11

Periprosthetic Femoral Fractures

*William M. Ricci, MD
George J. Haidukewych, MD

Abstract

Periprosthetic fractures of the femur are increasing both in the absolute number of fractures per year and in frequency (proportion of fractures among patients with hip arthroplasty). As a result, orthopaedic surgeons will face these challenging injuries more often. The optimal treatment must be individualized, taking into consideration the fracture location relative to the arthroplasty component, the implant stability, the underlying quality of the bone, and the medical and functional status of the patient. Based on these factors, successful treatment usually involves some combination of open reduction, internal fixation, and revision arthroplasty with or without adjuvant bone grafting.

Instr Course Lect 2009;58:105-115.

Periprosthetic fractures continue to increase in frequency, in part because of the increasing number of primary and revision hip and knee arthroplasties performed annually and also because of the increasing age and fragility of patients with such implants. Periprosthetic femoral shaft and supracondylar femoral fractures can present significant treatment challenges. The presence of an arthroplasty component obviates the use of or increases the difficulty of standard fixation techniques. Additionally, these fractures often occur in elderly patients with osteoporotic bone, making stable fixation more difficult.

The difficulty in managing these fractures is evidenced by the array of treatment options described in the literature, without a clear consensus emerging on the most appropriate method.[1,2] Most recently, treatment of periprosthetic femoral (shaft and supracondylar) fractures has focused on open reduction and internal fixation (ORIF) or revision arthroplasty procedures with or without supplementary autologous or allogeneic bone grafting.[3-5] Successful application of these techniques requires consideration of the fracture location relative to the femoral component, the implant stability, the quality of the surrounding bone, and the medical and functional status of the patient.[6]

Periprosthetic Femoral Shaft Fractures

The Vancouver classification of periprosthetic femoral shaft fractures about hip arthroplasty stems is useful in directing treatment.[6] This system considers the location of the fracture relative to the stem, the stability of the implant, and associated bone loss. Type A fractures are located in the trochanteric region, type B fractures involve the tip of the stem, and type C fractures are distant to the tip of the stem. Type B fractures are further subdivided into type B1 fractures, which are associated with a stable implant; type B2 fractures, which are associated with an unstable implant; and type B3 fractures, which are associated with bone loss.

For a femoral shaft fracture about a well-fixed implant (Vancouver type B1 fracture), stabilization using ORIF with plates and screws, cortical onlay allografts, or a combination of both has been advocated[7-10] (Figure 1, *A* and *B*). Newer indirect fracture reduction techniques have favorable biologic features that minimize soft-tissue disruption, preserve the vascular supply to bone,

**William M. Ricci, MD or the department with which he is affiliated has received research or institutional support from AONA, Synthes, Smith & Nephew, and Wright Medical; has received royalties from Smith & Nephew; and is a consultant for or an employee of Smith & Nephew, Wright Medical, and OrthoVita.*

