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The Use of Fibular Allograft in Complex Periarticular Fractures Around the Knee

Ashley E. Levack, MD, MAS,

Resident Physician, Orthopaedic Trauma Service, Hospital for Special Surgery, New York, NY, USA

Naomi Gadinsky, MD,

Research Fellow, Orthopaedic Trauma Service, Hospital for Special Surgery, New York, NY, US

Elizabeth B. Gausden, MD, MPH,

Resident Physician, Orthopaedic Trauma Service, Hospital for Special Surgery, New York, NY, USA

Craig Klinger, BA,

Research Coordinator, Orthopaedic Trauma Service, Hospital for Special Surgery, New York, NY, USA

David L. Helfet, MD, and

Chief Emeritus, Orthopedic Trauma Service, Hospital for Special Surgery and Weill Cornell Medical College, New York Presbyterian Hospital, New York, NY, USA

Dean G. Lorich, MD[†]

Associate Director, Orthopaedic Trauma Service, Hospital for Special Surgery and Weill Cornell Medical College, New York Presbyterian Hospital, New York, NY, USA

Abstract

Although the use of fibular strut allografts in proximal humerus fractures has gained popularity, their use in other types of fractures is less well described. Fibular allografts have recently been used in the repair of complex periarticular fractures of the proximal tibia and distal femur. Fibular allografts can be inserted in a variety of manners to achieve goals specific to each individual fracture pattern. In the proximal tibia, insertion through a fracture line or cortical window facilitates joint surface elevation, prevents subsidence and enhances overall construct stability. In distal femoral fractures, including complex periarticular fractures, insertion through the fracture or cortical window permits indirect reduction of the medial cortex and provides necessary medial column support. An additional option in distal femur fractures includes fibula insertion as an

Correspondence: Ashley E. Levack, MD, MAS, 535 East 70th Street, Department of Academic Training, New York, NY 10021, levacka@hss.edu, Fax: 212-606-1477, Phone: 860-463-8605.

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intramedullary nail, allowing enhanced fixation in short distal fracture segments. In all cases, the use of a fibular allograft augments poor bone stock and provides improved screw purchase and construct stability when combined with conventional plating methods. Here we present a series of cases at our institution illustrating an array of novel techniques utilizing endosteal fibular allografts in the fixation of complex periarticular fractures about the knee.

Keywords

Fibula allograft; endosteal augmentation; periarticular fracture; proximal tibia; tibial plateau; distal femur

INTRODUCTION

Structural non-vascularized frozen fibular allografts have resulted in substantial improvements in clinical and radiographic outcomes in periarticular fractures of the proximal humerus (1–8), and new evidence documenting the success of fibular strut allografts in femoral neck and proximal tibia fractures is emerging (9–13). The biologic graft serves several purposes during surgical fixation of metaphyseal bone. During fracture reduction, the graft can be inserted as a reduction tool to facilitate indirect reduction of the far cortex or elevation of a joint surface. Once in situ, the fibula also acts as a bone substitute to fill osseous voids. The fibula also serves as structural support in the form of additional cortices for screw fixation, a distinct advantage over alternative bone substitutes.

The use of fibular allografts in proximal tibia fractures with articular depression has been described previously by two groups (12, 13). Advantages of this technique include the broad fibular surface that aids in elevation of articular depression, and improved structural support in metaphyseal voids to limit post-operative subsidence. The rate of subsidence after fixation augmented by the fibular strut allograft is substantially lower than rates seen with cancellous autograft or calcium phosphate cement (12, 14). In proximal tibia fractures, the allograft can be inserted parallel to the joint surface to raft the articular surface (in purely depressed fractures), or inserted in retrograde fashion as an obliquely oriented kickstand through a pre-existing vertical fracture line or cortical window in order to support the subchondral bone of the tibial plateau. Using these techniques, articular subsidence rates have been reported to be less than 2mm at minimum 1 year follow-up, with knee flexion of 118–130 degrees on average (12, 13). The combined rate of infection following the use of endosteal fibular allograft in the two studies evaluating these fractures was low at 2.3% (12, 13).

Distal femoral fractures often occur in elderly osteoporotic individuals with poor bone stock. The difficulties of fixation and achieving union in these patients has been reported by several investigators, with non-union rates ranging from 10–25% and implant failure rates ranging from 5–16% in recent reports of locked lateral plating (15–21). When laterally-based plate fixation methods are used, endosteal allografts can aid in the reduction of the medial cortex, provide medial column support to enhance the biomechanical stability of the construct, and provide additional cortices for improved screw purchase. The allograft can be inserted through the fracture site or through the intercondylar notch using a standard entry point for a retrograde nail.

