase in arthroplasty, periprosthetic fractures have similarly become more frequent, encompassing up to 30% of distal femur fractures.[2]

As lateral precontoured locked plating has become a mainstay of treatment, new challenges including mechanical failure and plate-induced deformity have emerged.[3,4] Although initial studies on lateral locked plating seemed promising for union rates, recent reports have suggested nonunion rates ranging from 10% to 22%.[5-12] Some complications can be attributed to factors under surgeon control. The purpose of this article was to highlight surgical strategies to overcome common malreduction and implant-related problems and provide injury-specific technical tips.

Preoperative Planning

The importance of understanding the local anatomy, pathoanatomy of the injury, and implant design cannot be overemphasized. Fracture morphology is often best characterized with a CT scan, allowing the optimal visualization of fracture planes and the selection of appropriate reduction strategies. For example, intraarticular fractures will typically require reduction and fixation before the stabilization of the metaphyseal segment. "Hoffa" fractures (coronal plane fractures of one or both condyles) are present in as many as 40% of

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distal femur fractures with intercondylar extension[13] and merit reduction and fixation with anterior-to-posterior–directed screws before addressing the remainder of the injury.

Understanding the design of the intended implants is also important. Modern precontoured lateral locking plates are designed to reproduce the anatomic lateral distal femoral angle of 81° to 85° and permit the use of both locking and nonlocking screws. Nonlocking screws can facilitate the use of the plate as a reduction aid by first fixing the plate distally and drawing the shaft to the plate, or vice versa. Locking screws can be used for enhanced fixation in osteoporotic bone or to achieve adequate fixation in short distal segments, irrespective of bone quality.

Setup

Typically, the patient is positioned supine on a radiolucent table with a bump under the ipsilateral hip to avoid excessive external rotation of the distal femur. The C-arm is brought from the contralateral uninjured side. Obtaining appropriate imaging before the surgery is critical. Before prepping and draping, the contralateral limb is imaged for rotational purposes (Figure 1). An radiograph of the knee is first obtained with the patella centered. Without changing tilt and rotation, an radiograph of the lesser trochanter is then obtained. This "lesser trochanter profile" can be used as a template when assessing the rotation of the injured limb. In addition, a reproducible anterior-posterior (AP) image (which may be defined as showing 50% overlap of the fibular head by the tibial metaphysis) of the uninjured knee should be obtained. This radiograph will reveal the anatomic contour of the trochlear notch in the uninjured knee, which can be used as a template for the injured side when assessing whether the articular block is hyperextended relative to the shaft (a hyperextended articular block will have a trochlear notch that appears

Figure 1

Fluoroscopic images showing the assessment of rotation and alignment. Fluoroscopic images of the uninjured knee and hip (top left) obtained without changing the C-arm rotation are compared with images of the injured knee and hip (top right) and demonstrate a similar appearance of the lesser trochanter with similar knee rotation, confirming that a rotational malreduction has not occurred. AP fluoroscopic images of the hip, ankle, and knee with a bovie cord spanning from the femoral head to the middle of the ankle (bottom row) confirm that the mechanical alignment of the knee is anatomic after reduction and fixation.

"larger" than the contralateral uninjured side, Figure 2). Finally, an overlapping femoral condyle lateral of the uninjured knee can be obtained to characterize the native anatomy between the condyles and the shaft. This is often a useful template for reduction because posterior comminution may prevent the use of the posterior cortex as a key in reestablishing the shaft-articular block relationship.