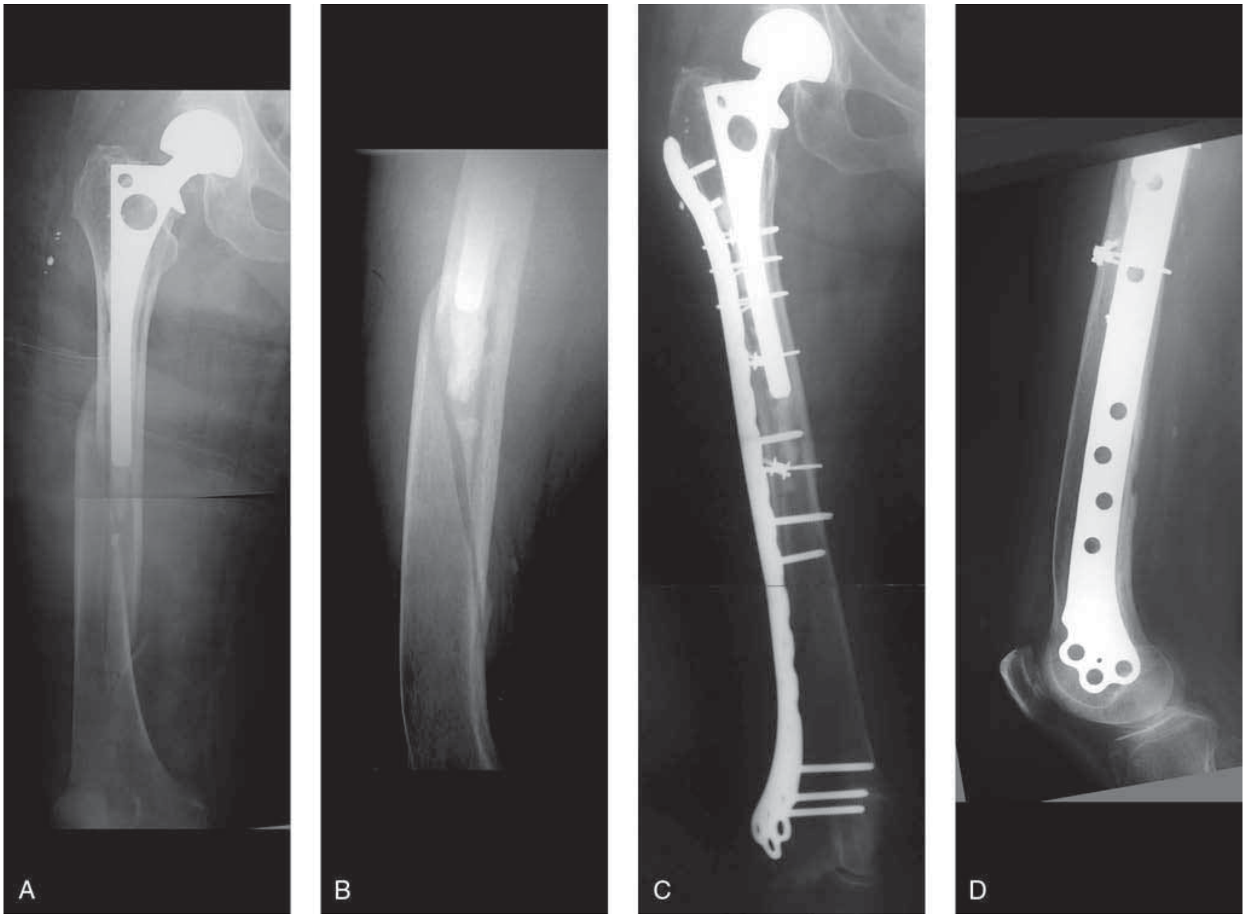

Figure 1 **A** and **B,** Radiographs of a Vancouver type B1 periprosthetic femoral shaft fracture. **C** and **D,** Radiographs showing fixation of the fracture with a lateral plate applied using biologic fracture reduction techniques.

enhance healing, decrease the incidence of nonunion for many fractures, and often obviate the need for supplemental bone grafting.[11,12] There is a limited role for revision arthroplasty for type B1 fractures because of the stable prosthesis. Types B2 and B3 fractures generally require femoral component revision with or without adjuvant plate and/or allograft strut fixation.

Internal Fixation

The results of traditional plate and screw fixation for periprosthetic femoral shaft fractures using older direct reduction techniques have varied.[9,13-22] Failure of traditional cable-plate constructs, with cable fixation in the zone of the intramedullary implant and distally nonlocked screws, is likely related to older direct reduction techniques and not necessarily to an inappropriate construct. Soft-tissue stripping associated with direct reduction techniques can delay healing, which manifests as implant failure. The addition of strut grafts at 90° to a lateral plate offers prolonged construct stability and improved results when these older direct reduction techniques are used. In a report on 40 patients, Haddad and associates[8] concluded that cortical allografts should routinely be used to augment fixation and healing of periprosthetic femoral fractures around well-fixed implants. Treatment methods varied and included either cortical onlay strut allograft alone, a plate and one cortical strut, or a plate and two struts. The nonstandardized use of adjuvant bone grafting materials in this study increased the heterogeneity of the treatment methods: 8 patients received autograft, 29 received morcellized allograft, and 15 received demineralized bone matrix. Based on 100% healing, it is logical to conclude that the use of strut allografts plus adjuvant bone graft and/or lateral plate fixation can achieve good results; however, it may be an overstatement to conclude allograft is required for the treatment of Vancouver type B1 fractures. Newer biologic plating techniques, which maximally preserve the soft-tissue attachments about a fracture, have been shown to be successful without adjuvant bone grafting for fractures in other anatomic areas that were traditionally treated with adjuvant bone grafts.

In a study of patients treated for Vancouver type B1 periprosthetic femoral shaft fractures with indirect fracture reduction and a single, laterally applied plate without the use of structural allograft, union occurred after the index procedure in all of the 41 patients who lived beyond the perioperative period[12] (Figure 1, *C* and *D*). The average time for healing was relatively short (11 weeks) and was homogeneous with the SD of ±4 weeks. All patients healed in satisfactory alignment (less than 5° of malalignment). Although minor implant-related complications, such as cable fracture, occurred in three patients, this did not appear to complicate the healing process. Each of these three fractures healed at between 10 and 12 weeks in satisfactory alignment and without the need for further surgery. These consistent healing times were attributed to care in preserving the soft-tissue envelope around the fracture. These results for healing compare favorably to the treatment of similar fractures using cortical onlay grafts alone, in which nonunion requiring revision surgery has been reported in 8% to 10% of patients and angular malunion has been reported in 5% to 10% of patients.[3,8,11,23] Because struts cannot be bent or contoured as can plates, higher malunion rates may occur when allograft strut fixation is used alone. Fracture alignment cannot be adjusted with struts as precisely as with plates.

Optimal proximal fixation typically includes cerclage cables. Unicortical locked screws can be used as an adjuvant to cables in the zone of the prosthesis, especially in the trochanteric region. Unicortical locked screws alone, without cables, have not been shown to provide adequate fixation for these fractures, primarily because of the poor rotational stability of such short unicortical screws. Therefore, locked screws should be used as an adjuvant but not as a substitute for cable fixation in the zone of the hip prosthesis. Any long-term detrimental effect of unicortical screws inserted into a cement mantle is unknown.

The preferred construct is a lateral plate contoured proximally to accommodate the trochanteric flare. Distally, the plate should either have a minimum of six to eight holes covering the native femur distal to the stem or extend to the condylar region (where a distal femoral plate design is used). Three or more equally spaced cables are used proximally between the lesser trochanter and the tip of the stem. Locked screws are placed in the trochanteric region after all cables are tensioned. Distal plate fixation is achieved with screws. Two screws are placed immediately distal to the prosthesis through the cement mantle, if present. The distal extent of the plate is secured with two additional screws. If the fracture pattern allows, lag screws are placed through the plate. The most critical screws are those nearest and farthest from the fracture, so in between holes can be left empty. If the diaphyseal bone is osteoporotic, as it is in many patients with periprosthetic fractures, locked screws are indicated. Locked screws should be placed after nonlocked screws and appear to be most advantageous when placed near the fracture. Postoperatively, early rehabilitation should concentrate on mobilization and knee range of motion, with protected weight bearing for approximately 6 to 8 weeks. **(DVD 11.1)**

In instances when strut allografts are indicated, such as with associated bone loss (Vancouver type B3 fractures), the strut is secured with cables independent of an associated plate (cables over the strut and under the plate) and with cables around both the plate and strut.

Revision Arthroplasty

For fractures around a loose implant (Vancouver types B2 and B3 fractures), revision of the femoral component typically is recommended (Figure 2). This strategy treats both the loose component and the fracture and provides intramedullary stability by virtue of the long femoral stems used for revision.