The use of dual surgical approaches has gained popularity in the treatment of complex periarticular fractures about the knee to allow for dual column fixation of the proximal tibia or distal femur. However, the biomechanical advantages afforded by combined medial and lateral plate fixation may, in some instances, be offset by the additional surgical insult to the surrounding soft tissues, periosteum, and vasculature in complex or high-energy fractures in which the soft tissues are already compromised. Furthermore, open wounds or fracture blisters may preclude a surgeon's ability to use a dual approach technique. In these cases, employing alternative options to enhance the strength of the fixation construct without creating additional incisions can protect from further soft tissue damage and improve outcomes. The following cases from our institution illustrate multiple techniques utilizing endosteal augmentation as an alternative option to dual column plate fixation in the treatment of complex proximal tibia and distal femur fractures.

PROXIMAL TIBIA OPERATIVE TECHNIQUE

Overview:

The goals of osteosynthesis in intra-articular proximal tibia fractures include restoration of limb alignment, anatomic articular reduction, and prevention of post-operative subsidence or change in alignment. The use of an endosteal fibular allograft can both help with fracture reduction and increase construct stability, thereby enhancing the resistance of the construct to subsidence.

External Fixation:

Injuries with significant soft tissue damage or the potential for significant swelling or blistering are initially temporized in a knee spanning external fixator on the day of or following the injury. 5.0mm Schanz pins are percutaneously inserted from lateral to medial and medial to lateral in the distal femur and distal tibia, creating a "box frame" construct to hold the fracture at length until the surrounding soft tissues are amenable for surgery. This external fixation construct is planned such that these Schanz pins can be used with medial and lateral femoral distractors intra-operatively.

Surgical Approach:

For definitive surgical fixation, the patient is positioned supine on a radiolucent operating table. The external fixator is prepped and draped into the operative field. The fixator bars are removed, leaving the Schanz pins in place. Femoral distractors are applied medially and laterally to guide a gentle closed reduction. A standard anterolateral approach to the proximal tibia is performed (22).

Allograft insertion:

Following this initial approach, several options are available for fibular allograft insertion depending on individual fracture characteristics. In cases with a metaphyseal split, the joint surface can be elevated en bloc, and the fibula can be inserted through the fracture site prior to plate application. Alternatively, if fracture lines do not provide an appropriate entry point, insertion through a corticotomy can often facilitate joint elevation with the aid of a tamp or with the fibula itself. The following case examples demonstrate the intra-operative

techniques for fibula insertion obliquely through a separate tibial tubercle fracture (technique 1), obliquely through a corticotomy (technique 2), and horizontally through a lateral plateau fracture (technique 3).

Proximal Tibia Technique 1: Fibula inserted obliquely through a fracture site to act as a bone void filler

A 57 year old female with insulin-dependent diabetes sustained a mechanical fall from ground level while ambulating at home, resulting in complex tibial shaft and tibial plateau fractures of the right leg. Pre-operative imaging (Figure 1) revealed an apex posterior comminuted fracture of the tibial metadiaphyseal junction with proximal intra-articular extension into the intertibial eminence. The intra-articular portion of the fracture was minimally displaced. Many factors were considered in preoperative planning, including the intra-articular extension of the fracture, the tibial shaft component with extensive comminution, the separate tibial tubercle fragment, and the radiographic evidence of osteopenia. Taking these complex fracture characteristics into account, it was decided to perform bridge plating from the tibial plateau to the tibial shaft in conjunction with an intraosseous fibular allograft to enhance stability without conferring excessive stiffness to the overall construct. Articular involvement in this pattern did not require elevation in the axial plane.

After exposing the fracture site as described above, the metadiaphyseal area was noted to be highly unstable. Figure 2 demonstrates the sequence of reduction maneuvers undertaken on fluoroscopic and intra-operative images. First, a structural Synthes 4.5mm Locking Compression Plate was applied to the lateral tibia with two 4.5mm cortical screws to bring the plate to bone and gain compression across the minimally displaced intra-articular split. The initial application of the plate aided further reduction by decreasing the number of mobile fragments and obtaining the gross fracture alignment. The fracture was then reduced to the plate in the sagittal plane and secured with cortical screws distally. A combination of Weber clamps refined the sagittal and coronal fracture alignment, building to the structural plate.