Exposure

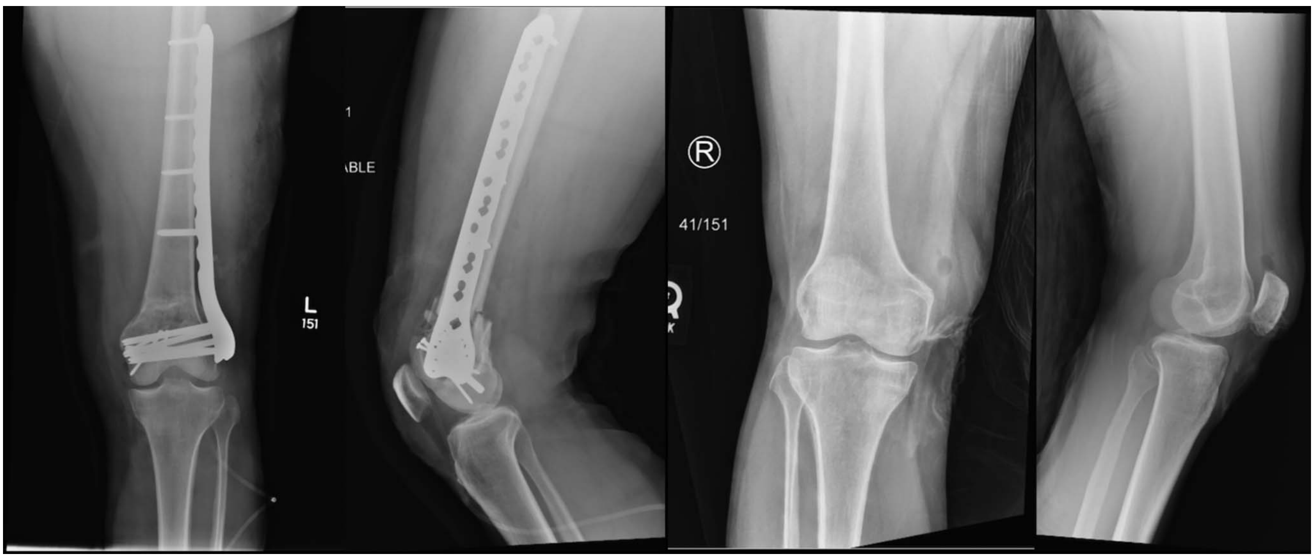
The choice of approach is often dictated by the degree of articular involvement and consequent need to visualize the joint. For extraarticular patterns or fractures with minimal articular displacement, a direct lateral approach can be used. The iliotibial band is incised and the vastus lateralis retracted anteriorly and medially, with care taken to cauterize perforating vessels. Retractor placement over the top of the metaphyseal region is avoided so as to minimize soft-tissue dissection. This approach allows for direct visualization of the comminuted metaphyseal region in addition to lateral Hoffa fragments. This approach is often combined with minimally invasive techniques for plate application.

Fractures with notable articular comminution often require more extensile approaches, including the "swashbuckler" or anterolateral approach.[14] This approach involves a lateral parapatellar arthrotomy with either a direct anterior or a curved anterolateral incision. This approach can be extended cranially in a subvastus fashion and can expose the articular block in addition to the femoral shaft. In intraarticular distal femur fractures, especially with medial Hoffa fragments, a midline incision with a lateral parapatellar arthrotomy is the authors' preferred approach (Video 1). Care should be taken to minimize soft-tissue stripping, with only the lateral soft tissue elevated from the distal femur to facilitate final plate application. When using a curved anterolateral approach, an oblique incision through the tendinous portion of the quadriceps can be done to increase medial exposure, although this must be repaired at the conclusion of the surgery (Supplemental Digital Content, Video E1, dual plate fixation of a comminuted intra-articular distal femur fracture, http://links.lww.com/JAAOS/A701).

Reduction

Reduction strategies are dictated by fracture morphology, including the presence or absence of intraarticular extension and metaphyseal comminution. Extraarticular patterns may be reduced before plate application or with the use of the plate as a reduction aid. Extraarticular patterns can typically be reduced with longitudinal traction; the use of a well-placed bump; and the manipulation of fragments with K-wires, Schanz pins, and/or