Knowledge of specific techniques is necessary to effectively treat these challenging revisions. Thorough, preoperative, medical optimization of the patient is recommended. Good quality orthogonal radiographs are mandatory to evaluate the fixation status of the acetabular component and remaining acetabular and femoral bone stock. If possible, the surgical note from the original arthroplasty should be obtained to determine the manufacturer of the components so that new acetabular liners are available if needed. The presence of prefracture hip symptoms, such as thigh or groin pain, can alert the surgeon to potential component loosening if

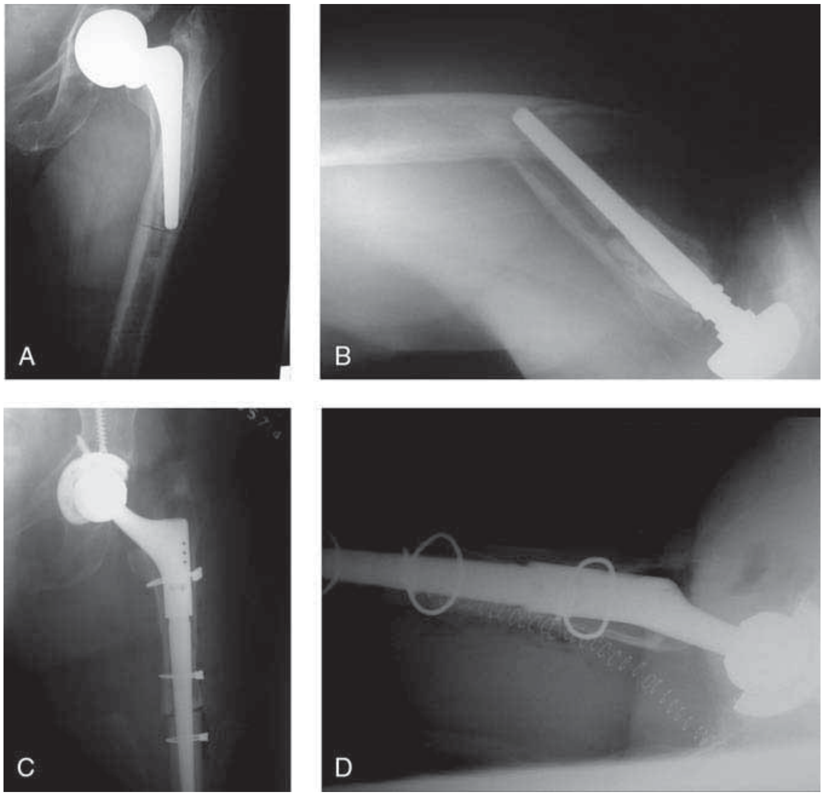

Figure 2 Radiographs of a Vancouver type B3 periprosthetic femoral shaft fracture (**A** and **B**) treated with revision arthroplasty (**C** and **D**).

the radiographs are equivocal. Serologies, such as erythrocyte sedimentation rate and C-reactive protein level, are of unknown benefit in the presence of an acute fracture. If there is concern for infection, a preoperative hip aspiration should be considered.

The specific revision strategy chosen depends on the quality of the remaining bone stock, the diameter of the femoral canal distal to the fracture, and patient factors such as age and baseline functional status. Various surgical exposures can be useful for revision surgery. We generally prefer a posterior approach about the hip because it is widely extensile. Through the fracture, cement and cement restrictors can be removed. If necessary, the proximal fracture fragment can be split coronally to allow access for stem removal and direct visualization of the distal canal to allow accurate reaming. The acetabular component typically is exposed after the femoral component is removed. The liner is removed, if modular, and the acetabular component is manually tested for stability. If it is loose, acetabular revision is performed. If it is well fixed, the liner is typically exchanged, and the head size is increased (if possible) to allow improved hip stability.

Several strategies can be used for the femur, but all rely on obtaining secure distal fixation. Only rarely is cemented long-stem revision considered. This can be useful in very osteopenic bone with capacious canals. If the fracture is anatomically reduced and fixed with cerclage cables and if the cement is not vigorously pressurized, cement extravasation typically will not occur. After cementation, intraoperative radiographs are recommended to determine if any problematic cement extravasation has occurred. It should be emphasized that cemented reconstructions are rarely useful for periprosthetic fractures. The most effective strategies include noncemented distal fixation techniques.

Several preoperative radiographic findings, such as the endosteal diameter and morphology of the distal fragment, can help guide the selection of the appropriate cementless reconstruction. If the distal fragment has parallel endosteal cortices with 5 cm or more of the tubular diaphysis (usually with a diameter of less than 18 mm), an extensively coated, cementless long-stem prosthesis is appropriate. These types of stems have demonstrated excellent long-term survivorship in revision surgery and for treating periprosthetic fractures.[1,2] The distal canal is reamed, and a trial stem is potted into the distal fragment. The proximal fragments can then be reduced using the trial implant as a template. We prefer to select a trial implant that is one size smaller than the definitive implant and to use that trial implant as a guide to proximal fragment alignment. Cerclage cables are applied and a trial reduction is performed. Once limb length and stability are acceptable, the trial implant is removed and the femoral component is impacted. The cerclage cables are then retensioned, crimped, and cut. The appropriate femoral head length is selected and the reconstruction is completed.

If the distal diaphysis has divergent endosteal morphology or large diameters (typically more than 18 mm), fluted, titanium, tapered modular stems can be used effectively. These stems are commercially available in diameters up to 30 mm and can be useful in capacious canals. Reaming, under fluoroscopic control and by hand, especially in osteopenic bone, can help avoid anterior femoral cortical perforation. When axial stability is obtained by diaphyseal reaming, the implant is impacted into place. It is recommended that a prophylactic cable be placed at the mouth of the distal fragment before impacting the stem. The proximal bodies of the modular implants are then chosen to restore appropriate limb length, offset, and hip stability. After the trial reduction is completed, the components are assembled and the hip reduced. The proximal fragments are then reduced and cerclaged around the body of the implant. This strategy is effective for Vancouver type B2 and some B3 fractures; however, concerns remain about the durability of the modular junction of such stems without proximal bony support.