As the tibial tubercle fracture was a separate fragment, the associated anterolateral fracture line was chosen as the entry point for the fibular allograft. A 2.8mm guidewire was inserted through this fracture site to the subchondral bone just inferior to the proximal rafting screws in the medial plateau. A 10mm cannulated drill was used to create a channel for subsequent allograft introduction. A 23mm fibular allograft was cut to length and shaped with a shallow beveled edge to ease introduction into the bone as well as provide a broad surface proximally when positioned at its final oblique angle intraosseously. A 3.2mm drill bit was advanced through the intramedullary canal of the fibula to ensure it would advance over the guidewire. The fibula was then introduced over the guidewire into the intramedullary canal. The guidewire was removed and the fibula was tamped into position, seated against the proximal screws. It was then cut flush with the tibia laterally and tamped gently until it was positioned fully within the intramedullary canal distally. The fibula position was secured with 4.5mm cortical screws through the plate into the proximal and distal aspects of the graft, achieving four cortices of fixation in these regions.

The intraosseous graft with traversing screws decreased gross motion, allowing for further fine tuning of the coronal reduction. The tibial tubercle fragment, anteromedial comminution and posteromedial comminution were reduced with a combination of Weber clamps. An additional 14-hole Synthes 3.5mm reconstruction plate was contoured in the sagittal and coronal planes and applied anteriorly to the apex of the tubercle fragment to resist the flexion deformity. Anterior to posterior 3.5mm cortical screws secured the plate to bone distally, while proximally cortical screws were used through the fibular graft in the region of posterior comminution. A 4.5mm locking screw was inserted into the final hole in the proximal rafting portion of the plate. Final cortical screws were inserted through the lateral plate, achieving fixation through the graft where possible. A tap was used following drilling for screws traversing the fibula allograft.

Finally, the meniscus and capsular tagging sutures were sutured to the proximal eyelets of the plate. Prophylactic anterior and lateral compartment fasciotomies were performed, and the fascial elevation performed during initial surgical exposure was repaired to the anterior plate with 0-vicryl sutures.

Proximal Tibia Technique 2: Fibula inserted through a corticotomy site to act as a bone void filler

A 47 year old male who was rendered paraplegic 20 years ago after a traumatic aortic rupture sustained a right knee injury after falling from his wheelchair. Imaging revealed a comminuted extra-articular proximal metaphyseal tibia and fibula fracture with slight apex anterior and shortening (Figure 4). Despite his paraplegia, the patient complained of significant pain from the injury. The patient's pain along with concerns for skin compromise during non-operative management prompted surgical management. Given the degree of comminution and disuse osteopenia present, the pre-operative plan included the use of a fibular allograft to avoid a dual incision approach that may have otherwise been necessary to achieve a stable construct in poor quality bone.

A standard anterolateral approach to the proximal tibia was performed as described above. Although femoral distractors could not be utilized in this case due to a 25 degree knee flexion contracture, a gross reduction was achieved with manual traction and Weber clamps. Figures 4 and 5 demonstrate the reduction and fixation strategy during this case. A lateral "jack-in-the-box" square corticotomy was performed with a combination of sagittal saw and osteotomes distal to the fracture site to allow for fibula allograft insertion at an angle that would allow the graft to sit proximal and distal to the fracture. A 2.8mm guidewire was inserted along the planned trajectory, the fibula was contoured and advanced over the guidewire as described in detail in case 1 above. With the fibula positioned appropriately, it was cut flush and then seated within the cortex. The corticotomy window was replaced and buttressed with a synthes 4.5mm proximal tibia plate. Fixation was achieved first with a cortical screw through the lateral plate, traversing the fibula. The fracture was further reduced to the plate with Weber clamps and additional 4.5mm compression screws were inserted into the shaft, through the fibula where possible. An additional 3.5mm reconstruction plate was applied anteriorly to control the fracture in the sagittal plane.

Screws through this plate captured the allograft where possible to obtain four cortices of fixation.

Proximal Tibia Technique 3: Fibula inserted parallel to the joint line acting as a broad rafting construct

In cases with significant articular depression that are susceptible to post-operative subsidence, the fibula can be inserted parallel to the joint surface to act as a large rafting surface. A standard anterolateral approach is again used and the fibula can be inserted through the fracture line or through a cortical window as described above following elevation of the joint surface. An example of this technique is demonstrated in Figure 6.