Figure 2



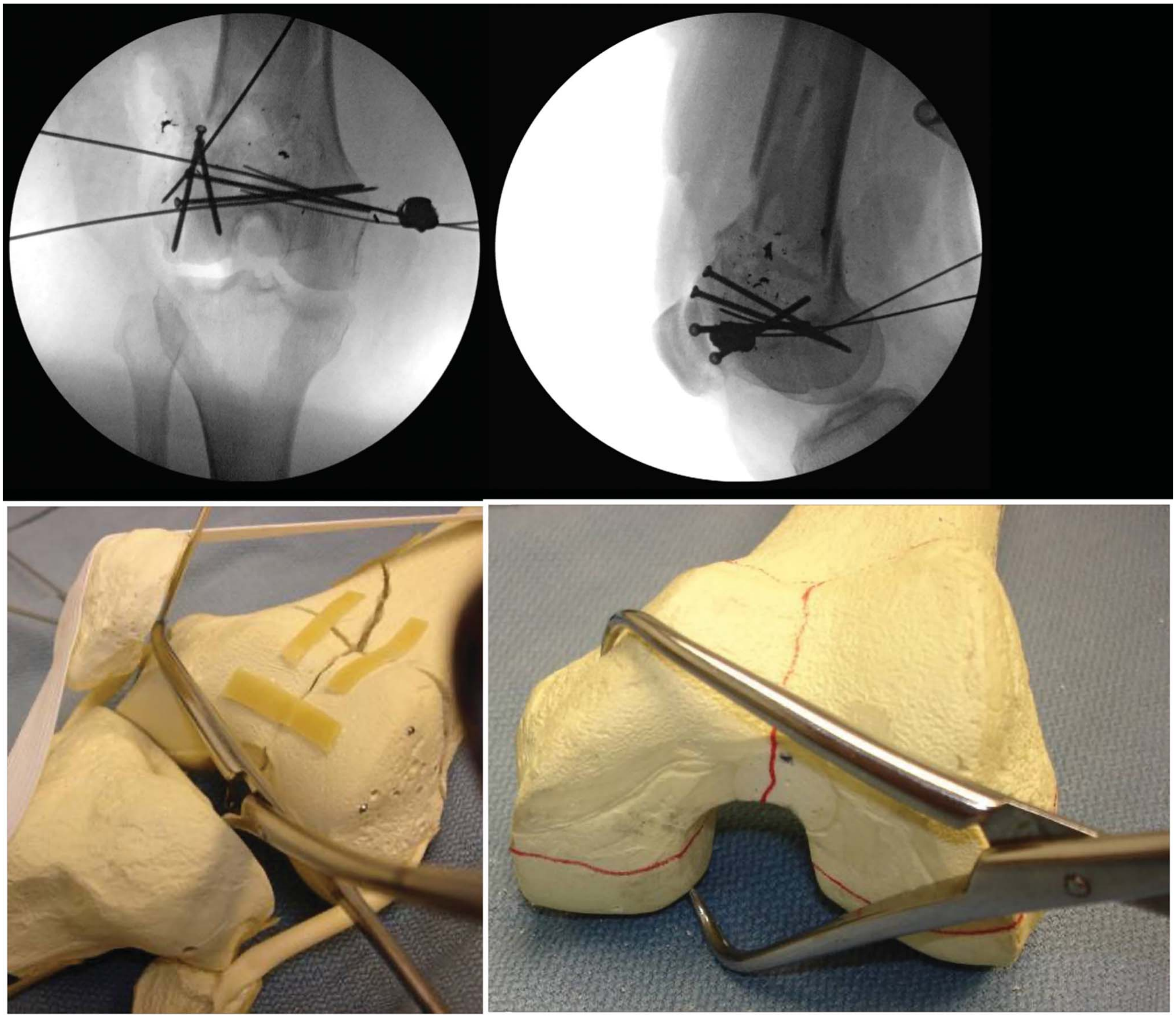
Radiograph showing the hyperextension of the articular block relative to the shaft. The contour of the trochlea in the postoperative AP image (left) is larger in height compared with the contour of the trochlea in the contralateral AP image (right), suggesting hyperextension of the articular block. Hyperextension is confirmed with comparison of the postoperative lateral image (left) with the contralateral lateral image (right). Plate-bone mismatch is also seen on the postoperative AP image because of the posterior condyles being anteriorly translated, increasing the distance from the shaft to the plate.

clamps. Although it is the authors' preference to achieve a reduction before plate application, the plate can also be used as a reduction tool. This involves positioning and fixing the plate distally and subsequently placing cortical screws proximally to draw the plate to the bone.

For intraarticular patterns, the surgeon may prefer to first reduce the articular block before stabilizing the metaphyseal implant (referred to as converting a "C-type" to an "A-type"). In the absence of metaphyseal comminution, however, the reduction of the articular block and metaphyseal segment may need to occur simultaneously, which can be very challenging. An alternative strategy is to reduce the largest articular fragment to the shaft and subsequently reduce the remaining articular fragments to these implants (converting a "C-type" to a "B-type").

The strategy for reducing intraarticular fragments depends on the location of the principle fracture planes. Medial Hoffa fragments are typically addressed first, with provisional clamp placement through the intercondylar notch followed by countersunk cortical screws in an anterior-to-posterior direction with divergent trajectories (Figure 3). The authors' preference is to use

Figure 3



Radiograph showing the distal femur fracture with a Hoffa fragment. This was fixed with divergent 2.7-mm screws. A model demonstrating clamp placement for the reduction of a medial Hoffa fragment.

2.7-mm cortical screws for this purpose, although headless compression screws and alternative sizes of interfragmentary screws remain viable options. When attempting to access very posterior Hoffa fragments, extreme hyperflexion of the joint combined with hyperextension of the metaphyseal segment will allow for optimal visualization. Hyperflexion of the joint in addition to hyperextension at the fractured metaphyseal segment allows for the posterior articular surface to be brought as anterior as possible, facilitating visualization when using an anterior-based or lateral-based approach.