Rarely, the proximal bone is so deficient that a modular proximal femoral replacement (so-called tumor prosthesis) is appropriate. These prostheses typically are used in very osteopenic bone; therefore, cemented distal fixation is recommended. Preserving a sleeve of remaining proximal bone, although deficient, can provide some soft-tissue attachment and assist in maintaining a stable hip. A coronal split (Wagner type) of the proximal bone can facilitate stem removal. The new implant is cemented into the distal fragment; the proximal sleeve of the remaining bone and soft-tissue are cerclaged around the body of the prosthesis with cable or heavy, braided suture. If the abductors are deficient, a constrained acetabular liner to minimize the risk of postoperative dislocation should be available if stability does not appear acceptable with a nonconstrained liner and the largest possible femoral head. If the acetabular component is of sufficient diameter and a compatible constrained liner is not available, some surgeons recommend cementing a constrained liner into a well-fixed acetabular component. Good containment of the locked liner by the acetabular component is required, and cup position should be acceptable. It is recommended that the backside of the liner (that is to be cemented) be contoured (if it is smooth) to allow cement interdigitation.

Patients are mobilized postoperatively, typically with 50% weight bearing initially, followed by full weight bearing at 6 weeks to allow some healing of the proximal fragments. A brace is used only if necessary to avoid hyperflexion and adduction to protect trochanteric and other proximal fragments.

Periprosthetic Supracondylar Femoral Fractures

Approximately 300,000 primary knee arthroplasties are performed annually in the United States, and this number continues to increase. It is estimated that 0.3% to 2.5% of patients will sustain a periprosthetic fracture as a complication of a total knee arthroplasty (TKA)[18,24,25] (Figure 3, *A* and *B*). Patient-specific risk factors (such as rheumatoid arthritis, osteolysis, osteopenic bone, and elderly patient population who are more prone to falling) and technique-specific risk factors (such as anterior femoral cortical notching) have been implicated as potential causes of periprosthetic fractures. Unique challenges are involved in the treatment of patients with supracondylar femoral fractures associated with TKA prostheses. Nonsurgical treatment is associated with poor results for displaced fractures, especially relative to the results of surgical fixation.[13-17,19] The presence of a TKA prosthesis can complicate surgical treatment of these fractures by interfering with or precluding the use of standard fixation methods. A TKA prosthesis with a narrow or closed intracondylar space either limits the diameter for a retrograde nail or completely obviates its use.[26] Traditional plate fixation is prone to varus collapse, whereas blade plates or condylar screws have limited applicability for very distal fractures or when associated with a TKA prosthesis with a deep intercondylar box.[25] New locked-plate devices offer many theoretic advantages for these patients. The multiple locked distal screws provide both a fixed angle to prevent varus collapse and the ability to treat distal fractures even when associated with a deep intercondylar box. The provision for locked screw insertion into the diaphyseal fragment theoretically improves fixation in the often associated osteoporotic bone. These devices also can be inserted with relative ease and familiarity. The results of locked-plate fixation for the treatment of periprosthetic supracondylar femoral fractures above a TKA have been investigated by several authors.[27,28] Distal femoral replacement, although having limited longevity,[19,29] has a role in certain subsets of patients. Patients with loose TKA prostheses and those for whom ORIF is undesirable should be considered for distal femoral replacement.