DISTAL FEMUR OPERATIVE TECHNIQUE

Overview:

The biomechanical deficiencies seen with locked lateral bridge plating of distal femur fractures can be minimized with endosteal augmentation. Adding a fibular allograft provides intramedullary support of the medial column, enhances stability during fine tuning of reduction, and improves screw purchase, allowing for the preferential use of cortical screws. The allograft can be inserted through a lateral cortical window, through the fracture site, or through the intercondylar notch, with the ultimate result being a fully intramedullary graft.

Surgical Approach:

The patient is positioned in a sloppy lateral position on a radiolucent table using a bump under the ipsilateral hip. The surgical approach involves a lateral sub-vastus (if no intra-articular work is planned) or swashbuckler approach (if intra-articular involvement is present or if the fibula is to be inserted through the intercondylar notch). When performing a swashbuckler incision, a lateral parapatellar approach to the knee is performed distally to reveal the intra-articular fracture and/or intercondylar notch as needed. Intercondylar and hoffa fractures are addressed first with anatomic reduction and independent compression screws. When intra-articular work is not planned, the distal incision extends towards the tibial tubercle and the exposure remains extra-articular. Along the femoral shaft, the vastus fascia is incised in line with the incision and sub-vastus elevation is performed. When possible, percutaneous fixation is achieved proximally, and at a minimum, the vastus musculature is left on bone proximally to avoid excess periosteal stripping.

Allograft insertion:

Following exposure, the fibular allograft can again be inserted in a variety of ways as indicated by the fracture characteristics. Insertion through the fracture line allows indirect reduction of the medial cortex, especially in oblique patterns or fractures with medial comminution. Insertion through the intercondylar notch allows for enhanced fixation in fractures with short distal segments and controls micromotion during reduction of severely comminuted fractures. The following case examples demonstrate the intra-operative techniques for fibula insertion through a corticotomy (technique 1), through the fracture site (technique 2) and through the intercondylar notch (technique 3).

Distal Femur Technique 1: Fibula insertion through a cortical window

Figure 8 demonstrates the intra-operative photographs and fluoroscopy and images of a 64 year old morbidly obese female who sustained a periprosthetic distal femur fracture around a total knee arthroplasty. The fibula was chosen for augmentation of the construct given significant osteoporosis and poor bone quality. The closed box femoral component precluded fibula entry through the intercondylar notch, while the obliquity and location of the fracture with respect to the implant prevented insertion through the fracture site without a cortical window. After sub-vastus lateral exposure, the fracture was debrided and grossly aligned with manual traction. A “jack-in-the box” cortical window was performed as described above (Figure 7). A fibula allograft was cut and contoured on the back table to allow a beveled edge for insertion. A 2.4mm threaded k-wire was placed through the midportion of the allograft, perpendicular to its long axis, to act as a joystick and facilitate medialization and distal impaction of the graft. Medialization of the fibula confers an indirect reduction of the medial cortex while providing medial column support. The allograft was first inserted retrograde into the proximal segment of the fracture and seated into the intramedullary canal. While obtaining a gross reduction with manual traction and Weber clamps, a push-tool was used to medialize the fibula within the canal.

Distal Femur Technique 2: Fibula insertion through the fracture

Figure 8 shows the pre-operative and 6 month post-operative images of a 70 year old female with a history of chronic kidney failure on hemodialysis who sustained a periprosthetic spiral fracture of the distal femur with minimal comminution. A fibula allograft was again chosen to augment construct strength in the setting of poor bone quality. The obliquity of the fracture pattern and ability to judge the reduction on cortical keys made this fracture pattern amenable to fibula insertion through the fracture site. After exposure and fracture debridement, the fibula is again inserted in a retrograde fashion and tamped medially and distally using a joystick k-wire as described in technique 1 above. In this case, where posterolateral comminution was present, additional posterolateral plate was added to aid in the final reduction prior to structural lateral plate application.

Distal Femur Technique 3: Fibula insertion through the intercondylar notch

Figure 9 shows the pre-operative images of a 79 year old female with severe aortic stenosis and a history of left total hip and cruciate retaining total knee arthroplasty, who presented with a left distal femoral peri-prosthetic fracture after a slip and fall. The fracture occurred at the proximal flange of the knee arthroplasty femoral component with significant displacement, anterior comminution and bone loss laterally. To augment the deficiencies of lateral locked plate constructs, especially in light of the short distal segment with a total hip stem proximally, the pre-operative surgical plan included a long lateral locking plate to prophylax against future fracture in the femoral shaft distal to the hip arthroplasty stem, and an intramedullary fibular strut allograft inserted as a retrograde intramedullary nail to enhance fixation strength in the osteoporotic metaphysis.