With simple articular splits (usually in the sagittal plane, in contrast to the coronal plane Hoffa fractures), the use of a well-placed clamp can facilitate reduction. Often this clamp can be placed through the arthrotomy with tines on the medial and lateral epicondyles. K-wires or Schanz pins can be used as joysticks to help control the rotation of the condylar segments. It is important to avoid eccentric clamp placement because this can malreduce the fracture; anterior placement of the tines can cause compression of the anterior portion of the articular block and gapping of the posterior aspect of the articular block (Figure 4). Articular splits in the sagittal plane can be fixed with lateral-to-medial lag screws before definitive plate fixation (Figure 5).

Once the articular reduction is achieved, metaphyseal reduction can commence. As the articular block is often hyperextended relative to the shaft of the femur due to the pull of the gastrocnemius, longitudinal traction over a triangle with a well-placed bump can aid in reduction. For simple fracture patterns, a periarticular clamp can be placed with tines on the medial and lateral epicondyles for improved control of the articular block, allowing for the fine-tuning of varus, valgus, flexion, or extension relative to the shaft. A Schanz pin or Cobb elevator can also be used to help control articular block hyperflexion or hyperextension relative to the shaft. The Schanz pin is placed anterior to posterior in the distal articular block (Figure 6). A Cobb elevator placed on the articular block posterior cortex with a posterior-to-anterior–directed force can facilitate flexion.

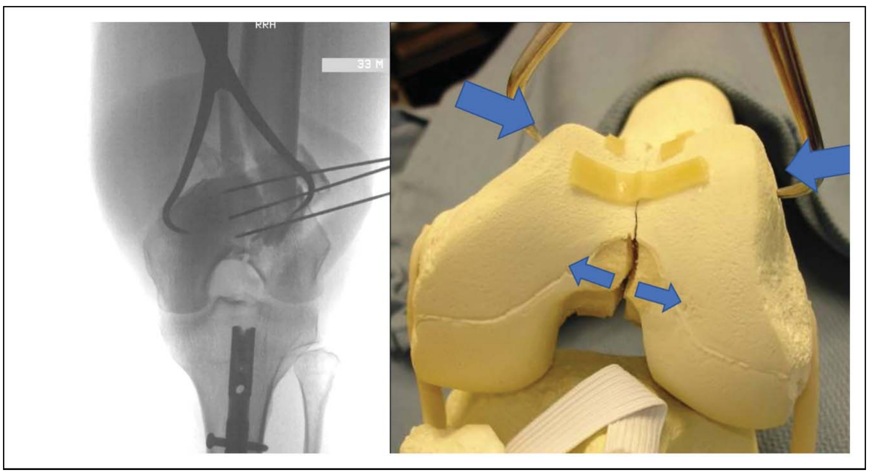
Provisional Fixation

Once the reduction of the metaphyseal segment is obtained, crossing 2.0-mm K-wires can provisionally maintain the reduction (Figure 6). Notably, these wires are often not adequate to maintain the reduction alone, and the longitudinal traction and flexion used to obtain the initial reduction must be maintained.

An external fixator or unicortical plates can augment this provisional reduction (Figure 6). To use an external fixator for this purpose, 2 to 3 anterior-to-posterior Schanz pins are placed in the shaft of the femur and the articular block. Typically, a proximal pin in the femoral shaft and an articular block pin are placed first. Sequential traction, manipulation, and clamp tightening helps the surgeon achieve anatomic length with relative control of rotation. An additional femoral shaft pin can be placed closer to the fracture site to improve control of the shaft of the femur.

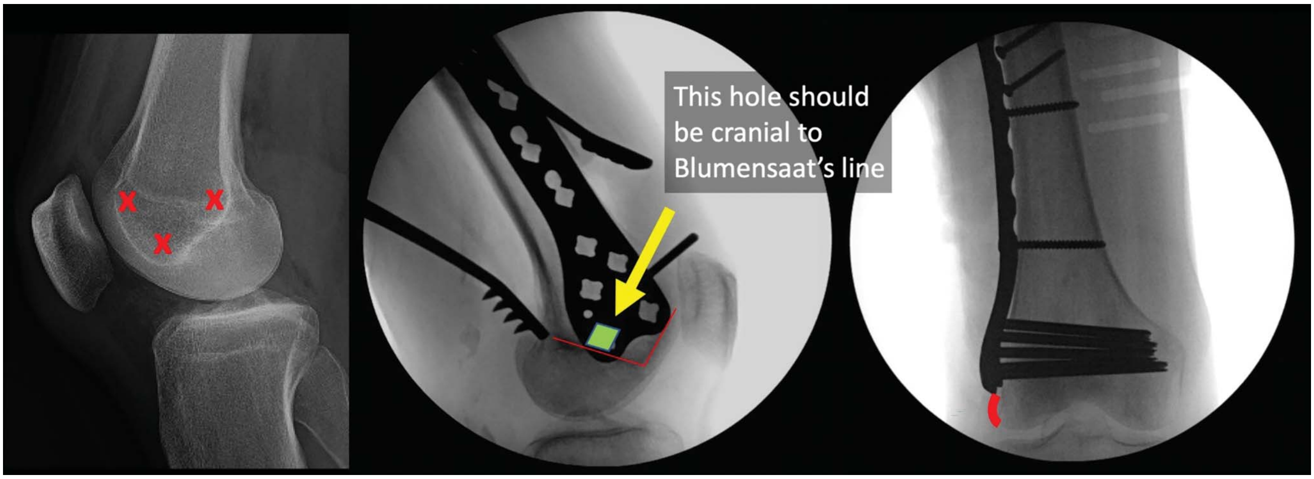
Unicortical plates can also augment provisional fixation. The authors' preferred implants for this purpose are 2.7-mm reconstruction plates which are flexible and allow for some degree of contouring with application