Internal Fixation

Plate fixation of supracondylar femoral fractures with traditional

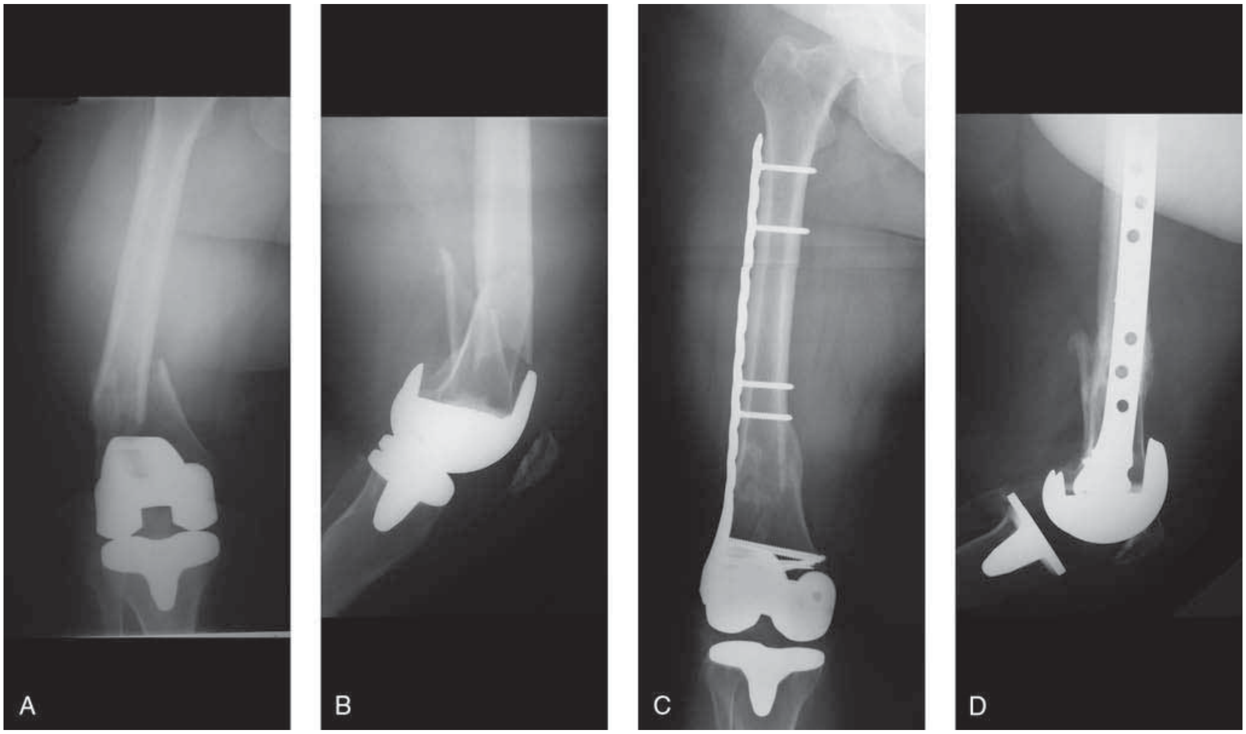

Figure 3 Radiographs showing a femoral fracture above a TKA **(A** and **B)** treated with a distal femoral locking plate **(C** and **D)**.

condylar buttress-type plates are prone to complications. When comminution is present, these non–fixed-angle implants are especially prone to varus collapse. Davison[25] reported more than 5° of collapse in 11 of 26 (42%) of such comminuted distal femoral fractures. These complications can be magnified in patients with fractures associated with a TKA because these patients are often elderly and have osteoporotic bone that makes stable internal fixation even more unreliable. Treatment is further confounded by the reduced ability to gain bicondylar screw purchase because of interference of the TKA prosthesis. Figgie and associates[15] reported a failure of internal fixation in 5 of 10 patients (50%) with periprosthetic femoral fractures above a TKA treated with traditional plating methods, and Merkel and Johnson[17] reported satisfactory results in only 3 of 5 such patients. Traditional fixed-angle plate constructs, such as 95° condylar plates and blade plates, reduce the risk for varus collapse but have limited application for fractures about a TKA prosthesis because of interference with the femoral component.

Retrograde intramedullary nailing has evolved as a satisfactory treatment option for the fixation of supracondylar femoral fractures that are not associated with TKA. This fixation method is advantageous because of the indirect nature of the fracture reduction and associated minimization of soft-tissue disruption about the fracture. However, difficulty obtaining stable fixation with intramedullary nails in patients with wide metaphyseal areas, with osteopenia, or both can lead to a loss of fixation and malalignment.[30] When a TKA prosthesis is present, the potential difficulties of retrograde nailing of supracondylar femoral fractures also are increased. Some TKA designs, because of a closed or narrow intercondylar notch, preclude the use of retrograde nails or limit their maximal diameter, respectively. The specific prosthesis type may be unknown at the time of fracture fixation. In these situations, the choice of an anterior surgical approach for retrograde nailing may need to be aborted in favor of a lateral approach for plate fixation if a nonaccommodating prosthesis is encountered.

Plates designed for placement along the distal lateral femur with the capacity for locking screws have potential advantages for the fixation of supracondylar femoral fractures associated with TKA (Figure 3, *C* and *D*). In contrast to traditional 95°

plate devices, locking plates offer multiple, rather than single, distal fixed-angle screw options. Ricci and associates[28] showed that at least two such locked screws typically could be placed across the medial condyle despite the presence of a TKA femoral component. When the TKA blocked bicondylar screw fixation, unicondylar locked screws were used. This combination of bicondylar and unicondylar locked-screw fixation provided excellent distal fixation with no distal fixation failures occurring in the study. These results are consistent with those of other locking-plate devices.[31,32] With such secure distal fixation, repetitive stresses led to screw failure in the proximal fragment in four patients (18%).[28] Of note, three of the four proximal screw failures occurred when exclusively nonlocking screws were used in the shaft fragment. This study was the first to describe modern "hybrid" locked fixation, in which nonlocked and locked screws were used in the same construct. Inserting nonlocked screws before locked screws in any given fragment allows the plate to be used as a reduction aid, where the contour of the plate helps dictate the reduction in the coronal plane. Malreductions were present in only 2 of 22 fractures (9%).[28] This result compares favorably with the malreduction rate (6% to 20%) reported with internal fixator systems (such as the Less Invasive Stabilization System; Synthes, Paoli, PA) in which reduction is independent of plate contour.[31-34] Only a single failure, in a diabetic obese patient in whom aseptic nonunion developed, occurred in 14 fractures in which locking screws supplemented nonlocked fixation in the shaft.[28] Biomechanical investigations suggest that locked screws in the diaphysis may protect from this type of screw failure, especially in osteoporotic bone.[35,36] The three patients with healing complications in this study were at exceedingly high risk for complications.[28] All had associated comorbidities of insulin-dependent diabetes mellitus, neuropathy, and obesity.

Fixation of supracondylar femoral fractures associated with a stable, nonstemmed TKA with a locking plate designed for the distal femur yields satisfactory results. Use of such plates in hybrid fixation provides the advantage of using the plate as a reduction aid (familiar to most surgeons) to help acquire satisfactory reduction and the ability to use the plate as a fixed-angle device. Locking screws placed in the diaphyseal fragment to supplement nonlocked fixation appear to reduce the risk of proximal screw failure. **(DVD 11.2)**

Revision Arthroplasty

For patients with loose implants associated with a supracondylar femoral fracture, revision typically is considered. Bony defects, areas of osteolysis, osteopenia, and short periarticular fragments all pose challenges to successful revision arthroplasty. In elderly patients, distal femoral replacement "megaprostheses" are often required to reconstruct massive bony defects. Attention to specific technical details is necessary for a successful outcome. The surgeon should be experienced in both arthroplasty and fracture management techniques. In patients with a loose implant or a history of prefracture knee pain, the routine preoperative evaluation should include a complete blood count with a manual differential count, erythrocyte sedimentation rate, C-reactive protein level, and a knee aspiration analysis to exclude occult infection. Medical optimization for frail elderly patients also is recommended.