After surgical exposure with a swashbuckler approach, the distal femur fracture was noted to be grossly unstable, but the prosthesis was well fixed. Fluoroscopic steps of reduction and fixation as well as intra-operative photographs are shown in Figure 10, and post-operative

images are shown in Figure 11. A Synthes 4.5mm distal femoral locking plate was reduced to bone distally with a combination of manual traction, Weber clamps, and a periarticular clamp. It was held in place with a central k-wire and single compression screw in the metaphyseal region. Proximally, the plate was reduced to bone and provisionally fixed to the proximal femoral shaft with a cortical screw for gross stability and alignment. A 4.5mm cortical screw was passed through the proximal aspect of the plate, posterior to the proximal femoral arthroplasty stem. Fracture reduction was fine tuned distally with Weber clamps and a periarticular clamp to reduce the condyle and total knee component to the plate.

Given the short segment of bone distal to the fracture, an intramedullary strut allograft was used to provide additional gross stability and improved purchase for screw fixation. A 2.8mm guidewire was introduced through the intercondylar notch and across the fracture using a standard starting point for a retrograde femoral nail. A 13mm cannulated drill was inserted over the wire to create a pilot hole for the allograft through the notch of the prosthesis. A long 3.2mm drill bit was used to core the intramedullary canal of a 24cm fibular allograft. A burr was used to shape the leading edge of the fibula into a point for ease of insertion. The edges of the allograft were shaped with a burr to ensure adequate fit within the 13mm pilot hole. The fibula was advanced retrograde over the guidewire, the guidewire was removed, and the fibula was tamped into its final intramedullary position. The initial shaft screw holding the plate position prior to proximal screw insertion was backed out to allow the graft to pass and then reinserted through the fibula graft. Once in its final position, the fibula was cut flush with the condylar notch in situ, and the edge was smoothed with a burr. Reduction of the condyles was fine tuned about the fibula using Weber clamps. The locking guide was used to insert a central 7.3mm and multiple peripheral 5.0mm distal locking screws through the lateral aspect of the plate, many of which captured the fibula allograft. A cortical interfragmentary screw was inserted, along with additional cortical screw fixation of the femoral shaft, all capturing the allograft intramedullary nail.

Finally, to control the flexion-extension vector of the fracture, an 8-hole 3.5mm locking reconstruction plate was applied posterolaterally to buttress the distal femur. This was applied with cortical screws above and below the fracture line, all of which captured the fibular allograft with excellent purchase, compressing the plate to bone for a buttress effect..

CONCLUSION

Complex periarticular fractures about the knee are challenging cases often treated with locked plate fixation in metaphyseal bone. Multiple exposures for dual column fixation are often necessary when the pattern involves both columns or comminution confers instability in both sagittal and coronal planes. A fibular strut allograft is a useful reduction tool that also serves as a bone void filler and supplementary cortex, enhancing columnar support and overall construct stability. With greater screw purchase, the allograft affords options for cortical screw fixation and compression in poor quality metaphyseal bone. Additionally, techniques utilizing a fibula allograft in combination with a locked lateral plate offer the distinct advantage of providing subchondral or dual column support when dual plating via two separate incisions is contraindicated by a patient's soft tissue compromise. Plate augmentation with a fibular allograft is a flexible technique that can be adapted to best fit the

individual fracture pattern at hand by changing the way in which the allograft is inserted. Although clinical studies evaluating the outcomes of these techniques in proximal tibia and distal femur fractures are currently limited, in our experience, the surgical techniques described herein are safe and effective. Larger long-term studies are needed to better evaluate these techniques and establish them as reliable methods of fixation in complex periarticular fractures about the knee.

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Figure 1. (Proximal Tibia Technique 1):

Preoperative imaging of a 57 year old female with insulin-dependent diabetes.

Anteroposterior (AP) (a) and lateral (b) knee x-rays demonstrate a complex fracture of the of the tibial metadiaphyseal junction with significant comminution, a separate tibial tubercle fragment, and concomitant fracture of the proximal fibula. Preoperative axial and coronal MRI images (c) reveal the intra-articular extension of the fracture into the tibial eminence, with minimal intra-articular fragment displacement.