Figure 4



A fluoroscopic image and a corresponding model demonstrating anterior clamp placement with resultant posterior gapping of the articular block.

Figure 5



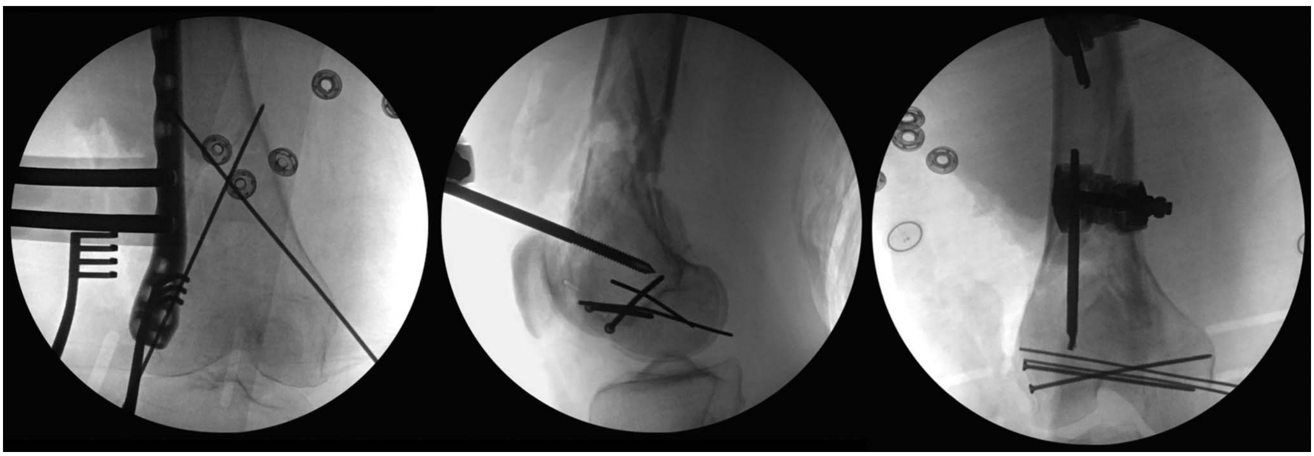
Radiograph showing the proper placement of lag screws and the lateral plate. A lateral radiograph (left) is labeled with typical locations for lateral-to-medial lag screws. Lateral and AP fluoroscopy images (middle and right) demonstrate the appropriate position of a lateral plate with the posterior distal hole cranial to Blumensaat's line and the lateral contour of the plate matching the supracondylar flare of the distal femur.

while minimizing the displacement of reduced fragments. The authors' preference is to place unicortical provisional plates laterally, where they will end up underneath the definitive plate because this minimizes the added "biologic cost" of periosteal stripping and plating in a second location. Anterior placement of provisional plates, for example, may require increased periosteal stripping and impose an added "biologic cost."

Definitive Fixation

A common strategy of definitive fixation for intra-articular distal femur fractures is lateral locked plating. Proper plate placement requires an understanding of the distal femur anatomy and the design of modern precontoured plates. The distal femur articular block is shaped as a trapezoid in the axial plane and is narrower anteriorly than posteriorly. The lateral cortex has a 10° slope, and the medial cortex has a 25° slope in the axial plane. Because of this trapezoidal shape, it can be relatively easy to place the plate too posterior on the wider part of the trapezoid and therefore medialize the articular block relative to the shaft, known as a "golf club" deformity. Indeed, the prevalence of this technical error has led some authors to state that these plates do not fit the "normal anatomy."[15] However, these plates were designed for normal anatomy determined by the averaging

Figure 6



Fluoroscopic images showing crossing K-wires (left) and placement of an external fixator (middle and right) for provisional fixation.

of adult populations, and although exceptions exist, precontoured plates closely approximate the "fit" of most adult distal femurs when they are placed in the correct location. In a paper by Campbell et al,[15] for example, plate fit was assessed by overlaying plate templates on AP radiographs of the femur and was determined to be imperfect. Because of the slight internal rotation of the lateral distal femur, however, the proper plate position is anterolateral, and a template of the plate against an AP radiograph will show an imperfect fit even if the plate does fit clinically.