High-quality radiographs are necessary to evaluate the fixation status of the arthroplasty and the amount and quality of remaining periarticular bone stock. The patient's history and physical examination should focus on prefracture knee symptoms, such as pain, instability, or stiffness. If available, the surgical note from the original arthroplasty should be obtained. This is especially important if isolated component revision is contemplated. Older implant designs may not offer options such as varying degrees of constraint, augmentations, and polyethylene insert sizes; therefore, such compatibility issues may necessitate complete arthroplasty revision. Previous incisions and the status of the soft tissues should be circumferentially evaluated, and the neurovascular status of the limb should be carefully documented.

The need for revision TKA after periprosthetic fracture has become less common with the advent of improved internal fixation devices such as locked plates. Typically, revision arthroplasty is reserved for fractures around a loose prosthesis, fractures with inadequate bone stock to allow stable internal fixation, or recalcitrant supracondylar nonunions that require resection and implantation of a megaprosthesis (Figure 4). Surgeons who treat periprosthetic fractures around TKAs must have the expertise and technical support to perform either long-stemmed revision TKA or revision to a megaprosthesis because it is often impossible to determine which reconstructive option is necessary until the fracture has been exposed in the operating room. Bony defects secondary to comminution, multiple previous procedures, the presence of broken

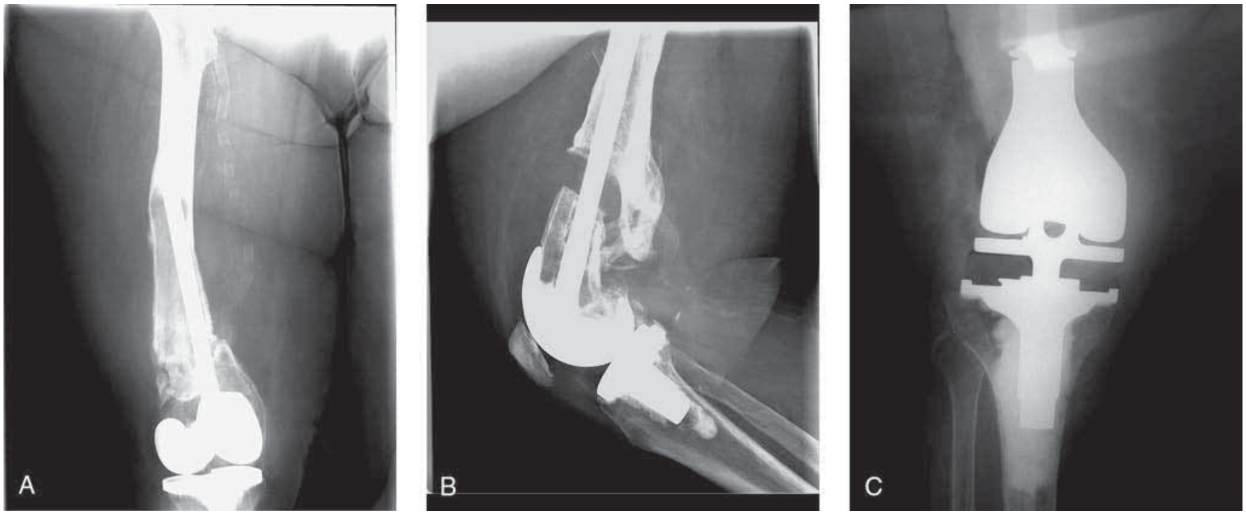

Figure 4 Radiographs showing a supracondylar femoral nonunion about a stemmed TKA **(A** and **B)** treated with a distal femoral replacement **(C)**.

hardware, and the presence of deformity all may present technical challenges to a successful outcome.

Revision TKA with intramedullary femoral stems that engage the diaphysis and simultaneously stabilize the fracture can be used. Cemented stems may be used, but care must be taken to prevent extrusion of cement into the fracture site. Allograft struts with cerclage wiring can be used to reinforce the stability provided by a long-stem prosthesis. It is unusual, however, to have distal femoral bone stock that is inadequate for internal fixation yet adequate for formal revision. The ideal indication for long-stem revision TKA would be the presence of adequate bone stock in a supracondylar fracture with a grossly loose femoral component.[24,37] Most of the clinical data evaluating the outcomes of a simultaneous revision arthroplasty with intramedullary stem fixation of a supracondylar fracture have been gathered from the treatment of distal femoral nonunions. Kress and associates[38] reported on a small series of nonunions about the knee that were treated successfully with revision and cementless femoral stems with bone grafting; union was achieved in 6 months.

Distal femoral replacement megaprostheses have been used for the salvage of failed internal fixation of supracondylar periprosthetic femoral fractures. The long-term results of the kinematic rotating hinge prosthesis for oncologic resections about the knee have been good, with a 10-year survivorship of approximately 90%. As their success becomes more predictable, the indications for megaprostheses are expanding. Elderly patients with refractory periprosthetic supracondylar nonunions or those with acute fractures with inadequate bone stock for internal fixation are reasonable candidates for megaprostheses. Davila and associates[39] reported on a small series of supracondylar distal femoral nonunions in elderly patients who were treated with megaprostheses. A cemented megaprosthesis in this patient population permitted early ambulation and return to the activities of daily living. Freedman and associates[40] performed distal femoral replacement in five elderly patients with acute fractures and reported four good results and one poor result secondary to infection. The four patients with good results regained ambulation in less than 1 month and had an average arc of motion of 99°. All patients had some degree of extension lag.