Figure 2. (Proximal Tibia Technique 1, continued):

Intraoperative photographs from the case in Figure 1 illustrate the surgical steps for fibula allograft insertion, reduction and fixation including creating a channel for the allograft through the anterolateral tibial tubercle fracture site (d), contouring of the allograft on the back table (e), allograft insertion over a guidewire (f), tamping into position (g), cutting the graft flush with the outer cortex (h), sinking the graft into the intramedullary canal (i), and securing the allograft in place with screws through the provisionally attached lateral plate (k) and augmentative anterior plate (j). Fluoroscopic images further reveal the overall sequence of fracture reduction, starting with initial lateral plate fixation (l), insertion of the allograft in an oblique fashion (m), placement of screws through the plate to capture the allograft (n,o), and finally reduction of the tibial tubercle with an additional pelvic reconstruction plate (p,q).

Figure 3. (Proximal Tibia Technique 1, continued):

Three month postoperative AP (r) and lateral (s) knee and full length tibia (t, u) x-rays from the case in Figures 1 & 2 demonstrate the implants and allograft in place without loss of reduction.

Figure 4. (Proximal Tibia Technique 2):

Pre-operative AP (a) and lateral (b) radiographs revealing a comminuted extra-articular proximal tibia/fibula fracture with significant comminution in a 47 year old paraplegic man. Intraoperative photographs demonstrate creation of a cortical window with a micro-sagittal saw and osteotome for fibula allograft insertion (c) and elevation of the cortical window for access to the intramedullary canal (d).

Figure 5. (Proximal Tibia Technique 2):

Fluoroscopic imaging of the case demonstrated in Figure 4 illustrates guidewire placement through a cortical window (e, f), insertion of the allograft over the guidewire in an oblique orientation (g, h) to decrease fracture site motion and provide extra cortices for fixation, followed by lateral proximal tibial locking plate placement (i, j), and final reduction with addition of an anterior pelvic reconstruction plate (k, l). Postoperative AP (m) and lateral (n) radiographs at 2 week follow-up reveal overall maintained alignment.

Figure 6. (Proximal Tibia Technique 3):

Case example of Schatzker II tibial plateau fracture. Pre-operative radiographs (a) as well as preoperative computed tomography (b) demonstrate lateral articular depression and comminution. Anterior to posterior horizontal fibula insertion and lateral buttress plating was performed to raft the articular surface (c). Additional case examples of horizontal fibula insertion to prevent post-operative articular subsidence are also demonstrated (d, e).

Figure 7. (Distal Femur Technique 1):

Figure 7 demonstrates a 64 year old female with an oblique periprosthetic fracture surrounding a total knee arthroplasty. Intraoperative images outline the surgical steps undertaken to insert the allograft through a corticotomy window, including opening the window (a), inserting the allograft in retrograde fashion (b), medializing and tamping the graft distally (c), and closing the cortical window before plate application (d). Fluoroscopic images demonstrate the displaced distal periprosthetic femur fracture with the allograft inserted retrograde through the cortical window (e), k-wire joystick and tamp used to medialize and seat the graft in the subchondral bone (f) and final intra-osseous location of the allograft on lateral imaging (g).

Figure 8. (Distal Femur Technique 2):

Pre-operative AP (a) and lateral (b) x-rays reveal a spiral periprosthetic distal femur fracture in a 70 year old female with chronic renal failure. Six month post-operative radiographs (c, d) demonstrate a healed fracture with the intact fixation construct consisting of a vertically oriented fibular allograft that was inserted through the fracture site, a lateral distal femur locking plate with screw fixation through the allograft, and an additional posterolateral pelvic reconstruction plate.

Figure 9. (Distal Femur Technique 3):

AP and lateral pre-operative radiographs of a 79 year old female reveal a displaced supracondylar periprosthetic distal femur fracture above a well-fixed total knee arthroplasty (a, b). Fluoroscopic imaging illustrates the reduction and fixation sequence including the initial fracture displacement (c), gross reduction and application of a laterally placed distal femur locking plate to obtain overall alignment (d, e), fixation of the plate proximal to the hip arthroplasty stem (f), allograft insertion and fine tuning of the reduction around the allograft intramedullary nail (g), placement of screws through the plate to capture the allograft (h), and final addition of a posterior pelvic reconstruction plate (i). Intra-operative photographs depicting reaming for nail insertion through the intercondylar notch (j) and insertion of a long segment of fibula serving as a structural intramedullary allograft (k).

Figure 10. (Distal Femur Technique 3, continued):

Six week post-operative AP and lateral radiographs from the clinical case presented in Figure 9, revealing a healing distal femur periprosthetic fracture in excellent alignment (a, b, c).