When the plate is applied distally and remains elevated off the shaft of the femur proximally, this can mean that the plate is placed too distal, too posterior, or the fracture is not adequately reduced. Distal or posterior placement can cause the plate to be lateralized relative to its ideal position, causing the plate to sit off the shaft. When the plate is then brought flush with the shaft, this will medialize the articular block relative to the shaft (ie, "golf clubbing"). A similar problem can arise with malreduction. If the distal femoral block is hyperextended or internally rotated relative to its anatomic position, this will bring the wider posterior condyles more anterior and thereby similarly lateralize the plate. This again increases the distance of the plate from the shaft of the bone and results in medializing the articular block relative to the shaft when the plate is drawn to the shaft proximally.

One method for optimal plate placement can be reproduced with an overlapping femoral condyle lateral fluoroscopy image (Figure 5). The plate should be placed on the articular block with the posterior distal hole of the plate above Blumensaat's line and the anterior distal hole cranial to the trochlear groove on the lateral image. On the AP image, the plate is typically 1 to 1.5 cm cranial to the joint line, with the lateral contour of the plate matching the supracondylar flare. Proximally, the plate typically is seated anterolaterally on the shaft of the femur.

Alternatively, the plate can be applied on an optimal AP image, with a joint axis reference wire used. This wire is placed in the articular cluster of the plate and should be parallel to the joint axis and articular line of the femoral condyles. The supracondylar flare should be matched with the contour of the plate, and a lateral image is used to ensure that the distal articular screw cluster is centered within the subchondral margin of the trochlea and Blumensaat's line.

With the intended anterolateral position of the plate on the femoral shaft, the screws are designed to have a slight anterior-to-posterior trajectory to remain bicortical. It is imperative to avoid placement of the plate too far anteriorly. Overly, anterior placement on the shaft results in eccentrically placed screws with resultant unicortical fixation.[3,16,17] Overly, anterior placement distally may lead to painful encroachment of the plate on the extensor mechanism or screw placement into the patellofemoral joint. This can be avoided with either visual inspection through the approach (if permitted) or the use of an overlapping femoral condyle lateral view to ensure that there is no distal or anterior extension of the plate beyond the radiographic outline of the lateral femoral condyle.

A properly placed plate that is flush with the anterolateral cortex of the articular block and along the anterolateral surface of the shaft will not appear in profile on an AP fluoroscopy image but will instead be seen obliquely in the AP image due to the plate's internal rotation. If the plate is in fact visualized in profile with an AP image of the knee, this often means that the plate is externally rotated relative to its ideal position and not optimally abutting the lateral cortex of the articular block.

One additional assessment of the reduction involves using a bovie cord to evaluate the mechanical alignment of the limb. With the knee in extension, the bovie cord is elongated from the femoral head to the middle of the ankle joint on AP images and its position relative to the center of the knee joint is assessed on an additional AP image. Gross medial or lateral displacement of the bovie cord relative to the center of the knee should raise suspicion for malreduction of the fracture.

The optimal length of the definitive plate is dependent on the intended method of stabilization, absolute or relative stability. The use of longer plates with at least eight plate holes proximal to the fracture has been recommended regardless.[12,18] Typically, four bicortical screws are placed in the shaft, with as many distal screws in the articular block as possible. In noncomminuted patterns where anatomic reduction can be achieved and absolute stability is intended, the surgeon should consider applying compression with four bicortical screws in the shaft. Comminuted fractures are typically treated with longer bridging constructs, where the plate length is at least twice the zone of comminution,[19] and four well-spaced bicortical screws are placed in the shaft.

It is important to assess the position of articular block screws on fluoroscopy relative to the intercondylar notch and the medial cortex. A "notch" view can be obtained with the knee flexed to show the intercondylar notch in profile (Figure 3, top left). This can demonstrate whether screws cross the intercondylar notch, which may cause impingement on the cruciate ligaments or limit knee motion.[20] A 20° to 25° internally rotated view can alert the surgeon about screws that breach the medial cortex, a complication that can cause notable irritation (Figure 7). In both cases, screws should be exchanged to avoid violating the notch or medial cortex.