For a younger, active patient, an allograft prosthetic composite may be a better treatment alternative. Distal femoral reconstruction with an allograft prosthetic composite, providing a biologic interface, can help restore bone stock and potentially make future revision easier.[37,41] Kraay and associates[29] reported on a study of allograft prosthetic reconstructions for the treatment of supracondylar fractures in patients with TKAs. At a minimum 2-year follow-up, the mean Knee Society score was 71, and the mean arc of motion was 96°. All femoral components were well fixed at follow-up. The results of this study indicate that large segmental distal femoral allograft prosthetic composites can be a reasonable treatment method in this setting.

Periprosthetic fractures of the tibia associated with TKA are rare, and the tibial component is almost always loose. Tibial fractures associated with loose components are best treated with revision arthroplasty, frequently using a long stem to bypass the fracture.[24,37,42] It is recommended that the entire revision system be available because the femoral component often will need to be revised for sizing, constraint, exposure, or gap balancing. Often these fractures are associated with extensive osteolysis and may require structural or morcellized bone grafting, the use of metal wedges, or, in the most severe cases, proximal tibial megaprosthesis or allograft prosthetic composites. Maximizing host bone support is critical for a good result. General principles include the use of stem extensions with either metaphyseal cementation or longer, diaphyseal press-fit strategies. More contemporary techniques use metaphyseal filling sleeves that provide rotational and axial stability; however, long-term data on such reconstructions are unavailable. The largest study of periprosthetic tibial fractures around loose prostheses was reported by Rand and Coventry.[43] They reported that all 15 knees had varus axial malalignment when compared with a control group. Similar studies have confirmed that varus malalignment may be a potential risk factor for periprosthetic tibial fractures.[44,45] Specific technical considerations include careful soft-tissue dissection and retraction to minimize soft-tissue trauma to the already compromised skin flaps. It is important that the surgeon be experienced in revision arthroplasty and fracture management techniques to achieve a successful outcome.

Summary

Periprosthetic fractures around total hip arthroplasties and TKAs remain challenging injuries to treat. With an increasing elderly population, the incidence of these fractures will undoubtedly increase. Decisions regarding ORIF or revision arthroplasty are based on the fixation status of the implant, the remaining bone quality, the physiologic age of the patient, and the location and stability of the fracture. Recent advances in biologic plating techniques and locked-plate technology show promise for improved fixation of such complex fractures with minimal additional soft-tissue trauma. The most effective strategies for revision hip arthroplasty include noncemented distal fixation techniques. Revision arthroplasty for supracondylar fractures about TKAs frequently requires modular designs, metal or allograft augmentation of bony deficiency, and long stems to bypass deficient bone. These reconstructions are demanding and are fraught with complications. Regardless of the treatment method selected, attention to specific technical details is essential for a successful result.

References

1. Kolstad K: Revision THR after periprosthetic femoral fractures: An analysis of 23 cases. *Acta Orthop Scand* 1994;65:505-508.
2. Lewallen DG, Berry DJ: Periprosthetic fracture of the femur after total hip arthroplasty: Treatment and results to date. *Instr Course Lect* 1998;47:243-249.
3. Chandler HP, Tigges RG: The role of allografts in the treatment of periprosthetic femoral fractures. *Instr Course Lect* 1998;47:257-264.
4. Haddad FS, Marston RA, Muirhead-Allwood SK: The Dall-Miles cable and plate system for periprosthetic femoral fractures. *Injury* 1997;28:445-447.
5. Radcliffe SN, Smith DN: The Mennen plate in periprosthetic hip fractures. *Injury* 1996;27:27-30.
6. Duncan CP, Masri BA: Fractures of the femur after hip replacement. *Instr Course Lect* 1995;44:293-304.
7. Brady OH, Garbuz DS, Masri BA, Duncan CP: The treatment of periprosthetic fractures of the femur using cortical onlay allograft struts. *Orthop Clin North Am* 1999;30:249-257.
8. Haddad FS, Duncan CP, Berry DJ, Lewallen DG, Gross AE, Chandler HP: Periprosthetic femoral fractures around well-fixed implants: Use of cortical onlay allografts with or without a plate. *J Bone Joint Surg Am* 2002;84:945-950.
9. Tower SS, Beals RK: Fractures of the femur after hip replacement: The Oregon experience. *Orthop Clin North Am* 1999;30:235-247.
10. Wong P, Gross AE: The use of structural allografts for treating periprosthetic fractures about the hip and knee. *Orthop Clin North Am* 1999;30:259-264.
11. Holden CE: The role of blood supply to soft tissue in the healing of diaphyseal fractures: An experimental study. *J Bone Joint Surg Am* 1972;54:993-1000.
12. Ricci WM, Bolhofner BR, Loftus T, Cox C, Mitchell S, Borrelli J Jr: Indirect reduction and plate fixation, without grafting, for periprosthetic femoral shaft fractures about a stable intramedullary implant. *J Bone Joint Surg Am* 2005;87:2240-2245.
13. Cain PR, Rubash HE, Wissinger HA,

McClain EJ: Periprosthetic femoral fractures following total knee arthroplasty. *Clin Orthop Relat Res* 1986;208: 205-214.