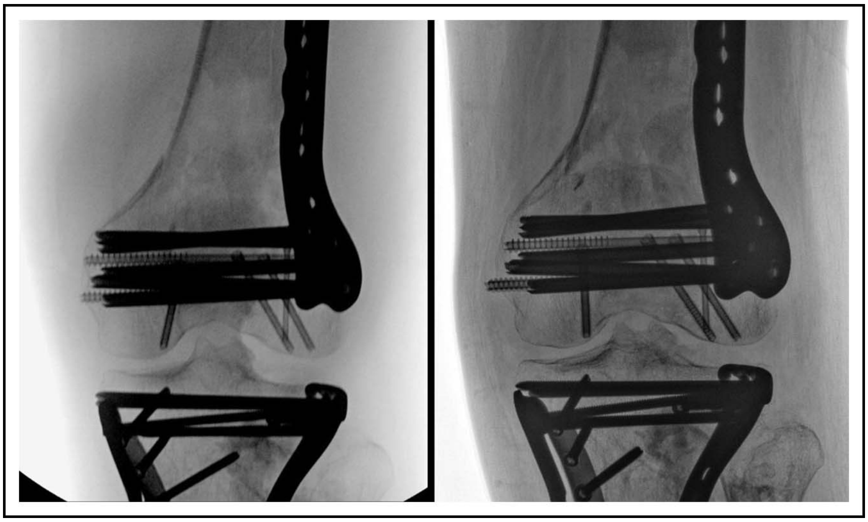
Adjunctive Fixation

For fractures with severe medial metaphyseal comminution and/or missing metaphyseal bone, adjunctive fixation may be warranted (Figure 8). One option is medial plating, which can be done through minimally invasive methods in a "safe zone" on the anteromedial aspect of the distal femur.[21-23] This "safe zone" was characterized by Kim et al[23] in a study of the CT angiography of 30 patients as the anteromedial aspect of the femur from the adductor tubercle up to a point halfway from the adductor tubercle to the lesser trochanter (15 cm below the lesser trochanter). In this distal aspect of the femur, the deep femoral artery has already given off its final perforator (8 cm distal to the lesser trochanter) and the superficial femoral artery has moved posteromedially, posterior to a coronal plane–bisecting line through the femur.[23]

A multitude of plate options exist for medial plate application, with the proximal tibia variable angle locking plate found to contour well with the medial supracondylar femur anatomy.[24] A 12-hole 3.5-mm recon plate (168 mm in length) is the authors' preferred option. This can be contoured to allow for fixation in the medial femoral condyle and has adequate length to obtain proximal fixation above most metaphyseal comminution. This plate length allows for fixation within the "safe zone" of percutaneous medial plating because less than 15 cm of the plate will project above the adductor tubercle. Typically, a 5-cm incision is made just anterior and distal to the adductor tubercle. Dissection is carried down to the level of the vastus medialis, with the vastus medialis retracted anteriorly and the sartorius fascia retracted posteriorly. The contoured plate is then slid submuscularly along the anteromedial aspect of the femur, with fluoroscopy used to guide placement. Once confirmed proximally, a distal cortical screw is placed. Next, a 2- to 3-cm incision is made along the cranial aspect of the plate, with dissection carried down superficially between the sartorius and rectus femoris. The vastus medialis is then isolated and retracted anteriorly, and a variable angle drill guide is placed in the cortical slot of the plate. A long 2.5-mm drill bit is then used, followed by removal of the inner sleeve. It is important to first unseat the inner sleeve with the drill bit engaged in the bone so as to facilitate abutment of the outer sleeve against the screw slot and to carefully remove the drill bit and inner sleeve simultaneously with immediate screw placement because the outer sleeve does not engage within the cortical screw slot (the inner sleeve does engage in this slot).

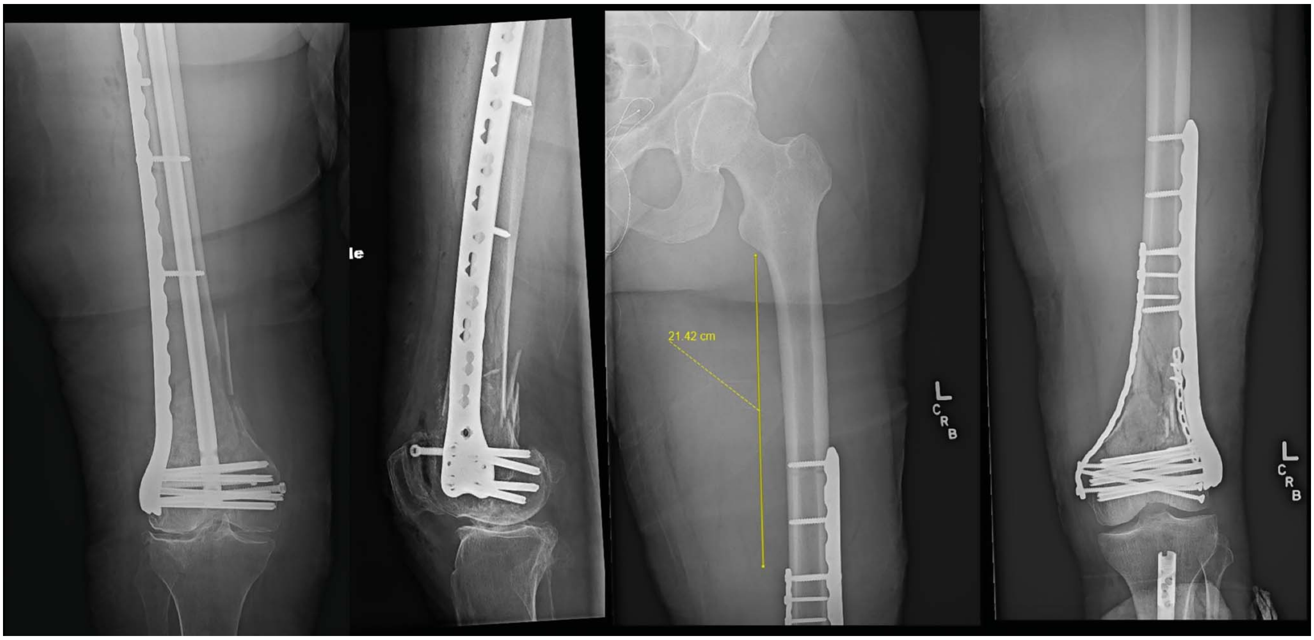
Another option for adjunctive fixation is the addition of an intramedullary nail to a lateral plate. Fixation constructs combining plates and intramedullary nails

Figure 7



Radiograph showing the assessment of screw length for the medial cortex of the distal femur. The AP fluoroscopic image on the left shows a distal cannulated screw that appears to be contained within the medial cortex, but when a 20° to 25° internally rotated image is obtained (right), the screw appears long.

Figure 8



Radiograph showing the adjunctive fixation options. The postoperative AP and lateral radiographs on the left show the use of a construct combining a lateral plate and an intramedullary nail. The postoperative AP radiographs on the right show the use of both medial and lateral plates with the medial plate greater than 15 cm distal to the lesser trochanter and therefore in the “safe zone” on the anteromedial distal femur.

initially emerged for the treatment of long bone nonunions.[25] More recently, this construct has been advocated for the acute treatment of distal femur fractures, both native and periprosthetic.[26-28] The authors’ preferred approach involves fracture reduction with initial plate application and subsequent nail placement (Figure 8). A midline approach is made with a lateral parapatellar arthrotomy. The fracture is reduced as described above, and a 16- to 18-hole plate is placed with an apex medial bend over the cranial aspect of the plate in addition to an external rotation twist to allow for screw placement into the femoral neck. For native distal femur fractures, the most distal posterior screw is placed followed by a cortical screw cranial to the fracture. One to two unicortical locking screws (typically 12 to 14 mm) in the distal shaft cranial to the fracture and one cortical screw through the femoral neck are placed, followed by removal of the cortical screw in the shaft. The retrograde nail is then placed, and distal interlocks can be placed from medial to lateral or placed through the plate, thus unitizing the construct. Proximal interlocks are placed using a perfect circles’ technique with an anterior-to-posterior trajectory. Distal locking screws are then placed through the plate. Finally, screws are placed in the shaft, bicortically where possible, with unicortical locking screws in areas blocked by the nail. In periprosthetic fractures where retrograde nail insertion typically begins more posteriorly, the most distal anterior locking screw through the plate can be placed first in lieu of the distal posterior screw to avoid interference with eventual nail placement.

Summary

The treatment of distal femur fractures with modern precontoured locked plating is complex and challenging. Complications including “golf club” deformity (excessive medialization of the articular block relative to the shaft) and nonunion have been widely reported in the literature. Commonly held principles to reduce malalignment include obtaining adequate imaging, obtaining and maintaining a reduction throughout the duration of the procedure, and ensuring proper plate application. Adjunctive techniques to assist in the application of these principles include the use of a radiolucent triangle with a well-placed bump, the use of an external fixator for provisional stabilization, the use of unicortical plates, and the use of crossing K-wires. It is important to understand the common pitfalls involved with distal femur plating and to maintain a wide array of techniques in your armamentarium to combat these challenges.

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