14. Culp RW, Schmidt RG, Hanks G, Mak A, Esterhai JL Jr, Heppenstall RB: Supracondylar fracture of the femur following prosthetic knee arthroplasty. *Clin Orthop Relat Res* 1987;222:212-222.
15. Figgie MP, Goldberg VM, Figgie HE III, Sobel M: The results of treatment of supracondylar fracture above total knee arthroplasty. *J Arthroplasty* 1990; 5:267-276.
16. Garnavos C, Rafiq M, Henry AP: Treatment of femoral fracture above a knee prosthesis: 18 cases followed 0.5-14 years. *Acta Orthop Scand* 1994; 65:610-614.
17. Merkel KD, Johnson EW Jr: Supracondylar fracture of the femur after total knee arthroplasty. *J Bone Joint Surg Am* 1986;68:29-43.
18. Mont MA, Maar DC: Fractures of the ipsilateral femur after hip arthroplasty: A statistical analysis of outcome based on 487 patients. *J Arthroplasty* 1994;9:511-519.
19. Moran MC, Brick GW, Sledge CB, Dysart SH, Chien EP: Supracondylar femoral fracture following total knee arthroplasty. *Clin Orthop Relat Res* 1996;324:196-209.
20. Tadross TS, Nanu AM, Buchanan MJ, Checketts RG: Dall-Miles plating for periprosthetic B1 fractures of the femur. *J Arthroplasty* 2000;15: 47-51.
21. Venu KM, Koka R, Garikipati R, Shenava Y, Madhu TS: Dall-Miles cable and plate fixation for the treatment of peri-prosthetic femoral fractures: Analysis of results in 13 cases. *Injury* 2001;32:395-400.
22. Zenni EJ Jr, Pomeroy DL, Caudle RJ: Ogden plate and other fixations for fractures complicating femoral endoprostheses. *Clin Orthop Relat Res* 1988;231:83-90.
23. Chandler HP, King D, Limbird R, et al: The use of cortical allograft struts for fixation of fractures associated with well-fixed total joint prostheses. *Semin Arthroplasty* 1993;4: 99-107.
24. Ayers DC: Supracondylar fracture of the distal femur proximal to a total knee replacement. *Instr Course Lect* 1997;46:197-203.
25. Davison BL: Varus collapse of comminuted distal femur fractures after open reduction and internal fixation with a lateral condylar buttress plate. *Am J Orthop* 2003;32:27-30.
26. Maniar RN, Umlas ME, Rodriguez JA, Ranawat CS: Supracondylar femoral fracture above a PFC posterior cruciate-substituting total knee arthroplasty treated with supracondylar nailing: A unique technical problem. *J Arthroplasty* 1996;11:637-639.
27. Ricci WM, Borrelli J Jr: Operative management of periprosthetic femur fractures in the elderly using biological fracture reduction and fixation techniques. *Injury* 2007;38(suppl 3): S53-S58.
28. Ricci WM, Loftus T, Cox C, Borrelli J: Locked plates combined with minimally invasive insertion technique for the treatment of periprosthetic supracondylar femur fractures above a total knee arthroplasty. *J Orthop Trauma* 2006;20:190-196.
29. Kraay MJ, Goldberg VM, Figgie MP, Figgie HE III: Distal femoral replacement with allograft/prosthetic reconstruction for treatment of supracondylar fractures in patients with total knee arthroplasty. *J Arthroplasty* 1992;7:7-16.
30. Althausen PL, Lee MA, Finkemeier CG, Meehan JP, Rodrigo JJ: Operative stabilization of supracondylar femur fractures above total knee arthroplasty: A comparison of four treatment methods. *J Arthroplasty* 2003;18:834-839.
31. Schandelmaier P, Partenheimer A, Koenemann B, Grun OA, Krettek C: Distal femoral fractures and LISS stabilization. *Injury* 2001;32(suppl 3): SC55-SC63.
32. Schutz M, Muller M, Krettek C, et al: Minimally invasive fracture stabilization of distal femoral fractures with the LISS: A prospective multicenter study. Results of a clinical study with special emphasis on difficult cases. *Injury* 2001;32(suppl 3):SC48-SC54.
33. Kregor PJ, Stannard JA, Zlowodzki M, Cole PA: Treatment of distal femur fractures using the less invasive stabilization system: Surgical experience and early clinical results in 103 fractures. *J Orthop Trauma* 2004;18: 509-520.
34. Markmiller M, Konrad G, Sudkamp N: Femur-LISS and distal femoral nail for fixation of distal femoral fractures: Are there differences in outcome and complications? *Clin Orthop Relat Res* 2004;426:252-257.
35. Egol KA, Kubiak EN, Fulkerson E, Kummer FJ, Koval KJ: Biomechanics of locked plates and screws. *J Orthop Trauma* 2004;18:488-493.
36. Perren SM, Linke B, Schwieger K, Wahl D, Schneider E: Aspects of internal fixation of fractures in porotic bone: Principles, technologies and procedures using locked plate screws. *Acta Chir Orthop Traumatol Cech* 2005; 72:89-97.
37. Engh GA, Ammeen DJ: Periprosthetic fractures adjacent to total knee implants: Treatment and clinical results. *Instr Course Lect* 1998;47: 437-448.
38. Kress KJ, Scuderi GR, Windsor RE, Insall JN: Treatment of nonunions about the knee utilizing custom total knee arthroplasty with press-fit intramedullary stems. *J Arthroplasty* 1993;8:49-55.
39. Davila J, Malkani A, Paiso JM: Supracondylar distal femoral nonunions treated with a megaprosthesis in elderly patients: A report of two cases. *J Orthop Trauma* 2001;15:574-578.
40. Freedman EL, Hak DJ, Johnson EE, Eckardt JJ: Total knee replacement including a modular distal femoral component in elderly patients with acute fracture or nonunion. *J Orthop Trauma* 1995;9:231-237.
41. Clatworthy MG, Ballance J,

Brick GW, Chandler HP, Gross AE: The use of structural allograft for uncontained defects in revision total knee arthroplasty: A minimum five-year review. *J Bone Joint Surg Am* 2001;83:404-411.

42. Felix NA, Stuart MJ, Hanssen AD: Periprosthetic fractures of the tibia associated with total knee arthroplasty. *Clin Orthop Relat Res* 1997;345:113-124.
43. Rand JA, Coventry MB: Stress fractures after total knee arthroplasty. *J Bone Joint Surg Am* 1980;62:226-233.
44. Lotke PA, Ecker ML: Influence of positioning of prosthesis in total knee replacement. *J Bone Joint Surg Am* 1977;59:77-79.
45. Wilson FC, Venters GC: Results of knee replacement with the Walldius prosthesis: An interim report. *Clin Orthop Relat Res* 1976;120:39-46.